RELATIONS BETWEEN ORCHARD SOILS AND COVER CROPS

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R. C. COLLISON

ABSTRACT

Data are presented bearing on the relation of cover crops to soil nitrates, moisture, and organic matter production in the orchard. The question whether cover crops in the orchard interfere with the nitrogen and water requirements of trees is also considered.

The data have been collected during the past 16 years with soils and crops in large outside tanks from which the drainage was collected and examined.

Soil which grew alfalfa for 2 years and then laid bare for 2 years lost nitrogen equivalent to 450 pounds of nitrate of soda per acre per year for a 16-year average. During the years when the soil was cultivated but not cropped, nitrogen was lost equivalent to from 587 to 1,835 pounds of nitrate of soda per acre per year.

Where a crop of barley and then one of wheat followed the alfalfa, the nitrogen losses were greatly reduced, amounting to only 136 pounds per acre per year.

When timothy sod replaced alfalfa and the two grain crops followed the timothy, the nitrogen loss was still further reduced, being equivalent to only 51 pounds of nitrate of soda per acre per year.

The nitrogen loss during the second year of alfalfa or timothy, when the stand was well established, was very small and of the same order for both crops, amounting to only 1.8 pounds of nitrogen per acre per year for alfalfa and 1.6 pounds for timothy. This indicates that alfalfa may utilize soil nitrates as completely as timothy sod and, if growing in orchards, the trees in both cases may have to be fertilized with nitrogen.

After plowing down alfalfa or other legume crops, much nitrogen may be lost if they are not soon followed by another crop. Advantage of this fact may be taken by using non-leguminous cover crops after alfalfa or other legumes.
Data on water relations of the crops in the tanks indicate that the commonly accepted belief that a legume or non-legume sod used as a cover in orchards, or an early seeded annual cover crop, seriously compete with the trees for moisture, is considerably exaggerated.

The sod-fertilizer system and the cultivation-cover crop system of orchard soil management are discussed and some of their similarities and differences emphasized. The use and value of legumes as orchard covers and the value of alternating them with non-legumes in a cover crop rotation system are also discussed.

INTRODUCTION

One of the fundamental requirements of a system of permanent agriculture is the maintenance of soil organic matter. It is well known that in a soil in the virgin state, carrying a natural cover of forest or grass, organic matter or humus is either increased or at least maintained at a more or less constant level. It is also known that when such a soil is plowed up and cultivated large losses of organic matter immediately take place. If these losses are allowed to occur without adequate replacement, sooner or later, depending on the kind of soil, the original organic matter content, the climate as regards temperature and moisture, and the extent of cultivation, the organic matter may become so low that a permanent agriculture can no longer be maintained. The effects of such conditions become evident in the burnt out, droughty condition of sandy soils and the lack of good tilth and poor physical condition of heavier soils. These physical evidences of low organic matter sooner or later affect the production of crops on such soils. These effects are noted more quickly in shallow-rooted field crops, less quickly in tree crops.

It is the feeling of fruit growers that many orchards in New York are fast approaching the above-described conditions as evidenced by the poor physical condition of heavy soils and a gradual decrease in yields. Many such orchards have been given a new lease of life by the application of nitrogenous fertilizers, but it is a question as to how long the fertilizer effects will continue if, at the same time, no provision is made for additional organic matter.

Cultivation of orchards has been and still is, to a major extent, the favorite system of orchard soil management. Many orchards, however, are being put down to grass or legume sod. It is well known
that laying down a soil to grass conserves its organic matter. The grass to a large extent, and legumes perhaps to a less extent, compete with the trees for the available soil nitrates, so that orchards in sod must receive additions of nitrogenous fertilizers in order to maintain tree vigor and growth and fruit production. A system of this kind, consisting of sod adequately fertilized with nitrogen and perhaps phosphorus, will undoubtedly maintain both soil humus and tree growth and production. In case that the grass competes too heavily with the trees for the nitrogenous applications, the sod can be turned under and the soil reseeded.

In the case of the cultivated orchard, however, special provision must be made sooner or later for organic matter maintenance. It is wise to anticipate this condition by making provision for organic matter regularly rather than to wait until the condition has advanced to such a degree that it becomes much more difficult to bring the soil and the orchard back to a favorable growth and production level. This provision for organic matter for the cultivated orchard can be made thru the use of farm manures or by growing cover or green manure crops. Since farm manure in most commercial fruit sections is scarce and in most cases out of the question, the growing of green manures must be resorted to.

THE VALUE OF COVER CROPS

Cover and green manure crops are more or less equivalent terms. A green manure crop seeded or allowed to grow for the purpose of covering soil at a time of year when no other crop would naturally occupy the soil and used mainly for its covering value may be called a cover crop, while any cover crop when incorporated with the soil, especially before maturity, becomes a green manure crop. Such crops have a number of more or less distinct values from the standpoint of orchard soil management, as follows:

1. They provide organic matter for the soil. To what extent they provide this important soil ingredient depends on the kind of crop used, the kind of soil, and the time of seeding and plowing down the crop.

2. Such crops, developing in the orchard late in the growing season, as they do, are thought to be valuable for checking tree vegetative growth, thus allowing the fruit to develop and color and preventing a too succulent development of wood.
3. Reaching their main development late in the season when the fruit is approaching maturity, the cover crop absorbs unused nitrates which might otherwise leach away and be lost from the soil. In the winter time, if such crops are left standing, they may help to hold the snow, thus giving a certain amount of protection to the soil and the tree roots.

4. If the cover crop is a leguminous one, a certain amount of nitrogen may be gained by fixation.

On the other hand, there may be some disadvantages, theoretical or otherwise, in the growing of cover crops in the orchard, as follows:

1. If the cover crop is seeded early, it may prove injurious to the trees by using up soil moisture and nitrates at a time of year when the tree is most in need of them. This may also happen later in the season if rainfall happens to be deficient.

2. If the crop is highly carbonaceous, that is, with a wide ratio of carbon to nitrogen as are many of the non-legumes, and if it is allowed to stand over winter and is plowed down in the spring, its decomposition may temporarily lock up the available soil nitrate supply at a time when the tree most needs it and thus be injurious to growth and fruit setting. If this trouble is encountered, it can be overcome by the use of available fertilizer nitrogen applied in the early spring, thus supplying both the tree and the soil organisms which must have nitrogen in their work of decomposing the cover crop.

3. Cost of the seed, especially of some legumes, and interference of the standing crop with harvest operations are minor disadvantages which will not be considered here.

EXPERIMENTAL DATA BEARING ON THE WATER AND NITROGEN RELATIONS BETWEEN SOIL AND COVER CROPS

NITROGEN RELATIONS

It is very desirable to know if the advantages and disadvantages of cover crops mentioned above are more or less theoretical or have a real basis in fact. It is obvious that cover crops when plowed down will furnish a certain amount of organic matter. Since such crops require moisture and nutrients for growth, it is equally obvious that they will compete to a certain extent with the trees around which they are growing. The extent and seriousness of such competition,
however, are not nearly so obvious, so that the following data bear particularly on that point.

For the past 16 years this Station has been studying the water and nutrient relations of various crops growing in rotation in outside tanks from which drainage water is collected. Measurement of the drainage water and chemical analysis for nitrates give important data on water and nitrogen relations of the various crops. In addition to this, the same kind of data are available for the same clay loam soil on which only clean cultivation is practised for 2 years out of the 4-year rotation. In this way the water and nitrate relations can be compared for bare soil and soil covered by crops. It happens also that in one case the crop covering the soil thru the fall and winter is alfalfa and in another case timothy, thus giving a comparison of legume and grass sod covers with clean cultivation without a cover crop. In all cases the soil is originally exactly alike for all tanks. These tanks were about 5 feet in diameter and each contained over 7,000 pounds of soil.

It should be explained here that the crops which are grown on the tank soils are alfalfa 2 years followed by barley and wheat each 1 year. Comparisons of this rotation are made with two others, first timothy 2 years likewise followed by barley and wheat, and second, alfalfa 2 years followed by 2 years of clean cultivation. The alfalfa and timothy are left until the spring of the second year, then are turned under and barley seeded. The barley is harvested in the late summer or early fall and winter wheat sown which remains on the tanks thru the winter until harvest the following summer. In this way the wheat crop would correspond closely to a cover crop of rye as used in many orchards, while the alfalfa and timothy correspond to semi-permanent covers of legume and non-legume crops, respectively. Comparisons of the alfalfa-fallow combination with the alfalfa-barley-wheat combination give directly the effects on nitrogen and water relations of uncropped soil with soil seeded to a cover crop, while these same relations for a legume and a non-legume may be studied by comparing the alfalfa-barley-wheat combination with the timothy-barley-wheat combination.

It will be noted from Table 1 that first of all there was a very great difference in the amount of nitrogen lost from the soil, depending on whether or not it was continuously cropped. The legume not only adds nitrogen to soil by atmospheric nitrogen fixation, but also leaves soil in excellent physical condition for nitrogen loss when the legume
### Table 1.—Pounds per Acre of Nitrogen Lost from Soil Under Various Crops.

<table>
<thead>
<tr>
<th>Year</th>
<th>Alfalfa-barley wheat combination</th>
<th>Alfalfa-fallow combination</th>
<th>Timothy-barley wheat combination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop</td>
<td>Tank 1</td>
<td>Tank 2</td>
</tr>
<tr>
<td>1916</td>
<td>Alfalfa</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>1917</td>
<td>Barley</td>
<td>0.4</td>
<td>2.4</td>
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<tr>
<td>1918</td>
<td>Wheat</td>
<td>2.4</td>
<td>4.9</td>
</tr>
<tr>
<td>1919</td>
<td>Alfalfa</td>
<td>69.3</td>
<td>64.5</td>
</tr>
<tr>
<td>1920</td>
<td>Alfalfa</td>
<td>3.5</td>
<td>1.6</td>
</tr>
<tr>
<td>1921</td>
<td>Barley</td>
<td>5.2</td>
<td>3.6</td>
</tr>
<tr>
<td>1922</td>
<td>Wheat</td>
<td>63.7</td>
<td>54.5</td>
</tr>
<tr>
<td>1923</td>
<td>Alfalfa</td>
<td>26.5</td>
<td>16.8</td>
</tr>
<tr>
<td>1924</td>
<td>Alfalfa</td>
<td>1.9</td>
<td>0.8</td>
</tr>
<tr>
<td>1925</td>
<td>Barley</td>
<td>10.2</td>
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<td>Wheat</td>
<td>78.9</td>
<td>84.1</td>
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<td>1927</td>
<td>Alfalfa</td>
<td>35.3</td>
<td>32.6</td>
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<tr>
<td>1928</td>
<td>Alfalfa</td>
<td>2.9</td>
<td>1.5</td>
</tr>
<tr>
<td>1929</td>
<td>Barley</td>
<td>1.2</td>
<td>6.3</td>
</tr>
<tr>
<td>1930</td>
<td>Wheat</td>
<td>30.6</td>
<td>26.9</td>
</tr>
<tr>
<td>1931</td>
<td>Rye...</td>
<td>33.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Total</td>
<td>366.5</td>
<td>334.0</td>
<td>........................</td>
</tr>
<tr>
<td>Mean</td>
<td>350.3</td>
<td>1,145.6</td>
<td>........................</td>
</tr>
</tbody>
</table>

is plowed down. Further, legume plants readily and quickly decompose in soil, setting free their nitrogen. This means that if no crop follows the plowing down of the legume so as to absorb the nitrogen released, there may be large amounts of this element lost.

During the 16 years of regular cropping each year, there was lost from the soil 350 pounds per acre of nitrogen while from soil which was not seeded to any crop following the alfalfa the loss was very much greater, amounting to 1,146 pounds of nitrogen per acre. The difference in nitrogen lost, therefor, was 796 pounds, equivalent to 4,975 pounds of nitrate of soda per acre, or 311 pounds per acre per year. This amount of nitrate is equivalent to the nitrogen in an application of 1,000 pounds per acre of a high grade 5-10-5 fertilizer.

The loss from soil growing timothy and grain crops was considerably less and therefore the difference between such a system and that of clean cultivation following the legume was even greater, namely, 1,015 pounds of nitrogen equivalent to 6,344 pounds of nitrate of soda, or about 400 pounds per acre per year. To be sure the legume crop combination lost more nitrogen than the grass combination.
because there was more nitrogen present to lose since the legumes elaborate nitrogen by fixation. These figures show, however, that when a legume is plowed down it should be followed as soon as possible by some strong-growing crop which will retain the nitrogen which would otherwise be lost. This same result can be clearly seen if the nitrogen losses for individual years are studied. Thus, in the alfalfa-barley-wheat combination in 1919, considerable nitrogen was lost. This was due to two reasons. First, wheat is generally fall sown but makes little growth until spring so that on these tanks this crop was able to utilize only a small part of the nitrates available in the soil. Second, alfalfa is seeded after wheat and makes little growth before winter so that here again the excess nitrates were not well utilized. By the next year, namely 1920, the alfalfa had completely established itself and its vigorous growth utilized the soil nitrates almost completely so that only 3.5 and 1.6 pounds of nitrogen per acre were lost during 1920. The same thing was also true for the years 1923 and 1924 and again for 1927 and 1928.

In the crop combination where no crop follows the legume for 2 years, alfalfa again was able to utilize only a small proportion of the nitrogen until the second year when only negligible amounts were lost from the soil. On the other hand, the losses of nitrogen during the cultivation period without cropping were very large, especially the second year, amounting in one case to as much as 293.7 pounds which is equivalent to a loss of 1,835 pounds of nitrate of soda per acre in a single year.

These facts are quite applicable to the handling of cover crops in orchards. In many orchards which are cultivated no special provision is made for any crop to take up and retain the extra nitrogen rendered available by cultivation at a time of year when the trees themselves have already taken up almost their full quota. Weeds may be allowed to grow but are for the most part uncertain and may be troublesome, altho they are much better than no crop at all. Other orchards are indifferently worked up in the spring and the soil then allowed to take care of itself. Many such orchards have a very sparse growth of any kind of grass or weeds. Nitrates which become available are largely lost at the expense of the soil organic matter, so that the soils become poorer and poorer in plant covering, and consequently in nitrogen and humus, and more difficult to handle. If the nitrogen was utilized by cover crops, seeded preferably rather early in the growing season, these orchard soils could be maintained
in fertility and good tilth instead of undergoing gradual decline. Or if the orchards were seeded down to grass, nitrogen losses would be reduced to a minimum and organic matter conserved. This fact is shown by the nitrogen losses under the timothy-grain combination in Table 1. It will be noted that losses were very small with the exception of one year. The total nitrogen lost during 16 years was only 131 pounds per acre, equivalent to a little over 50 pounds per acre of nitrate of soda per year. For the first 10 years this figure was much less, namely, 18 pounds per acre per year. In fact, the utilization of soil nitrates is so complete under grass that trees in grass sod must receive applications of nitrogen from outside if they are not to suffer from nitrogen starvation. These nitrogen applications are not lost, however, since what is not utilized directly by the trees is used to produce better grass and consequently more organic matter. If in time such a heavy grass growth is produced that it seriously competes with the trees for nitrogen, in spite of conservative applications of nitrogenous fertilizers, the grass can be turned under and the soil reseeded.

Two other points of practical importance are brought out in Table 1. After the alfalfa has established itself the second year, soil nitrates may be almost as effectively and completely utilized by this crop as by timothy. It will be noted that there was very little difference in the amount of nitrogen lost from the soil, comparing alfalfa with timothy sod for the years 1916, 1920, 1924, and 1927. This indicates that orchards seeded down to permanent or semi-permanent legume sod may require applications of nitrogenous fertilizers and also that it may be advisable to leave the legumes for only 2 or 3 years before plowing down and reseeding. The author has seen sweet clover handled in some orchards very successfully in this way. The orchard is seeded to this crop and allowed to stand for 2 years without any mowing of the crop whatsoever. The planting the second year, being undisturbed, sets a good crop of seed. It is rolled down for harvest operations and is disked up late in the fall and usually again the following spring. An excellent new stand results without the necessity of purchasing seed after the first year. A number of other legumes, such as red clover, alfalfa and vetch, might be similarly handled.

The other point brought out by Table 1 is one already referred to, namely, the advisability of seeding a crop as soon as possible on soil in which a legume crop has been incorporated. The large amounts
of nitrate nitrogen lost after the incorporation of the legume with the soil are ample proof of the advisability of this procedure. In orchards, if the legume is plowed down early in the season, the trees will benefit from the nitrogen released before the newly seeded crop has attained sufficient growth to be a serious competitor.

WATER RELATIONS

Besides the nitrogen relation between orchard soils and cover crops, there is another equally important relation, namely, that of water. When grass and permanent or semi-permanent legume sod or early seeded cover crops are spoken of, the question of soil moisture immediately arises. This may be a real factor prohibiting or at least limiting certain cover crop practises in orchards. The tank soils and crop combinations furnish some interesting data on this relation also and are presented in Table 2.

Table 2.—Percentage of Total Precipitation Lost from Soil Under Various Crop Combinations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Alfalfa-barley-wheat combination</th>
<th>Alfalfa-fallow combination</th>
<th>Timothy-barley-wheat combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Tank 1</td>
<td>Tank 2</td>
<td>Crop</td>
</tr>
<tr>
<td>1916</td>
<td>Alfalfa</td>
<td>8.49</td>
<td>6.37</td>
</tr>
<tr>
<td>1917</td>
<td>Barley</td>
<td>16.08</td>
<td>19.12</td>
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<tr>
<td>1918</td>
<td>Wheat</td>
<td>16.23</td>
<td>16.31</td>
</tr>
<tr>
<td>1919</td>
<td>Alfalfa</td>
<td>24.65</td>
<td>19.68</td>
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<tr>
<td>1921</td>
<td>Barley</td>
<td>27.88</td>
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<td>Wheat</td>
<td>32.42</td>
<td>28.02</td>
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<td>Alfalfa</td>
<td>19.92</td>
<td>16.86</td>
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<tr>
<td>1924</td>
<td>Alfalfa</td>
<td>15.41</td>
<td>20.71</td>
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<tr>
<td>1925</td>
<td>Barley</td>
<td>40.45</td>
<td>37.80</td>
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<tr>
<td>1926</td>
<td>Wheat</td>
<td>31.65</td>
<td>25.27</td>
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<tr>
<td>1927</td>
<td>Alfalfa</td>
<td>27.80</td>
<td>28.30</td>
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<td>1928</td>
<td>Alfalfa</td>
<td>22.20</td>
<td>19.70</td>
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<tr>
<td>1929</td>
<td>Barley</td>
<td>35.70</td>
<td>32.70</td>
</tr>
<tr>
<td>1930</td>
<td>Wheat</td>
<td>23.00</td>
<td>13.60</td>
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Means

<table>
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<tr>
<th>Crop</th>
<th>Tank 1</th>
<th>Tank 2</th>
<th>Tank 5</th>
<th>Tank 6</th>
<th>Tank 3</th>
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<tbody>
<tr>
<td>Alfalfa</td>
<td>17.2</td>
<td></td>
<td>20.7</td>
<td></td>
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</tr>
<tr>
<td>Barley</td>
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<td></td>
<td></td>
<td>All crops</td>
<td></td>
<td>15.9</td>
</tr>
</tbody>
</table>

These figures indicate in the first place that a surprisingly large proportion of the available water was retained by the soil, used by
crops, or evaporated. From uncropped soil 36.4 per cent of the total precipitation was lost thru drainage which means that about 60 per cent was used, either by the soil itself to equalize its moisture content after alfalfa or evaporated from the soil surface.

The main drainage from these soils occurs in late winter or early spring when the winter snow melts. If we assume, therefore, that the soil in the tanks has an equal degree of saturation in the early spring after the main drainage is over, the mean percentages in Table 2 subtracted from 100 would represent the proportion of the precipitation used by crops or evaporated. Thus, in the case of uncropped soil, almost 64 per cent of the total water was evaporated from the bare soil. It would seem then that any crop used as a cover crop on this soil would have two sources of available water. It could utilize some of the 36 per cent which drained thru the uncropped soil or it could take toll from the 64 per cent which is lost by evaporation. In reality a cover crop does both. It utilizes considerable water which would otherwise be lost and its shading effect, together with the lower soil temperatures which result from the shading, reduces evaporation greatly, so that still more water becomes available.

Another factor in water utilization in orchards is the rooting habit of trees. Trees are able to tap subsoil moisture closer to the water table and are thus more independent of drainage losses. Alfalfa might for this reason be a less desirable crop in the orchard than some others, because it is a deep-rooting crop and takes water from the subsoil where the trees also take considerable water. Alfalfa, as can be noted from Table 2, used more water than any other crop, from 80 to 83 per cent of the total precipitation being used by the crop or evaporated. The grain crops, barley and wheat, used considerably less water. The mean difference between alfalfa and the grain crops was 8 per cent. This is considerably smaller, however, than the real difference, because there is more shading effect from alfalfa and therefore less evaporation, and furthermore alfalfa occupies the soil during a much longer growth period, which would further reduce evaporation for the growing season.

Grass sod, as represented here by timothy, used considerably less water than alfalfa and about the same as the grain crops. Water utilization by a crop is more or less a function of total dry matter production, so that alfalfa for this reason in part used more water than timothy and the grain crops after timothy used less water than similar crops after alfalfa because there was much less crop growth
after timothy. Some of these relationships as to crop yields can be seen from Table 3, since after all one important test of the value of a cover crop is the total amount of dry matter which it furnishes to the soil.

It will be noted in Table 3 that alfalfa produced twice as much dry matter as timothy. The difference in fact was greater than this, since the weights are for crop removed and did not take into account the difference in root growth in the two crops. In addition to this, the barley and wheat crops following alfalfa were much heavier than those following timothy, which indicates a further value of legumes as covers and humus producers in an orchard. In fact after alfalfa, barley produced $2\frac{1}{2}$ times as much dry matter and wheat 1.2 times

**Table 3.—Yield of Crops in Pounds of Dry Matter per Acre.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Alfalfa-barley-wheat combination</th>
<th>Alfalfa-fallow combination</th>
<th>Timothy-barley-wheat combination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop</td>
<td>Tank 1</td>
<td>Tank 2</td>
</tr>
<tr>
<td>1917</td>
<td>Barley</td>
<td>9.382</td>
<td>8.201</td>
</tr>
<tr>
<td>1918</td>
<td>Wheat</td>
<td>5.314</td>
<td>4.333</td>
</tr>
<tr>
<td>1920</td>
<td>Alfalfa</td>
<td>8.206</td>
<td>8.137</td>
</tr>
<tr>
<td>1921</td>
<td>Barley</td>
<td>6.051</td>
<td>5.572</td>
</tr>
<tr>
<td>1922</td>
<td>Wheat</td>
<td>7.003</td>
<td>7.032</td>
</tr>
<tr>
<td>1923</td>
<td>Alfalfa</td>
<td>7.134</td>
<td>7.703</td>
</tr>
<tr>
<td>1924</td>
<td>Alfalfa</td>
<td>7.488</td>
<td>7.439</td>
</tr>
<tr>
<td>1925</td>
<td>Barley</td>
<td>6.120</td>
<td>5.545</td>
</tr>
<tr>
<td>1926</td>
<td>Wheat</td>
<td>7.134</td>
<td>8.264</td>
</tr>
<tr>
<td>1929</td>
<td>Barley</td>
<td>3.897</td>
<td>3.557</td>
</tr>
<tr>
<td>1930</td>
<td>Wheat</td>
<td>7.162</td>
<td>8.002</td>
</tr>
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</table>

**Means**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Tank 1</th>
<th>Tank 2</th>
<th>Tank 5</th>
<th>Tank 6</th>
<th>Tank 3</th>
<th>Tank 4</th>
<th>Tank 5</th>
<th>Tank 6</th>
<th>Tank 3</th>
<th>Tank 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>8.032</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>6.041</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>6.781</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

as much as when they followed timothy. This fact indicates from the standpoint of humus production not only that alfalfa may be a very valuable crop in an orchard, but also that alternating non-legume cover crops with alfalfa may be a very valuable practise. In other words, alfalfa may be left down 2 years or more and may then be followed by such crops as rye, oats, buckwheat, or other non-legumes
used as annual covers. The legumes can then be reseeded as would be done in a crop rotation.

As can be seen in Table 3 the crops in these three combinations were unusually heavy, in fact much heavier than when grown in the field or orchard, which further indicates that they did not suffer from deficient water. If these crops were growing in the orchard along with bearing apple trees, the situation might be different as regards water relations, because then the trees also would be removing soil water. Observations in orchards growing alfalfa, sweet clover, timothy, and other semi-permanent covers during the dry years of 1930 and 1931 indicate that unless the soil is of light texture, the organic matter low, or the growing season extremely dry, the trees do not appear to suffer from lack of moisture. Apparently, the fear that permanent, semi-permanent, or early seeded cover crops may seriously deplete the soil moisture is ungrounded, at least in seasons of normal rainfall.

It should be remembered also that, altho a green manure crop in the orchard uses up available moisture, when incorporated with the soil it raises the water-holding capacity of that soil and enables it to retain more of the water which would otherwise be evaporated or carried beyond the reach of plant roots.

Therefore, if the fruit grower wishes to keep his orchards in sod, even in legume sod, the nitrogen made available may be so completely utilized by the sod that the needs of the trees will have to be met thru the use of manures or artificial fertilizers, at least nitrogen and perhaps phosphorus also. If a good sod is maintained, the organic matter problem will largely be taken care of. This conservation of organic matter will in turn help to conserve and retain soil moisture. If on the other hand, the grower wishes to practise clean cultivation which means that he is supplying the trees with food from the storehouse of the soil thru more rapid decomposition and nitrification, this storehouse must ultimately be replenished by the addition of farm manures or the growing of cover crops, fertilizing the cover crops when necessary in order to secure a worthwhile growth.

In either case, something must be added to replace what is taken away. It may take years to deplete the soil to a point of unprofitable production, but someone must pay the penalty both in unprofitable crops and the expenditure of time and money in rebuilding such depleted soils.
LEGUMES AS ORCHARD COVER CROPS

Legumes supposedly possess several characteristics which make them superior to non-legumes as crops for orchard soils. Their chief superiority lies in their well-known property of nitrogen fixation. This has caused many fruit growers to raise the question as to whether permanent seedings of legumes will meet all the nitrogen needs of trees, since at the present time this element is practically the only one which is applied generally to orchards. Besides this outstanding property, legumes have other important properties which may or may not be possessed by non-legumes. The composition of the legume plant itself is very important in the nitrogen economy of soils. For example, the soil on which the crop rotations already described were grown was not a natural alfalfa soil, but with adequate liming it produced excellent yields of this crop throughout the 16 years of the experiment. On this soil alfalfa hay contained from 3 to 3½ per cent of nitrogen on a dry matter basis. On this same soil timothy hay contained from 1.0 to 1.6 per cent; barley (whole crop), 1.3 to 1.9 per cent; and wheat (whole crop) from 1.0 to 1.4 per cent nitrogen.

Excluding the nitrogen of the grain, the barley and wheat straw contained as low as 0.3 per cent nitrogen in several cases and an average of 0.7 per cent. It is now well recognized that crop materials such as cereal straw and stubble and non-legume hay, with their large content of carbon and their small content of nitrogen, during their decomposition in soil in the humus-forming process, may lock up all available soil nitrogen for several months. If such materials, are incorporated in early spring, as is usually the case, and if no fertilizer nitrogen is applied, fruit trees or other plants on such soil may be unable to obtain sufficient nitrogen for growth until too late in the season for satisfactory growth. The necessity of applying nitrogen to orchards in grass sod may be due in part to this cause, that is, the decomposition of the grass residues. This same principle is involved in the making of artificial manure from such high-carbon residues. In this case, available nitrogen in some form is added to the materials in an amount sufficient to narrow the ratio of nitrogen to carbon to a degree more conducive to rapid decomposition and the quick liberation of the nitrogen in available forms. This is also the reason why it may be wise to apply some form of nitrogenous fertilizer to soil in which a growing crop follows the incorporation
of large amounts of such materials as straw, non-legume hay, or manure with a large proportion of litter.

Now legumes are quite different from non-legumes in this regard. Their high nitrogen content gives them a much narrower ratio of nitrogen to carbon so that when they are plowed or disked into soil, they very quickly decompose and give up their nitrogen in available forms to the crop which follows.

Legumes have a further valuable contribution to make to soil due to their root development. It was found that on this same tank soil, alfalfa roots contained almost as high a percentage of nitrogen as the tops, and even to plow depth only contributed one-half as much nitrogen per acre as did two cuttings of alfalfa hay. A still better showing for roots and short stubble would have been made if the roots below plow depth could have been included. Furthermore, the roots of some legumes leave the soil in excellent physical condition for subsequent crops.

In regard to the adequacy of legumes to supply orchard soils with nitrogen, two kinds of data from the tanks bear on the subject; first, the amount of nitrogen fixed by legumes; and second, the amount of nitrogen used by the legume.

Nitrogen balance was determined in the tank soil after 16 years of rotation cropping. During this period there had been eight crops of alfalfa and four crops each of barley and wheat. Alfalfa took from the air and made available for crop growth over 2,000 pounds of nitrogen per acre in the 16 years. The actual figure was 260 pounds per acre per year for each year of alfalfa, equivalent to over 1,600 pounds of nitrate of soda. This is a large amount of nitrogen and if it could have been spread out uniformly over the total period of 16 years would have been equivalent to an annual application of 800 pounds of nitrate of soda per acre. It is quite obvious that such an application would take care of any nitrogen needs of trees in orchards when it is remembered that even an application of 10 pounds per tree to trees 33 feet apart would require only one-half of that amount.

The difficulty, however, is that this fixed nitrogen does not become uniformly available, for two reasons. In the first place, alfalfa itself uses nitrogen in very large amounts to build up its high protein content. This tends to withdraw available nitrogen from the soil while the legume is actively growing. That this may become an almost complete withdrawal when the legume is thoroughly established
may be seen from Table 1. In every case in both alfalfa rotations there was a large surplus of nitrate nitrogen available in the soil during the year of seeding, as is shown by the amount found in the drainage. During the second year, however, the alfalfa utilized the soil nitrogen so completely that almost no nitrogen was lost as a surplus. It is probably safe to assume that if the legume had been left down additional years, this same condition would prevail as long as vigorous legume growth was maintained.

In the second place, the usual practise in orchards is to mow the legume and let the material lie on the soil surface. This removes considerable nitrogen from the soil temporarily, while undoubtedly considerable is lost by oxidation of the old residues. Mowing also stimulates new growth which uses additional soil nitrogen.

These facts make it appear that legumes in orchards might be better handled in short periods and plowed or disked into the soil, after which short cultivation and reseeding could be done. Even short rotations of legumes followed by non-legume crops might be very desirable if quicker nitrogen turnover and prevention of nitrogen loss is desired. For example, in Bulletin No. 629 of this Station it is shown that in one orchard in particular a system of red clover 2 years followed by a short cultivation period and reseeding the clover was very effective in supplying organic matter and available nitrogen to apple trees.

There is one factor that in time would tend to compensate for the withdrawal of nitrogen by the legume itself, and that is that if the legume was left down over a considerable period of years and no cuttings removed, the accumulation of mulch would cause less nitrogen volatilization and more rapid decomposition and nitrogen turnover. This would tend to spread out more uniformly the nitrogen fixed by the legume.

The adequacy of legumes in supplying trees with nitrogen depends, therefore, on the soil, that is whether it already has a high or low organic matter content, its biological activity and lime supply which render the nitrogen of crop residues available, and also on the way the legume is handled. Soils may be so deficient in humus that nitrogen itself may have to be applied to secure a legume stand, while, on the other hand, the legume itself may absorb the available nitrogen so completely in the spring when tree growth starts, that fertilizer nitrogen may have to be applied to the trees. After a good legume stand and vigorous growth are secured and if no material is
removed, nitrogen fixation and liberation may be sufficient to take care of the nitrogen demands of the trees.

During the 16 years of cropping described here all crops were removed and no manure returned to the soil. Under this system even the soil in alfalfa rotations, in which were fixed the large amounts of nitrogen mentioned, lost nitrogen, as shown by the original and final soil nitrogen analyses. Even when the alfalfa in this same soil received applications of dried blood at the rate of 700 pounds per acre, the soil lost nitrogen, that is it contained less at the end than at the beginning of the 16-year period. These facts show that in order to maintain the nitrogen level in a soil under a cropping system the greatest care must be used to return as much nitrogen as possible in the form of manure and crop residues.

In an orchard, therefore, it is not wise to intercrop for any length of time or to remove any of the cover or green manure crops from the orchard. If careful attention is paid to this matter, legumes will go a long way toward maintaining a nitrogen level favorable to tree growth and production.