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IS IT NECESSARY TO FERTILIZE AN APPLE ORCHARD?

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*** Riverhead, N. Y. † Absent on leave. ‡ Connected with the Chautauqua Grape Work.**

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IS IT NECESSARY TO FERTILIZE AN APPLE ORCHARD?

U. P. HEDRICK.

SUMMARY.

1. This bulletin is a report of a fifteen-year experiment to determine whether it is necessary to fertilize apple orchards.

2. Current recommendations for fertilizers in orchards are unreliable because there have been few investigations of the subject which have furnished trustworthy information. Present practices are largely based on the fertilization of field and garden crops, but the needs of apples cannot be compared, in the least, with the needs of herbaceous crops because of the great difference in the habits of growth of the two kinds of plants. Fertilizing apples is a difficult problem, too, for, beside variability of plant and environment to contend with, as with all plants, it is necessary to take thought of the tree and of the crop of the future.

3. This experiment has to do with apples — not apples and grass. Attention is called to this fact because most of the investigations of fertilizers for apples have been carried on with trees in sod. In all such experiments the interactions of soil, apples, grass and fertilizers are so complicated that a crucial test is impossible.

4. The experiment under discussion was carried on in a Station orchard, the soil of which is a clay loam too heavy for a good orchard soil and not better than the average clay soil in the farm lands of western New York. The orchard has been given the care it would have received in a commercial plantation.

5. There are twelve plats in the experiment the arrangement of which is shown in Figure 1, page 160. The fertilizers applied each year are as follows:

Stable manure	Plats 1 and 9, average per tree	415.15 pounds
Acid Phosphate	" 2 and 8, " " "	12.66 "
Muriate of potash	" 6 and 10, " " "	7.26 "
Acid phosphate		12.6 "
Muriate of potash	" 4 and 12, " " "	7.26 "
Acid phosphate		12.6 "
Nitrate of soda		3.67 "
Dried blood		12.84 "

6. An important consideration is that the fertilizers were put on only underneath the branches of the trees so that a tremendous excess of each has been used and the experiment, therefore, throws light on the question as to whether excessive fertilization is deleterious to trees.

7. The apple in the experiment is the Rome top-worked on Ben Davis, the Rome buds all having come from one tree and the stocks having been selected carefully. These precautions were taken to exclude individual variations. Cross-pollination is provided for, there being over a hundred other varieties separating and bounding the plats.

8. The results of the experiment are gaged by the yield, size, color, flavor, maturity and keeping quality of the fruit, the diameter of tree, amount, color and weight of foliage and the length and weight and the annual growth of the branches.

The fertilizers have had no sensible effects upon the yield of fruit in this experiment.

The size of the apples is possibly increased by the fertilizers since the percentage of culls and seconds is a trifle higher in the check plats.

The several current generalizations as to the effects of fertilizers on apples find no verification in this experiment.

All of the trees in the several plats have borne crops very uniform in maturity, keeping-quality, texture and flavor of apples.

A study of the tables giving the diameter of the trees in the experiment shows no differences outside the range of variation in the several plats.

The foliage in the plats receiving nitrogen was greener than in other plats during the last season, the first difference to be certainly counted as an effect of a fertilizer.

There was also a measurable effect of the nitrogen in the weight of the leaves.

There is slight evidence that the trees on plats to which nitrogen is applied are making a greater annual growth of branches.

9. The trees in this experiment would have been practically as well off had not an ounce of fertilizer been applied to them. One must conclude that if fertilizers have no value in this orchard, they have no value in many other orchards in New York.

10. From the data at hand there seems to be but one interpretation of the results of this experiment. An analysis of the soil before the experiment was begun shows that at that time there was, in the upper foot of soil, enough nitrogen per acre to last mature apples trees 183 years, of phosphoric acid, 295 years, of potash, 713 years. From this well-nigh inexhaustible storehouse, tillage, cover-crops and good care have made available all the plant food these trees needed.

11. It may be necessary to fertilize some apple orchards in New York. Such cases will be found on sandy and gravelly soils, on lands very subject to drought, on very shallow soils and on soils quite devoid of humus. Some soils may require one of the chief elements of fertility; some, though few, indeed, need the three which usually constitute a complete fertilizer.

12. A fruit-grower may assume that his trees do not need fertilizers if they are vigorous and making a fair amount of new wood. If the trees are not vigorous the drainage, tillage and sanitary condition of the orchard should be looked to first and the fertilization afterward if then found necessary. Lastly, before using fertilizers the fruit-grower should obtain positive evidence by experimentation as to whether an orchard needs fertilizers, and what ones.

INTRODUCTION.

FERTILIZING THE APPLE A DIFFICULT AND UNSOLVED PROBLEM.

Plants are extremely complex and changeful organisms and live in environments which are also extremely complex and changeful. To furnish food to them, therefore, is a difficult and an unending problem. In particular, it is perplexing to know how to nourish the apple without waste, because, beside variability of plant and environment to contend with, it is necessary to take thought for the tree and the crop of the morrow. These difficulties have seemingly driven experimenters with fertilizers to other fields where the harvest is more certain and more immediate; for there have been in the past, either at home or abroad, almost no long-continued experiments to ascertain what the fertilizer requirements of apples are. In America there have been less than a half dozen experiments, planned and carried out for more than two years, which could, without greatly expanding the imagination, be called fertilizer experiments with apples.

Having but little definite data as to fertilizer requirements for the apple, practically all the recommendations for fertilizing this fruit are based on the differences in the chemical composition of the apple-tree and crop, as compared with truck and grain crops. But the chemical composition of a crop affords only a rough approximation of its fertilizer requirements, and the needs of the apple cannot be determined for actual practice by comparing its chemical composition with that of herbaceous crops. Its habit of growth differs greatly in many ways from that of annual crops — in age of fruiting, in length of growing season, in spread of roots, in character of the product removed, in amount of water transpired and in the continuous cropping of the apple without chance for rotation. The current recommendations for fertilizing orchards, which have thus been deduced from experiments with other plants, are so at variance with experience that orchard fertilization is now a maze in which most fruit-growers lose themselves.

With the hope of letting in light on some of the phases of orchard fertilization, this Station has undertaken several experiments. One of these, to test the effects of potash, acid phosphate and lime in an apple orchard, after continuing for twelve years, was discussed in Bulletin 289. Another was combined with a test of tillage and sod-mulch for the apple and is described on page 94 of the report on tillage and sod-mulch in Bulletin 314. A third experiment is now under progress in a continuation of the orchard management test just mentioned. Lastly, there is the experiment here under discussion.

INVESTIGATION.

THE PRESENT PROBLEM OUTLINED.

The problem in this experiment may be stated by amplifying a very little the question under which this bulletin is put out. Is it necessary to fertilize an apple orchard? Are the yield, color and quality of apples and the vigor, health and longevity of the trees influenced by the addition of nitrogen, phosphorus and potash? The question is whether it is necessary to add these elements to a soil such as ours, under our conditions, rather than what combination of these elements should be used, or, what quantities can be applied without waste. So, too, time, method and frequency of application, important though they may be, do not enter into this experiment except as very secondary considerations. Our ignorance of the manurial requirements of apples is so profound that the necessity of fertilizing the average orchard is still debatable. It is, therefore, proper that an attempt be made to solve this part of the puzzle first.

This experiment was planned by Director W. H. Jordan of this Station and Professor S. A. Beach, Horticulturist. The work was in the hands of Professor Beach until his removal from this Station to Ames, Iowa, in 1905, since which time it has been in the charge of the writer.

AN EXPERIMENT WITH APPLES — NOT WITH APPLES AND GRASS.

This experiment has to do with a single crop — *apples* — not *apples* and *grass*. It would seem that this statement is gratuitous; but it is called forth by the fact that nearly all of the experiments we have had in America with fertilizers for apples have been with orchards in sod. Exactness is not obtainable in such experiments; the conclusions drawn from them are not only loose but they are deceptive. This is illustrated in an orchard under control of this Station in which nitrate of soda is wholly inert in its effects on the apple under tillage; in another half of the same orchard, all other conditions being identical, trees in sod respond markedly to this fertilizer. There is a supposition, with sufficient evidence to give weight to it, that grass exerts a poisonous effect on trees. How can it be known with trees in grass whether salutary fertilizers are beneficial as food for the trees or as counter-influences to a possible toxin? The interactions of trees, soils and fertilizers are most complex; the addition of grass multiplies the complications and makes a crucial experiment well-nigh impossible.

It is of course worth knowing that better apples can be grown in sod if fertilizers are used. But a fertilizer experiment in sod furnishes but little trustworthy evidence as to the food requirements of the apple — much needed information for the proper culture of this fruit.

THE SITE AND THE SOIL.

The orchard in which the fertilizers are being tried is situated one and one-half miles west of Seneca lake on an upland about 100 feet above the lake and 550 feet above the sea. The land is level and is now well drained. To make sure of good drainage, tile drains two and one-half feet deep and two rods apart were laid in the orchard before planting was begun in the spring of 1896. In the wettest seasons and after the heaviest showers surface water passes away within a few hours. The field had been used for a number of years before this experiment was begun, for the ordinary rotation of farm crops and had the reputation of being very good farming land in a locality somewhat noted for the productivity of its soils.

The soil is a heavy Dunkirk clay loam from twelve to eighteen inches deep, resting on a still heavier and more compact clay subsoil; this in turn rests on shale which is to be found at a depth of from ten to twelve feet from the surface. A mechanical analysis of the soil, made by Mr. J. Davison of the New York

State College of Agriculture, is given in Table I, with analyses[1] of soils from other apple regions in New York to allow of comparisons.

TABLE I.— MECHANICAL ANALYSES OF APPLE-PRODUCING SOIL TYPES IN WESTERN NEW YORK.

		Stone 2mm.	Fine gravel 0-1 mm.	Coarse sand 1.-.5 mm.	Medium sand .5-.25 mm.	Fine sand .25-.1 mm.	Very fine sand .1-.05 mm.	Silt .05-.005 mm.	Clay .005 mm.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct*
Station	Soil...	3.86	1.64	1.54	3.76	9.44	27.06	34.11	22.37
	Subsoil	3.62	1.42	1.22	3.56	9.26	25.83	29.71	28.93
Niagara County	Soil...	......	0.9	4.2	3.3	6.4	13.5	52.9	18.4
	Subsoil	......	0	1.7	1.4	5.5	4.3	54.9	[2]32.1
Livingston County	Soil...	......	1.0	4.0	4.0	13.6	19.7	45.1	12.5
	Subsoil	......	1.1	4.8	4.1	13.9	20.3	35.2	20.4
Wayne County	Soil...	......	2.58	3.74	3.44	16.26	24.70	37.90	[3]10.98
	Subsoil	......	1.90	3.06	3.52	17.82	24.14	34.54	14.84
Cayuga County	Soil...	......	0.5	1.9	2.6	16.8	12	34.0	32.1
	Subsoil	......	tr.	1.5	1.5	9.2	6.6	40.1	[4]40.5

Further light is thrown upon the character of the soil by the following calculations per acre foot of the chief food constituents of the Station soil made from analyses of the soil of the experimental orchard before the experiment was begun.

TABLE II.— CHEMICAL COMPOSITION OF THE FIRST FOOT OF SOIL IN THE STATION ORCHARD.

	Lbs.
Organic matter	142,528
Iron and alumina	325,480
Lime	21,605
Magnesia	29,620
Potash	31,015
Phosphoric acid	3,240
Nitrogen	7,318

The Station soil is not an ideal one for apples, at best not better than the average western New York clay soil for this fruit. Though well drained, the land is yet hard and heavy and much of the time unworkable, coming from the plow in great lumps

[1] Furnished by Professor E. O. Fippin of the New York State College of Agriculture.
[2] Slightly heavier than typical.
[3] Rather coarser than typical.
[4] Considerably heavier than typical.

hardly to be crushed. In such a soil the root-run is limited,— a fact we have had forced upon our attention in early spring when the soil is wet, by the blowing over of several trees. Manifestly, food would be better utilized by trees in a soil where the roots could develop better. Despite the physical condition of the soil, apple trees make a very fair growth and the fruit sets in abundance, but with most varieties, and the Rome, used in this experiment, is not a marked exception, the apples run small, fail to color well and do not always mature properly.

THE PLATS AND THE FERTILIZERS.

The first applications of fertilizers were made in the fall of 1899. Figure 1 shows the arrangement of plats for the experi-

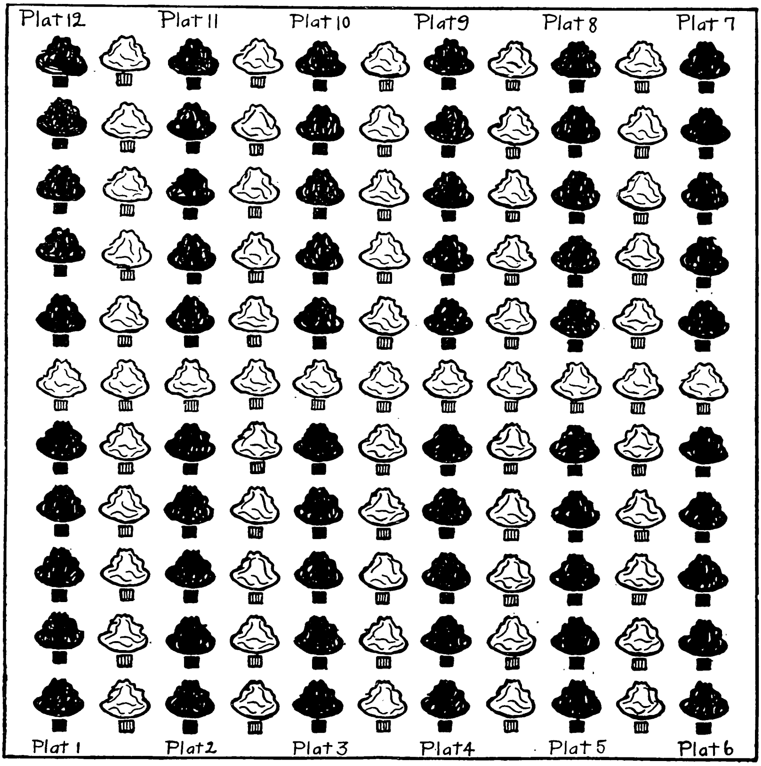

FIG. 1.— PLAN OF ORCHARD SHOWING LOCATION OF PLATS DIFFERENTLY FERTILIZED.

ment. The orchard, as the illustration shows, is divided into twelve plats, of five trees each, separated by single rows of trees not in the experiment. There are four fertilizer plats in duplicate in the experiment and four check plats. Unfortunately one of the twelve plats had to be discarded early in the experiment. Plat 7 in the southwest corner of the orchard is so near the brow of a small hill that the soil is shallower and poorer and the trees did not start off quite as well nor keep up in growth with those in the other plats. One of the trees also blew over. This plat had been intended as one of the four checks but the disparities in growth before the fertilizers had been applied, together with the accident a few years later, made it necessary to discard Plat 7 and retain but three of the checks. The remaining eleven plats were very uniform in vigor and health when the orchard received its first coating of fertilizer.

The experiment as planned calls for the use of fertilizers in the quantities commonly recommended for mature orchards, namely: 50 pounds of nitrogen per acre in stable manure on two plats; phosphoric acid at the rate of 50 pounds per acre on two plats; the same quantity of phosphoric acid plus 100 pounds of potash on two plats; with the quantities given above foro the three chemicals for two other plats; and three check plats. The chemicals were applied, beginning in 1900, in fertilizers[1] and in amounts determined each year by analyses as follows:

Stable manure	Plats 1 and 9, average per year	415.15 lbs. per tree
Acid Phosphate	" 2 and 8, " " "	12.6 " " "
Muriate of potash	" 6 and 10, " " "	7.26 " " "
Acid phosphate		12.6 " " "
Muriate of potash	" 4 and 12, " " "	7.26 " " "
Acid phosphate		12.6 " " "
Nitrate of soda		3.67 " " "
Dried blood		12.84 " " "

The fertilizers were put on as soon as the ground could be tilled in the spring and were distributed over an area about each tree slightly greater than that covered by the branches of the tree. The subsequent cultivations worked them in more or less deeply. The time of the applications varied a little from year to year in accordance with the weather and the availability of labor.

[1] The approximate values of the different applications per acre yearly are: Stable manure at $2.50 per ton $14.00; phosphoric acid $2.25; potash and phosphoric acid $6.50; complete fertilizer $15.50.

AN IMPORTANT CONSIDERATION.

The plan of this experiment calls for certain amounts of nitrogen, phosphorus and potash per acre. *Since the fertilizers have been put on only underneath the branches of the trees, a tremendous excess of each has been used.* By actual measurement the branches of the trees now cover less than one-eighth of the ground area. We are, therefore, applying this year eight times as much fertilizer per acre as would be applied if the trees were mature and covered approximately the whole area. Obviously the excess was much greater in years past when the trees were smaller; probably, at the beginning, twenty-five times the amounts planned were used per acre. There has been and is much talking about the harmful effects of fertilizers when used in quantities greater than the estimates as to what the tree could use. This experiment should throw light on the time-honored belief that excessive fertilization is deleterious to trees.

THE TREES: VARIETY, PROPAGATION, SETTING, TRAINING.

The apple in this experiment is Rome top-worked on Ben Davis. The choice as to variety fell to Rome because the trees bear at an early age; are exceptionally productive; the apples are red and any influence on the color is therefore readily detected; and Rome is a late keeping sort so that the effects of the several treatments on storage qualities should show to advantage. The variety was top-worked on another apple because Rome lacks vigor. Ben Davis was used as the stock because it is very vigorous, hardy, bears early, is productive, the fruit is red and keeps well. In the last four qualities Ben Davis resembles Rome, and should there be any influence of stock on cion it would be in a desirable direction for the purposes of this experiment.

Exceeding care was taken to obtain an orchard as free from individual variation in the trees as possible. To this end the Ben Davis stocks were selected as nearly alike as trees grow in height, caliper, mode of branching and character of root system. All came from the same nursery block in which they had been set as root-grafts three years previous. To further obviate variation, the buds for the trees in the experimental orchard came from a Rome tree of good growing and bearing habits in the Station variety orchard.

The trees in the orchard are amply cross-pollinated, though doubtfully necessary with the apple, the Rome especially, by the rows surrounding and separating the plats. In these divisional rows a variety test is being carried on with 117 varieties of apples, — 170 trees. The most ardent advocate of mixed planting for cross-pollination cannot find fault with the provisions for inter-pollination in this experiment.

Figure 2 shows a typical Ben Davis tree as it came from the nursery — about six and one-half to seven feet in height and from three-fourths to seven-eighths inch in diameter at the collar. When pruned for planting the trees averaged four and one-half feet in height. The work of transplanting was done in the spring of 1896 and beyond a somewhat severe drought there was no hindrance to the proper starting of the young orchard. The trees were set forty feet apart each way. The Romes were top-worked on the Ben Davis stocks, by budding, the last three days in July, 1896. Figure 3 shows the tree in Figure 2, budded, with the branches cut back to the buds in the spring of 1897. Figure 4 shows the same tree pruned in the spring of 1908.

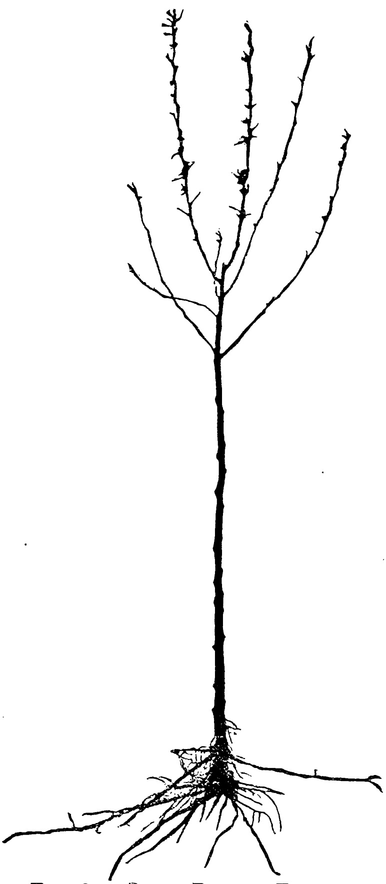

FIG. 2.— BEN DAVIS TREE FROM NURSERY, 1896.

It is very important that the reader take into account the severe pruning to which these trees have been subjected, made necessary by the top-working and by the desire to have a high headed tree. Cutting back the Ben Davis stocks to the Rome buds and the subsequent severe pruning for several seasons to obtain a well formed head and a long trunk, on the average about five feet from the lowest branch to the ground, in the opinion of the writer, delayed the bearing time of this orchard at least three years. Figure 5 is the same tree shown in the preceding illustrations but taken in October, 1899, two years

FIG. 3.— SAME TREE BUDDED; PRUNED FOLLOWING YEAR, 1897.

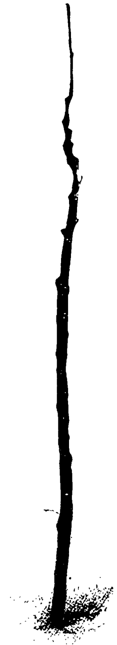

FIG. 4.— TREE IN FIG. 3 WITH BRANCHES CUT BACK, 1898.

after budding. A glance shows that the amount of wood to be taken out is considerable if a well-formed head is to be obtained.

The great number of relatively small branches produced in all over-pruned trees, especially those that have been top-worked, thus bringing about faults of the head to be corrected; or those that have been severely cut back to secure a high head, is shown in Figure 6 from a photograph taken December 18, 1901, and

Figure 7 from a photograph taken December 19, 1902. This digression from fertilizers to pruning is made not only to account for the late bearing of the trees under discussion and to illustrate the steps in the development of this experimental orchard, but to show the effects of high-heading and top-working, both practices which the writer does not advocate.

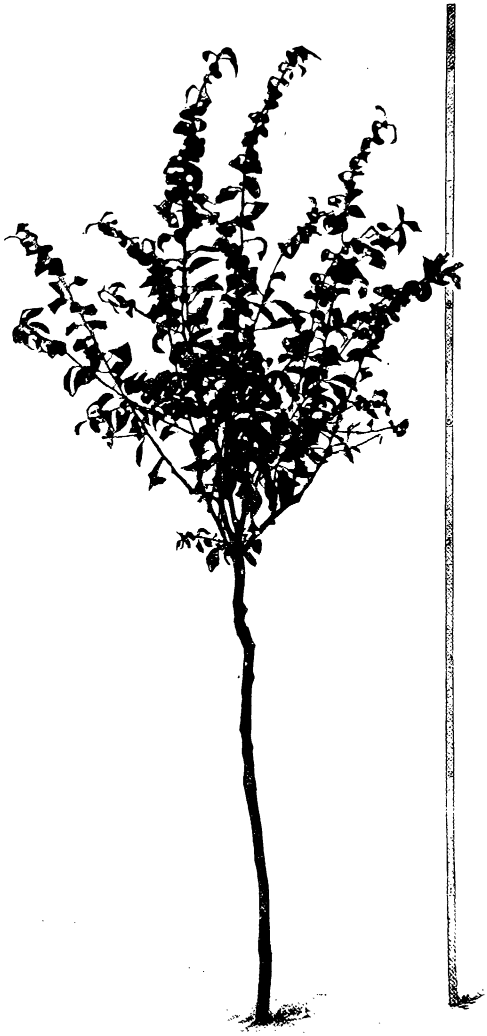

FIG. 5.—SAME TREE IN OCTOBER, 1899.

The further development of the orchard is shown by Plate I, made from a photograph taken on September 26, 1905; Plates II and III from photographs of October, 1910; and Plate IV illustrating the orchard just before plowing in the spring of 1911. The trees have been pruned as little as possible during the past six years with the hope that the bearing period might not be fur-

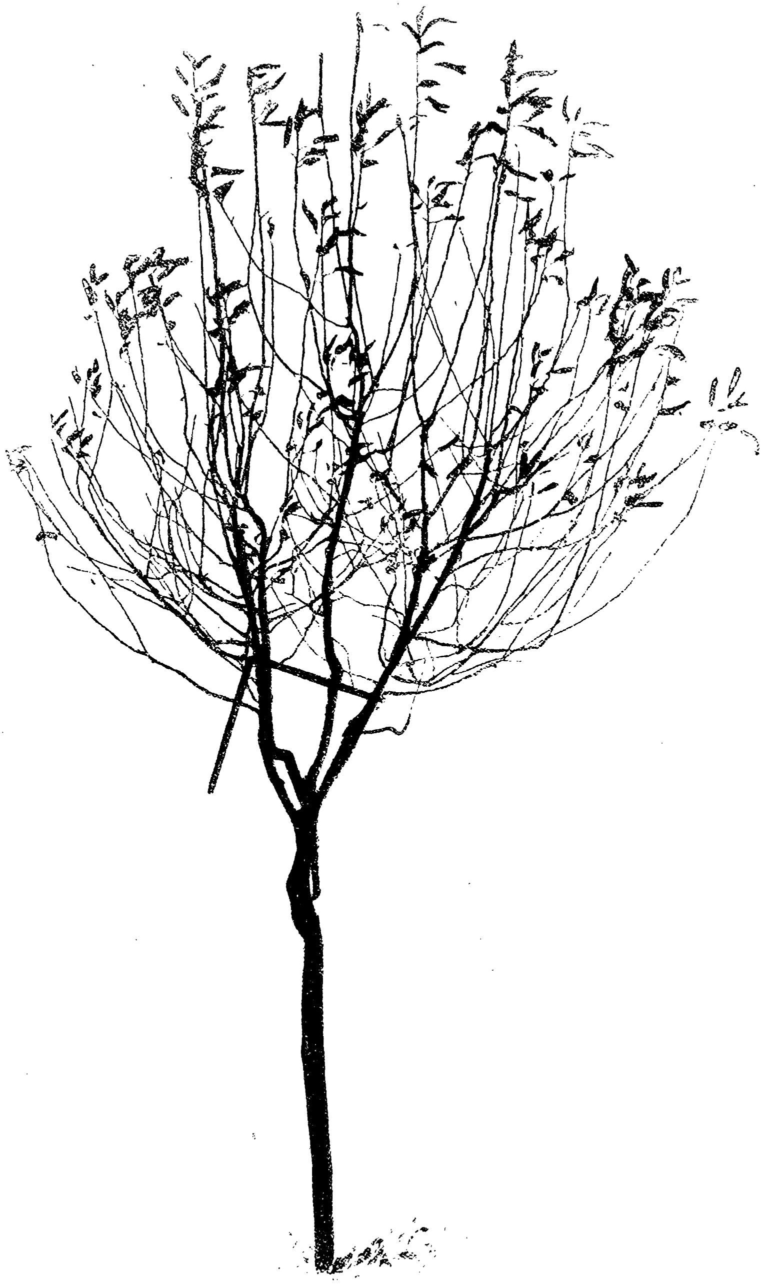

FIG. 6.— SAME TREE, DECEMBER, 1901.

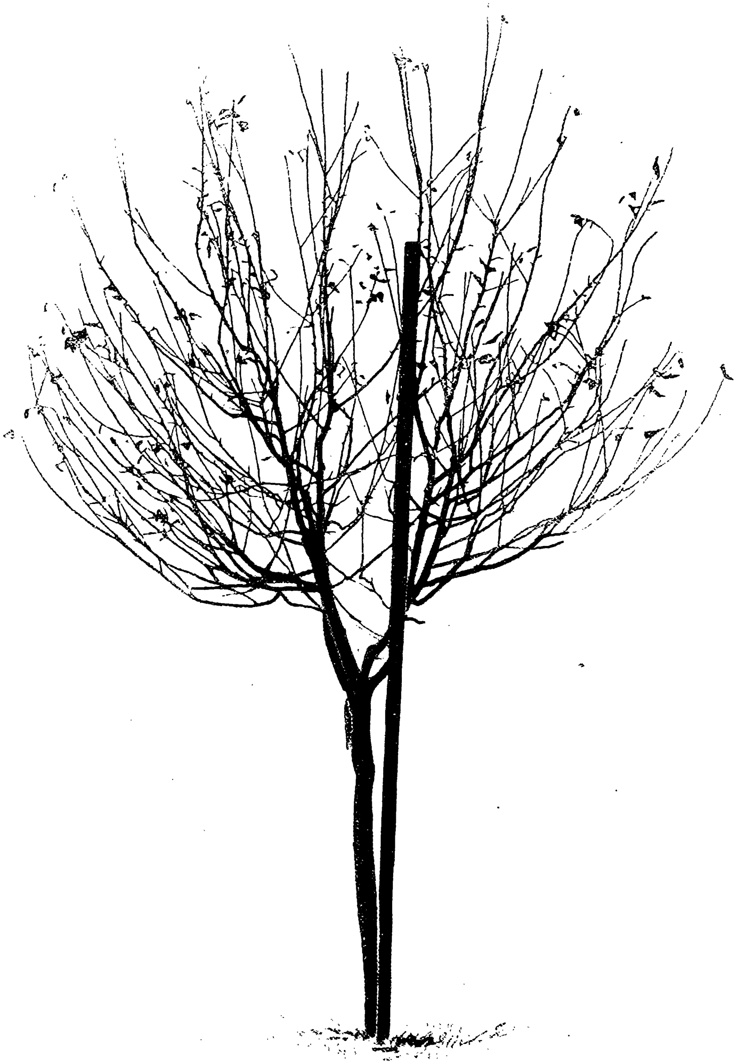

Fig. 7.—Same Tree, December, 1902.

ther delayed. In this later pruning, all that has been done has been to cut out crossed and injured branches, and these have been few, until the past winter, when the tops had become so very thick that they were thinned somewhat.

Every season since 1904, the trees have been sprayed for San José scale with lime and sulphur with one exception, discussed on p. 169, when a miscible oil was used. Since 1900 the trees have been regularly sprayed with bordeaux mixture and an arsenite at the times and in the manner practiced in commercial orchards.

CARE OF THE ORCHARD.

The aim has been to give the trees in this experiment the same care they would have received in a commercial plantation. The tillage has consisted of an early spring plowing, cultivation once in ten days or two weeks until the last of July, followed by a cover crop. Since leguminous cover crops would have added an unknown and variable amount of nitrogen to the soil, legumes have not been used. The cover crops grown, with a record of the time of planting and plowing under, are as follows:

COVER-CROPS IN EXPERIMENTAL ORCHARD.

YEAR.	Crop.	Sown.	Plowed under.
1896	Rape	Aug. 1	June 1.
1897	Wheat	Oct. 1	....
1898	Rye	Aug. 12	May 20.
1899	Rye	....	May 9.
1900	Rye	Sept. 24	May 28.
1901	Rye	Oct. 1	May 21.
1902	Rye	Sept. 13	May 13.
1903	Oats	July 30	June 4.
1904	Rye	Oct. 18	May 19.
1905	Barley	Sept. 8	May 8.
1906	Barley	July 21	May 1.
1907	Oats	Aug. 6	May 2.
1908	Rye	Oct. 5	May 19.
1909	Rape and cow horn turnip	Aug. 19	April 13.
1910	Barley and cow horn turnip	Aug. 6	April 27.

Plate I.—Tree in Figs. 2–7, Photographed in September, 1905.

Plate II.—Tree and Section of Orchard, October, 1910.

Plate III.— Closer View of Same Tree, October, 1910.

Plate IV.—Same Tree Before Plowing Orchard in Spring, 1911.

The rather extreme variations in the dates of planting and plowing under the cover crops are due to weather conditions and inability to command labor when the work needed to be done.

UNUSUAL CONDITIONS AFFECTING THE EXPERIMENT.

There were the usual seasonal fluctuations of temperature and humidity during the fifteen years of this experiment but there have been no meteorological conditions having any very unusual influence on the trees. If the fifteen years be compared with the fifteen just preceding[1] it will be found that the recent period is a much more favorable one for tree growth than the former one. In particular the last ten years have been favorable to the growth of trees and to fruit-bearing, there being no year in the decade that there has not been an average growth for apple trees and an average crop of apples in western New York.

The orchard, in common with all orchards in this part of the State, suffered severely during one season from an insect and another from disease. In the summer of 1903 there was a severe outbreak of apple aphis in New York and despite four sprayings with whale oil soap the trees were much injured by this pest. In June, 1906, there was an uncontrollable epidemic of blight in New York and all of the trees in this experiment were attacked by the disease and suffered terribly in both the new and old wood, the trees losing at least ten per ct. of their tops. The orchard has also suffered from an unfortunate accident. By mistake, the trees were experimentally sprayed with one of the miscible oils in the winter of 1907, wholly destroying the fruit-buds and many of the leaf-buds for that year. In all three of these disasters, however, the trees in the orchard were injured in equal degree so that the comparisons have not been materially changed by them. Two were calamities that occurred to all orchards in New York and there are but few orchards that do not suffer from some accident

[1] See U. P. Hedrick, Relation of Weather to Setting of Fruit, *N. Y. Sta. Bul. 299.* 1908.

in the course of fifteen years so that these trees can hardly be said to be abnormal because of the unusual circumstances in their lives.

RESULTS.

FACTORS CONSIDERED.

In gaging the value of fertilizers it is imperative that both fruit and tree be considered. Too often fruit alone is used to measure the value of a fertilizer and not infrequently only the yield of fruit is used. While fruit-bearing is the most important character it is so subject to extrinsic influences and consequent large accidental variations that it becomes necessary to use all characters of fruit and tree in determining the influence of a fertilizer. In the fruit, not only yield but size, color, flavor, time of maturity, texture of flesh, and keeping quality must be considered. For the measure of tree vigor there are also several characters available. Those we have chosen for this experiment are diameter of tree, color and weight of foliage, and the length and weight of the annual growth of the branches. All of these criteria taken separately are open to some objections — even when taken together it is impossible to draw wholly satisfactory deductions.

EFFECTS OF FERTILIZERS ON THE FRUIT.

Yield of fruit.— In Table III the amounts of fruit borne in the different plats for each year of this experiment are given, with averages per tree for all of the crops borne. The yearly yields of individual trees in the experiment, with the averages per tree, are given in Table IV.

The tables need little amplification. The orchard bore its first crop of fruit in 1902, when the trees were in their seventh year, and has borne six crops since. An examination of the figures in Table III for the eleven plats shows that the fertilizers have had no sensible effects upon the yield of fruit in this experiment; and the figures in Table IV, for the individual trees, emphasize this conclusion. If two or three seasons in this fifteen-year experiment be considered as a single period, advantages might be claimed for some one or another of the plats, but when a longer period, or the total, is considered, the advantage is in every case contradicted — incidentally these contrarieties show the necessity of a long-time experiment with fertilizers for apples.

Total crop production is not the fairest criterion of the value of the treatment of the different plats in this experiment; for, the 1910 crop is nearly as large as the six other crops combined and a variation from some cause other than the fertilizers in this one season destroys the value of the total crop figures. A fairer criterion is the average rank of the plats as to productivity for the seven years. So gaged, we find that the plats rank as follows: Stable manure was third in productivity three times, fourth three times and fifth once. The phosphoric acid plat in two seasons was most productive, once second, three seasons fifth and once fourth in productivity. The plat to which potash and phosphoric acid were applied was twice most productive, twice second in productivity, once third, once fourth and once fifth. The complete fertilizer plat yielded most fruit only one year, was twice second on the list, twice third, once fourth, and once fifth. The differences between the plats represented in the above figures are so small, however, that they do not prove in the least the superiority of one treatment over the other.

TABLE III.— YIELD OF FRUIT FROM DIFFERENT PLATS IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZERS.	1902.	1903.	1905.	1906.	1908.	1909.	1910.	Average per tree.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Stable manure.....	27.85	71.64	597.73	215.73	1,822.98	288.62	3,308.60	90.47
Phosphoric acid....	15.79	119.59	545.46	238.67	1,950.09	325.00	2,936.24	87.57
Phosphoric acid and potash..........	42.03	90.65	556.39	137.17	1,930.17	622.74	3,855.48	103.34
Phosphoric acid, potash and nitrogen............	53.59	67.34	644.71	203.28	1,914.23	496.55	3,658.09	99.10
*Check...........	60.95	145.45	1,029.50	358.10	2,589.37	752.97	4,750.84	92.25

* Yearly yields are from fifteen trees; ten trees in all other plats.

TABLE IV.— YEARLY YIELDS OF INDIVIDUAL TREES IN ORCHARD FERTILIZER EXPERIMENT.

	Location.		1902.	1903.	1905.	1906.	1908.	1909.	1910.	Total.
	Row No.	Tree No.								
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Plat 1. Stable manure	1	1	9.06	3.50	66.56	20.25	211.00	21.75	368.25	700.37
	2	1	1.50	5.93	97.43	26.12	259.87	42.50	421.75	855.10
	3	1	.37	28.43	87.75	40.62	244.31	15.00	482.62	899.10
	4	1	....	.68	29.00	13.25	107.37	15.00	219.25	384.55
	5	1	3.37	....	90.06	43.62	293.25	42.50	429.00	901.80
Plat 9. Stable manure	7	7	6.06	16.25	85.12	18.25	185.50	20.00	319.62	650.80
	8	7	6.62	8.18	61.75	19.12	168.50	26.00	314.12	604.29
	9	7	....	1.68	49.25	17.00	128.00	43.00	283.75	522.68
	10	7	.87	2.06	12.75	6.50	102.75	27.00	242.37	394.30
	11	7	....	4.93	18.06	11.00	122.43	35.87	227.87	420.16
Average per tree	......	......	2.78	7.16	59.77	21.57	182.29	28.86	330.86	633.31
Plat 2. Phosphoric acid	1	3	5.81	.56	35.62	11.87	184.25	36.50	242.87	517.48
	2	3	1.25	....	96.68	44.75	356.37	11.50	488.50	999.05
	3	3	.56	22.43	71.00	42.00	241.81	23.00	431.25	832.05
	4	3	....	13.81	76.37	28.12	208.00	22.50	129.37	478.17
	5	3	1.56	52.31	123.75	61.81	229.75	25.50	382.25	876.93
Plat 8. Phosphoric acid	7	9	1.43	12.62	10.81	8.25	166.62	34.50	292.00	526.23
	8	9	....	....	17.00	10.87	75.00	16.50	126.75	246.12
	9	9	3.62	8.93	60.62	21.25	222.18	56.00	410.50	783.10
	10	9	....	8.93	15.43	5.00	105.93	48.50	149.25	333.04
	11	9	1.56	....	38.18	4.75	160.18	50.50	283.50	538.67
Average per tree	......	......	1.57	11.95	54.54	23.86	195.00	32.50	293.62	613.08

Plat 6. Phosphoric acid and potash...	1	11	7.68	4.43	59.62	14.87	252.00	137.87	466.50	942.97
	2	11	9.12	....	81.18	7.00	196.37	89.50	330.25	713.42
	3	11	3.25	3.25	21.87	12.37	108.00	43.50	291.12	483.36
	4	11	14.12	10.68	98.43	16.00	264.00	88.50	531.12	1,022.85
	5	11	.56	7.31	48.68	5.25	123.00	36.37	372.00	593.17
Plat 10. Phosphoric acid and potash...	7	5	1.31	10.18	31.37	22.43	289.37	45.50	486.75	886.91
	8	5	1.37	8.81	66.50	17.75	120.00	49.00	304.62	568.05
	9	5	.50	8.25	59.75	13.00	168.75	48.00	416.75	715.00
	10	5	4.12	22.06	47.37	7.50	299.00	40.50	411.00	831.55
	11	5	....	15.68	41.62	21.00	109.68	44.00	245.37	477.35
Average per tree..............	......	......	4.20	9.06	55.63	13.71	193.01	62.27	385.54	723.46
Plat 4. Phosphoric acid and potash and nitrogen..................	1	7	15.43	1.75	109.87	23.12	326.00	60.50	516.62	1,053.29
	2	7	6.25	1.68	96.68	33.12	272.62	67.50	465.37	943.22
	3	7	4.43	3.93	66.37	11.12	120.00	47.50	449.75	703.10
	4	7	....	.25	7.18	4.00	53.00	27.18	212.50	304.11
	5	7	3.43	30.62	116.31	40.25	260.00	34.00	401.25	885.86
Plat 12. Phosphoric acid and potash and nitrogen..................	7	1	.68	12.12	29.31	16.12	151.68	28.37	191.87	430.15
	8	1	2.50	1.00	33.25	11.50	88.25	38.50	100.12	275.12
	9	1	9.75	14.56	90.93	18.43	277.00	35.00	521.87	967.54
	10	1	11.12	....	81.50	35.12	280.68	75.00	571.87	1,055.29
	11	1	....	1.43	13.31	10.50	85.00	83.00	226.87	420.11
Average per tree..............	......	......	5.35	6.73	64.47	20.32	191.42	49.65	365.80	703.77
Plat 3. Check......................	1	5	....	....	15.68	12.00	98.25	39.50	146.62	312.05
	2	5	4.37	6.43	91.93	16.75	185.00	27.18	331.50	663.16
	3	5	3.81	10.56	130.06	17.75	256.00	34.18	288.75	741.11
	4	5	2.56	7.56	81.62	30.50	207.87	23.37	374.12	727.60
	5	5	15.37	38.68	131.81	39.75	200.25	55.00	550.62	1,121.48

Table IV.— Yearly Yields of Individual Trees in Orchard Fertilizer Experiment — (*Concluded*).

	Location.		1902.	1903.	1905.	1906.	1908.	1909.	1910.	Total.
	Row No.	Tree No.								
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Plat 5. Check	1	9	3.12	3.75	56.00	6.50	168.00	101.37	233.37	572.11
	2	9	1.93	1.87	70.18	35.37	156.00	26.00	370.00	661.35
	3	9	4.93	....	62.87	24.87	144.00	63.00	343.75	643.42
	4	9	....	....	35.25	18.50	117.00	36.87	207.37	414.99
	5	9	1.93	27.37	68.62	20.87	121.50	53.00	261.75	555.04
Plat 11. Check	7	3	....	.37	18.62	22.75	76.00	15.50	126.25	259.49
	8	3	7.00	8.56	52.00	22.50	123.25	70.50	241.25	525.06
	9	3	7.06	16.18	80.93	37.12	216.00	87.50	422.37	867.16
	10	3	8.81	12.87	86.75	32.62	235.00	36.00	527.50	939.55
	11	3	....	11.25	47.18	20.25	195.25	84.00	325.62	683.55
Average per tree	......	......	4.06	9.69	68.63	23.87	172.62	50.19	316.72	645.80

Size of apples is possibly increased by the fertilizers.— Table V is a comparison of the first, second and cull apples in the different treatments in 1910. All apples between two and one-half and two and one-quarter inches are seconds, under two and one-quarter inches, culls. This harvest possibly shows an influence of the fertilizer. Table V gives the percentage of seconds for the check plats a trifle higher than the average and the percentage of culls higher than the maximum. The differences, however, are very slight and unless future crops show the same falling off in size for the checks, increased size must not be counted as an asset for the fertilizers in the experiment up to the present, but rather as an accidental variation. Table VI shows a greater number of apples on the check plats.

TABLE V.— YIELDS OF FIRST, SECOND AND CULL APPLES, 1910, IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZERS.	Firsts.	Seconds.	Culls.	Percentage of seconds.	Percentage of culls.
	Lbs.	*Lbs.*	*Lbs.*		
Stable manure	3,160.8	107.7	40.3	3.2	1.2
Phosphoric acid	2,784.5	105.7	46.1	3.6	1.6
Phosphoric acid and potash	3,585.5	187.0	83.0	4.9	2.1
Phosphoric acid and potash and nitrogen	3,421.5	168.2	68.5	4.6	1.8
*Check	4,407.6	216.4	98.8	4.6	2.9

* Fifteen check trees; ten in all other treatments.

TABLE VI.— WEIGHT OF APPLES IN 1910, DIFFERENT PLATS OF ORCHARD FERTILIZER EXPERIMENT.

FERTILIZERS.	Number of apples.	Average weight per apple.
		Ounces.
Stable manure	1,134	6.4
Phosphoric acid	1,163	6.1
Phosphoric acid and potash	1,126	6.3
Phosphoric acid and potash and nitrogen	1,115	6.5
Check	1,748	6.2

The value of the tables showing the differences in the size of the fruits from the several plats is greatly reduced because we do not know how to interpret the facts shown. It is an open question as to whether the size of individual apples or the number of fruits is the more accurate measure of the vigor of the trees and therefore of the plant food used. Small apples contain as many seeds, and a relatively larger amount of dry matter than large apples. Total quantities being the same, then, small apples should have exhausted the soil more than large ones. But the figures given in the several tables do not fit this theory, nor any other, thus strengthening the supposition that the differences are but expressions of accidental variations.

The fertilizers exert no influence on the color of fruit.—It is commonly thought that the color of fruits can be modified by the use of fertilizers. This phase of the experiment was therefore approached with much interest. The clay soil in this orchard is a very favorable one upon which to try to influence color since it is common knowledge that apples take on bright colors on sandy soils and run to dull or green hues on clays.

The annual notes on color for these seven crops of apples can be summed up with the expression for each crop, "No differences in color can be noted." The apples were looked at in different quantities, in different lights, at varying intervals after being put in storage, and by several persons, with the invariable conclusion that the color was the same on the fruits of all the plats. The coloring has varied more or less from year to year but not at all with the different treatments. Color in fruit in New York is usually an indication of vigor in a tree. Other things being equal the more vigorous the tree, with a red apple like the Rome, the more green is the fruit. The fact that the fruits in the several plats in this experiment are all colored alike is another proof that the fertilizers have not affected the growth of these trees.

The popular generalizations as to the effects of fertilizers on the color of fruits, as "potash paints fruits," and "manure makes green apples," find no verification in this experiment.

Effects on maturity, keeping-quality, texture and flavor of apples.— There is a general supposition that all of the qualities named in the heading of this paragraph are more or less affected by fertilizers. Facts to bear out such a supposition usually arise as the vigor of the tree is influenced. Great vigor in a tree delays maturity somewhat, thereby producing a better keeping apple, and influences favorably the texture and flavor of the apple by making the flesh more juicy and crisp. These effects of vigor were very manifest in an experiment carried on by this Station in comparing tillage and sod-mulch in an apple orchard.[1] But in none of these qualities were there noteworthy differences in the apple growth under the several treatments in this experiment. Very commonly, in comparison of orchard management methods, the flesh of the apple shows the result of some disturbance of the "protoplasmic gearing" in the production of dry or corky spots in the flesh, in water-coring or in a tendency to mealiness. There have been no such manifestations of physiological trouble in any of the plats in this experiment. The great uniformity in the product of all of the trees seems to point to the conclusion that the fertilizers have had trifling or no effects.

INDIVIDUALITY OF TREES.

The advocates of individuated strains of fruits may find valuable material for buttressing their theories in the yields given for individual trees in Table III. There is food for thought as one notes the wide variations in the performance of individuals in the several plats of this experiment and remembers that all of the trees came from buds from a single tree. Can the yield performance of the best trees, as shown by the table, be transmitted to trees propagated from them? There has been no precise experimenting and but little precise thinking on the subject of individuated strains of fruits now so much before fruit-growers. The writer fears that the data given here, if used to substantiate any of the current theories, would but add to existing inexactness and in-

[1] Hedrick, U. P. A Comparison of Tillage and Sod-Mulch in an Apple Orchard. *N. Y. Sta. Bul.* **314**:98–102.

definiteness. This experiment, while suggestive, does not warrant the conclusion that there are great differences in the disposition of trees in fruitfulness. Fruit-bearing is hardly an established habit of the orchard as yet; and the trees have not recovered from top-working and over-pruning and the consequent upsetting of natural habits. The lack of uniformity in the yields of the trees in the several plats in this experiment is probably most largely due to outside influences. In all other characters these trees seem to be chips of the old block. Experimenters, fruit-growers and nurserymen are not distinguishing sharply enough between what is due to "nature" and what is due to "nurture" in the "individuality," "tendency" or "character"— phrase it as you will, none are precise — of trees. This inexactness is leading to much fallacious endeavor in perpetuating fruits as "pedigreed stock."

EFFECTS OF THE FERTILIZERS ON TREE CHARACTERS.

Crop performance is the ultimate measure of soil treatment in an orchard. But in a period of so few years as the one in which the orchard under experiment has been in bearing, it is possible for the trees to bear large crops at the expense of vigor and therefore curtail future bearing capacity; variations in the amounts of fruit may also arise from other causes than the supply of food.

It is necessary, then, to consider the effects of the several fertilizers on tree growth. In doing so, as many characters of the tree must be used as possible, for all may not respond in the same degree to the treatment. If the characters for measuring tree vigor have been well chosen and if accurate methods have been used, there should be close agreement in the growth of different parts of trees as affected by the several treatments. Thus, as we have seen, in fruit characters there has been nearly perfect agreement as to the influence of the different fertilizers. It will be interesting to note whether the trees have responded in like agreement.

Diameter of trees.— Probably the best tree character by which to measure vigor, especially over a long series of years, is the diameter of the trunk. From a cross-section of a tree one can tell very accurately of the fat and lean seasons in its life by the thickness of the rings. The increase in the diameter of the trunk is thus in direct proportion to the vigor of the tree. Unfortunately it is somewhat difficult to secure a high degree of accuracy in applying this test of vigor. Tree trunks are by no means perfect cylinders, and in taking the diameters it is hard to decide where the measurement should be taken.

In this experiment, after various preliminary trials, two measurements were made on each trunk from which an average was drawn. The diameter was taken one foot from the ground and again four feet above the ground. The summarized averages are shown in Table VII and the measurements for individual trees are shown in Table VIII. A critical study of the two tables shows no differences outside the range of accidental variation. In the mind of the writer the evidence afforded by the tree trunks in this experiment is the clearest cut of any offered. One trained in statistical niceties can juggle the figures of fruit-yields and make them prove several things, but there is little opportunity for juggling with the figures from the tree-trunks.

TABLE VII.— SUMMARY OF INCREASE IN DIAMETERS OF TREE TRUNKS IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZER.	Diameter in 1905.	Diameter in 1910.	Gain.
	Inches.	*Inches.*	*Inches.*
Stable manure	3.85	6.26	2.41
Phosphoric acid	3.58	5.98	2.40
Phosphoric acid and potash	3.86	6.35	2.49
Phosphoric acid, potash and nitrogen	3.75	6.18	2.43
Check	3.73	6.14	2.41

TABLE VIII.—INCREASE IN DIAMETERS OF TREE TRUNKS IN ORCHARD FERTILIZER EXPERIMENTS.

FERTILIZER.	Row.	Tree.	Dia. in 1905.	Dia. in 1910.	Gain.
			Inches.	*Inches.*	*Inches.*
Plat 1. Stable manure.	1	1	4.25	6.62	2.37
	2	1	4.25	6.62	2.37
	3	1	3.93	6.68	2.75
	4	1	3.81	6.06	2.25
	5	1	3.68	6.02	2.34
Plat 9. Stable manure.	7	7	3.74	6.37	2.63
	8	7	3.68	6.12	2.44
	9	7	4.06	5.81	1.75
	10	7	3.43	6.12	2.69
	11	7	3.68	6.18	2.50
Average..	.....	.....	3.85	6.26	2.41
Plat 2. Phosphoric acid.	1	3	3.74	6.15	2.41
	2	3	3.87	6.56	2.69
	3	3	3.87	6.56	2.69
	4	3	3.56	5.81	2.25
	5	3	4.06	6.49	2.43
Plat 8. Phosphoric acid	7	9	3.37	5.87	2.50
	8	9	3.18	5.31	2.13
	9	9	3.62	6.12	2.50
	10	9	3.25	5.50	2.25
	11	9	3.31	5.50	2.19
Average..	.....	.....	3.58	5.98	2.40

FERTILIZER.	Row.	Tree.	Dia. in 1905.	Dia. in 1910.	Gain.
			Inches.	*Inches.*	*Inches.*
Plat 6. Phosphoric acid and potash.	1	11	4.24	6.75	2.51
	2	11	4.00	6.25	2.25
	3	11	3.75	6.56	2.81
	4	11	4.18	6.98	2.80
	5	11	3.87	6.25	2.38
Plat 10. Phosphoric acid and potash	7	5	3.75	6.62	2.87
	8	5	3.75	6.31	2.56
	9	5	3.74	6.37	2.63
	10	5	3.99	5.87	1.88
	11	5	3.37	5.56	2.19
Average..	.....	.....	3.86	6.35	2.49
Plat 4. Phosphoric acid, potash and nitrogen.	1	7	4.25	6.68	2.43
	2	7	3.93	7.00	3.07
	3	7	4.18	6.56	2.38
	4	7	3.25	5.37	2.12
	5	7	4.00	6.37	2.37
Plat 12. Phosphoric acid, potash and nitrogen.	7	1	3.24	5.93	2.69
	8	1	3.24	5.00	1.76
	9	1	3.99	6.68	2.69
	10	1	4.06	6.68	2.62
	11	1	3.37	5.56	2.19
Average..	.....	.....	3.75	6.18	2.43

FERTILIZER.	Row.	Tree.	Dia. in 1905.	Dia. in 1910.	Gain.
			Inches.	*Inches.*	*Inches.*
Plat 3. Check.	1	5	3.68	5.59	1.91
	2	5	3.81	6.31	2.50
	3	5	4.24	6.18	1.94
	4	5	3.81	6.25	2.44
	5	5	4.31	6.93	2.62
Plat 5. Check.	1	9	4.00	6.56	2.56
	2	9	3.81	5.99	2.18
	3	9	3.62	6.68	3.06
	4	9	3.00	5.43	2.43
	5	9	3.49	5.87	2.38
Plat 11. Check.	7	3	3.06	5.25	2.19
	8	3	3.68	5.81	2.13
	9	3	3.68	6.43	2.75
	10	3	4.12	6.59	2.47
	11	3	3.62	6.25	2.63
Average..	.....	.....	3.73	6.14	2.41

The foliage.— When light falls upon the green coloring matter of the leaf, plant machinery is set in motion which makes new compounds out of water and carbon dioxide and combines them with nitrogen and other elements. The material so made becomes living matter. The leaf in this complex work responds to every change in the condition of the plant and is especially responsive to the materials which it assimilates and transforms into organic matter. Yet because of the countless number, and since there is great variation in individual leaves, it is exceedingly difficult to measure accurately the changes that take place in the foliage through changes in the diet of the plant. Very largely reliance must be placed upon the observation of the experimenters. Leaves are, however, so delicate an index of the state of nutrition of a plant that a practiced eye can be relied upon to tell how well a tree is nourished from leaves even though to the untrained eye they look "all the same."

Color of foliage.—As good a gage to the vigor of a tree as any of the characters of the leaf, is the color. The leaves of a well-fed, healthy, vigorous tree are a dark rich green. With even a slight departure from good-feeding, health and vigor, the foliage takes on a lighter color varying toward yellow. To an experienced observer the color of the foliage in an orchard in which soil, variety, age, care and the great majority of conditions are the same, should find color of foliage as ready a test of the tree's condition as is the pulse or the temperature in animal life. Until 1910 the notes of this experiment record no differences in the color of the foliage in the different plats, but in the year named, especially after mid-season, there was a perceptibly greener tinge in the foliage of trees on plats to which nitrogen had been applied — the first difference to be counted as an effect of the fertilizers used in this experiment.

Size of leaves.— The size of the leaves must of course be a valuable index to the condition of the tree. Differences here, however, cannot be detected accurately enough by the eye; there seems to be no feasible way of obtaining the leaf area either of individual leaves or the total area; and there are objections to measuring size by taking the weight. The last method, however, is the only one that could be devised for this experiment and leaf weights were therefore taken the figures for which are set forth in Tables IX and X.

TABLE IX.— WEIGHTS OF 100 LEAVES FROM INDIVIDUAL TREES IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZER.	Row.	Tree.	Green.	Dry.
			Gms.	*Gms.*
Plat 1. Stable manure.	1	1	93.2	39.6
	2	1	92.0	39.5
	3	1	105.8	45.0
	4	1	97.9	43.7
	5	1	74.0	32.1
Plat 9. Stable manure.	7	7	88.5	40.2
	8	7	86.9	38.7
	9	7	120.2	53.6
	10	7	103.2	46.5
	11	7	97.2	45.0
Average...	......	......	95.9	42.4
Plat 2. Phosphoric acid.	1	3	85.8	39.3
	2	3	91.4	40.8
	3	3	105.8	48.4
	4	3	104.8	47.3
	5	3	84.1	39.0
Plat 8. Phosphoric acid.	7	9	94.0	42.9
	8	9	81.5	37.7
	9	9	77.7	34.6
	10	9	83.4	39.3
	11	9	76.1	37.0
Average...	......	......	88.5	40.6

FERTILIZER.	Row.	Tree.	Green.	Dry.
			Gms.	*Gms.*
Plat 6. Phosphoric acid and potash.	1	11	100.0	47.1
	2	11	95.6	44.5
	3	11	89.5	40.9
	4	11	105.6	47.5
	5	11	82.3	37.1
Plat 10. Phosphoric acid and potash.	7	5	96.0	42.7
	8	5	78.5	36.8
	9	5	104.5	46.5
	10	5	83.5	36.2
	11	5	73.0	32.8
Average...	......	......	90.9	41.2
Plat 4. Phosphoric acid, potash and nitrogen.	1	7	93.7	42.2
	2	7	90.3	39.5
	3	7	105.0	45.6
	4	7	94.3	43.0
	5	7	100.2	46.6
Plat 12. Phosphoric acid, potash and nitrogen.	7	1	111.4	47.0
	8	1	105.5	45.6
	9	1	86.2	37.8
	10	1	116.1	47.0
	11	1	91.9	40.2
Average...	......	......	99.5	43.5

FERTILIZER.	Row.	Tree.	Green.	Dry.
			Gms.	*Gms.*
Plat 3. Check.	1	5	76.4	36.9
	2	5	74.9	34.6
	3	5	75.2	34.8
	4	5	83.9	38.0
	5	5	83.9	38.2
Plat 5. Check.	1	9	82.4	38.9
	2	9	74.7	34.1
	3	9	77.5	36.3
	4	9	84.2	39.2
	5	9	87.4	40.2
Plat 11. Check.	7	3	69.8	34.3
	8	3	80.6	37.0
	9	3	80.6	36.6
	10	3	87.3	38.7
	11	3	82.7	37.0
Average.....	......	......	80.1	36.9

TABLE X.— SUMMARY OF WEIGHTS OF 100 LEAVES IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZER.	Green.	Dry.
	Gms.	*Gms.*
Stable manure	95.9	42.4
Phosphoric acid	88.5	40.6
Phosphoric acid and potash	90.9	41.2
Phosphoric acid, potash and nitrogen	99.5	43.5
Check	80.1	36.9

Leaves from the several plats were taken for weighing as follows: Beginning at the base of the year's growth the first four were discarded because these first leaves are usually poorly developed. The next five were taken for weighing, the process being repeated twenty times from shoots well distributed about the tree, making 100 selected leaves from each tree. Within an hour after being picked the leaves were weighed, all of the work being done in the middle of the day. The leaves were then air-dried in a warm, dry room and reweighed — both weights appearing in the tables.

Here again we seem to have a measurable effect of the nitrogen. While the effect is very appreciable, it must be remembered that the leaf weights were taken only in 1910 and that weighty conclusions are not warranted. The nitrogen plats are scarcely above the average in fruit-bearing and it may be that the increase in leaf-size is due to the falling short, as compared with the maximum yields, in the fruit; or, of course it may be an initial gain for the nitrogen — a prophecy of larger gains for the coming years.

Leafing-time and blooming-time.— The time of the life events under discussion often varies a few days when plants are subjected to different treatments. Thus, in a comparison of tillage and sod-mulch made by this Station, the leafing time of the plants of tilled trees comes first and the leaves of the sod-mulched trees drop first.[1] If the fertilizers were influencing the trees markedly differently in this experiment, it might be expected that there would be some differences in leafing-time and blooming-time. There have been none, however,— contributory evidence to the inertness of the fertilizers so far as these trees are concerned.

Annual growth of branches.— The amount of new wood a tree makes in a season is an important criterion of the response of the tree to the treatment. It measures not only present vigor but future bearing capacity. It must be remembered, however, that there is much variation in the annual growth of a tree depending upon the position of the branches. With the Rome, the difficulty is great, too, because of the much branched, twiggy habit of growth of the variety. After considering several methods of selecting the shoots for measuring and weighing, twenty annual growths were cut, distributed throughout the periphery of the head of each tree. The length and weight of these growths for each tree and each plat are shown in Tables XI and XII.

Here again we have evidence, slight though it be, that the trees on plats to which nitrogen is applied are making greatest growth. The annual growth on the trees in the stable manure plat averages for 1910 nearly an inch longer than the average for all of the trees in the experiment. If this average were for a number of years it should be counted as a most marked influence of nitrogen, but unfortunately we have data for only 1910, a serious defect in our note-taking, and in 1910 the trees in the stable manure plat, for example, bore less than an average crop of fruit for the whole experiment and it is possible, indeed probable, that these trees made a relatively large growth of wood because they were bearing a relatively small crop of fruit. So while this greater annual growth must be looked upon, together with color and weight of leaves, as proof that the nitrogen-fed trees made in 1910 greatest growth, it must be remembered that from the evidence of the diam-

[1] Hedrick, U. P. A Comparison of Tillage and Sod Mulch in an Apple Orchard; *N. Y. Sta. Bul.* **314**:106. 1909.

TABLE XI.— LENGTH AND WEIGHT OF ANNUAL GROWTH, 1910, IN ORCHARD FERTILIZER EXPERIMENT.

FERTILIZER.	Row.	Tree.	Length.	Weight.	FERTILIZER.	Row.	Tree.	Length.	Weight.	FERTILIZER.	Row.	Tree.	Length.	Weight.
			In.	*Gms.*				*In.*	*Gms.*				*In.*	*Gms.*
Plat 1. Stable manure.	1	1	10.9	111.0	Plat 6. Phosphoric acid and potash.	1	11	7.7	69.2	Plat 3. Check,	1	5	6.4	52.0
	2	1	9.4	83.4		2	11	7.7	79.4		2	5	8.4	83.2
	3	1	9.9	96.6		3	11	8.9	87.4		3	5	8.8	87.0
	4	1	9.1	80.0		4	11	9.6	101.4		4	5	10.5	100.4
	5	1	9.0	80.0		5	11	9.7	101.0		5	5	9.5	89.0
Plate 9. Stable manure.	7	7	11.0	117.0	Plate 10. Phosphoric ac'd and potash	7	5	9.3	98.4	Plate 5. Check.	1	9	6.3	55.2
	8	7	8.7	77.0		8	5	8.1	79.4		2	9	7.9	67.2
	9	7	8.8	86.0		9	5	8.8	89.0		3	9	7.7	68.4
	10	7	10.1	90.0		10	5	9.3	87.0		4	9	7.9	72.0
	11	7	8.0	76.4		11	5	5.3	43.8		5	9	8.2	84.0
Average...	...	...	9.5	89.8	Average....	...	...	8.5	88.6	Plat 11. Check.	7	3	7.4	56.6
Plat 2. Phosphoric acid.	1	3	8.9	79.0	Plat 4. Phosphoric acid, potash and nitrogen.	1	7	8.7	82.0		8	3	8.2	68.0
	2	3	9.8	95.6		2	7	9.9	107.0		9	3	8.6	80.8
	3	3	9.3	89.0		3	7	9.5	102.0		10	3	9.4	89.6
	4	3	10.6	96.2		4	7	7.9	67.6		11	3	7.4	62.0
	5	3	9.5	93.4		5	7	9.3	98.0	Average....	...	...	8.2	74.4
Plate 8. Phosphoric acid.	7	9	10.7	106.0	Plate 12. Phosphoric acid, potash and nitrogen.	7	1	10.6	102.0					
	8	9	7.7	69.6		8	1	8.7	77.8					
	9	9	7.7	58.6		9	1	8.7	79.6					
	10	9	6.9	57.2		10	1	10.0	103.0					
	11	9	8.2	72.6		11	1	6.3	47.6					
Average...	...	...	8.9	81.7	Average....	...	...	9.0	86.7					

Table XII.— Summary of Length and Weights of Annual Growth in Orchard Fertilizer Experiment, 1910.

FERTILIZER.	Length.	Weight.
	Inches.	*Grams.*
Stable manure	9.5	89.8
Phosphoric acid	8.9	81.7
Phosphoric acid and potash	8.5	88.6
Phosphoric acid, potash and nitrogen	9.0	86.7
Check	8.2	74.4

eters of the trunks, such has not been the case in the past. We await with interest data to show whether this increased growth is to take place annually in the coming years.

SUMMARY OF RESULTS.

Fertilizers for apples make a very poor showing in this experiment. Thus, the growth of tree trunks, for the ten seasons fertilizers have been applied, has been the same for treated and check plats — almost conclusive evidence against the fertilizers if the whole period be considered. The yield of seven crops of fruit seems not to have been increased by the use of the fertilizers. Color, flavor, keeping quality and the like have not been influenced by the fertilizers. The favorable evidence is all furnished in 1910. The apples in the crop of this year run slightly largest on plats to which nitrogen was applied; the leaves on the plats were greenest and largest and the annual growths were largest and heaviest. Unfortunately, this data was not taken for the years previous to 1910, but it may be assumed that even the slight favorable influences shown in the characters named, if of annual occurrence, would have told in the crops and in the trunk diameters. It is fair, lacking definite evidence, to call them the initial influences of nitrogen and to await coming years to see if they be continued and if the effects in 1910 make a permanent impression on the trees. It may be that the differences should be set down as due to some accidental circumstance. At the most they are not of sufficient magnitude as yet to warrant the conclusions that the applications of fertilizers have been materially beneficial.

The nitrogen applied is for most part lost. The potash and phosphoric acid are stored where " neither moth nor rust can corrupt." The storage, however, of these two food constituents in a soil such as ours, where there are already from three hundred to seven hundred times the quantities of them needed, is unprofitable business.

It would seem that these trees ought to respond to additions of nitrogen. For fifteen years nitrogen has been leaching from the soil and none applied artificially except in the nitrogen plats. The supply ought soon to be running low. As to potassium, phosphorus and other minerals, however, it must be remembered that an apple tree possesses a very extensive root system and a long season of growth, fitting it well to obtain the mineral constituents needed, all of which, analyses show, are abundant in this soil.

May not lime be the limiting factor in this orchard? Probably not; for calcium was plentiful in the soil at the beginning of the experiment and a superabundance of it has been added in the phosphates in four plats without appreciable effects. Besides, in a neighboring apple orchard lime was used as a fertilizer in wood ashes for twelve years without benefit. Even alfalfa in a similar soil in a nearby field did not respond to a dressing of 2,000 pounds of lime to the acre. These facts seem to rule lime out as a factor in this experiment.

The final conclusion must be that the trees in this experiment would be practically as well off in every respect had not an ounce of fertilizer been used about them. If fertilizers have no value for young apple trees in this orchard, they have no value in innumerable other orchards in New York. Fruit-growers are spending money and losing time, as we shall try to show in the next paragraphs, in " carrying coal to Newcastle." Again in must be said that the soil in this orchard is about the same as the average of the apple lands in western New York — no better, no worse. If there is any material difference, it is that this experimental plantation has been better tilled and better cared for in most respects than the average orchard. But the trees have not been coddled — the care has not been better than that given in the best commercial orchards. One of the lessons the experiment should teach is that fertilizers are not necessary in some soils if tillage and good care be the rule,— the truth of the old adage "tillage is manure."

INTERPRETATION OF RESULTS.

The facts have been given but facts signify little unless they fit into a theory. Farm and garden crops on the Station grounds respond to applications of fertilizers. Why do not apples? The answer is: 1st. There is an abundance of plant food in the soil. 2d. The apple-plant is preëminently able to help itself to what is before it.

The soil contained at the beginning of this experiment and continues to contain a sufficient amount of plant food for the apple.— This soil, differing but little from average soils, is a storehouse for an enormous quantity of plant food as the following figures show. The upper twelve inches contain, as we have seen in Table II:

Nitrogen	7318 lbs. per acre.
Phosphoric acid	3240 lbs. per acre.
Potash	31015 lbs. per acre.

Van Slyke[1] of this Station made a careful study of the plant-food constituents used by bearing apple trees and found that trees thirty years old, forty feet apart, and bearing twenty bushels of apples took, in the fruit, leaves and new wood, approximately:

Nitrogen	40 lbs. per acre.
Phosphoric acid	11 lbs. per acre.
Potash	43.5 lbs. per acre.

[1] Van Slyke, L. L. *N. Y. Exp. Sta. Bul.* 265:208–210. 1905.

There was, then, at the beginning of this experiment enough nitrogen per acre to last apple trees bearing twenty bushels of fruit per tree, in round numbers, 183 years; of phosphoric acid, 295 years; of potash, 713 years. It is true that the nitrogen is in a highly soluble condition, and that there is some leaching of the other materials, but were this a commercial orchard the supply of nitrogen would probably be kept up by plowing under leguminous cover crops. The fact that the roots of the trees would obtain potash and phosphoric acid from a greater depth than twelve inches much more than offsets the probable leaching of these materials. The calculations given postulate mature trees; the trees in this experiment, since they are but coming in bearing, could not have taken nearly the amounts set down in the calculation.

We hasten to say that we are not attempting to teach that apples can be grown on this soil for 183, or 295, or 713 years without adding nitrogen, phosphoric acid or potash. These figures are given only to show the direction in which the clue may be found to explain the present inertness of fertilizers in this soil. Students of the soil now very generally argue that the capacity of a soil to grow crops does not depend upon the quantities of the food compounds present as determined by a chemical analysis, but upon the quantities of them which are available to the plants. But the soil is the seat of physical and biological interactions as well of chemical ones, and is withal so complex a medium that no one would assume to say what proportions of its nutrient components are or may be made available.

It may be safely said that the yearly plowing and thorough cultivation given this orchard have loosened, pulverized, and aerated the soil and regulated moisture, and with the addition of humus by plowing under cover crops whereby the solvent action of humus and the bacteria that thrive in soils containing humus have been secured, have made available some plant food that was unavailable at the beginning of the experiment. This, with the available food, has been quite sufficient for the trees so far.

We have no explanation to offer as to why the trees have not suffered, especially in the nitrogen plats, from over-feeding. It is a dogma of horticulture that trees are easily and harmfully over-fed by excessive quantities of nitrogen, especially in stable manure. Yet these young trees have had given to them from ten to twenty-five times the amount of this element usually recommended, and in three compounds, including stable manure, without harm. There is not much experimental evidence to show that an excess of nitrogen is harmful, but in practice, so far as animal manures at least are concerned, no one has doubted the harmful effects of large quantities.

The apple is better able than farm and garden plants to use the food of a soil.— The temptation so often arises to draw comparisons between the fertilization of orchards and of field and garden crops that it may be well to state, as the writer has done in numerous addresses and papers, the differences in the habits of growth between orchard plants and field and garden plants. Such a statement should help to show why these trees have behaved so differently on the Station grounds from herbaceous plants, which as a rule, in nearby fields, respond most markedly to nitrogen and phosphoric acid, at least.

Difference I.— Trees have a preparatory time of several seasons before fruit-bearing begins. The trees in this experiment were six years old before a crop was borne and this consisted of but a few apples. In the life of any orchard plant there are usually several "off years" in which the trees do not bear — periods of rest. Farm and truck crops make their growth, bear a crop and pass away in a single season.

Difference II.— Trees begin early in the spring and continue to grow until late fall so that fruit, leaf and wood have a relatively long period in which to develop. Annual and biennial crops, as a rule, have a much shorter season of growth and in particular their fruits are developed in a shorter time. There would seem to be less need for highly concentrated foods for the slower growing tree-plants.

Difference III.— The roots of trees run much deeper in the soil and probably spread relatively as far as those of succulent plants. The larger root-run and feeding ground should enable trees to thrive with less artificial feeding than is necessary with farm and garden crops. That trees, fruit or forest, can grow vigorously under natural conditions for a century or more, often in poor soils, is an indication of their ability to obtain nourishment from a soil upon which successive growths of most farm plants would speedily fail.

Difference IV.— Trees probably transpire larger quantities of water than herbaceous crops. There are calculations in all of the standard texts on soils showing how many tons of water are required to produce a ton of dry matter in various farm and garden crops. The drift of the figures for most of the crops upon which data can be had is to show that the more woody and fibrous the plant, the greater the number of tons of water required for a ton of dry matter. From this consideration and others, especially the relatively great number of stomata on the leaves of the apple, we are warranted in assuming that the apple is a "heavy drinker" and transpires a greater amount of water in proportion to its leaf area than do most cultivated succulent plants. If this hypothesis is correct, the nutritive soil solution may be less concentrated for the apple than for grains and vegetables and the tree be equally well fed.

Difference V.— The apple crop is about 85 per ct. water, leaving but a small percentage of solids and minerals, especially of those that it is necessary for man to supply to plants, to come from the soil. In field crops the percentage of solids taken from the soil is much larger. With the apple the leaves are left on the ground; the roughage for most part is removed from fields and gardens.

A disadvantage.— Fruit-growing differs from most other kinds of plant-growing in that it is continuous cropping of one kind, there being no opportunity to change the crop to some other which might require different amounts of the plant-food constituents. The growing of cover crops overcomes some of the disadvantages of the single-cropping formerly and yet too often practiced in fruit-growing. In an apple-tree generation it seems certain that the nitrogen, at least, must have to be replaced.

PRACTICAL OUTCOME OF THIS EXPERIMENT.

Is it necessary to fertilize an apple orchard? This experiment indicates that in the average western New York tilled apple orchard, if well drained, well tilled and properly supplied with organic matter from stable manure or cover crops, commercial fertilizers are little needed. The exceptions will probably be found on sandy and gravelly soils deficient in potash or the phosphates and subject to droughts; or on soils of such shallowness or of such mechanical texture as to limit the root-range of apple-plants; or in soils so wet or so dry, or so devoid of humus, as to prevent proper biological activities in the soil. These exceptions mean for the most part that a soil in this region possessing the unfavorable qualities named is unfitted for apple culture — at any rate there are still thousands of acres of available fruit land in every part of the apple regions of New York that do not fall in with the exceptions. There are probably many apple orchards in New York that may be benefited by an application of one of the chief elements of fertility. Some may require two of the elements. Few, indeed, should require a complete fertilizer.

If it be true, as we surmise, from this and other experiments, that good apple lands in New York, of which there are an abundance, need little artificial fertilization if the trees are well cared for, it follows that it is folly to plant apples on the lands coming under the exceptions noted; for the cost of production is increased by the cost of the fertilizers, and, of more importance, the fertilizers may often be wasted, though the operation of the "laws of diminishing returns" under which the first application of fertilizer is most effective while each additional one produces smaller and smaller returns; and, because there is sure to be waste on poor lands where growth would be limited by other factors than fertility, as water, soil texture and the like. In other words, it is doubtful if land too poor to grow apples without fertilizers can be profitably converted into permanent good apple land, at least, by the use of the mineral manures.

How may a fruit-grower know whether his trees need fertilizers? It may be assumed at once that if trees are vigorous, bearing well and making a fair amount of new wood each season, they need no additional plant food. If the trees are not in the healthful condition described, the logical thing to do is to look to the drainage, tillage and health of the trees first and the more expensive and less certain fertilization afterward.

As a last resort, fertilizers ought not to be used to rejuvenate trees unless the owner has obtained positive evidence that his soil is lacking in some of the elements of plant food. To obtain such evidence a fruit-grower should carry on a fertilizer experiment.

PLAN FOR A FRUIT-GROWER'S FERTILIZER EXPERIMENT.

The following is a plan, adapted from this experiment, whereby a man may determine, in some measure at least, what fertilizers his orchard needs. The trees selected should be of the same variety and age and should stand in a soil as uniform in texture and fertility as the orchard affords. There should be a sufficient number of trees in each plat to offset individuality in the trees. Five trees for each plat is probably the least number that can be used with any degree of accuracy. In New York, the following fertilizers might be tried:

On Plat 1, use stable manure to supply 50 pounds of nitrogen to the acre per year. On the average, this would take about 5½ tons of well-rotted stable manure per acre. In an orchard where the trees stand 40 feet apart, use about 400 pounds per tree.

On Plat 2, use a phosphate fertilizer in sufficient amount to supply 50 pounds of phosphoric acid per acre per year. A good recommendation is, 360 pounds of 14 per ct. guaranteed acid phosphate per acre, or 13 pounds of the fertilizer per tree.

On Plat 3, apply muriate of potash, guaranteed 48 per ct. to 52 per ct. actual potash. Apply 100 pounds of the potash per acre, which would require, of 50 per ct. actual potash, 200 pounds of the muriate of potash per acre, or 8 pounds per tree.

Combine with the potash the acid phosphate in the amounts prescribed for Plat 2.

On Plat 4, use a "complete" fertilizer, consisting of nitrogen as applied in Plat 1, and of phosphoric acid and potash as applied in Plat 3. Or, for the stable manure, substitute dried blood and nitrate of soda. The former may be had with a guaranteed analysis of from 9 per ct. to 12 per ct.; the latter contains from 15 per ct. to 16 per ct. of nitrogen. The following amounts of these two substances should be applied: 350 pounds of dried blood per acre, or 13 pounds per tree; and 100 pounds of nitrate of soda per acre, or 3⅔ pounds per tree.

Plat 5 should be a check.

If thought desirable to test the influence of lime, duplicate Plat 4 with the addition of 25 pounds of slaked stone lime per tree.

The best time to apply fertilizers, all things considered, is spring, as soon as the ground can be worked. Spread broadcast about the tree over an area slightly greater than that covered by the branches of the tree. In cultivated orchards the commercial fertilizer should be harrowed in and the manure plowed under. If the results are to be at all conclusive, such an experiment should run several years. Weigh or measure the crop at harvest time to determine the relative value of the different treatments. It is not sufficient to keep count of the number of barrels of marketable fruit from each plat; culls and windfalls should be accounted for. The plats can be laid out, the materials weighed, and all plans made for such experimentation in the winter, so that the actual work in the spring need not be great.