HOW SOD AFFECTED AN APPLE ORCHARD

SUMMARIZED BY
F. H. HALL

FROM BULLETIN BY
U. P. HEDRICK

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HOW SOD AFFECTED AN APPLE ORCHARD.

F. H. HALL.

As a rule, men are keenly interested in the details of any enterprise that directly affects their purses. Since thousands of farmers in New York State, particularly in its northwestern quarter, derive a large part of their incomes from apple orchards, they are very much alive to any argument over a fundamental principle or practice in the management of those orchards.

Such a discussion arose several years ago relative to giving orchards clean cultivation or leaving them in sod. The topic was so interesting, so vital, that the discussion became a keen controversy and advocates of both methods appealed to the Station for data to support their contentions. The horticulturists of the Station were, therefore, obliged to give careful consideration to the question.

The two methods are radically different. Both, evidently, can not be equally right; yet advocates of each system found orchards whose yields and condition lent force to theoretical arguments for sod mulch or tillage. The latter method apparently rests on a firm scientific foundation; and should be the more successful unless the apple tree is an anomaly among cultivated plants; for with practically all crops men grow, tillage is a most efficient means for increasing yields and improving quality. "Clean cul-

* This is a brief review of Bulletin No. 314 of this Station, on A Comparison of Sod Mulch and Tillage in an Apple Orchard, by U. P. Hedrick. Any one interested in the detailed results of the investigations will be furnished, on application, with a copy of the complete bulletin.
ture" for orchards, followed by cover crops, has been urged for a quarter of a century or more by nearly all college and station horticulturists; and the general tendency among progressive orchardists is toward closer adherence to the practice of turning over the soil of their orchards every spring, cultivating them thoroughly until midsummer to keep down grass and weeds and to hold the moisture, and sowing some cover crop to grow in fall and early spring as a check to undue luxuriance and sappy wood-growth and as a source of humus and nitrogen for the next season's crop. Of 700 orchards on which report was made to the Station, more than 400 are cultivated annually or every other year; while the owners of many other orchards said they believed tillage would be better, but feel themselves obliged to leave the trees in sod through lack of time to cultivate, because the orchard area is needed for pasturage, or for similar reasons of expediency not governed by the welfare of the trees as fruit producers.

Data lacking. The question was considered settled by most students of horticultural problems; but the ardent advocacy of sod mulch by its supporters reopened the discussion. The situation called for definite figures based on scientific comparison of the two methods under similar conditions; but it was found that such data were surprisingly scanty. The adherents of each method had been using the success of particular orchards to support their views; they did not know whether the other method would have given similar, better or poorer results in the same orchard in the same years.

Indeed, only two true comparison tests were found recorded, one at the Ohio Station, one in England.

The Ohio experiment, on which recent advocates of the sod-mulch system have laid such stress, was, as reported in Ohio Station Bulletin 171, only a preliminary report on a young orchard, the entire crop of fruit on the two plats being less than 400 apples; while almost no fundamental data are given to prove the reliability of the test or the applicability of the results to other orchards.

The English test, at the Woburn Experimental Fruit Farm, showed marked harmful effects from grass about the trees;—a
result the investigator attributed to a poisoning of the soil, for apples, by the grass roots.

To meet this lack of definite data from scientific, side-by-side comparison of the two systems, the Station leased two orchards in 1903 and laid down to grass half of each, the other half being given clean culture each year until the sowing of a cover crop in mid-summer. One of these orchards, that of Grant Hitchings near Syracuse, is somewhat inaccessible, making it more difficult to secure all the needed data, and some of the trees are quite young, so no report will at present be made on the experiment there. This bulletin deals entirely with work in the Auchter orchard near Rochester; and discusses five full seasons’ results.

This is an orchard of Baldwins, trees set 40 feet apart each way and 26 years old when the test began. The entire orchard contains about 9½ acres in a long rectangle, divided in halves lengthwise; but a few trees, not Baldwins or in poor condition, are excluded so that the sod-mulched trees number 118, the tilled trees 121. The orchard in practically all respects is typical of the western New York apple belt. A low, slightly stony ridge crosses the area diagonally from which the land slopes gently north and south, with a small area in one corner low enough to require some tile drainage. On the ridge and high ground the soil is a fertile Dunkirk sandy loam nine or ten inches deep underlaid by a compact sandy subsoil; while on the slopes and lower land the loam is darker, an inch or so deeper, and the subsoil finer sand, more compact. Both soils and subsoils are very uniform.

The treatment of the trees has been alike except for the soil management, so that variations can very justly be attributed to the different effects of grass and tillage. As sod mulch, or the so-called “Hitchings method,” was most strongly advocated of any of the non-tillage methods of orchard management, this was adopted as the system for one-half of the orchard. This area was seeded down on October 15, 1903, to a mixture of orchard
grass and blue grass, and in the spring of 1904 an additional seeding was made of these two grasses with a little timothy. All the grasses were evident the first season, but the orchard grass took the lead the second year, so that since that time the trees in grass have been surrounded with a fine, uniform, heavy-yielding, orchard-grass sod. If used for hay the crop would average two tons to the acre; but nothing is removed from the soil except the apples. The grass has been cut each year late in May or in June and in three of the seasons mowed again in July or August. The material is allowed to lie where it falls, as the tree roots extend through all the soil so it is necessary to mulch the entire surface.

The other half of the orchard has been plowed each year during the last week in May or the first week in June, rolled, harrowed from four to six times, and sown to a cover crop of clover or oats about August 1st.

Phosphoric acid and potash were used at first, in quite liberal quantities, and, of course, like amounts on each plat. In no case have these given appreciable results, whether alone or in combination; so their use has been discontinued. This is in harmony with several other fertilizer tests recently ended; and would apparently indicate that additional mineral fertilizers are not needed for apple trees on many western New York soils.

*General results.*

Fortunately for the experiment there has been no "failure" in any year of the five. Each season, some or all of the trees have borne fruit and in three seasons the yields have been above the average. The trees have grown, each year, particularly on the tilled plat. Neither have insects or disease interfered with the interpretation of the results, although both plats have showed some insect work in one or more years.

*Effect on trees.*

While crop production must be the final measure of the success or failure of a method of management, it might, in a short test, be an unfair measure because failing or dying trees sometimes bear heavily, or, on the contrary, healthy trees may occasionally overbear and suffer long-continued weakening. In
a fair test, all possible points of comparison should be included, and the attempt has been made to do this in comparing the sod mulch and tillage methods.

The effect on the trees really comes first and is a most valuable index, for the trees are always present for study; and differences, if noteworthy, are permanent. Fruit is available for only a comparatively short time and the crops for a single year may yield deceptive figures.

In the Aucbter orchard, there is now, at the end of five years, as there has been to a gradually increasing degree in the passing seasons, a marked contrast between trees in sod and trees on tilled soil. The cultivated trees are more uniform, larger, show much more new growth, both in number of twigs and in their length and size; they are practically free from dead wood and are noticeable, as far as the orchard can be seen, for that indescribable, clean, rich, full, glistening, smooth-barked appearance that denotes perfect health and surplus vitality. The trees in sod, on the contrary, lack so many of these indexes of vigor that anyone familiar with healthy trees would be dissatisfied with these unthrifty looking ones.

Careful measurements have been made wherever size or length means anything, and a few of these are given below:

### Table I.—Growth of Apple Trees Under Sod-Mulch and Tillage. Gain in Diameter of Trunks.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sod—118 trees</th>
<th>Tillage—121 trees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Row 1</td>
<td>Row 2</td>
</tr>
<tr>
<td>1908</td>
<td>In.</td>
<td>15.2</td>
</tr>
<tr>
<td>Gain</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Avg. gain for Sod</td>
<td>1.1 in.</td>
<td>Avg. gain for Tillage</td>
</tr>
</tbody>
</table>
### Average Length of Annual Growth and Average Number of Laterals

<table>
<thead>
<tr>
<th>Year</th>
<th>Sod</th>
<th>Tillage</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In.</td>
<td>In.</td>
<td>In.</td>
</tr>
<tr>
<td>1904</td>
<td>5.8</td>
<td>7.9</td>
<td>2.1</td>
</tr>
<tr>
<td>1905</td>
<td>4.2</td>
<td>7.2</td>
<td>3.0</td>
</tr>
<tr>
<td>1906</td>
<td>2.7</td>
<td>6.5</td>
<td>3.8</td>
</tr>
<tr>
<td>1907</td>
<td>2.5</td>
<td>6.9</td>
<td>4.4</td>
</tr>
<tr>
<td>1908</td>
<td>1.9</td>
<td>5.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Total</td>
<td>17.1</td>
<td>33.5</td>
<td>16.4</td>
</tr>
<tr>
<td>Average annual growth</td>
<td>3.4</td>
<td>6.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Average number laterals per year</td>
<td>1.9</td>
<td>4.4</td>
<td>2.5</td>
</tr>
</tbody>
</table>

For the diameters, two measurements were taken on each tree, one a foot above the soil and the other a foot below the first branches. The table shows a uniformly smaller gain for the five years for the trees in sod, as compared with those on tilled soil, compared row by row or as a whole. If the outer row, Row 1, be excluded, which had some advantage since its roots passed under a stone wall and fed in an old lane, the comparison is still more favorable to the cultivated trees, the average gain in diameter for the other four rows being less than an inch, as compared with 2.1 inches for the trees on the tillage plat.

In comparing the "new growth," outside trees were excluded in both plats because of the lack of uniformity of growth on such trees. Branches were cut on five sides of each of 48 trees in the center of each plat, 240 in all, and the figures show the averages from measurements of all these branches. Weights taken after the branches had been measured showed the new growth from the tilled trees to be three times as heavy as that from the trees in sod,—strong testimony to the better health of the tilled trees.

The trees on the tilled ground showed very uniform, symmetrical heads, with few straggling, abnormal branches, and little dead wood; but those on sod revealed many such irregularities. This contrast was even more noticeable with roots than with branches; for wherever there was a chance the roots from trees in sod shot
out to long distances to secure food or to get away from the grass roots. Many roots on the sodded row next the tilled ground extended over the boundary, running thirty feet or more to get into conditions that suited them better. The same was true also of trees on the other edge of the plat, whose roots in many cases ran to and under a stone wall out into the old lane. Plate I shows such a foraging root.

Great as was the contrast between the trees in winter, it was even greater when the trees were in full foliage. "The dark, rich green of the tilled trees indicated an abundance of food and moisture and the heyday of health, while the pale and sickly foliage of the sodded trees suggested drouth, starvation or some serious physiological disturbance. More than one man of the hundreds who visited the orchards was heard to say as his eyes lighted on the contrasting colors of tilled and sodded trees, 'that satisfies me.'"

While it was impossible to secure an exact measure of this color difference, some weights were taken that show how much larger and better were the leaves under tillage. From the same trees used in comparing wood growth, groups of 10 leaves were taken from the tips of shoots on five sides of the trees, 2,400 leaves from each plat. These weighed, for the sod-mulch trees $132\frac{1}{2}$ grains and for the tilled trees $177\frac{1}{2}$ grains. That is, considering size alone and not taking into account the apparently much greater number of leaves on the cultivated trees, these had one-third more leaf area than the sodded trees; consequently one-third more laboratory space to evaporate sap and manufacture starch and chlorophyll. The leaves on the tilled trees also opened three or four days earlier than the others, probably because the cultivated soil was warmer, and they remained green and vigorous a week or ten days after the trees on the sod began to show the autumn hues which betoken the end of labor. In every respect but one this added life was an advantage. The falling of the leaves, however, let in more sunlight on the apples above the grass, and helped to color them a brighter, deeper red. - In this character-
istic, color, and in this alone, the fruit from trees in sod was better than that from tilled trees.

The crop of fruit for one year might not be a reliable index to the value of any orchard practice; but consistent results for five years with increasing contrasts should be decisive. Such results were secured in this test, as shown by the yields given in the table below and by various characteristics discussed in later paragraphs.

**Table II.—Yield of Fruit on Sod and Tillage Plats.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sod Plat—118 trees</th>
<th>Tilled Plat—121 trees</th>
<th>Diff. in favor of tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st class</td>
<td>2nd class</td>
<td>Culls</td>
</tr>
<tr>
<td>1904</td>
<td>278 Bbls.</td>
<td>51 Bbls.</td>
<td><strong>286.1 Bbls.</strong></td>
</tr>
<tr>
<td>1905</td>
<td>123.3 Bbls.</td>
<td>38 Bbls.</td>
<td>71.7 Bbls.</td>
</tr>
<tr>
<td>1906</td>
<td>135.3 Bbls.</td>
<td>32 Bbls.</td>
<td>43 Bbls.</td>
</tr>
<tr>
<td>1907</td>
<td>144.3 Bbls.</td>
<td>44 Bbls.</td>
<td>87 Bbls.</td>
</tr>
<tr>
<td>1908</td>
<td>255.3 Bbls.</td>
<td>17.5 Bbls.</td>
<td>52.5 Bbls.</td>
</tr>
<tr>
<td>Avg.</td>
<td>187.2 Bbls.</td>
<td>36.5 Bbls.</td>
<td>108 Bbls.</td>
</tr>
<tr>
<td>Avg. on basis of 121 trees</td>
<td>191.9 Bbls.</td>
<td>37.4 Bbls.</td>
<td>110.7 Bbls.</td>
</tr>
<tr>
<td><strong>Acre Avg.</strong></td>
<td>41.1 Bbls.</td>
<td>8 Bbls.</td>
<td>23.7 Bbls.</td>
</tr>
</tbody>
</table>

* A September storm blew half the crop from the trees.
† Increase in culls and seconds due to aphis injury of fruit.
‡ Increase in culls and seconds due to curculio injury of fruit.
** On basis of 27.2 trees per acre.

The first year, as shown by the table, the yield was slightly better on the sod plat; but in every succeeding year the balance has favored the tilled plat, and the difference the last year was greater than any preceding one. The good effect of the tillage or the bad effect of the grass or the combination of the two is evidently a cumulative factor, not a diminishing one. There is nothing here to indicate that the trees will "become accustomed to grass."
This increased yield on cultivated trees is due to two factors, greater number of apples setting and maturing and greater size of the individual apples. No count was made of fruits on the trees, but observations on bloom and fruit setting showed that practically the same percentage of the blossoms set fruit, whether the bloom was full or scanty; and in two of the three years when observations were taken the percentages of bloom on the tilled plat and on the sod plat were 21.6 compared with 36.4 and 25.3 compared with 55.4. That is, the trees under culture set one and two-thirds times as many fruits the first year and more than twice as many the second year. For size, the apples in several barrels from each plat were counted, the average number being 434 for the fruit from sod and 309 for fruit from tilled trees. The average weights of sod and tillage apples were 5.01 ozs. and 7.04 ozs. That is, the apples from the cultivated trees weighed one-third more than the others.

A very noticeable feature of the crops on the tilled plat was their uniformity. As the trees themselves were very uniform in growth and very symmetrical, so the apples were well distributed over the branches on all sides of each bearing tree, thus insuring a much larger crop than would scattered heavily loaded branches among barren ones, as was often the case on the sod mulch plat. The even distribution of the fruits also makes easier harvesting, and so tends to economy in handling the crop. The trees in sod showed marked abnormalities in their tendency to produce large fruits or large crops on a part of the trees and small fruits or none at all on another part. The fruits, also, were much more uniform in size and more even in color on the cultivated trees than on those in sod,—a contrast which is not shown by the figures for firsts, seconds and culls, because aphid injury, curculio injury and a severe windstorm threw among the culls of the tillage plat many barrels of apples that did not belong there through small size. In a discriminating market, even fruit like that from the tilled trees would sell more readily than the uneven grades from trees in sod.

The trees in sod gave fruit of better color; but the color was no index to quality; for the larger fruit from the tilled trees, though slightly duller in tint, was unmistakably finer in every-
thing that goes to make a pleasant apple to eat — aroma, flavor, texture, and freedom from internal blemishes. This difference was a surprise to all who tasted the fruit, either at the Station or at the various horticultural gatherings where the apples were exhibited.

The difference in texture was largely due to the relative difference in maturity of the fruits at the same time; for the trees in sod ripened ten days or two weeks earlier nearly every year and, in ordinary storage, would not keep as long by nearly a month. In cold storage, however, the difference in keeping quality was much less or disappeared entirely.

The early ripening of the sod apples was very noticeable in warm autumns and was a decided disadvantage for a winter apple in such seasons.

It is not always certain that the larger crop will give the greater profit, for a good yield at a moderate cost of production often leaves the grower richer than a maximum crop obtained by heavy fertilizing, extraordinary thoroughness in cultivation and special care. It is one of the strongest arguments of the sod-mulch method advocates, that that system is an inexpensive one. The cost was slightly less in that half of the Auchter orchard, but the gains were so much less that the tillage proved by far the most profitable. This is clearly shown by the table below in which the main points of varying expense by the two systems are contrasted. Fertilizing and spraying cost the same, and pruning cost about $8 more for the tilled trees.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sod plat — 118 trees</th>
<th>Tilled plat — 121 trees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cutting grass</td>
<td>Harvesting crop</td>
</tr>
<tr>
<td>1904....</td>
<td>$13.09</td>
<td>$219.25</td>
</tr>
<tr>
<td>1905....</td>
<td>7.46</td>
<td>82.89</td>
</tr>
<tr>
<td>1906....</td>
<td>3.36</td>
<td>104.30</td>
</tr>
<tr>
<td>1907....</td>
<td>3.67</td>
<td>138.07</td>
</tr>
<tr>
<td>1908....</td>
<td>6.14</td>
<td>173.43</td>
</tr>
<tr>
<td>Total</td>
<td>$40.62</td>
<td>$717.94</td>
</tr>
</tbody>
</table>
Allowing 27.2 trees to the acre, these figures show that the average expense of production was $53.75 an acre annually under the sod-mulch system and $76.06 under tillage, an advantage for the sod-mulch of $22.31 an acre; but the net income from an acre in sod was $71.52 and from an acre in tillage $110.43, an advantage for tillage of $38.91. That is, every dollar of the additional expenditure ($22.31) made necessary by adopting the sod-mulch method was not only returned but brought an extra $1.74 of profits with it. Surely the less expensive method was not the more profitable one here.

Considering all the evidence, then, there can be no question that tillage is far better than sod-mulch in the Auchter orchard; and the Auchter orchard is typical of the great majority of orchards in western New York. It is safe, therefore, to make the statement general and say: "Tillage has been proved better than sod-mulch for orchards." There remains only the need of analyzing the conditions and results to see why it is better. By such an analysis it is plainly shown that the tilled soil supplies more water to the trees and the water carries with it more plant food, that tillage makes the soil warmer, allows the air freer access and favors the growth of beneficial bacteria in the soil, and that the turning under of a cover crop increases the supply of humus—all factors favorable to better plant growth. It is possible also, as held by the English investigator and others, that the grass roots in some way cause conditions in the soil that really poison the apple roots.

But one factor, moisture supply, is enough to account for practically all the difference in results between the two plats. The best soils may fail to produce good crops because of drought, poor soils produce good crops if rains are copious and well distributed; so it needs little argument to prove water the leading factor in crop production. Indeed, many hold now that, in the final analysis, the only factor which the cultivator needs to control or can control is the moisture supply.

In this water supply the two plats showed striking differences.
On the sod-mulch plat the growing grass in spring and early summer rapidly lowers the store of moisture in the soil while on the tillage plat the repeated harrowings make an earth mulch that effectively conserves the water. Careful studies have been made, by Prof. King at the Wisconsin Station, and by German investigators, of the amount of water needed for different crops. They find that a grass crop, like barley, uses 464 tons of water to produce a ton of dry matter in the crop. Now, the grass on the sod-mulch plat produced the equivalent of two tons of hay every year, according to the estimate of several good farmers, or 1.7 tons of dry matter. This would require for its growth at least 64 inches of rainfall; and the water escaping by running off the land after heavy showers, by drainage and by natural evaporation accounts for 6 inches more of rainfall, at the lowest estimate. But only 174 inches of rainfall come during the six months of tree growth, as shown by the records at Rochester for 25 years. Accordingly, on the sod-mulch plat only 64 inches would be left for the apples. This is an amount entirely too small for a heavy crop, since the apple demands more moisture than other crops because of its vast extent of leaf surface. Prof. Loughridge, of California, made some studies along this line and found that the apple required three times as much water as the apricot, olive or peach, twice as much as orange, lemon, or fig, one and a half times as much as the almond and plum and one and one-fifth times as much as the grape. Is it surprising that the crops competing with the grass were small, especially as the grass was growing most vigorously just when the developing leaves, the swelling fruit buds, the growing fruits and the shooting new wood needed water most?

This reasoning is founded on indirect observations and logic; it is confirmed by actual moisture determinations made repeatedly during two seasons on samples of soil from different parts of the two plats. In all, 120 determinations were made covering the growing seasons of 1907 and 1908, and in every case more moisture was found in the tilled soil in both the first six inches and the second six inches of soil. In some cases considerably less than half as much water was found in the sod soil as in the
tilled soil and in only one case was the difference less than ten per ct. of the water in the soil. The average percentages and the value of these percentages in tons and gallons of water to the acre are shown in the following table:

**Table IV.—Moisture per Acre in Tilled and Sod Plats.**

<table>
<thead>
<tr>
<th>Soil depth</th>
<th>Plat</th>
<th>1907</th>
<th>1908</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Amount of moisture</td>
<td>Amount of moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Per ct.</td>
<td>Tons</td>
</tr>
<tr>
<td>1-6 in.....</td>
<td>Tillage..</td>
<td>12.20</td>
<td>109.80</td>
</tr>
<tr>
<td></td>
<td>Sod......</td>
<td>7.30</td>
<td>65.70</td>
</tr>
<tr>
<td></td>
<td>Difference</td>
<td>4.90</td>
<td>44.10</td>
</tr>
<tr>
<td>1-12 in....</td>
<td>Tillage..</td>
<td>11.53</td>
<td>152.64</td>
</tr>
<tr>
<td></td>
<td>Sod......</td>
<td>6.52</td>
<td>84.60</td>
</tr>
<tr>
<td></td>
<td>Difference</td>
<td>5.01</td>
<td>68.04</td>
</tr>
</tbody>
</table>

The figures show that in 1907 the soil under sod had only three-fifths as much water in the upper six inches as did the cultivated soil and a little less than that proportion in the entire upper foot. In 1908, both soils held more moisture, but the sod soil nearly one-third less than that cultivated.

That the available supply of plant food was a negligible factor in this orchard is shown in two ways: First, the addition of considerable supplies of such food in the form of readily soluble acid phosphate and muriate of potash gave no results and, second, chemical analyses of many soil samples showed abundance of plant food in both soils, with no consistent differences. Such slight variations as there were favored the soil in sod and would apparently show, if anything, that the soils were very much alike in available fertility at first and that a little more plant food had been removed from the tilled plats by the larger crops of apples. However, it should be
said that most of the variations were within the range of error in sampling and analysis and really mean nothing.

But the trees in sod undoubtedly suffered from lack of food, as well as from lack of water; because plants take food only in solution and very dilute solution, at that, and the water was not present to dissolve from the soluble store in the soil anything like the amount needed by the grass and the trees in sod. The grass roots surrounded the tree roots and ate at the first table; the trees starved on the crumbs left.

Chemical determination did prove one thing, though, and that was the fallacy of stock phrase constantly presented by sod-mulch advocates, "Tillage burns up humus." The tilled soils averaged 1\(\frac{3}{4}\) tons to the acre more of humus than the soils in sod. Of course, tillage without any addition of organic matter in manure, cover crops or catch crops would soon use up the supply of humus in the soil; but a properly balanced method of tillage and a cover crop each year increases the supply instead of diminishing it. It is an improper tillage the sod-mulch promoters have been comparing with their system as a humus destroyer, not the system which students advocate and leading orchardists follow.

The tilled soils are warmer than the sod soils. Observations made for four weeks, mostly in July, at 7 o'clock in the morning and at 6 o'clock at night, showed, for the first 6 inches of soil, a difference of more than a degree in the morning and more than 1\(\frac{1}{2}\) degrees at night, and for a depth of 12 inches a difference of 2\(\frac{1}{2}\) degrees in the morning and 1\(\frac{3}{4}\) degrees at night, all in favor of the tilled soil. Just how much part this added warmth in the tilled soil plays in apple growing we do not know; but, in general, heat hastens the solution of food substances and makes the solutions diffuse more rapidly, it increases the movement of air in the soil, it develops stronger osmotic pressure, the force that sends sap into the roots and through the plant, and it stimulates the beneficial bacteria in the soil, especially those that form nitrates.

A quite evident manifestation of the influence of warmer soil was the earlier coming into leaf of the trees on the tillage plat.
A tilled soil is a aerated soil and free circulation of air in the soil is beneficial in many ways. A warm, well ventilated, moist soil is favorable to the growth of beneficial bacteria, those that cause the fermentations, decays and putrefactions which break down organic matter into forms available to plants; and, as mentioned above, especially those that change other forms of nitrogen to nitrates, which are the main, if not the only forms of this element which enter plants.

A tilled soil is also free from weeds and other plants; so there can be no danger from poisonous excretions from their roots or from bacteria which associate with them. It is a quite common belief, now, that many plants do, by actual poison, disastrously influence successors or associates; and this factor, in the English experiment, mentioned on page 4, was regarded as the main reason for difference between trees in sod and tilled trees.

It is not necessary to lay much stress on other factors, however, in this experiment; for the small amount of water available for trees on the sod-mulch plat, with the consequent poor supply of food, is amply sufficient to account for the crop differences.

The well being of nearly all the plants which minister to the needs of man is improved by tillage. It does not appear from this experiment that the apple is an exception. This fruit responds to high cultivation in the nursery row; it seems to continue to do so when transplanted to the orchard. Results as positive as in this experiment can be made very comprehensive. They will, it is believed, apply to all varieties of apples, and to all fruits, for that matter, and to practically all fruit soils and conditions. It should not be expected, however, that sod will be deleterious in the same degree under all conditions. It should be expected, for instance, that in a deep soil, where the apple roots can escape from the grass roots, or in one containing a great amount of soil moisture, the harmful effects of the grass will not be so marked as otherwise. The experiment does not show that apples can not be grown in sod. There are many orchards in New York which would prove the contrary.
It suggests, however, that apples thrive in sod, not because of the sod, but in spite of it. The fact that there are many thrifty orchards in sod in New York is not proof that these orchards would not do better under tillage.

In considering the two methods of management, of all the factors affecting the growth of trees in this experiment, conservation of moisture should receive first attention from the apple grower. This statement is affirmed not only by the results in the Auchter orchard but in practice the world over. The climate of Europe is moist; sod orchards are the rule there. Near the Atlantic seaboard in America, as in New England, where the rainfall is comparatively high, thrifty orchards are found in sod. In the western fruit regions where irrigation is practiced, sod orchards are hardly to be found; water is purchased and must be conserved. In irrigated lands tillage is found to be the best means of moisture conservation. Moisture is by no means the only factor to be considered in the controversy over the sod and tillage methods of management, but it appears to be the chief one.

To manage the soil of an orchard properly requires nice adjustments and delicate balancing for each particular case. Soils vary much and all are complex; quite diverse chemical, physical, and biological changes take place in diverse soils. Every apple-grower, therefore, has a problem of his own. But the individual problem can be best solved by the rational application of the ordinary laws of nutrition and growth — those which apply to cultivated plants in general. The apple is not unique among plants.
"I have found every stage of cultivation strongly marked: those orchards which have been two years under cultivation, exhibit a striking superiority over those which have been but one year under the plough."—WILLIAM COXE, *A View of the Cultivation of Fruit Trees*, 1817.

"It has been ascertained by experience and observation, that apples, pears, peaches, etc., attain to their highest perfection only when the soil about the roots is kept open."—JAMES THACHER, *The American Orchardist*, 1822.

"Of two adjoining orchards, one planted and kept in grass, and the other ploughed for the first five years, there will be an incredible difference in favor of the latter. Not only will these trees show rich dark luxuriant foliage, and clean smooth stems, while those neglected will have a starved and sickly look, but the size of the trees in the cultivated orchard will be treble that of the others at the end of this time."—A. J. DOWNING, *The Fruits and Fruit Trees of America*, 1845.

"All sown crops are to be avoided, and grass is still worse. Meadows are ruinous."—JOHN J. THOMAS, *The Fruit Culturist*, 1847.

"Trees need manure and culture, as much as corn or potatoes, and they will pay as well for care and expenditure."—S. W. COLE, *The American Fruit Book*, 1849.

"If no root crops are cultivated, the ground should be kept clean and mellow with the one-horse plough and cultivator."—PATRICK BARRY, *The Fruit Garden*, 1860.

"If the ground, which has been appropriated to the orchard, be also occupied as farming land, as is usually done for a few years after planting, while the trees are small, it should be exclusively devoted to hoed crops; by which is meant those that require constant cultivation and stirring of the soil."—JOHN A. WARDER, *Apples*, 1867.

The entire soil where an orchard is growing should be either mulched, or cultivated, or hoed over so frequently during the growing season, that all vegetation will be completely subdued."—S. E. TODD, *The Apple Culturist*, 1871.

"Trees or vines should have the full strength of the land, and all the help which can be given them in the shape of thorough cultivation."—E. J. WICKSON, *The California Fruits*, 1889.

"Apples and standard pears may now and then be seeded with safety, but it is certainly true that, in general, fruit decreases in proportion as sod increases."—L. H. BAILEY, *The Principles of Fruit Growing*, 1897.

"Unfruitfulness may also come from a lack of moisture, and hence a lack of nourishment, at critical periods in the life of the tree. It will be seen how intelligent must be the use of the earth-mulch, manures, cover crops and the liberation of moisture and plant-food by systematic tillage, if the highest profitable success is reached."—I. P. ROBERTS, *The Fertility of the Land*, 1897.

"We may lay it down as a rule, subject to minor exceptions only, that the commercial orchard is always to be cultivated."—F. A. WAUGH, *The American Apple Orchard*, 1908.