New York Agricultural Experiment Station.

Geneva, N. Y.

A Comparison of Tillage and Sod Mulch in an Apple Orchard.

Second Report for Auchter Orchard.

U. P. Hedrick.

Published by the Department of Agriculture.
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Frontispiece.—Type and Size of Apples on Tilled Soil.
BULLETIN No. 383.
A COMPARISON OF TILLAGE AND SOD MULCH IN AN APPLE ORCHARD.
SECOND REPORT FOR AUCHTER ORCHARD.
U. P. HEDRICK.

SUMMARY.

This is the third account of studies by the New York Agricultural Experiment Station to determine whether the apple thrives better under tillage or in sod. The first account was published in Bulletin No. 314, 1909; the second in Bulletin No. 375, 1914.

The experiment of which this Bulletin is a report was begun in 1903 in the orchard of Mr. W. D. Auchter, near Rochester, New York. In this orchard are nine and one-half acres of Baldwin trees, 40 feet apart each way, set in 1877. Of these, 118 are in sod, 121 under tillage.

The Auchter orchard was chosen for this experiment because it was uniform in soil and topography and quite typical of the apple lands of western New York. The land is slightly rolling and is a fertile Dunkirk loam, about ten inches in depth, underlaid by a sandy subsoil.

The tilled land was plowed each spring and cultivated from four to seven times. The grass in the sod plat was usually cut once, sometimes twice. In all other operations the care was identical.

The experiment is divided into two five-year periods. During the first period the orchard was divided in halves by a north and south line, during the second period by an east and west line. One-quarter of the orchard, then, has been tilled ten years; another tilled five years and then left in sod five years; the third quarter has been in sod ten years and the fourth quarter in sod five years, then tilled five years.

The following is a statement of results:

The average yield on the plat left in sod for ten years was 69.16 barrels per acre; on the plat tilled ten years, 116.8; difference in favor of tilled plats, 47.64 barrels per acre per year.

The fruit from the sod-mulch plats is more highly colored than that from the tilled land. The sodded fruit matures from one to three weeks earlier than the tilled fruit.

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The tilled fruit keeps from two to four weeks longer than the sodded fruit; it is also better in quality, being crisper, juicier and of better flavor.

The average gain in diameter of the trunks for the trees in sod for the ten years was 2.39 inches; for the trees under tillage 3.90 inches; gain in favor of tillage 1.51 inches.

The trees in sod lacked uniformity in every organ and function of which note could be taken. The uniformity of the trees under tillage in all particulars was in striking contrast.

The grass had a decided effect on the wood of the trees, there being many more dead branches on the sodded trees and the new wood was not as plump or as bright in color.

The leaves of the tilled trees came out three or four days earlier and remained on the trees several days longer than on the sodded trees. They were a darker, richer green, indicating greater vigor, were larger and more numerous on the tilled trees.

The average cost per acre of growing and harvesting apples in sod was $51.73; under tillage $83.48; difference in favor of sod $31.75. Subtracting these figures from the gross return leaves a "balance" per acre for the sodded plats of $74.31; for the tilled plats, of $140.67, an increase in favor of tillage of $66.36. For every dollar taken from the sodded trees, after deducting growing and harvesting expenses, the tilled trees gave one dollar eighty-nine cents.

The effects of the change from sod to tillage were almost instantaneous. Tree and foliage were favorably affected before mid-summer of the first year; and the crop, while below the normal, consisted of apples as large in size as any in the orchard, the falling off in yield being due to poor setting.

The change for the worse was quite as remarkable and as immediate in the quarter of the orchard turned from tillage into sod; the average yield in this quarter was not half that of any one of the other three quarters.

The use of nitrate of soda in the sod plats greatly increased the vigor of the trees and was a paying investment, yet for the five-years period they bore but a trifle more than half as much as the tilled trees.

The very marked beneficial influence on the sodded trees of ground adjacent under tillage teaches that not only should apples not be grown in sod but that for the best good of the trees there should be no sod near them.
Only in the amount of humus and nitrogen has the soil been appreciably changed by the two treatments. The quantities of humus and nitrogen in the plat tilled ten years are so much greater that it is safe to assume that the tillage and cover-crop treatment conserves humus and nitrogen better than the sod-mulch treatment.

Grass militates against apples growing in sod in several ways which act together, as:

1. Lowering the water supply,
2. Decreasing some elements in the food supply,
3. Reducing the amount of humus,
4. Lowering the temperature of the soil,
5. Diminishing the supply of air,
6. Affecting deleteriously the beneficial micro-flora,
7. Forming a toxic compound that affects the trees.

General statements are:

Sod is less harmful in deep than in shallow soils.

There is nothing in this experiment to show that apples ever become adapted to grass.

Sod may occasionally be used in making more fruitful an orchard growing too luxuriantly.

Other fruits than the apple are probably harmed quite as much or more by sod.

The effects of grass occur regardless of variety, age of tree, or cultural treatment, and are felt whether the trees are on dwarf or standard stocks.

Because of their shallow root systems, dwarf trees are even more liable to injury from grass than standards.

Hogs, sheep or cattle pastured on sodded orchards do not overcome the bad effects of the grass.

Owners of sodded orchards often do not discover the evil effects of the grass because they have no tilled trees with which to make comparisons.

It is only under highest tillage that apple trees succeed in nurseries and all the evidence shows that they do not behave differently when transplanted.

Grass left as a mulch in an orchard is bad enough. Grass without the mulch is all but fatal — it makes the trees sterile and paralyzes their growth. It is the chief cause of unprofitable orchards in New York.
INTRODUCTION.

A few years ago it was thought that some method of growing apples in sod might take the place of cultivation in the orchards of New York. The Hitchings method of cutting the grass and letting it lie as a mulch seemed to meet the conditions in this State better than any other of the sod or mulch systems and in response to a popular demand this Station began a comparative test of tillage and the Hitchings sod-mulch method in two orchards. The two tests were begun in 1903, and in 1909 a preliminary report was made in Bulletin No. 314 of one of the experiments, that in the Auchter orchard near Rochester, and in Bulletin No. 375, published in March, 1914, a complete report was made of the other test which was carried on in the Hitchings orchard near Syracuse. This is, therefore, the third account of these orchard-management experiments and is given to complete the preliminary report of 1909 of the work in the Auchter orchard.

THE AUCHTER ORCHARD EXPERIMENTS.

LOCATION.

The orchard in which the experiment under discussion was carried on is located on the farm of W. D. Auchter, Elmgrove, New York, seven miles west of Rochester. The site is in the center of the great apple belt of western New York. The orchard was selected because it was the most typical one to be found in topography, soil, variety of apples and in condition at the beginning of the experiment.

The land lies in a rolling plain, one of the ridges of which begins at about the center of the west end of the orchard and runs diagonally lengthwise towards the southeast corner. From this low and somewhat stony ridge the land falls gently away both north and south. About an acre in the southwest corner of the orchard is more depressed than the rest of the field, dropping at the lowest point fifteen feet from the summit of the ridge. This lowland is tile drained but artificial drainage for the rest of the orchard is not needed.
SOIL.

Though the orchard was chosen because variations in the land were few and not great, yet the character of the surface soil changes slightly with the lay of the land. On the ridge and its slopes the surface soil is a sandy loam of the Dunkirk series, nine or ten inches deep and underlaid by a compact sandy subsoil. In the acre depression the type changes to a dark colored Dunkirk loam, ten to twelve inches deep, also underlaid by a fine compact sand. The subsoil grows coarser as the depth increases providing very good natural drainage. Table I shows the composition of the soil and subsoil as determined by mechanical analysis. Table II gives the necessary data as to the chemical constituents of the soil.

Table I.—Mechanical Composition of the Soils and Subsoils in the Auchter Orchard.

<table>
<thead>
<tr>
<th>Description</th>
<th>Coarse sand, 1—0.5 mm.</th>
<th>Medium sand, 0.5—0.25 mm.</th>
<th>Fine sand, 0.25—0.1 mm.</th>
<th>Very fine sand, 0.1—0.05 mm.</th>
<th>Silt, 0.05—0.005 mm.</th>
<th>Clay, below 0.005 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunkirk sandy loam, 0—9 inches</td>
<td>11.7</td>
<td>52.3</td>
<td>3.6</td>
<td>11.1</td>
<td>15.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Subsoil</td>
<td>9.0</td>
<td>60.5</td>
<td>7.1</td>
<td>9.7</td>
<td>8.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Dunkirk loam, 0—11 inches</td>
<td>4.4</td>
<td>26.2</td>
<td>9.7</td>
<td>30.0</td>
<td>19.1</td>
<td>10.6</td>
</tr>
<tr>
<td>Subsoil</td>
<td>3.0</td>
<td>15.6</td>
<td>21.5</td>
<td>27.9</td>
<td>29.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table II.—Chemical Composition of Soil Samples from Auchter Orchard.

<table>
<thead>
<tr>
<th>Location</th>
<th>Pounds per acre in first seven inches.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₂O₅</td>
</tr>
<tr>
<td>Plat 1</td>
<td>2.380</td>
</tr>
<tr>
<td>Plat 2</td>
<td>3.080</td>
</tr>
<tr>
<td>Plat 3</td>
<td>2.200</td>
</tr>
<tr>
<td>Plat 4</td>
<td>2.940</td>
</tr>
<tr>
<td>Plat 5</td>
<td>2.660</td>
</tr>
<tr>
<td>Plat 6</td>
<td>2.800</td>
</tr>
<tr>
<td>Plat 7</td>
<td>2.940</td>
</tr>
<tr>
<td>Plat 8</td>
<td>2,940</td>
</tr>
</tbody>
</table>
Diagram 1.—Plan of Auchter Orchard.
See opposite page.
PLATS.

The Auchter orchard consists of a little over nine and one-half acres of Baldwin trees set in 1877 at a distance apart of 40 feet. There are ten rows in the orchard, each having 26 trees. During the first twenty years of its existence the orchard was badly neglected, the results of which are shown in several derelict trees which, with a few replaced trees, are not in the experiment. For several years before the land was leased by the Station, the orchard had been under tillage with an annual cover-crop and had borne very good crops. Diagram I is a chart of the orchard showing the plats, which may be further described as follows:

Plat 1 was in sod the first five years; cultivated the last five years.
Plat 2 has been cultivated for ten years.
Plat 3 has been in sod ten years.
Plat 4 was cultivated five years; in sod during the past five years.
Plat 5 has been in sod ten years with applications of nitrate of soda the past five years.
Plat 6 was cultivated the first five years; in sod the last five years with applications of nitrate of soda.
Plat 7 has been in sod ten years.
Plat 8 was cultivated five years and has been in sod during the past five years.

MANAGEMENT OF PLATS.

The trees in all of the plats have received as nearly identical care as possible in all operations excepting soil treatment. The soil in the sod area and the tilled area has been managed as follows:

Sod plat.—Since one half of the area which was to be under sod during this experiment had been under cultivation the previous five years, it was necessary to seed down this part in 1909. The ground was fitted in the spring and on June 2 a mixture of blue grass, orchard grass, timothy and clover seed was sowed. The half of the area which was in sod at the beginning of the experiment was cut June 3 and August 3. Throughout the experiment the grass was left where it fell, none being removed from the orchard. The dates of mowing for the five years were as follows:

1909—June 3 and August 3; 1910—June 6; 1911—May 30 and July 27; 1912—June 7; 1913—May and July 26.
Tilled plat.—The following is the record of the treatment of the tilled area:

1909.—Plat plowed April 11–13; rolled and dragged April 16; harrowed May 27–28, June 9, June 25, July 9, July 21. On July 28 clover was sown and covered with a weeder.

1910.—Plowed and fitted May 27–31; harrowed June 17–18, July 2, July 12, July 25. Clover was sown July 28 and covered with a weeder. The following day it was rolled down.

1911.—Plowed and fitted April 30–31; harrowed June 1, June 16, June 26, July 4, July 12, July 21–24. Mammoth clover seed was sown on July 24 and dragged in.

1912.—Plowed May 18; harrowed June 11, June 25, July 4, July 13, July 23. A cover-crop of "medium" red clover was sown and dragged in July 25.

1913.—Plowed and harrowed May 5–9; harrowed May 21–24, June 11, July 11, July 25. On July 26 oats were sown as a cover-crop and dragged in.

FERTILIZERS.

Applications of fertilizers were quite incidental to the main purpose of this experiment but their use turned out to be an episode of considerable importance. Fruit-growers who have followed the fertilizer experiments in New York will remember that in this State there is little direct evidence to show that trees profit from potassium or phosphorus applied as commercial fertilizers. In fact, in the orchards of this Station fertilizers containing these two elements were thrown away in one experiment with old trees for twelve years\(^1\) and in another for fifteen years\(^2\) with young trees. The plants gave no adequate response in the first case and none at all in the second. The results in the Auchter orchard tally closely with those at the Station as the following statements show:

When the experiment was in its infancy it was thought that all apple orchards in New York needed phosphorus, accordingly acid phosphate was prescribed and applied to the whole orchard at the rate of 400 pounds per acre. There seems to have been more doubt about the need of potassium; for this element in muriate of potash at the rate of 400 pounds per acre was used experimentally on but two cross-rows, 8 and 9 in the chart, running through both the

tilled and the sodded plats. In the light of present knowledge and practice, the quantities used are excessive and the trees should have shown results if this land needed phosphorus or potassium. These superabundant applications were made for three years without visible results.

The fourth season, 1907, the use of acid phosphate for the whole orchard was discontinued but it was applied to cross-rows 12 and 13 at the rate of 15 pounds per tree. The muriate of potash was again applied on rows 8 and 9 and on rows 16 and 17. Negative results followed:—neither in 1907 nor thereafter was there evidence that the trees had been "fertilized." It may be said that nitrogen was the limiting factor and that without it the potassium and phosphorus were inert. But there seemed to be no lack of nitrogen in the tilled plat; rich green foliage, ample annual growth, fruitful trees and large apples, all betokened an abundance of nitrogen presumably supplied by the luxuriant growths of the clover cover-crops plowed under in four of the five years.

In 1910 the whole orchard received an application of quicklime at the rate of one ton per acre. At that time the opinion was current that land for most of our cultivated crops needed lime. It was assumed that the apple could not be hurt and might be benefited, and, not wishing to complicate the experiment with more plats, the whole orchard was limed. There being no checks, the effects cannot be told; but the men in watchful charge of the orchard feel that the use of lime was wholly destitute of definite indications of benefits — no response whatsoever came from the trees.

Beginning five years ago, nitrate of soda has been applied in certain plats in sod as heretofore mentioned. The results were rather remarkable but these are most properly discussed later.

MEASURING THE EFFECTS OF THE TWO TREATMENTS.

Trees probably respond in all characters to cultural treatment, and in like degree. Thus, in the first five years of this experiment, differences were found in fruitfulness, in size, color, maturity and quality of fruit, in diameter of trunk, color of foliage, size and weight of leaves, leafing-time, fall of leaves, annual growth of branches, color and size of new wood, amount of dead wood, depth of roots and spread of roots. In all of these characters the differences are

\[1\] N. Y. Sta. Bul. 314.
in accord, showing, one and all, that the welfare of the orchard is best served by tillage. With this concurrent response of characters established in the first period of the experiment, it did not seem necessary to use all of the criteria in showing the effects of the two treatments on the orchard during the last period. The ultimate criterion of a method of management is, of course, crop performance. The yield of fruit, then, has been chosen as the chief measure of merit of the two methods in this report. So, too, diameter of trunk is the best standard to measure tree performance and is given as the chief gage of the growth and vigor of the trees.

**YIELD OF FRUIT.**

The Baldwin is usually a biennial bearer but now and then the trees bear two years in succession and it is seldom that all of the trees in an orchard take the same year off. In the Aucinter orchard we have been fortunate enough to have ten crops in succession, the yields being given in Table III. In calculating the value of a crop

**Table III.—Yield of Fruit on Sod and Tillage Plats in the Aucinter Orchard.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sod Plats.</th>
<th>Tillage Plats.</th>
<th>Gain of Tillage over Sod in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>118</td>
<td>329 Bbls.</td>
<td>286.1 Bbls.</td>
</tr>
<tr>
<td>1905</td>
<td>118</td>
<td>161.3 Bbls.</td>
<td>71.7 Bbls.</td>
</tr>
<tr>
<td>1906</td>
<td>118</td>
<td>167.3 Bbls.</td>
<td>43 Bbls.</td>
</tr>
<tr>
<td>1907</td>
<td>118</td>
<td>188.3 Bbls.</td>
<td>87 Bbls.</td>
</tr>
<tr>
<td>1908</td>
<td>118</td>
<td>272.8 Bbls.</td>
<td>52.5 Bbls.</td>
</tr>
<tr>
<td>1909</td>
<td>118</td>
<td>84 Bbls.</td>
<td>91 Bbls.</td>
</tr>
<tr>
<td>1910</td>
<td>118</td>
<td>180 Bbls.</td>
<td>122.3 Bbls.</td>
</tr>
<tr>
<td>1911</td>
<td>118</td>
<td>28 Bbls.</td>
<td>26.3 Bbls.</td>
</tr>
<tr>
<td>1912</td>
<td>118</td>
<td>523 Bbls.</td>
<td>141.3 Bbls.</td>
</tr>
<tr>
<td>1913</td>
<td>118</td>
<td>349 Bbls.</td>
<td>81.4 Bbls.</td>
</tr>
</tbody>
</table>

| Average | 118 | 228.3 Bbls. | 100.3 Bbls. | 328.5 Bbls. | 121 | 376.2 Bbls. | 178.8 Bbls. | 554.8 Bbls. | 147.9 | 226.3 Bbls. |
| Average | 48.06 | 21.11 Bbls. | 69.16 Bbls. | 116.8 Bbls. | 119 | 79.2 Bbls. | 37.62 Bbls. | 116.8 Bbls. | 31.14 | 47.64 Bbls. |
| Tree average | 1.766 | .776 Bbls. | 2.542 Bbls. | 4.29 Bbls. | 1.14 | 47.64 Bbls. | 1.75 Bbls. | 1.75 Bbls. | 1.14 | 47.64 Bbls. |

of apples we must, of course, know the quantities of the barreled stock and culls. These data are given in the table presented. But the figures for total yield are by far the most important in comparing the results of the two treatments in this orchard; for, while grading assorts apples somewhat in accordance with size, yet the quantities of seconds and culls are always more or less increased by fruits.
made imperfect by insects, fungi or other injuries. Attention, then, is especially directed to the columns of total yields and still more especially to the column showing the difference between the total yields of the sodded and tilled plats.

Taking, then, the differences in total yield as the best measure of the two methods of treatment, we have no difficulty in coming to a conclusion as to whether sod or tillage is better for the apple. A summary of the figures speaks eloquently for tillage. Thus, during the ten years of this experiment the tilled trees have produced nearly twice as much fruit as those in sod; the bearing capacity of the tilled trees the last five years was greater by 450 barrels than the first five, whereas during the second five years the sodded trees bore 33 barrels less than in the first period—showing that apple trees in sod cannot hold their own but fall behind. Sod is not only less beneficial than tillage but it is positively harmful.

The showing for tillage, of course, would have been still better had not Plats 5 and 6 in the sodded section received applications of nitrate of soda which increased the yield, as shown in Table VI.

**SIZE, COLOR, MATURITY AND QUALITY OF FRUIT.**

*Size.*—The size of Baldwin apples is important only as it has a bearing on the yield, for the fruits of this variety are large enough, as grown either in sod or under tillage, to be acceptable in the markets. But the yield in fruit, of course, is greatly increased by increase in size, and thus this character becomes important.

Data taken in the first five-year period, published in Bulletin No. 314 (page 97) show that the tilled apples are nearly one-third larger than those grown under sod—a very telling advantage in crop production. Size alone considered, if the 5–7 ratio of bigness holds for the whole crop, the proportion of culls and seconds is much larger in the sodded than in the tilled plat. Since the yield of the tilled trees is nearly double that of those in sod the number of fruits must be greater on tilled than on sodded trees. To those who have been in the orchard in harvest time, however, figures are unnecessary to show that tillage gives more and larger apples—in no other way is the tale of the deleteriousness of the sod told so strikingly as to the eye at picking time when the size and number of fruits are compared. The Frontispiece shows the type and gives an idea of the size of the apples grown under tillage.
Color.—In America, fashion calls for red apples. The apples grown in sod in this experiment, as is the case in all sodded orchards in New York, comply with the fashion and are brilliantly colored, while those grown under tillage are of sombre hues. This is the single instance in which sod-mulched fruit surpasses tilled fruit. But as we have pointed out in the two previous bulletins from this Station having to do with apples under these two methods of treatment, abnormally bright color indicates constitutional disease or decrepitude. The coloring matter in the skins of apples is modified chlorophyll and as the chlorophyll of leaves becomes brilliantly colored in autumn tints, preceding maturity and decay, so the bright red of the sod-grown apple may be regarded as premature ripening preliminary to decay; for the sodded apples, as we shall see in the next division of our subject, mature and pass out of season more quickly than the tilled apples.

The fact that sod-grown apples are always the most highly colored fruits, disproves the current opinion that the color of apples is almost wholly a matter of climate. The statement is found everywhere in pomological literature that sunlight produces brilliant colors in fruit—that, like the complexion of Shakespeare’s dusky Moor, the red color of apples “is but the burnished rays of the burning sun.” Rather, we shall find, as in this experiment, that high color is more a matter of maturity than of climate, maturity, of course, often, but not always, being dependent on climate.

Maturity and keeping-quality of apples.—In all of the ten years of this experiment the sod-mulched fruit has ripened materially earlier and has been picked from one to three weeks sooner than that under tillage, depending upon the weather. Thus, if the season was wet and cool the difference in ripening time was but a few days but if dry and warm it ranged from one to three weeks. This is an intensification of the deleterious action of the sod and affects the product in three ways; it causes smaller fruit, a shorter season of usefulness in common storage, and poorer quality.

The difference in keeping quality was usually more marked in common storage than that of time of maturity. In cold storage, tests carried on by the United States Department of Agriculture during the first five years, as reported in Bulletin No. 314 \(^1\) from this

Station, showed but little difference, fruit under both treatments keeping equally well until the end of the commercial storage season.

Quality of the fruit.—What is quality? The word is rolled under the tongue by both fruit-growers and consumers as meaning much, but like "good cheer" in the fable is "fish to one, flesh to another, and fowl to a third." As the word is here used, quality is, in brief, that combination of flavor, aroma, juiciness and tender flesh which makes fruits agreeable to the palate. Quality has, and is coming more and more to have, commercial value and the effects, therefore, of the two treatments on apples in this respect are most important.

The tilled fruit in this orchard is much better in quality than that from the sod-mulch plats, a fact affirmed every year by those who have to do with the experiment and attested by all fruit-growers who have eaten the apples with a comparison in mind. Let us take the evidence of Mr. G. Harold Powell, of the United States Department of Agriculture, as one of the witnesses. In this report on the keeping qualities of this fruit, noted in the second paragraph before this, he says:

(March 1st, 1907.) "The texture of the sod fruit was coarse and the flavor was insipid, with a trace of bitterness in it. The tillage apples were brittle and semi-firm in texture, aromatic and good in flavor."

(End of the commercial storage season, 1908.) "There was a distinct difference in quality in favor of the apples from the cultivated land, the fruit from the sod trees, though finer in color, having a coarse texture and an insipid, slightly bitter flavor."

"At the time this report is made, February 8, 1909, there is considerable Baldwin spot in the different lots of fruit and the apples from the cultivated trees though of poorer color were finer in quality than the fruit from the sod trees."

As to the findings at the Geneva Station we cannot do better than to quote a part of the preliminary report on quality in Bulletin No. 314 \(^1\) from this Station:

"The difference in quality is due chiefly to a difference in the texture of the flesh. In eating, the tissues of the tilled fruit are turgid and crisp while in the apples from the sod-mulch plat there is a tendency to dryness and mealiness. A determination of the water content, however, does not show much difference in this

respect, the tilled fruit having 84.37 per ct. moisture, the sod-mulch fruit 84.17 per ct. There is no appreciable difference in the specific gravity of the most of the fruit from the two plats as indicated by the hydrometer, showing that the percentage of soluble solids is practically the same in the two products.”

“There are noteworthy differences in the flesh of the two fruits. That of the apples from the sodded trees is yellowish in color and frequently tinted with red at the circumference while that of the apples from the tilled trees is greenish and never tinted. Of more importance commercially is the fact that the flesh of the sodded fruit is more frequently spotted with the "Baldwin spot," a dry, corky condition of portions of the flesh due probably to some physiological trouble. This corky tissue sometimes envelops the core and in other specimens involves not a little of the circumference of the fruit. Such a physiological defect must be considered as a result of some harmful disturbance in the well-being of the tree.”

**EFFECTS OF THE TWO TREATMENTS ON THE TREES.**

*Diameter of trunks.*—Experience with several orchard experiments shows plainly that if but one phase of growth is chosen to measure health and vigor of tree, increase in diameter of trunk is much the most satisfactory. Increase in growth and vigor of the whole tree is directly proportional to the increase in the diameter of the trunks. Table IV shows the gains in diameter of the trunks of the trees tilled ten years over those in sod ten years. The diameters are those of mid-trunk, the lengths of these trunks averaging about four and one-half feet. The final figures show most strikingly the greater growth of the tilled trees. We begin to realize the magnitude of

**Table IV.**—*Gain in Trunk Diameters of Trees Ten Years in Sod and Ten Years Under Tillage.*

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SOD-AVERAGE OF 61 TREES</th>
<th>TILLAGE-AVERAGE OF 60 TREES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Row 1</td>
<td>Row 2</td>
</tr>
<tr>
<td>Gain</td>
<td>2.77</td>
<td>2.31</td>
</tr>
</tbody>
</table>

Average gain for sod 2.39 in., average gain for tillage 3.90 in., average gain of tillage over sod, 1.51 in.
the deleterious effect of sod when we add the illuminating evidence, that the trees have grown comparatively little in ten years, to that regarding yields which shows that they were actually bearing less fruit than formerly. The conjunction of the two spells ruin.

Plate I, though made from a photograph taken at a considerable distance from the orchard, shows that the trees in sod, corresponding to the trunk diameters, are smaller than those under tillage.

Uniformity of trees.—In no respect do the trees in sod in this orchard show injury more strikingly than in the matter of uniformity. They lacked uniformity in every organ and function of which note could be taken. To particularize: A tree in sod would bear on one branch, not on others; fruit on one side would be large, on another small; or, the crop would be well-colored in part and the remainder poorly colored; branches and foliage differed much on individual trees; the circumference of the root system of the sodded trees was very irregular in outline and uneven in depth. The lack of uniformity was, of course, much more noticeable in the respects named in distinct trees in sod, even though growing side by side, than in branches of individual trees. Intermittency in bearing of all trees in sod was greater than under tillage.

On the contrary, one of the most illuminating pieces of evidence favoring cultivation for this or any other crop was the uniformity of the trees in tillage—a condition the desirability of which is so obvious as to need no discussion.

The reason for this difference in uniformity, set forth at greater length in the previous report on this orchard, is the lack of uniformity in the environment of the sodded trees and the greater uniformity brought about by tillage,—as, surface uniformity, equal depths of soil, and evenness in the amount and availability of air, food, moisture and temperature.

Color and condition of wood.—There is an extraordinary effect of the grass on the color of the new wood, which was mentioned in the previous report and, while it may be of minor importance to the trees, is well worth again noting, since the phenomenon has intensified as the experiment progressed. The differences in the wood can best be described in the words of the first description.¹

twigs and the tautness of the bark. The tree tops on the sod-mulch plat were darker, of a brownish cast and less glossy and bright, giving a prevailing color that distinguished the sod-mulch plat from the tilled plat a mile away."

Any one with experience would pick the tilled trees as the healthier from the condition of the new wood.

As the experiment has progressed the dead wood in the sodded trees, noted in the first report, has increased out of all proportion to expectations from the first few years' work. This dead wood, in the quantities present, was so certain a sign of failing vigor and decrepitude that the owner at the close of the ten-year period feared for the life of his trees if they were to be kept in sod. The decrepit and moribund condition of sodded orchards in New York, even when mulched, as indicated by dead wood, has done much to drive sod mulching out of practice in commercial orchards in this State.

FOLIAGE.

The importance of good foliage.— In the most literal sense "light is life" for plants. Foliage absorbs energy from the sun's rays and, as every school-boy knows, plants have a marvelous faculty of developing and placing their leaves so that the largest possible amount of sunlight will be absorbed. Under the influence of the sun's rays the carbonic acid of the air and the soil solution are synthesized into the organic materials from which the plant tissues are constructed. The foliage, then, is the assimilating apparatus of the apple-tree. In a slightly different sense it may be said to be the breathing apparatus of the tree. Or, in another way a leaf is well called a solar engine getting its energy from the light rather than from the heat of the sun. In any and all of these aspects of the functions of foliage it is seen at once that the efficiency of an apple-tree depends in large measure upon its foliage. What is the effect of these two methods of treatment upon the foliage of the trees in this experiment?

Color of foliage.—The part of the leaf which acquires energy from light is the chlorophyll, the green coloring matter, found in the leaves of all higher plants. Now the amount of this indispensable chlorophyll in the leaf of an apple is measured by the depth and richness of the green of the foliage. Leaf-color is the readiest and most delicate gage the fruit-grower can use in determining the well-
Plate I.—Relative Size of Trees under Tillage and in Sod Mulch.
Plate II.—Tree on Tilled Plat Showing Character of Foliage
Plate III.—Tree on Sod-mulch Plat Showing Character of Foliage
being of his trees even though reliance must be placed on the eye alone to secure evidence. Judged by color of foliage there was, in any year, no time while the leaves were out that even the novice in fruit-growing would not have declared the tilled trees the more vigorous and healthy. The pale, sickly color of the sodded trees could be distinguished from the rich green of those under tillage fully a half mile away as one approached the experimental plats.

The appearance of the foliage of sodded trees is so characteristic that we venture the assertion that we can recognize a sod-bound apple-tree from its unthrifty foliage, mulch or no mulch, find it where you may in western New York, at any time from June to October. In passing, it must be said that, everywhere in New York, in driving by orchards the tell-tale tints of the leaves speak convincingly of the better health and greater vigor of tilled apple-trees to those who have eyes to see.

Number and size of leaves:—The number and size of the leaves tell the same tale of some kind of interference in the protoplasmic activity in the leaves on the sodded tree. It required but a glance to satisfy oneself that the leaves on the tilled trees were larger and more numerous, and therefore total leaf area much greater on the tilled than on the sodded trees. Undoubtedly the number and the size of the leaves shut out the sunlight somewhat from the fruit and thus help to account for its later maturity and poorer coloring on the tilled trees. Plates II and III give some idea of the relative size and denseness of the leaves in the two plats.

In the first report on this experiment an attempt was made to measure roughly the relative efficiency of the foliage of the trees under the two treatments by weighing leaves.\(^1\) It was found, in short, that the leaves of the tilled trees weigh one and one-third times as much as those of the sodded trees indicating one and one-third greater efficiency of the foliage of the tilled trees.

Leafing-time and fall of leaf.—Not only were the leaves on the tilled trees more efficient in furnishing food for the trees because of more chlorophyll and greater size and larger numbers but they remained on the trees longer at both ends of the season and thus contributed to superior vigor and health. The leaves of the tilled trees came out from two to five days earlier in the Auchter orchard and remained on from a week to two weeks longer. In the northern

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climate of New York this curtailment of the season for the sodded trees must have lessened growth of tree considerably and hastened maturity of fruit not a little. In these life events the trees in the Auchter and the Hitchings orchards behaved alike.

FINANCIAL STATEMENT.

After all it is the pecuniary rewards that mean most for a method of farm management. The method that makes fruit-growing most profitable is best. It is safe to use financial data in fruit-growing only provided they be taken over a sufficiently long time to offset

**Table V.—Expenses of Culture and Harvesting and Balance in Auchter Orchard for Ten Years.**

<table>
<thead>
<tr>
<th>Sod Plat — 118 Trees.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YEAR</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1904</td>
</tr>
<tr>
<td>1905</td>
</tr>
<tr>
<td>1906</td>
</tr>
<tr>
<td>1907</td>
</tr>
<tr>
<td>1908</td>
</tr>
<tr>
<td>1909</td>
</tr>
<tr>
<td>1910</td>
</tr>
<tr>
<td>1911</td>
</tr>
<tr>
<td>1912</td>
</tr>
<tr>
<td>1913</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Per acre per year</strong></td>
</tr>
<tr>
<td><strong>Per barrel</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tilled Plat — 120 Trees.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YEAR</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1904</td>
</tr>
<tr>
<td>1905</td>
</tr>
<tr>
<td>1906</td>
</tr>
<tr>
<td>1907</td>
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<tr>
<td>1908</td>
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<td>1909</td>
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<tr>
<td>1910</td>
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<tr>
<td>1911</td>
</tr>
<tr>
<td>1912</td>
</tr>
<tr>
<td>1913</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Per acre per year</strong></td>
</tr>
<tr>
<td><strong>Per barrel</strong></td>
</tr>
</tbody>
</table>

accidental variations. Average figures for ten crops ought to give a fairly safe standard of measurement. Table V gives the figures of expenses and profits,—of which the following is a brief summary.

The average cost per acre of growing and harvesting apples in sod was $51.73, while under tillage the cost was $83.48, the difference in favor of sod being $31.75. Subtracting these figures from the gross income gives an average "balance" per acre for the sodded plats of $74.31 while the "balance" per acre from the tilled plats was $140.67, an increase of $65.36 in favor of tillage. In other words, for every dollar remaining from the sod income, after deducting cost of growing and harvesting, the tilled trees gave a similar balance of one dollar eighty-nine cents. That is to say, since the remaining fixed charges are practically equal for the tilled and sodded areas, tillage gave nearly double the profits in this ten-year period that sod gave.

The income from the tilled half of the Auchter orchard furnished a good basis for calculating the profits of a New York apple orchard. The cost of the various operations, of the materials used, and the selling prices and profits of this orchard for the ten years for which it was leased by the Station, are published in Bulletin No. 376.

MINOR EXPERIMENTS IN THE AUCHTER ORCHARD.

In the test as planned in 1903 the south half of the orchard, five rows of twenty-six trees each, was in sod; the north half under tillage. During the last five years the east half of the orchard has been in sod; the west half under tillage. Certain rows in the sod section of the last period have had annual applications of nitrate of soda while the remaining rows have not been so fertilized. Reference to the diagram on page 254 and to the plan of the plats on page 255 will make clear the redivision of the work made in 1909. We must now briefly discuss these minor experiments.

The change from sod to tillage.—Plat I, consisting of the southwest quarter of the orchard, was in sod the first five and under tillage the second five years. How long did it take the sodded trees to "come back"? The effects were almost instantaneous and soonest discovered and probably best measured by the eye. During the last season of the first period the leaves on the sodded trees were few, small and of a sickly, yellow color. In mid-season of the first summer of tillage in this plat the color was the normal healthy green
of tilled trees but the foliage was still somewhat sparse. The crop of this first season was a little below the normal in amount, the falling off being due to poor setting rather than to small size of apples. The second year the foliage was normal in all respects and the crop was the best per tree of all plats in the experiment as it was again in the third year and the fifth while the fourth season the yield was much above the normal, being exceeded in the tree average only by two other plats.

<table>
<thead>
<tr>
<th>Year</th>
<th>Plat 1 (57 trees)</th>
<th>Plat 2 (62-60 trees)</th>
<th>Plat 3 (15 trees)</th>
<th>Plat 4 (10 trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1909</td>
<td>129 bbls.</td>
<td>2.3 bbls.</td>
<td>390 bbls.</td>
<td>6.3 bbls.</td>
</tr>
<tr>
<td>1910</td>
<td>222.7 bbls.</td>
<td>4.0 bbls.</td>
<td>115 bbls.</td>
<td>1.9 bbls.</td>
</tr>
<tr>
<td>1911</td>
<td>378.1 bbls.</td>
<td>8.4 bbls.</td>
<td>246.1 bbls.</td>
<td>4.1 bbls.</td>
</tr>
<tr>
<td>1912</td>
<td>250.1 bbls.</td>
<td>4.4 bbls.</td>
<td>468.2 bbls.</td>
<td>7.8 bbls.</td>
</tr>
<tr>
<td>1913</td>
<td>393.5 bbls.</td>
<td>7 bbls.</td>
<td>307.7 bbls.</td>
<td>5.1 bbls.</td>
</tr>
<tr>
<td>Average per tree</td>
<td>5.17 bbls.</td>
<td>5.03 bbls.</td>
<td>1.92 bbls.</td>
<td>1.41 bbls.</td>
</tr>
</tbody>
</table>

Table VI. — Yield of Plats and Tree Averages in Auchter Orchard in Second-Half of Test.

<table>
<thead>
<tr>
<th>Year</th>
<th>Plat 5 (28 trees)</th>
<th>Plat 6 (30 trees)</th>
<th>Plat 7 (18 trees)</th>
<th>Plat 8 (19 trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1909</td>
<td>83 bbls.</td>
<td>3 bbls.</td>
<td>20 bbls.</td>
<td>66 bbls.</td>
</tr>
<tr>
<td>1910</td>
<td>107 bbls.</td>
<td>3.9 bbls.</td>
<td>66.7 bbls.</td>
<td>2.2 bbls.</td>
</tr>
<tr>
<td>1911</td>
<td>15.3 bbls.</td>
<td>54 bbls.</td>
<td>66.7 bbls.</td>
<td>72 bbls.</td>
</tr>
<tr>
<td>1912</td>
<td>225.7 bbls.</td>
<td>8.1 bbls.</td>
<td>170.7 bbls.</td>
<td>5.7 bbls.</td>
</tr>
<tr>
<td>1913</td>
<td>118.4 bbls.</td>
<td>4.2 bbls.</td>
<td>90.5 bbls.</td>
<td>3 bbls.</td>
</tr>
<tr>
<td>Average per tree</td>
<td>3.90 bbls.</td>
<td>2.46 bbls.</td>
<td>2.73 bbls.</td>
<td>2.59 bbls.</td>
</tr>
</tbody>
</table>

Table VI. — Yield of Plats and Tree Averages in Auchter Orchard in Second-Half of Test — (Concluded).

Table VI gives the yields of the several plats during the last five years of the experiment and shows graphically the change in productiveness with the change from sod to tillage.
Incidentally there is evidence here to show that the quantity of the chief food elements is a minor matter in this experiment. Of the eight plats in the orchard, the one changed from sod to tillage has least humus, as gaged by carbon, and is next to the lowest in nitrogen and phosphorus. Yet without additions of fertilizers in the change from sod to tillage, the plat almost immediately became the most productive in the orchard. It is doubtful if the humus or the available food turned over in the sod wholly accounts for the increased productivity of this plat.

The change from tillage to sod.— Plats 4, 6 and 8, constituting the northeast quarter of the orchard, were cultivated the first half of the ten years and were in sod the last half. The change for the worse was quite as remarkable in this quarter of the orchard as it was for the better in the quarter turned from sod into tillage. The trees began to show the effects of the grass in their foliage before mid-summer of the first season. The deterioration of the trees as a whole began this first season and became increasingly greater from year to year until the end of the experiment. In the quarter of the orchard ten years under tillage the average yield per tree for the last five years was 5.03 barrels per tree; in the quarter five years in sod followed by five years of tillage the average yield per tree was 5.17 barrels for the same period; but in the quarter five years in tillage followed by sod the average yield was but 2.32 barrels per tree for the five years of sod — not half that of either of the other two sections. These figures are modified somewhat to the advantage of sod by the application of nitrate of soda in Plat 6.

In accounting for the all but fatal effects of grass on the trees in this orchard we are almost forced to assign the toxic effect of grass as one of the causes of grass injury. One of the chief evidences that grass has a toxic effect on apples is to be found in the behavior of the trees in this newly sodded area. It does not seem possible that drought, lack of food, lack of air, or any other assignable cause than some toxic property, acting before mid-summer — almost immediately; — could have caused the trees in this plat to have taken on the symptoms of sod-bound trees as soon as the roots of the young grass came in contact with those of the trees.

The use of nitrate of soda in the sod plats.— Potassium, phosphorus and lime were all used liberally in the first half of the ten-year period, as we have seen in the discussion of fertilizers, page 256. Nitrogen
was supplied to the tilled trees during the whole period by plowing under clover cover-crops. It was reasonable to assume that the sodded trees were suffering from a lack of nitrogen in the last half of the experimental decade. Therefore, Plats 5 and 6 in the sodded half of the orchard, containing 52 of the 120 trees in sod, were given annual applications, five in all, of nitrate of soda at the rate of 350 pounds per acre, a heavy dose. In some respects the results were most surprising. The foliage was abundant and of a dark, rich green, nearly as luxuriant as that of the tilled trees. There were, therefore, high hopes of abundant harvests. Table VI, however, shows that, while the trees which were thus fertilized yielded more than those not so treated in sod, they bore on an average but a trifle more than half as much as those under tillage, the figures being 3.17 barrels per tree for those in sod which had nitrogen; 2.28 barrels for sodded trees without the nitrate and 5.03 barrels per tree for the trees cultivated ten years. A little calculation shows that the nitrate of soda paid well for itself.

The question will be asked, why was not the nitrate of soda tried on the tilled land? The answer is, that at all times the tilled trees seemed to be having too much nitrogen judging from leaf and wood growth and the size and color of the fruit. The clover cover-crops supplied more than the trees seemed to need.

*Influence on sodded trees of adjacent ground under tillage.*—Plats 7 and 8 show very considerably larger yields than Plats 3 and 4 though all had the same treatment. So, too, the diameters of the trees are greater in Plats 7 and 8. Why? Unquestionably, because the roots of the trees in the outside rows in Plats 7 and 8 found their way into adjacent ground under tillage though separated from the cultivated land by a strip of sod 20 feet wide. They have, too, far greater light area. Even the halves of the trees on the outside were superior to the halves on the inside, in yield of fruit and luxuriance of foliage. Account should be taken of this fact in considering the results, for the evil effects of the grass in the sodded plats have been diminished not a little by the escape of some of the roots of sodded trees from the sod to the tilled land which surrounds the orchard. Plates IV and V, reproduced from Bulletin No. 314, show how roots from the sod pass into tilled land though none were passing the other way.
The facts stated in the last paragraph clearly teach that not only should apple-trees not be grown in sod but that the root-run of the trees should not be restricted by sod on any side of the tree. For the best good of the trees, there should be no sod near the trees. Just as we have shown a most favorable influence on sodded trees from adjacent tilled land, so, too, trees can similarly escape from sod by sending their roots downward if the soil be deep.

EFFECTS OF THE SEVERAL TREATMENTS ON THE SOIL.

What were the effects of the two treatments on the soil? A positive answer would lead straight to the pith of our problem, that of determining the relative merits of two methods of soil treatment. But we cannot be as positive as we should like. Analyses were not made at the beginning of the experiment and in determining the effects of the two treatments on the soil one must rely chiefly on the behavior of the plants and much less on analyses made at the end of the ten years' treatment. The results as measured by plant behavior have been given and we have now to see how these correspond with the condition of the soil as determined by chemical analyses set forth in Table II, page 253.

We may as well dispense with a consideration of the figures for all of the compounds and elements in Table II excepting carbon and nitrogen; since there is an abundance of all, excepting the two named, for an orchard soil for this tree generation at least. Applications of phosphorus, potassium and lime, it will be remembered, were without result in this orchard. The carbon content, however, is important. It is an index of the quantity of humus in the soil and the response that the trees have made to nitrogenous cover-crops and fertilizers indicates that the addition and conservation of nitrogen is important in this soil. Figures are given for the top seven inches of soil only, since analyses made of the second layer of seven inches showed that it was improbable that the treatment has had appreciable effect on lower depths. Let us pass, now, to a consideration of figures for carbon and nitrogen in this upper layer as shown in the following summary:
Plat 1, in sod five and tilled five years.....................
Plat 2, tilled ten years...........
Plats 3, 5 and 7 (average of the three) in sod ten years.....
Plats 4, 6 and 8 (average of the three) tilled five and in sod five years.....................

Carbon  Nitrogen

29,400 pounds  2,600 pounds
41,800 pounds  3,400 pounds
39,400 pounds  3,100 pounds
34,300 pounds  3,000 pounds

One cannot draw positive conclusions from these figures. It is safe to assume, however, since the quantities of carbon and nitrogen are so materially larger in the plat tilled ten years than in any other plats in the orchard, that the tillage and cover-crop treatment has conserved humus and nitrogen rather better than any other treatment. In fact, since considerable quantities of nitrogen were added to a part of the trees in sod, thereby increasing the growth of vegetation and adding more nitrogen to the soil than the treated trees have probably taken from it, we are safe in assuming that the tillage and cover-crops of clover are unmistakably more conservative of humus and nitrogen than would the sod-mulch method have been without the application of nitrate of soda.

The lower carbon and nitrogen content of Plat 1 is probably accounted for by the difference in the soil type between this and other parts of the orchard, as explained in the description of the soil—the plat is in a depression which has more surface wash than other parts of the orchard. Yet, bear in mind that this was the most productive plat the last half of the experiment.

Comparison of the analyses of the tilled and the sodded soils proves, we again insist, that the miserable condition of the trees in sod cannot be wholly due, in fact can hardly be largely due, to differences in the food constituents in the two soils. Or, if it be a matter of food, the quantities removed from the soil by the apple are so small that they are not appreciable by our rough methods of sampling and analyzing. At any rate we think the statement is warranted from both the soil analyses and the behavior of the trees in this experiment, and from observation in other orchards, that the intensity of the deleterious action of sod is not much influenced by the richness of the soil.
WHY IS TILLAGE BETTER THAN SOD FOR THE APPLE?

In our first report on the Auchter orchard, Bulletin No. 314, we discussed at length the question, "Why is tillage better than sod for the apple." We were not then satisfied that the conclusions reached answered the question as fully or as accurately as might be wished, yet with five years' more work we have but few additional facts to modify the conclusions of the first report. As we tried to show in the previous report the ways in which grass militates against apples growing in sod are probably several, which act together, as:

(1) Lowering the water supply.
(2) Decreasing some elements in the food supply.
(3) Reducing the amount of humus.
(4) Lowering the temperature of the soil.
(5) Diminishing the supply of air.
(6) Affecting deleteriously the beneficial micro-flora.
(7) Forming toxic compounds that affect the trees.

Each of these supposed causes of injury to the sodded trees in this orchard may be briefly reviewed with such additions and corrections as the five more years of experimental work suggest.

Sod injures apple-trees by lowering the supply of water.—In the preliminary report of this experiment (Bulletin No. 314, pages 115 to 121) the reduction of the supply of water was held to be the main cause of the injury to the trees in sod. The results of 120 moisture determinations in the orchard in 1907–08 gave evidence that there was much less moisture in the sodded land than in the tilled soil; the behavior of the trees in sod seemed to show that they were suffering from thirst; and a consideration of the amount of water used by an apple-tree and of the rainfall of the region made plain that there was seldom a year when trees did not suffer from a shortage of water even if the supply was not interfered with by grass.

It is not necessary to review further the data and reasons given in the first report to show that injury by sod is at least in part a question of water supply. We wish here only to reiterate our belief that the great reduction of the water supply is the chief cause of the extraordinary injury to the sodded trees in this experiment. The results of a similar experiment in the Hitchings orchard, as set forth in Bulletin No. 375 from this Station forced us to the same
conclusion. Observations, too, of orchards in all parts of New York show clearly that apples in sod suffer most in soils in which the water supply is deficient.

Fruit-growers must bear in mind in comparing tillage with sod methods that the trees are not only robbed of water by the grass but that tillage conserves moisture — thus the difference in the results from these sodded and tilled trees is due to a bad effect of sod plus a good effect of tillage. It is, then, if we accept the teachings of this test, not only necessary to keep sod out of an orchard but to practice tillage, which, as all know, protects the soil from the drying action of wind and sun and conserves moisture.

'Sod injures apple-trees by decreasing some elements of the food supply.— It is impossible to establish a difference between results due to a deficiency of water and those due to a deficiency of food, for all of the food of the tree derived from the soil is taken up in the form of a solution. Therefore, a tree suffering from want of water of necessity suffers from want of food. We may have, then, and probably do have in this experiment, trees starving in a fertile soil because of a lack of water for the soil solution.

There is nothing to indicate that any of the food elements are lacking for either trees or grass in this orchard excepting, possibly, nitrogen in the sodded part — a matter to be discussed in a later paragraph. Analyses made in 1908\textsuperscript{1} and again in 1913, the results of the latter shown in Table II, show, as we have seen, a soil more than rich enough for the apple — a plant the food requirements for which are comparatively small. The trees, it will be remembered, were in no way improved in sod or under tillage by additions for several years of potassium and phosphorus and one heavy application of lime. The trees in the tilled land at no time gave evidence of thinness of fare — they flourished like the Biblical palm. Even in the sod such trees as could get any considerable portion of their roots in the tilled plats or in adjoining tilled fields, prospered in proportion. The growth of grass was always luxuriant, except in stresses of dry weather, giving further evidence that the land is not impoverished. Moreover, we have demonstrated that in this type of soil, in western New York at least, the starvation point for the apple is much lower than for field or garden crops\textsuperscript{2} — the trees thrive where grains or

\textsuperscript{1} N. Y. Sta. Bul. 314: 124. 1909.
\textsuperscript{2} N. Y. Sta. Bul. 339: 1911.
vegetables require fertilization. From all sides, too, come reports from apple-growers who augment, diminish or alter in various ways manurial treatments of their trees without appreciable results.

It must be borne in mind, however, that if these trees were in need of more food, tillage would make available some of the unavailable reserve food which the chemical analyses of the plat show to be present.

To the statements just made there is a seeming exception in the case of nitrogen. The action of nitrate of soda in reviving the sodded trees is almost instantaneous. Yet analyses show nearly as much nitrogen, on the average, for the sodded plats, as for those that have been tilled; indeed, in some of the sodded plats there is more. Moreover, as soon as the sod is turned under, without the addition of commercial nitrogen, the trees revive, grow vigorously and show no signs of the starvation they endured in grass. This behavior can best be accounted for in one of two ways. Either the grass takes the nitrogen, the cream of the land in this orchard, in which case applications of nitrate of soda would so supplement the natural supply as to give the trees a fairer share and thereby give new life; or the nitrate of soda may counteract a toxic effect of the grass. Of the two explanations we are inclined to the first, although we can offer no explanation as to how the grass can so completely exhaust the supply of nitrogen in the soil for apples and yet in a ten-year period not drain it of the fertility in this element upon which the grass itself retains its pristine vigor.

Lyon and Bizzell¹ have found that grasses have a strongly depressive influence on nitrate formation and suggest that this is a possible cause for the injurious effect of sod in orchards. Doubtless such effects would differ with different grasses and with different soils, thus accounting for the wide variations and seeming anomalies in sod and tillage methods in different localities. Lyon and Bizzell’s work opens up a promising field for investigation in the relationships of grass and trees.

_Sod has injured the trees in the Auchter orchard by reducing the humus content of the soil._—The statement just made is an assumption, pure and simple, so far as humus itself is concerned. It is extremely doubtful if humus in the quantities shown to be present

in all parts of this orchard is necessary for the apple. Fruit trees thrive in many soils in all parts of America where scarcely a tithe of the humus in either the tilled or sodded part of this orchard exists. The highest yields during the past five years in this orchard were in the plat having least humus. It can not be said that the excess of humus, as humus, in the tilled land of this experiment has made any great difference in either yield of fruit or growth of tree. But one of the postulates of agriculture is that humus increases the water-holding capacity of soils and it is not an assumption to say that in this way the greater amount of humus in the tilled land has been helpful.

The "burning out" of humus is one of the bugaboos that those who keep their orchards in sod see in tillage. Analyses made in 1908¹ and again in 1913 as shown in Table II, give satisfactory proof to those who till, that the reduction of humus in a soil through tillage is an imaginary evil. This statement holds, provided, of course, that a cover-crop is used with the tillage. It is not too much to assume, in the light of this and other experiments, that the difference in the amount of humus in a tilled orchard and a sod-mulched orchard will be about the difference in the quantity of cover-crop turned under in the former and the amount of grass left as a mulch in the latter.

_Sod injures apples by lowering the temperature of the soil._—Evaporation is a cooling process. It is to be expected, then, that the greater evaporation through the grass and the compact earth in the sodded land gives a cooler soil. The mulch obtained by cultivation, too, is a protection against evaporation with its cooling effects. Facts follow theory in this case and the expected happens. A series of observations made at depths of 6 and 12 inches in the soil in the summer of 1908² shows that the tilled soil in June and July is 1.1 degrees warmer at seven in the morning and 2.3 warmer at six in the evening than the sodded soil. Observations were not made at night but it is doubtful if the soil temperature of the early morning, at least, would be reversed though we might expect it to be less than that of the evening after a day of sunshine. The reversals of night would probably be more than offset by the higher temp-

² For a table showing the temperatures see Bulletin 314: 126. 1909.
peratures in the tilled land at noon. These results agree with those of other experiments and with the conclusions of some of the best authorities on soils.

We have no definite knowledge as to whether the apple prefers a warm or a cool soil but in the comparatively cold soils in which the apple is grown in New York, general considerations lead us to believe that the warmer soil is the better. To give reasons: Heat would cause food substances to dissolve more rapidly; hasten diffusion; aid in soil ventilation; develop stronger osmotic pressure in roots; and help in the formation of nitrates. The augmentation of these several processes would, it is almost certain, accelerate vegetative activity sufficiently to make the higher temperature of the tilled land one of the factors accounting for the more flourishing condition of the trees under tillage.

_Sod injures apples by diminishing the supply of air in the soil._—We have no data to prove the contention set forth in the heading of this paragraph but concrete evidence is not necessary. All must agree that air is of vital importance to every part of a plant—to the roots scarcely less than to the tops of trees. Beneficial bacteria depend, if anything, to even a greater extent upon an ever present supply of oxygen. The formation of nitrates requires the addition of oxygen to some one or another of the compounds of nitrogen. Oxidation plays an important part in all of the chemical changes which take place in the soil and is therefore necessary in keeping up fertility.

All will grant the proposition that there is more air in a cultivated than in a sodded soil. Nothing can be more apparent than that, when soil particles are held in a close, compact mass as in uncultivated land, there is comparatively little room for air and that when the particles are separated by stirring the soil fresh air must be drawn in. When the air is renewed by stirring the soil several times during a season there cannot but be a most beneficial effect on the plats growing therein. These considerations need no data to prove them, they are corner-stones in agriculture, and justify us in settling upon a diminished air supply as one of the causes for action against grass in an orchard.

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Sod affects deleteriously the beneficial micro-organisms in an orchard soil.—This is another statement which we cannot support with experimental evidence. We are assuming than an abundant humus content, good ventilation, comparatively high temperature, a more uniform supply of moisture, more nitrogen from the cover-crop turned under, all present and cooperating better in a tilled than a sodded soil, give the best environmental conditions for these bacteria. If the assumption is unwarranted, our agricultural teaching of the day is radically at fault. In the light of what we know about soil bacteria, little though it be, it is not unreasonable to suggest that the micro-organisms in tilled land are more helpful to apple-trees than in sod-covered land.

Sod may "poison" the apple-trees.—The fact is well established that all plants have a marked effect on soils. Just how plants affect soils is not so clear. Certain it is, in the case of a sod of whatever plant, much organic matter quite different from that present before the sod, is added. It is not in the least strange, rather it is to be expected, that this mass of new matter will change the chemical and bacteriological properties of a soil, for good or evil for other crops. There is, too, as everyone informed on recent agricultural experimentation knows, considerable evidence to show that plants, grass for instance, may excrete compounds toxic to other plants. Is it not possible that sod may, then, set going some action in a soil detrimental to apples? Literally, may not sod poison the apple?

Pickering\(^1\), at the Woburn Experimental Farm, Ridgemont, England, has been experimenting with apple trees in sod and under tillage since 1894, twenty years. The methods employed in the New York experimental work, both in treatment of plats and in gaging results are very similar and the results obtained are for all practical purposes the same. A good summary of the conclusions at Woburn as to causes is found in the following quotation\(^2\):

"Direct experiments seem to negative the possibility of explaining the action of grass on apple trees in the various ways which we have discussed above, and lead us to a conclusion, which has

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\(^1\) All who are interested from the experimental standpoint in this work should read Pickering's accounts of his work in the First, Second, Third and Fifth Reports of the Woburn Experimental Farm.

\(^2\) Third Report of the Woburn Experimental Fruit Farm, 1903: 47.
also gradually been forced upon us by the appearance itself of the
trees throughout the years that they have been under observation,
namely, that this action of grass is not merely a question of star-
vation in any form, nor of any simple modification of the ordinary
conditions under which a tree can thrive, but that the grass has
some actively malignant effect on the tree, some action on it akin
to that of direct poisoning."

Thus, it is seen that Pickering believes that there is but one
important factor in the injury of trees in sod; namely, grass "which
has some actively malignant effect on the tree, some action on it
akin to direct poisoning." But the case against grass as a poisoning
agent still rests largely on circumstantial evidence; or, rather, as
we understand Pickering's arguments, he arrives at his conclusions
as to the toxic effect of grass by eliminating all other possible causes,
admitting that he cannot present his supposition as a proved fact
"till the presence of such poison is definitely established."

Pickering's work has been so long continued and so carefully
carried on that great weight must be attached to his opinion. Yet
we cannot agree with him that the malignancy of grass is wholly or
even in largest part due to a poisoning effect. Rather, we are
inclined to think toxicity one of several causes, awaiting more crucial
experiments before attempting to say how large a part it plays
in the malign influence of grass.

GENERAL REMARKS ON TILLAGE AND SOD IN
AN ORCHARD.

The first report of this experiment has called forth many questions
and some objections which are not answered in the main body
of this report. It seems worth while to attempt to touch upon
the most important of these here.

In deep, fertile soils where trees have a deeper root-run than
in the shallow soil of the Auchter orchard, competition between
apples and grass may be less keen and the grass therefore less harmful.

There is nothing in this experiment to show that apple trees
eventually "adapt" themselves to grass—a statement often
heard. The sodded trees showed harmful effects from grass as
soon as sod formed and in every plat. The longer the trees remained
in sod the more exhausted and decrepit they became.
There are orchards in which, paradoxically enough, ill-treatment may prove beneficial. Thus, it is common knowledge that checking a tree which is luxuriating in growth may make it more fruitful. In rich, moist soils, then, sod may be beneficial as a permanent treatment for an orchard. So, too, in an orchard such as the one in which this work has been carried on, grass, in an occasional homeopathic dose, might prove valuable.

The question is often asked as to whether sod will have the same deleterious effect on other tree fruits that it has on the apple. Observation leads us to answer in the affirmative. Indeed, with peaches and plums at least, harm is done even more quickly and is more serious.

Occasionally we hear objections to the general application of our results on the ground that we have worked with but one variety — the Baldwin. To such objection we reply that the all but fatal effects of grass may be seen in innumerable orchards in New York quite regardless of variety, age of tree, whether dwarf or standard, or of cultural treatment, as spraying, pruning and the like.

The effect of sod on dwarf trees, the roots of which are much nearer the surface than those of standards, must in most situations be even more serious than on the trees in this experiment — a fact to be borne in mind by amateurs in planting in door-yards which are usually in grass.

Orchardists who pasture hogs, sheep or cattle in their plantations very generally hold that their trees behave differently than do those in our experiments. We have taken pains to visit many such orchards and have yet to find one in which cannot be recognized in greater or less degree the earmarks of grass injury.

Since the publication of the first report on the Auchter orchard many men whose trees are in sod have told me that they could not discover the evil effects of grass so apparent in our work. In most such cases there were no means of making comparisons — tilled trees were not at hand. Within my observation whenever men with sodded orchards in western New York have plowed, tilled and used a cover-crop in a part of their orchard, they have needed no further argument for tillage. The complaint is becoming very common that continuous tillage with leguminous cover-crops produces too many poorly colored apples. How best to avoid this
is a problem yet to be solved, but helpful means in securing more highly colored apples are earlier cessation of tillage, non-leguminous cover-crops and the withholding of nitrogenous fertilizers.

It is a most significant fact that apple-trees can be well-grown in nurseries only under the highest tillage. A nursery in sod is a sight never seen. It would be strange if the plant behaved differently when transplanted in an orchard.

IN CONCLUSION.

We have been considering grass left as mulch in an orchard—bad enough! But grass cut as hay, left to ripen, or pastured by hogs, sheep or cattle is worse. Grass makes apple-trees sterile and paralyzes their growth—it is the withering palsy of the apple industry in New York. It is the chief cause of the decrepit, somnolent, moribund orchards to be seen from the roadsides and car windows in all parts of the State. Cider mills and evaporators thrive on sod-grown apples. The small, gnarly, low-grade apples sent to the markets from orchards in sod have so displeased the eye and palled the appetite of consumers that they are bringing discredit to the apple industry of the State. The average orchard in sod is a liability rather than an asset to its owner. Apple-growing is going out of fashion in New York wherever sodded orchards are in fashion. These are not loose generalities; neither are they rhetorical over-statements. They are cold facts written under earnest conviction of their truth from state-wide observations covering several years. They can be verified by any open-eyed man in a day’s travel in any of the apple regions of the State.