1-1-1914

The effects of fertilizers in a cultivated orchard, Bulletin, no. 168

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New Hampshire Agricultural Experiment Station

Bulletins 152-168 OK - RBS. 4/10/12

163 = 23rd/24th Ann. Rpt 1905/1906 — ? OK - RBS 4/16/12

Bulletin 168 January, 1914

NEW HAMPSHIRE AGRICULTURAL

EXPERIMENT STATION

THE EFFECTS OF FERTILIZERS IN A CULTIVATED ORCHARD

By J. H. GOURLEY

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

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THE EFFECTS OF FERTILIZERS IN A CULTIVATED ORCHARD.

J. H. GOURLEY.

SUMMARY.

1.—This bulletin gives the results of various cultural and fertilizer treatments on a bearing Baldwin apple orchard for a five-year period.
2.—The factors considered are yield, growth and size of fruit.
3.—The five-year average shows all methods of treatment to be superior to growing trees in sod as regards yield and size of fruit, and growth of tree.
4.—Cultivation annually every two weeks until September 1st, has given results on yield and growth superior to cultivation every other year, including a cover crop the alternate years of cultivation.
5.—A good system of culture, namely, cultivating the orchard every two weeks until midsummer, then seeding down with crimson clover, has given practically as good results on yield of fruit and growth of tree as that obtained by the addition of a complete fertilizer or when either phosphoric acid, potash, or nitrogen are used in excess in the complete fertilizer.
6.—Up to the present time we have not received any cash return for the fertilizer that has been used in this orchard.
7.—The size of fruit has been increased by the use of fertilizers, especially by the use of excess nitrogen and potash, as shown by the percentage of No. 1 apples.
8.—Both the area and weight of the leaves were increased by the use of fertilizers in the year 1913, no records being taken of these factors previously.
9.—Lime had no appreciable effect on any of the factors considered.
10.—Color of fruit has not been increased by any combination of fertilizers employed.

INTRODUCTION.

The investigations which have been conducted up to the present time on the problem of maintaining soil fertility in the apple orchard, lead to but one general conclusion, namely, that it may or may not be necessary to use commercial fertilizers. This general conclusion would lead to the specific recommendation of

the home test. In all lines of soil fertility work, whether it be on the cereal crop, hay land, or some specialized crops the investigators have usually been of the opinion that the home fertilizer test led to the only safe and reliable information that could be obtained. Some general information has been secured through long time tests that is applicable over rather large areas, but this has often been misused and misquoted for the benefit of biased persons or commercial concerns. There can be little doubt that much fertilizer has been used in the orchard and on the farm that has been of no value to the land or crops; however, there are doubtless many sections where the sins of omission have been far greater than the sins of commission. But it is to be hoped that such valuable data as have appeared in the past few years will ultimately lead to a common agreement regarding our orchard policies for various conditions. The fact that fruit trees have not responded to artificial fertilizers in the same way that is reported for farm crops has been a constant source of trouble for it is quite natural to reason by analogy. Again it is little wonder that the growers are discouraged to find some investigators arriving at the general conclusion that it does not pay to fertilize the apple orchard and others by just as thorough investigations arriving at the opposite conclusion. Yet both, from their data, are warranted in their conclusions.

From the various investigations and tests reported upon there seems to be a general agreement that it will pay, and usually quite well, to apply fertilizers to trees standing in sod. But when the orchard is receiving a standard system of cultivation, including a cover crop the results are not in harmony. It appeals to the writer that one of the outstanding statements pertaining to any fertilizer investigation in an apple orchard should be, whether it is in sod or under cultivation, and the orchard's history in this respect.

It is doubtless a truism to say that the recommendations to "feed the trees" have been largely based on the information given us by the chemists. The chemical analysis of the tree and its product is made and then the analysis of the soil on which the tree grows is made. From this data is calculated the amount of plant food which should be returned artificially to maintain the fertility of the land. Obviously the trouble with such a theory is that it does not take into consideration the mechanical or physical condition of the soil or the important rôle of micro-organisms to soil fertility and the associated factors—heat, moisture, and soil sanitation. The physical theory and toxic theory have both shared in causing a new viewpoint to be taken of this important study, both of which have been accepted in whole or in part by many workers. These facts together with the results of the work appearing in this bulletin lead the writer to make the general

statement given in the opening remarks of this introduction, viz., that the only safe information is a home test.

SIMILAR INVESTIGATIONS ELSEWHERE.

Since we have noted that up to date the results of investigations on the fertilization of apple orchards do not agree we give a brief résumé of the leading work on the subject. While the problem discussed in this bulletin is as much a study of the results of cultivation as it is the results of fertilizer treatments, yet the latter is uppermost in the minds of so many investigators that special attention is here called to the results obtained elsewhere and their bearing on the problem. Of the experiments here noted only one report results contradictory to those recorded by the writer. We are here drawing a clear line between orchards in sod that have been fertilized and those under cultivation. Investigations seem to warrant this distinction.

THE WOBURN EXPERIMENT.

Some experimental work conducted in England at the Woburn Experimental Fruit Farm and reported in the fourth and fifth reports of that Station shows no effect from the annual application of manures or commercial fertilizers to an orchard under cultivation for a period of fourteen years. The fact that returns from the application of fertilizers in a cultivated orchard were not superior to returns from good cultivation is significant in this connection.

The following summary after eight years and the conclusions unchanged at the end of fourteen years are of interest: "Neither moderate nor heavy dressing of dung or artificial [fertilizers], nor of both combined, had any appreciable effect on any feature of the trees nor on the crops from them. The total effect did not amount to 5 per cent and even that effect was very doubtful.

"The only exception was in the case of nitrate applied in the early or late summer which in several seasons produced a good effect.

"In a lighter and poorer soil the results obtained indicate that manures will there have a more positive action."

THE MASSACHUSETTS EXPERIMENT.*

In Massachusetts a fertilizer test was conducted in an orchard of Gravensteins, Baldwins, Roxbury Russets, and Rhode Island Greenings for fifteen years. The trees were planted in 1890 and cultivated for five years. From 1895 till 1910 the trees were in sod and the following treatments of fertilizers were applied to the various plots:

*Manuring an Apple Orchard. 22d Annual Report Mass. Agri. Exper. Sta., Part II, 1910.

Plot.	Fertilizer.	Rate per acre —pounds.	Yield for 15 years—pounds.
1.	Barnyard Manure,	20,000	24,934
2.	Wood Ashes,	2,000	12,841
3.	Nothing,	——	3,940
4.	Bone Meal,	600	
	Muriate of Potash,	200	14,453
5.	Bone Meal,	600	
	Low grade Sulphate of Potash,	400	21,863

Results secured in this orchard are striking and indicate that it paid well to supply plant food in an artificial way. But the significant fact is that this orchard is in sod and is not comparable to the results which are recorded in this bulletin.

THE NEW YORK EXPERIMENT.*

The New York Experiment Station conducted an experiment on the effect of the application of wood ashes and acid phosphate on the yield and color of apples. The orchard was composed of the following varieties:—Baldwin, Fall Pippin, Rhode Island Greening, Roxbury Russet, and Northern Spy. It was 55 years old at the time the results were published (1907) and had been in sod prior to the experiment being inaugurated. During the experiment of twelve years' duration the orchard was given clean culture annually until August 1, when a cover crop of oats, barley, or clover was sown. Wood ashes were applied at the rate of 100 pounds per tree, and during the last seven years 8½ pounds of acid phosphate per tree were also applied.

Prof. U. P. Hedrick in commenting on this experiment says: "The returns obtained in this twelve-year experiment are negative from a practical standpoint. The experiment shows that it is not profitable to apply potash, phosphoric acid, or lime to the soil of the Station orchard. Fifty-seven years of orchard cropping has not reduced this soil to the condition where it needs a 'complete' fertilizer, yet the leguminous cover crops plowed under in the orchard have usually produced beneficial effects the same or the next season." Elsewhere he makes this significant statement: "An interesting fact is that both treated and untreated plots increased markedly in yield from 1893 to 1904. The probable explanation is that prior to 1893 the orchard was in sod but during the experiment was kept under cultivation and grew more productive under the treatment."

Here we have a notable case of an orchard under cultivation not responding materially to the application of potash, phosphoric acid and lime, but all plots improving markedly when a good system of culture was followed.

*Bull. 289, N. Y. Experiment Station, 1907.

NEW YORK EXPERIMENT STATION, BULL. 339.

In another bulletin by the New York Experiment Station Prof. U. P. Hedrick reports another experiment in which fertilizers failed to produce results. Here, again, the orchard is cultivated, *not in sod,* and the orchard is young. The following gives the treatments applied to the various plots:

Stable Manure	415.15 pounds per tree.
Acid Phosphate	12.66 pounds per tree.
Muriate of Potash	7.26 pounds per tree.
Acid Phosphate	12.6 pounds per tree.
Muriate of Potash	7.26 pounds per tree.
Acid Phosphate	12.6 pounds per tree.
Nitrate of Soda	3.67 pounds per tree.
Dried Blood	12.84 pounds per tree.

The experiment continued over fifteen years to determine whether it is necessary to fertilize apple orchards.

The author concludes from this work:

"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 plots.

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

"The trees in this experiment would have been practically as well off had not an ounce of fertilizer been applied to them."

He then calls attention to the fact that it may be necessary to fertilize some orchards in the state, especially those on light soils.

THE PENNSYLVANIA EXPERIMENTS.*

The Pennsylvania Experiment Station has under investigation the problem of orchard culture and fertilization in a number of orchards with a variety of soils, varieties and other conditions. This work has been in progress for six years and shows most striking results from the use of fertilizers. The conclusions of this Station are based on "13 experiments involving 10 soil types, 12 different locations, 2,653 trees and about 34,610 bushels of fruit in the last 5 years. Only six of these experiments, however, are entirely on fertilization and in bearing. Three of the others, involving 660 trees, are in young orchards, planted in 1908 in connection with these experiments and the remaining four are primarily on cultural methods, though fertilization is also involved." Dr. John P. Stewart, in charge of this work makes the following deductions from his work:

*Bull. 121, Penn. Exp. Station, 1913.

"The experiments of this Station have shown that the fertility of an orchard may be the most important check on its production. Variations in fertilization alone have resulted in average differences ranging from 50 to 460 bushels per acre annually for the past four or five years depending on the experiment. These results were accompanied by similar differences in the growth and general vigor of the trees."

These experiments show beneficial effects from fertilizers both on trees in sod and under cultivation. Manure is giving the best results when the orchard is in sod and commercial fertilizers the best results in cultivated orchards. This is the first one of the experiments noted where a decidedly beneficial effect has been secured by fertilizing an orchard which is receiving a good system of orchard culture including a leguminous cover crop. We wish to call special attention to this fact in view of the recommendations given in this bulletin, viz., it may or may not pay to fertilize a well-tilled orchard.

SOME OHIO EXPERIMENTS.

The Ohio Experiment Station has in progress a number of experiments in orchard fertility in the southeastern portion of the state where the soil is thin and the fertility low. The work there is confined to orchards in sod and under the sod mulch system. Remarkable results have been secured in their work and the following extract from a letter by F. H. Ballou,* in charge of the work, gives a summary of the work for the past five seasons: "To sum up the results in increased fruit production from the use of chemical fertilizers on the very thin orchard land in southeastern Ohio, taking into consideration all our different plots at the various places covering 60 miles of country we have the following:

Average per acre, per year fertilized, 100 barrels.
Average per acre, per year unfertilized, 44 barrels.
Gain per acre, per year from fertilization, 56 barrels.
Cost of gain per barrel per year, 17.8 cents."

THE PROBLEM.

The New Hampshire Experiment Station has had an apple orchard under treatment for the past six years to study the factors which influence the formation of fruit buds. A report was issued on this work by Prof. B. S. Pickett, Bulletin 153. But coincident with this study is a study of the effect of various cultural treatments and commercial fertilizers on the growth of the trees and yield of fruit. This state has a great number of apple trees which have not received either cultural treatment or

* Letter dated October 17, 1913. Newark, Ohio.

applications of commercial fertilizers and it was with this fact in view that such a study was undertaken.

Records have been made mainly on the effect of the treatments on yield and growth of trees and size of fruit, no special study aside from general observations being made on the color, quality, texture and keeping quality of the fruit from the various plots.

Unfortunately this experiment is not laid out in such a way as to give a check on the results derived from the various fertilizer ingredients, but rather the results which might be obtained from a complete fertilizer and from nitrogen, phosphoric acid, and potash in predominence.

THE ORCHARD IN QUESTION.

The orchard which has been used for this experiment is leased for a ten-year period from Mrs. S. J. Woodman. It is located two and one-half miles west from the college. When the orchard was leased it contained 302 trees, but a few have died during the past six years and some others are in bad shape and have been eliminated from the experiment. Black rot canker (*Sphaeropis malorum,* Peck) has caused most of the trouble, probably following injury to the limbs after the severe winter of 1906. The trees are Baldwins set 35 feet apart each way and are 31 years old at the present time (1913). Previous to 1908 when the orchard was leased the trees were standing in sod and yielding unsatisfactory crops. The land had never been plowed and the hay crop was removed annually.

The orchard is 62 feet above sea level, and lies quite level. The soil is of a sandy nature and rather uniform throughout, running a little lighter toward the northwest end. The land is naturally well drained and no tiling has been put in.

A VIEW OF THE ANALYSES OF THE ORCHARD.

A mechanical analysis of the soil as given in Table I shows it to be quite light. The surface soil is shallow, the sand and gravel being about seven inches below the surface. Such a soil is in marked contrast to the one used by the New York Experiment Station and the analysis of that soil is given as a matter of comparison. This analysis is taken from Bulletin 339, New York Experiment Station.

A chemical analysis still further reveals the character of the soil we are dealing with, as shown in Table 2. This shows the soil to be relatively high in potash, but very low in phosphoric acid, in fact about at the limit of productivity according to Hilgard.* Lime is also rather low.

While the percentage of some of these necessary ingredients are low yet the fact that the soil is light and allows a greater penetration of the roots may explain in part the fact that the plants have not responded to applications of these ingredients in the form of artificial fertilizers. Hilgard in his "Soils," page 347 states: "In 'light' or sandy lands the roots may penetrate to several times the depth attained by them in heavy clay soils.

* "Soils," by Hilgard.

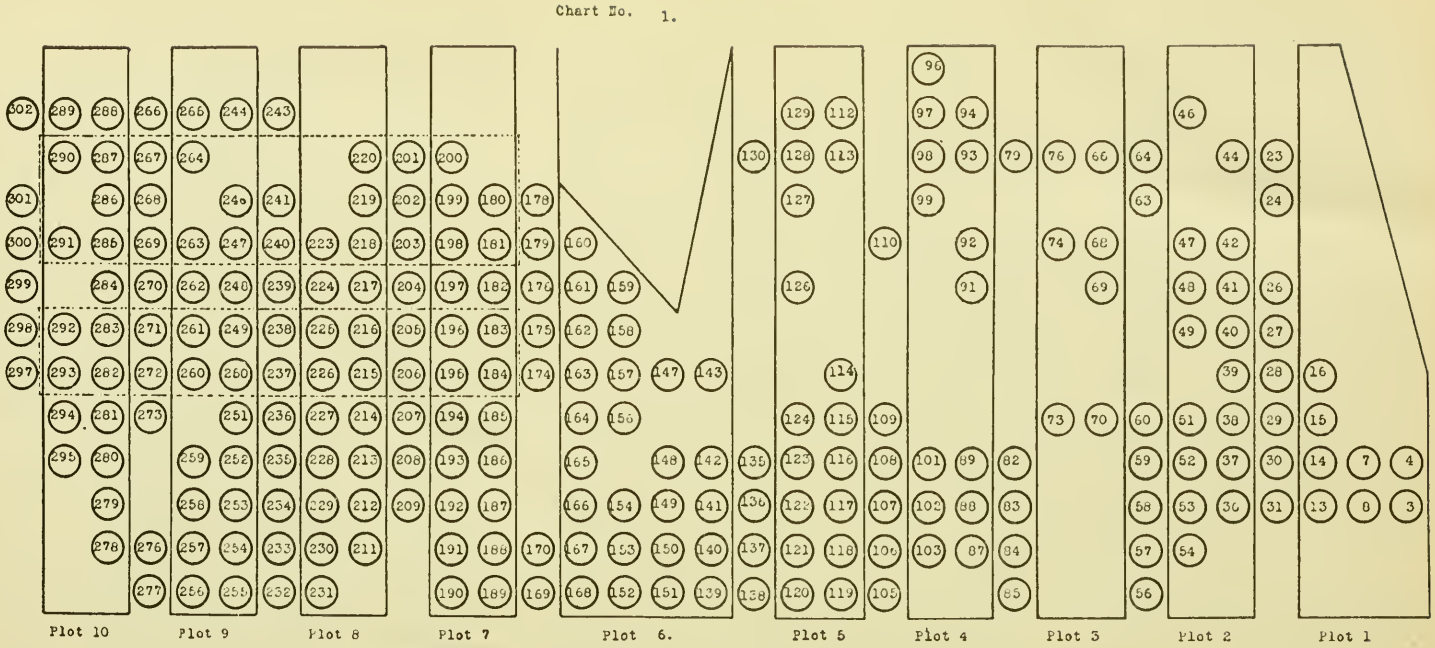


Chart No. 1. Plan showing the arrangement of plots in the experiment.

Having thus within their reach a soil-mass several times larger, and aërated to a much greater depth, it is but reasonable to expect that in deep sandy lands plants would do equally well with correspondingly smaller percentage of plant food than would suffice in clay soils, in which the root-range is very much more restricted.''

The following gives an approximate amount of the various ingredients in the upper seven inches of soil per acre.

	Pounds.
K_2O	21,620
Na_2O	18,860
CaO	12,420
MgO	12,420
Fe_2O_3 Al_2O_3	261,280
P_2O_5	1,150
Volatile matter	166,520

Mechanical Analysis.

This mechanical analysis of the soil is from a composite sample taken from various places in the orchard.*

TABLE I.

	Woodman Orchard. Surface Soil 0-7 in.	New York Exp. Sta.	Woodman Orchard. Subsoil 7 in.-3 ft.	New York Exp. Sta.
Fine gravel, 2 to 1 mm	3.6	5.50	8.3	5.04
Coarse sand, 1 to 0.5 mm	8.7	1.54	20.1	1.22
Medium sand, 0.5 to 0.25 mm	8.7	3.76	15.4	3.56
Fine sand, 0.25 to 0.1 mm	16.7	9.44	25.5	9.26
Very fine sand, 0.1 to 0.05 mm	17.2	27.06	10.4	25.83
Silt, 0.05 to 0.005 mm	33.5	34.11	14.5	29.71
Clay, 0.005 to 0 mm	11.1	22.37	5.8	28.93

*We are indebted to the Bureau of Soils, Department of Agriculture, for this analysis.

TABLE NO. 2.

Chemical Analysis of Soil in Woodman Orchard.†

	Surface Soil 0-7 in.	Subsoil. 7 in.-3 ft.
SiO_2+Insol. Matter	78.76%	82.96%
K_2O	.94	1.36
Na_2O	.82	.99
CaO	.54	.39
MgO	.54	.45
Fe_2O_3+Al_2O_3	11.36	11.21
P_2O_5	.05	.04
Volatile Matter	7.24	3.24
Total	100.25%	100.64%

†We are indebted to the Station Chemist, B. E. Curry for this analysis.

SCHEDULE OF TREATMENT OF PLOTS.

Crimson clover is used as a cover crop in every case. Seed is sown July 10 at the rate of 20 pounds per plot. In seeding plots 2 and 3 the following mixture is used:

10 pounds timothy,
10 pounds red clover,
5 pounds white Dutch clover.

Plot 1.—Sod.
To remain permanently in sod. Grass to be mown when inconveniently long and allowed to remain on the ground. No fertilizer to be applied.

Plot 2.—Cultivated the odd year, cover crop sown July 10, seeded the even. No fertilizer is applied.

Plot 3.—Cultivated the even year, cover crop sown July 10, seeded the odd. No fertilizer is applied.

Plot 4.—Clean cultivation.
This plot is plowed every spring and cultivated every two weeks until September 1. No cover crop is sown and no fertilizer is applied.

Plot 5.—Cultivation and cover crop.
This is plowed every spring and cultivated every two weeks. A cover crop consisting of 20 pounds of crimson clover is then sown. No fertilizer is applied.

Plot 6.—Cultivation and cover crop with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
7 pounds basic slag.

Plot 7.—Cultivation and cover crop, with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
8½ pounds acid phosphate.

Plot 8.—Excess Phosphorus. Cultivation and cover crop, with the following complete fertilizer per tree:

2 pounds nitrate of soda,
4 pounds sulphate of potash,
17 pounds acid phosphate.

Plot 9.—Excess Nitrogen. Cultivation and cover crop, with the following fertilizer per tree:

6 pounds nitrate of soda,
4 pounds sulphate of potash,
8½ pounds acid phosphate.

Plot 10.—Excess Potassium. Cultivation and cover crop, with the following fertilizer per tree:

2 pounds nitrate of soda,
10 pounds sulphate of potash,
8½ pounds acid phosphate.

Plot 11.—Limed. A portion of plots 7, 8, 9 and 10 receive 20 pounds slaked lime per tree in addition to the fertilizer treatments.

Plot 12.—This plot crosses plots 7, 8, 9 and 10 and serves as a check on Plot 11.

TABLE NO. 3.

A Comparative Tabulation of Results for the Various Factors Considered.

Plot.	Yield. 5-yr. Avg.	Twig Growth 4-yr. Avg.	Size of Fruit as shown by Per Cent. of No. I's. 5-yrs. Avg.	Area of Leaves 1913.	Fresh Weight of Leaves 1913.
1. Sod	100	100	100	100	100
2. Cultivation every other year.	132	140	168	107	111
3. Same as 2d	176	163	165	113	117
4. Clean culture	213	190	142	119	123
5. Cultivation and cover crop.	216	212	135	124	123
6. Cultivation and cover crop. Complete fertilizer	191	222	165	129	135
7. Same as 6. See description.	195	198	155	126	131
8. Cultivation and cover crop. Excess Phosphorus	166	200	168	126	131
9. Same as 8. Excess Nitrogen	163	217	196	125	128
10. Same as 8. Excess Potash.	161	202	206	131	134

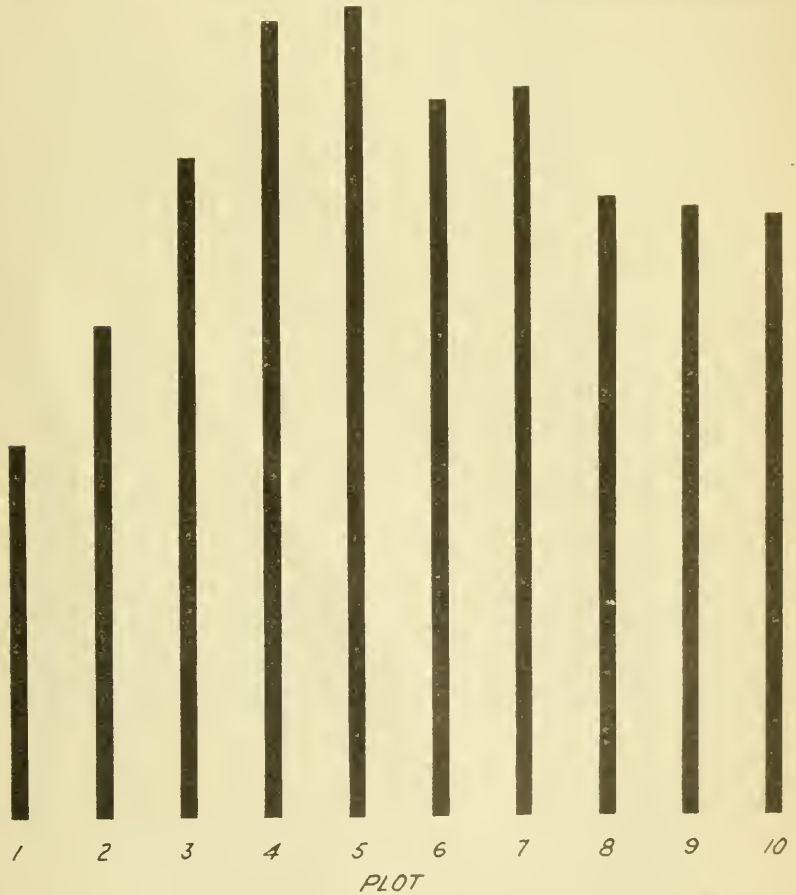


Chart No. 2. The above chart shows the comparative yield of the plots for the five-year period.

TABLE NO. 4.

Summary of Plots.

Average Annual Yield Per Tree.
Yield (by number of fruits).

Year.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Plot 6.	Plot 7.	Plot 8.	Plot 9.	Plot 10.	Plot 11.	Plot 12.
1908	467	167	118	105	77	67	67	59	106	124	—	—
1909	95	67	101	106	80	56	71	78	90	28	—	—
1910	481	1248	2313	1859	2381	1842	2027	1736	1738	2038	2373	2011
1911	795	701	154	549	99	248	131	185	164	94	30	129
1912	376	749	1232	2105	2162	2038	2046	1631	1530	1284	1245	1473
Avg. for 5 years	443	586	784	945	960	850	868	738	726	714		
Percentage increase over Sod Plot		32	76	113	116	91	95	66	63	61		
Percentage increase from fertilizers over Plot 5						−11	−9	−23	−24	−25		

TABLE NO. 5.

Weight of Crop from the Several Plots.

Average Weight Per Tree in Pounds.

Season.	Plots.											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1911	164.43	190.31	39.3	121.80	29.47	72.00	35.38	52.26	48.24	28.80	9.00	38.16
1912	99	184	378	459	501	506	462	400	434	364	304	415
Avg. for 2 years	131.71	187.15	208.6	290.40	265.23	289.00	248.69	226.13	241.12	196.40	166.50	226.58
Percentage increase over sod		42	58	120	101	119	88	71	83	49	26	72
Percentage increase from fertilizer over Plot 5					—	9	−6	−14	−9	−26		

This table is here included to serve to indicate that in weight the results are in accord with those given in previous tables where the yield was recorded by number of fruits. The weight has only been recorded since 1911, but since we are open to some criticism for recording yield in numbers rather than weight it will serve its purpose. There are some slight discrepancies but in general the results show no superiority of the fertilized plots.

TABLE NO. 6

FIVE YEAR AVERAGE (1908–1912).

Percentage of No. 1, No. 2, and Culls in Each Plot.

Percentage Grade.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Plot 6.	Plot 7.	Plot 8.	Plot 9.	Plot 10.	Plot 11.*	Plot 12.
No. 1.....	36	60.7	59.4	51.2	48.6	59.7	55.8	60.8	70.9	74.5	72.3	69.7
No. 2.....	43	32.6	32.6	40.7	44.7	35.0	37.5	33.7	23.6	21.9	25.0	25.6
Culls.....	20.5	6.8	7.9	8.0	6.5	5.2	6.5	5.4	5.2	3.5	2.5	4.5

*Plots 11 and 12 are three year averages (1910–1912).

This table shows the increase in size of fruit where the fertilizers have been applied especially in the nitrogen and potash plots (Plots 9 and 10). As noted elsewhere, however, part of this low percentage of No. 1 apples in Plots 4 and 5 is due to much greater crop. See Table No. 4.

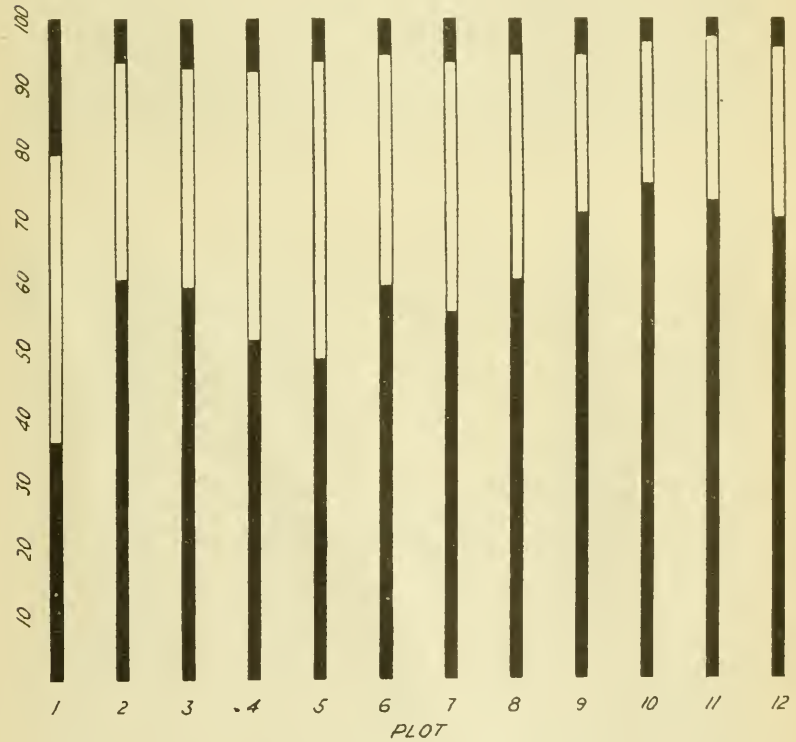
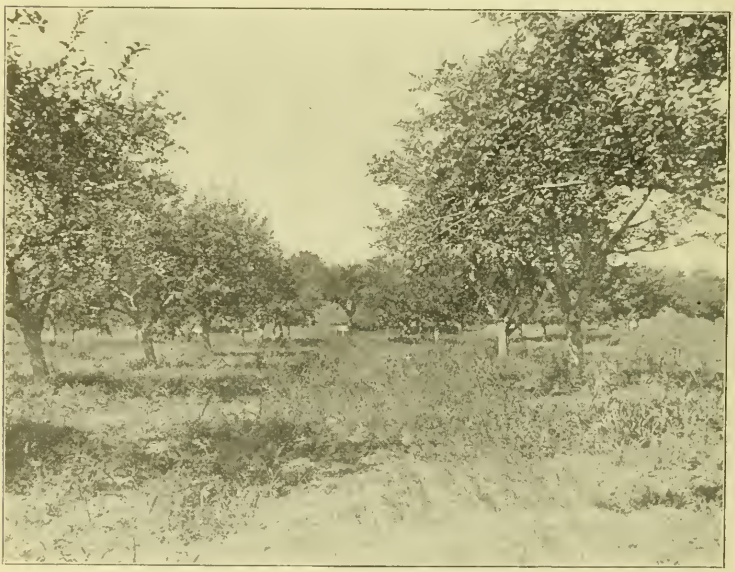


Chart No. 3. The above chart shows the comparative percentage of No. 1, No. 2, and culls, apples for a five-year period. The solid column below indicates No. 1, the open column No. 2 and the small solid column above the culls.

Plot 1.



Plot 2.

INFLUENCE OF CULTURE AND FERTILIZERS ON THE ORCHARD.

The first practical consideration in such an experiment as is being here considered is whether an increase in yield was secured. If an increased production of the trees has been brought about it is quite essential to determine what was limiting the yield previously and just how such results can be duplicated. Now we have essentially three distinct types of treatment included in this investigation, viz., 1st, growing trees in sod; 2d, growing trees under cultivation; and 3d, applying commercial fertilizers to trees under cultivation. The latter two treatments are subdivided into various modifications of these treatments. The results are striking and consistent in practically all particulars revealing information that is of value.

Table No. 3 gives a comparative tabulation for the results of the various factors that have been considered, giving the sod plot an arbitrary value of 100 as a basis.

Table No. 4 presents a summary of the work for five years, giving the average annual yield per tree. This yield is in terms of number of fruits produced and not in weight (a). The yield in weight is given in Table No. 5.

It should be noted in Tables No. 7 to 18 that there are only two heavy crops reported and the "off years" together with the low yield before the treatment had taken effect show a very low yield per tree for the five-year average (b).

In looking over Table No. 4 it will be seen that the years 1910 and 1912 are the heavy bearing years out of the five which would indicate that 1908 was the year for a heavy crop. A glance at the following figures shows this to be the case.

Total number of apples in orchard, division rows included.

1908	23,114
1909	11,607
1910	401,766
1911	34,155
1912	386,324

These figures show that in 1908 there were twice as many apples harvested from the orchard as in 1909. In 1911, however, the yield in the "off year" has been materially increased and it is a noticeable fact that Plot 1 which is in sod has the highest yield per tree, and similar results occurred again in 1913. There is not the remarkable difference in Plot 1 between the "bearing" and "off years" that is seen in the other plots under cultivation; it seems to be bearing more uniformly, but the average yield is quite low. One cannot help but be impressed with the influence that the treatments have had on the orchard as a whole. If 1908 was a typical yield for the "bearing" year in this orchard, and there is no evidence to the contrary, then an increase from 23,114 apples in 1908 to 401,766, or more than 17 times as many in 1910, and 386,324, or more than 16 times as many in 1912, indicates a practice that might well be recommended. Just which one of the several treatments has had the greatest influence is the important fact to determine.

DISCUSSION OF PLOTS.

Plot 1.—The yield of Plot 1, which is in sod, has not materially changed during the five years but the yield and also the trees themselves are far outstripped by the adjoining plots under cultivation. As we see the

(a) This investigation is primarily for another object in which the number of fruits set was of first importance and consequently the weight was not recorded in the early period of the work.

(b) This fact should be carefully noted and for the present bearing capacity of the trees the yields for 1910 and 1912 should be consulted.

Plot 3.

Plot 4.

increased yields in 1910 and 1912 in the other plots there is no reason to believe that the same would not have occurred in this plot as well, as in 1908 it was superior to any of the others, which puts it at least on an equal footing.

Plots 2 and 3.—These plots are cultivated every other year and seeded down when not cultivated. Plot 2 was not plowed up until 1909 which gave Plot 3 a year's advantage and the results are evident, but Plot 3 has a number of trees missing which gives a fewer number of trees to average, and Plot 2 contains some poor trees which makes the latter plot show a poorer average yield. But in both cases the trees given biennial cultivation are superior to the trees in sod in yield and in twig growth.

Plot 4.—This plot in which clean culture is practiced annually has made a remarkable showing in yield, but the length of time this can continue will be most interesting. But considering the fact that this soil is light, and had been subject to an exhaustive system of husbandry, it is surprising that clean culture should produce results approaching those obtained by the supposed best system in the experiment. The general appearance of the trees would not be distinguishable on general observation from those of any of the other plots in this experiment.

Plot 5.—This plot which receives what we might term an ideal system of culture, viz.—cultivation until the middle of July and then seeded with a leguminous cover crop—is making a notable showing. It is the highest yielding plot in the orchard and is making practically as good a twig growth as any. The trees are thrifty and in every respect equal to the subsequent plots which have been fertilized. By comparing the yield and twig growth of the fertilized plots with Plot 5 we can see no reason for believing that up to the present it would have been in any way improved by the addition of a complete fertilizer to the treatment it is receiving. However, an examination of Table No. 23 will show that the area and weight of the leaves in the season 1913 was superior in all plots receiving a complete fertilizer. No records were taken on these factors prior to the season of 1913. Table No. 6 shows a marked increase in size of fruit in the fertilized plots. This is in part due to the fact that the yield in Plot 5 was greater and consequently the apples were smaller. But, on the other hand, the fertilizers have evidently had a beneficial effect on size of fruit. Plot 10, which has the highest average percentage of No. 1 apples, has 25 per cent more than this plot; but, on the other hand, this plot has a 25 per cent greater yield than Plot 10 for the period under observation.

Plot 6.—This plot which receives the same cultural treatment as Plot 5 and in addition a complete fertilizer with basic slag as the carrier of phosphorus, shows a superiority in general appearance of the trees over any other plot in the orchard. But in yield it ranks fourth, in twig growth first, in weight of leaves third. The trees in this plot in the beginning of the experiment were probably in a little better condition than any others in the orchard. In Table No. 22 we see in the year 1909 that these trees were averaging a little higher in twig growth, but we would not be inclined to interpret these results as meaning that basic slag was responsible for the increase in growth.

Plot 7.—This plot, which receives a complete fertilizer, shows no material difference from Plot 6 which had basic slag as the carrier of phosphorus in a complete fertilizer, except in twig growth, the latter plot showing a gain of one inch in twig growth for the four-year period. Since the yield is higher in Plot 5 than in the fertilizer plots we might expect a greater growth to compensate for yield but this has not been the case, for the average twig growth of all the fertilized plots taken together is not as great as the growth in Plot 5. This is in accord with the findings of Stewart, that growth and yield within reasonable limits are not antagonistic.

Plot 5.

Plot 6.

Plot 8.—This plot, which receives an excess of phosphorus, does not show as good an average gain as Plots 6 and 7 and a glance at the yield in 1908 shows the plot to be a little lower in yield than any other. Table No. 18, however, does not reveal any lack of twig growth, which may be taken as a reasonable indication of general vigor. This would seem surprising when we consider the low percentage of phosphoric acid in this soil. As was seen in Table No. 2 we only have .05 per cent of phosphoric acid in the surface soil and .04 per cent in the subsoil. The general appearance of the trees also is up to the standard of the other plots. There is no apparent reason why Plots 8, 9 and 10 should be lower in yield as the trees are good, but a certain variation in plants themselves must be expected especially when dealing with apple trees.

Plot 9.—This plot while failing to respond to the excess nitrogen by an increased yield does show an increase in twig growth over the plots on either side of it as is indicated in Chart III. The size of fruit also shows an increase as compared with any plot preceeding it.

Plot 10.—This plot receiving an excess of potash and the last of the series of fertilized plots again failed to surpass Plot 5 in yield and growth, but is notable in the increased size of fruit as is seen in Table No. 6 and Chart IV. It has the largest percentage of No. 1 apples, the smallest percentage of No 2, and next to the smallest percentage of culls, there being slightly fewer in Plot 11. Potash has long been heralded as the first essential for apple orchards, producing more fruit, better color and a generally superior product, but again in this experiment it fails to produce "the goods." However, the increase in the size of the fruit is very notable in both Plots 9 and 10 and if the yield had been increased as well as the size we would here have something quite favorable to report for the use of fertilizers. Mr. Curry, chemist, New Hampshire Experiment Station, has shown that our soils are generally rich in potash.

Plot 11.—This plot, which crosses Plots 7, 8, 9 and 10 with a dressing of lime (first applied in 1909) behaves much the same as the other plots. The twig growth is the same as Plot 5 and the yield much the same as the other fertilized plots. In 1910 it showed a higher yield but this could scarcely be attributed to the application the previous season and it has failed to maintain a higher yield in 1911 and 1912.

Plot 12.—This plot serves as a check to Plot 11.

TABLE NO. 7.

PLOT 1. IN SOD.

Average number of apples per tree.

Number of trees 8. Acreage in plot .68 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	130	160	33	323	9	62	73	144	139	222	106	467
1909	13	20	5	38	23	23	11	57	36	43	16	95
1910	88	78	52	218	72	81	110	263	160	159	162	481
1911	198	206	56	459	74	174	87	335	272	380	143	795
1912	171	147	29	348	19	8	2	28	190	155	31	376
5-yr. average	120	122	35	277	39	70	57	165	159	192	92	443
Percentage of various grades									36%	43	20.5	

Plot 7.

Plot 8.

TABLE NO. 8.

PLOT 2. CULTIVATED EVERY OTHER YEAR.

Average number of apples per tree.

Number of trees 16. Acreage in plot .55 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	78	49	7	134	7	11	15	33	85	60	22	167
1909	45	8	1	54	7	3	3	13	52	11	4	67
1910	369	273	47	690	241	260	58	559	610	533	105	1248
1911	350	85	17	451	156	79	14	249	506	164	31	701
1912	497	169	32	697	28	19	4	52	525	188	36	749
5-yr. average	268	117	21	405	88	74	19	181	356	191	40	586
Percentage of various grades									60.7%	32.6	6.8	

TABLE NO. 9.

PLOT 3. CULTIVATED EVERY OTHER YEAR.

Average number of apples per tree.

Number of trees 7. Acreage in plot .55 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	60	27	5	92	5	8	13	26	65	35	18	118
1909	23	1	2	26	49	14	12	75	72	15	14	101
1910	906	514	76	1495	400	307	110	817	1306	821	186	2313
1911	67	4	11	82	42	18	13	73	109	22	24	154
1912	714	333	53	1100	63	55	14	132	777	388	67	1232
5-yr. average	354	176	29	559	112	80	32	225	466	256	62	784
Percentage of various grades									59.4%	32.6	7.9	

TABLE NO. 10.

PLOT 4. CLEAN CULTURE.

Number of trees 14. Acreage in plot .55 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	45	31	4	80	5	7	13	25	50	38	17	105
1909	38	3	3	44	41	8	13	62	79	11	16	106
1910	765	507	49	1321	188	273	77	538	953	780	126	1859
1911	230	54	45	329	113	50	57	220	343	104	102	549
1912	878	844	88	1810	115	147	33	295	993	991	121	2105
5-yr. average	391	288	38	717	92	97	39	228	484	385	76	945
Percentage of various grades									51.2%	40.7	8.0	

Plot 9.

Plot 10.

TABLE NO. 11.

PLOT 5. CULTIVATION AND COVER CROP.

Number of trees 17. Acreage in plot .55 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	23	24	9	56	3	8	10	21	26	32	19	77
1909	27	4	1	32	36	7	5	48	63	11	6	80
1910	763	786	127	1676	328	336	41	705	1091	1122	168	2381
1911	35	11	8	54	32	5	8	45	67	16	16	99
1912	922	739	82	1743	164	232	23	419	1086	971	105	2162
5-yr. average	354	313	45	712	113	118	17	248	467	430	63	960
Percentage of various grades									48.6%	44.7	6.5	

TABLE NO. 12.

PLOT 6. CULTIVATION, COVER CROP, COMPLETE FERTILIZER.

Average number of apples per tree.

Number of trees 26. Acreage in plot .86 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	24	20	3	47	2	9	9	20	26	29	12	67
1909	22	2	—	24	22	4	6	32	44	6	6	56
1910	822	395	56	1273	253	258	58	569	1075	653	114	1842
1911	129	19	17	165	51	17	15	83	180	36	32	248
1912	1056	549	36	1641	159	215	23	397	1215	764	59	2038
5-yr. average	411	197	22	630	97	101	22	220	508	298	45	850
Percentage of various grades									59.7%	35.0	5.2	

TABLE NO. 13.

PLOT 7. CULTIVATION, COVER CROP, COMPLETE FERTILIZER.

Average number of apples per tree.

Number of trees 21. Acreage in plot .52 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	27	18	1	46	2	7	12	21	29	25	13	67
1909	21	4	1	26	33	8	4	45	54	12	5	71
1910	970	418	54	1442	294	232	59	585	1264	650	113	2027
1911	52	6	9	67	19	10	35	64	71	16	44	131
1912	757	508	35	1300	251	420	75	746	1008	928	110	2046
5-yr. average	365	191	20	576	120	135	37	292	485	326	57	868
Percentage of various grades									55.8%	37.5	6.5	

TABLE NO. 14.

PLOT 8. EXCESS PHOSPHORUS.

Average number of apples per tree.
Number of trees 19. Acreage in plot .52 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	22	13	1	36	3	7	13	23	25	20	14	59
1909	27	3	1	31	33	8	6	47	60	11	7	78
1910	759	348	34	1141	321	223	51	595	1080	571	85	1736
1911	77	12	21	110	26	19	30	75	103	31	51	185
1912	790	271	8	1069	186	339	37	562	976	610	45	1631
5-yr. average ..	335	129	13	473	114	119	27	260	449	249	40	738
Percentage of various grades									60.8%	33.7	5.4	

TABLE NO. 15.

PLOT 9. EXCESS NITROGEN.

Average number of apples per tree.
Number of trees 21. Acreage in plot .52 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	63	12	0	75	8	9	14	31	71	21	14	106
1909	22	2	1	25	49	8	8	65	71	10	9	90
1910	901	314	23	1238	392	54	54	500	1293	368	77	1738
1911	61	7	18	86	30	24	24	78	91	31	42	164
1912	729	152	9	890	322	279	39	640	1051	431	48	1530
5-yr. average ..	355	97	10	463	160	75	28	263	515	172	38	726
Percentage of various grades									70.9%	23.6	5.2	

TABLE NO. 16.

PLOT 10. EXCESS POTASH.

Average number of apples per tree.
Number of trees 17. Acreage in plot .48 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1908	82	15	4	101	7	9	7	23	89	24	11	124
1909	16	0	0	16	10	1	1	12	26	1	1	28
1910	1171	186	14	1371	305	299	63	667	1476	485	77	2038
1911	42	2	11	55	17	13	9	39	59	15	20	94
1912	688	108	10	806	320	152	6	478	1008	260	16	1284
5-yr. average ..	400	62	8	470	132	95	17	244	532	157	25	714
Percentage of various grades									74.5%	21.9	3.5	

TABLE NO. 17.

PLOT 11. LIME.

Average number of apples per tree.

Number of trees 26. Acreage in plot .66 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1910	1326	333	22	1681	375	275	42	692	1701	608	64	2373
1911	16	1	4	21	4	3	2	9	20	4	6	30
1912	661	144	9	814	260	160	11	431	921	304	20	1245
3-yr. average	668	159	12	839	213	146	18	377	881	305	30	1216
Percentage of various grades									72.3%	25.0	2.5%	

TABLE NO. 18.

PLOT 12. CHECK FOR LIME PLOT.

Average number of apples per tree.

Number of trees 22. Acreage in plot .62 acre.

Season.	Picked Apples.				Dropped Apples.				Totals.			Grand Total.
	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	Total.	No. 1.	No. 2.	Culls.	
1910	960	277	30	1267	389	287	68	744	1349	564	98	2011
1911	55	8	9	72	22	12	22	57	77	20	32	129
1912	861	219	12	1092	185	175	19	382	1049	393	31	1473
3-yr. average	625	168	17	810	199	158	36	394	825	326	53	1204
Percentage of various grades									69.7%	25.6	4.5	

TABLE NO. 19.

AVERAGE NUMBER OF APPLES PER TREE IN PLOTS 1 AND 4.

Average for 5 years.

Plot No.	Culture.	Fertilizer.	Cover Crop.	No. 1.	No. 2.	Culls.	Total.	Twig Growth.
1.	None—In sod	None	None	159	192	92	443	4.18
4.	Clean culture	None	None	484	385	76	945	7.98

TABLE NO. 20.

AVERAGE NUMBER OF APPLES PER TREE IN PLOTS 4 AND 5.

Average for 5 years.

Plot No.	Culture.	Fertilizer.	Cover Crop.	No. 1.	No. 2.	Culls.	Total.	Twig. Growth.
4.	Clean culture	None	None	484	385	76	945	7.98
5.	Cultivated till July 10	None	Crimson Clover	467	430	63	960	8.90

TABLE NO. 21.

AVERAGE NUMBER OF APPLES PER TREE IN PLOTS 5, 8, 9, 10.

Average for 5 years.

Plot No.	Culture.	Fertilizer.	Cover Crop.	No. 1.	No. 2.	Culls.	Total.	Twig Growth.
5.	Cultivated till July 10th	None	Crimson Clover	467	430	63	960	8.90
8.	Cultivated till July 10th	Excess P.	Crimson Clover	449	249	40	738	8.37
9.	Cultivated till July 10th	Excess N.	Crimson Clover	515	172	38	726	9.10
10.	Cultivated till July 10th	Excess K.	Crimson Clover	532	157	25	714	8.47

TABLE NO. 22.

*AVERAGE ANNUAL TWIG GROWTH IN ALL PLOTS.

Length in inches.

Season.	Plots.											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1909	4.59	4.08	5.34	6.29	8.31	8.33	7.08	6.85	8.02	7.24		
1910	4.15	6.78	6.95	8.79	10.19	11.00	9.85	10.14	10.93	9.85	10.04	9.42
1911	3.21	6.69	7.55	8.43	8.19	9.13	7.68	7.94	8.20	7.87	7.94	7.83
1912	4.79	5.93	7.46	8.43	8.92	9.72	8.64	8.55	9.26	8.93	8.74	8.73
Avg. for 4 years	4.18	5.87	6.82	7.98	8.90	9.29	8.31	8.37	9.10	8.47	8.91	8.66
Percentage increase over sod plot		40%	63	91	113	122	98	100	117	102	113	107
Percentage increase of fertilizers over Plot 5					—	4	−7	−6	2	−5	0	−3

*Measurements for 1908 not recorded. 3-yr. Average only for Plots 11 and 12.

This growth is based on the average of 20 twigs per tree, half are taken from branches which can be reached from the ground and the others are taken up through the top of the tree. The twigs making an average growth are measured as far as the judgment of the recorder can determine.

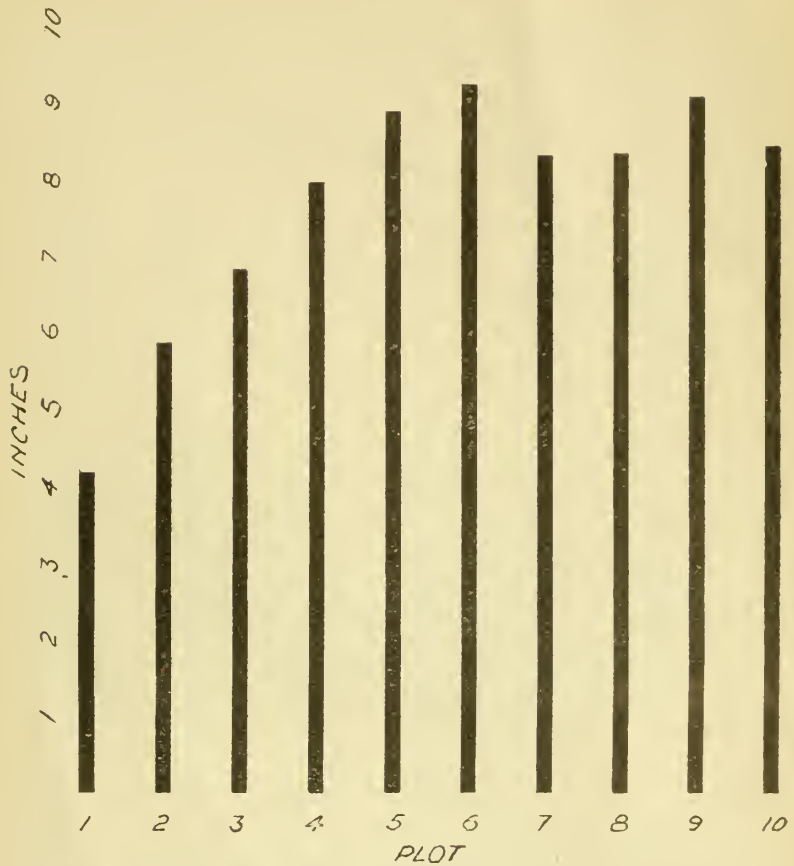


Chart No. 4. The above chart shows the comparative twig growth in the various plots for a four-year period.

Table No. 20 gives the comparative results of sod and clean culture. Here we see that cultivation alone has given more than twice as much fruit as sod treatment, and nearly twice as great a twig growth.

Table No. 21 shows the superiority of turning in a leguminous cover crop, there being an inch increase for each twig recorded each year and some gain in yield.

Table No. 22 gives the comparison of fertilization and non-fertilization in this orchard, both being treated exactly the same otherwise. While we cannot assign a reason for the trees in Plots 8, 9 and 10 failing to respond as did those in Plot 5, yet it is a notable fact that they are not superior.

TABLE NO. 23.

AVERAGE WEIGHT AND AREA OF LEAVES IN ALL PLOTS.

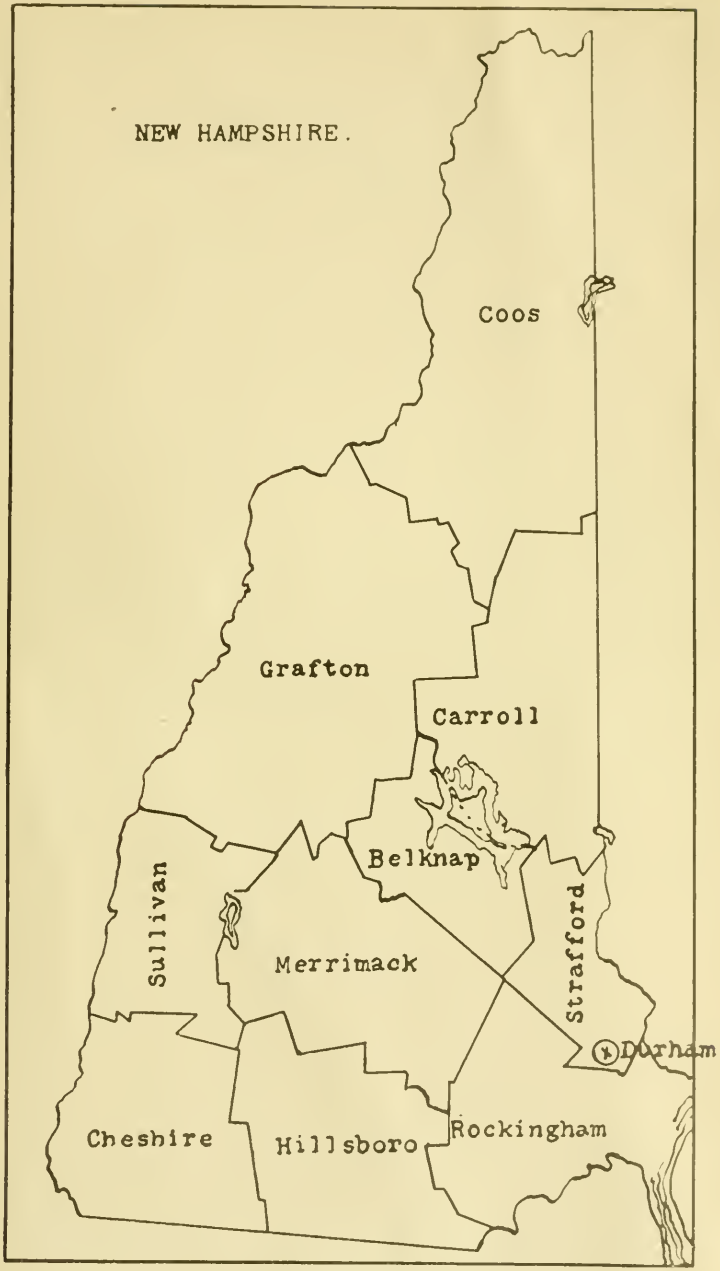
Plot No.	Treatment.	Avg. Area in sq. ins.	Weight per 100 Leaves gr.	
			Green.	Air Dried.
1.	Sod	4.24	70.75	27.32
2.	Cultivation the odd year	4.56	78.81	30.97
3.	Cultivation the even year	4.83	83.02	32.82
4.	Clean culture	5.07	87.34	34.33
5.	Cultivation and cover crop	5.28	87.62	33.82
6.	Root pruning, deep plowing	5.51	96.11	36.72
7.	Complete fertilizer	5.36	92.09	35.98
8.	Excess phosphorus	5.37	92.76	36.44
9.	Excess nitrogen	5.33	91.68	36.38
10.	Excess potash	5.57	95.50	37.19
11.	Lime	5.55	93.61	37.46
12.	Check for Plot 11	5.45	90.98	36.28

The above table is given to show the weight and area of the leaves. It will be seen that the fertilized plots show an increase in both for the season of 1913. The records on the leaves were not made prior to last summer and hence no average can be given. But it is interesting to note that the increase has been constant throughout the fertilized plots regardless of the fact that the twig growth is not increased.

On examination of the leaves from Plot 1 they showed that the palisade cells were quite short and the second row about half the length of the first row. The parenchyma tissue is loose and the chlorophyll has a yellowish cast, in marked contrast to that seen where the trees are cultivated. These records were made during July of 1913. The area of the leaves was taken by the use of a polar planimeter; 100 leaves from each tree were taken and measured then averages were computed for trees in the various plots.

CONCLUSIONS.

A five-year average of the results from this orchard do not show an increase in the yield of the fertilized plots over those receiving good culture, or a sufficient increase in the growth of the trees to warrant the use of fertilizers. We have applied approximately $250 worth of fertilizers in this orchard, not including the cost of hauling it four miles and its application. It is on such light soil as is found in the Woodman Orchard that one would expect trees to respond to fertilizers if they would anywhere, but such has not been the case. Such a light soil favors maturity and there is not the difference in color of fruit between sod and cultivation that might be expected; it varies some with the season, however. What the future may reveal in this experiment can not be told. But in a very positive way this work shows the advantage that has been gained by plowing this orchard land and practicing a good system of culture.



(X) shows location of orchard.

DATE DUE