EXPERIMENTS IN ORCHARD SOIL MANAGEMENT:
FERTILIZERS, MULCHES, AND COVER CROPS

R. C. COLLISON
ABSTRACT

ORCHARD soil management includes all practices in an orchard which have to do with the soil. These are cultivation, sodding down, manuring, use of mulches, selection and use of cover and green manuring crops, and the use of commercial fertilizers, including kind, amount, time, and methods of application.

This report gives a brief résumé of this Station's recommendations on some of these practices and presents the results of experiments on sub-surface placement of orchard fertilizers, the relation between fertilization and mulching, and 7 years of cover crop studies. It also touches on work dealing with differences in varietal response, a subject in which this Station is now interested.

In the studies on sub-surface placement of manure and fertilizers, the McIntosh orchard under experiment gave over a 3-year period no better responses to any method of deep placement used than to the usual surface broadcast application. The conclusion drawn was that until more is known of phosphorus and potassium deficient orchard soils in New York State, the greater expense of placing fertilizers in the root zone of trees is unjustified, at least from the results of this experiment.

The studies of nitrogen fertilization in a well-mulched McIntosh orchard on medium light soil indicated that applications normally recommended for un-mulched orchards could not be used with a heavy mulch of nonlegume material without seriously affecting color and drop of fruit. The more quantitative relations involved are being made the object of further study.

The studies on the differences in response of apple varieties, which will be made the subject of a separate report, indicate that these differences may be of a character amply justifying such studies. For example, the fact that Delicious was found to have in its leaves appreciably more calcium than Baldwin, McIntosh, or Spy may be related to the apparent susceptibility of the Delicious to acid soil conditions as reported in the literature. Spy took up the least calcium of the four varieties and furthermore was least resistant to adverse nutrient conditions presented.

The cover crop studies deal with some 15 different crops available for temporary or permanent orchard covers. The crops are compared from as many angles as possible with stress on seeding, persistance, dry matter production, weed competition, self-seeding, type of cover produced, water relations, and snow retention property.

It is hoped in a later report to present something of the relations of the various crops to nitrogen and humus build-up in the soil on which they have been grown for 7 years.
BULLETIN No. 691

EXPERIMENTS IN ORCHARD SOIL MANAGEMENT: FERTILIZERS, MULCHES, AND COVER CROPS

R. C. COLLISON
Chief in Research (Pomology)

INTRODUCTION

AGRICULTURAL methods in use today are the results of both practical experience and experiment, accumulated over long periods of time. One can not say that any agricultural procedure is completely standardized and final, since new findings may demand changes in details if not in major essentials. The complexity of the interacting factors which make up the environment of growing plants makes it difficult to lay down any hard and fast rules which will completely hold for orchard soil management in a State as widely divergent in conditions as New York. In this State the factor which will furnish the largest number of exceptions to any such standardization of orchard soil management procedure is the soil itself as regards texture, structure, and topography. Since it is being recognized increasingly, however, that orchards should not be set on unadapted soils, such exceptions should become more rare as new plantings are made and older plantings in such marginal or unadapted locations eliminated.

The management of orchard soils has to deal with several rather overlapping operations. There is the question of culture to decide, that is, shall the soil be cultivated, sodded down, or mulched. Then if crops are grown in the orchard for sod, green manure, or other purpose, suitable ones have to be selected. Further, a fertilizer program has to be established which will most nearly fit the cultural method adopted.

Among these three operations perhaps fertilization procedure has been standardized, as far as any agricultural operation can be, to a greater degree than the other two. This is probably because more intensive as well as more extensive work has been done on it than on either purely cultural methods or the study of cover crops.
The kinds of fertilizers and the rate, time, and methods of application, altho all rather flexible in practical use, are fairly definitely established. It is true that some finer points require further study such as new or unusual methods of application of fertilizers, varietal differences in fertilizer response, rates of application with different methods of culture, the evaluation in terms of standard materials of newly introduced fertilizers, and the making of an inventory of the orchard soils of the State which shall serve as a basis for nutrient deficiency information and recommendations as to what nutrients should be advised in particular orchards or orchard sections.

It is the purpose here to give first a brief résumé of the best established points in fertilizer practice, then a discussion and presentation of data on a few of the finer points such as sub-surface fertilizer application, varietal differences in response, and new fertilizers, then some results of mulching in its relation to fertilizer practice, and finally the results of some cover crop experiments which have been conducted at this Station for the past 6 or 7 years.

RÉSUMÉ OF ORCHARD FERTILIZATION

If we assume the average commercial apple orchard in New York to be one on good soil, fairly well pruned and sprayed, and largely uncultivated or in poor or only fair grass sod, the following statements will hold for such an orchard.

Production can be fairly well maintained for a long time by the use of nitrogen alone without any particular attention being paid to the soil cover. The length of such period will depend on the condition of the orchard soil when the trees were set and on the annual amount of natural cover produced. Such a period may be the lifetime of the grower or under other conditions much less. The period can be greatly prolonged under almost any orchard soil conditions by paying more attention to the plant cover. Such attention would be directed toward establishing and maintaining a cover thru soil preparation, seeding, and fertilization, not only with nitrogen but also with phosphorus and potassium if the need of such is indicated.

When nitrogen alone is consistently used, it can be said within rather narrow limits that almost any of the common carriers are satisfactory, providing care is used in application consistent with any special characteristics of the carrier. This can be said to be true of all the following:

Purely mineral carriers, including nitrate of soda, Nitrano, cal-
cium nitrate, ammonium nitrate and ammonium nitrate-lime, potas-
sium nitrate (as a nitrogen source), Calnitro, ammonium sulfate, 
Cyanamid, and Ammo Phos (as a nitrogen source).

Organic nitrogen and combination carriers, including urea, Cal-
urea, Uramon, Ureor, and Calci-Ureor. Under this heading would 
also have to be included such materials as tankage of various kinds, 
including sewage preparations, dried blood, cottonseed meal, various 
commercially mixed fertilizers, and even farm manures when used 
as nitrogen sources.

This Station has for many years worked with practically all the 
above materials and their relatively small differences in value (out-
side of cost) as orchard fertilizers have been fairly well established, 
as well as the differences in methods of application and use which 
should be observed based on their individual characteristics. It can 
also be said that within the limits imposed by these individual dif-
f erences such as, for example, soil effects after prolonged application, 
soil texture and reaction, and ease of handling, the carrier furnishing 
nitrogen at the lowest cost per unit can fairly safely be chosen.

There has been considerable effort expended in recent years to-
ward getting fertilizers into better mechanical condition. Perhaps 
the initial step in this direction was made in some of the German 
synthetics such as Calnitro and Nitrophoska. The former came on 
the market in distinct pellet form while the latter was a good ex-
ample of granulation. "Champion" brand nitrate of soda appeared 
rather early, followed by granular Cyanamid and other materials.

Since such a large part of orchard fertilizer application is made 
broadcast to the soil surface, granulation of various kinds has little 
significance from the standpoint of effectiveness or the temporary 
prevention of soil fixation. Applied as they are, the materials have 
to dissolve before being carried downward into the soil, which allows 
maximum fixation, a fact which has perhaps been one factor in the 
negative response of orchards to phosphorus and potassium. From 
the standpoint of ease and uniformity of application, however, granu-
lation is important in an orchard fertilizer as anyone who has broad-
cast the older type Cyanamid can testify. More recent attempts have 
been made to coat fertilizer particles with materials which will lessen 
their hygroscopic nature. The method has also been utilized to add 
certain other ingredients which will either serve as neutralizing 
agents or supply some of the minor elements. If such methods add 
very much to the cost of the fertilizer, they are to be discouraged,
since in an orchard fertilizer, at least, soil reaction is affected seriously only after prolonged applications and can be easily controlled by liming or by changing the type of fertilizer, while up to the present boron is the only minor element found valuable in some orchard soils of the State and, when necessary, would have to be applied in much larger amount than could be effected thru such a fertilizer.

The rates of application are also fairly well established. For the average orchard as described above, the rule of $\frac{1}{4}$ pound of a carrier such as nitrate of soda or sulfate of ammonia for each year of the tree's age, applied each year will hold quite well. Amount and kind of sod growth, variations in size of trees, amount of cultivation, seasonal moisture conditions, and the use of mulch will all affect the rate of application as laid down in the above rule. Considerable judgment will have to be used here and tree growth and performance from year to year are probably the best guides to rate of application.

Time of application is another point which has been fairly well established. In general, late fall and early spring applications are about equally effective. With some nitrogen carriers like Cyanamid, for example, fall application is advised. Many others are equally well applied either fall or spring. With spring applications earliness is stressed.

It may be well to sound a note of warning here in regard to fall applications. There is some indication that in a few cases, due perhaps to seasonal conditions, peculiarities in location or to varietal differences, increase in winter injury seems to be traceable to fall fertilizer applications. The author has seen in one instance at least serious winter injury in which the only suspicious factor seemed to be fall application of nitrogen. Altho such cases are rare and the connection difficult to establish, the possibility should be kept in mind.

Method of application as far as nitrogen carriers are concerned is also fairly well standardized. In the average orchard under consideration, the method of broadcasting the carrier on the surface from near the trunk of the tree to some feet beyond the branch spread is quite satisfactory. However, if it is desired to stimulate the orchard cover, the rate of application should be increased some and the material spread over the whole soil surface. If sod growth is heavy, it is best to confine the application to a 3- or 4-foot ring near the
outer branch spread, otherwise the grass will compete too heavily for the nitrogen and excessive applications will have to be used. Other methods such as drilling in or dusting the fertilizer on the soil are also quite satisfactory.

UNSETTLED FERTILIZER PROBLEMS

NEW FERTILIZERS

From time to time there are new fertilizers and fertilizer materials introduced to the trade and to growers. These may be really new materials, old materials under new names, or mixtures and modifications of older materials. This Station has tried to keep up to date on such materials because growers want to know their relative value, since some of them may be still cheaper sources of nutrients or may have other properties more desirable than the ones in common use.

Nitrapo, or Chilean potash nitrate, for example, is a less common material which is found in limited amounts in some of the Chilean deposits. Altho it has been known for a long time, it is only recently that it has been offered to fruit growers. It is a very excellent source of nitrogen and also carries around 14 per cent potash in the valuable form of the nitrate.

Ammonium nitrate-lime is a mixture of a very good nitrogen source, ammonium nitrate, with enough lime to take care of its potential soil acidity and to prevent its rather bad caking tendency. Calnitro is a product of similar make-up. Both have proved very good nitrogen sources in orchards. A new Calnitro has been introduced recently containing more nitrogen than the old product and with 7 per cent magnesium oxide.

Uramon is an example of an older material under a new name. Urea has been imported into the United States for 15 years or more as a nitrogen source. It has been used in orchards by this Station for almost that length of time with good results. Its high price and its hygroscopic character have prevented extensive use for some purposes. The new Uramon produced in this country is urea modified by coating the small crystals with a non-hygroscopic agent which reduces its nitrogen content a little. As at present produced it furnishes nitrogen at comparatively low cost.

Ureo and Calsi-Ureor are some new materials of very recent manufacture. Ureo is a coated urea in pellet form while Calsi-Ureor contains lime for neutralization and better handling properties.
Altho the new urea products have not been compared with the older urea as yet, they undoubtedly can be counted on to give similar results when used in equivalent amounts based on their nitrogen content.

It may be well to keep in mind the fact that, altho all the nitrogen carriers compared by this Station during the past 15 years or more have given good results, they have not given identical results under various orchard conditions. Some gave better and some poorer results than others, but such differences for the most part have not been found statistically significant over the usual 6-year period of the tests. If, however, such comparisons were prolonged say to 10, 12, or 15 years, such differences might prove to be quite significant. For all practical purposes, however, the statements made about the similarity of results with the various carriers will hold. If the orchard conditions happen to be exceptional, it may be advisable to select a carrier whose characteristics meet most nearly such conditions.

THE USE OF PHOSPHORUS AND POTASSIUM

Altho this is still a controversial subject a rather brief statement will suffice to present this Station's present attitude toward it. Such consistently negative responses to these two elements have followed their application in so many orchards and over so many years that from the standpoint of expense their use, at least as far as tree performance is concerned, has seemed unjustified. It has to be kept in mind, however, that orchards in New York are on many soil types, some of which may respond to potassium especially, and this point will not be established until an inventory of New York orchard soils is made thru examination of the soils and the trees growing on such soils. Then again the orchard cover must be considered and this may be greatly benefitted by phosphorus and perhaps also by potassium applications. The removal of fruit crops year after year, especially when increased in volume thru nitrogen applications, sooner or later may cause a need for potassium and even phosphorus also. These points must be kept in mind by the grower as well as the investigator.

When potash or phosphorus deficient orchard soils are found in the State it will be interesting to know what proportion of them are deficient due to causes inherent in the original soil and what proportion are deficient due to causes within the control of the fruit
grower, such as for example, failure to supply soil organic matter regularly, poor soil structure caused by low organic matter, poor drainage, compaction by heavy machinery, and soil erosion. When these latter causes are present trees can not function properly even in the midst of a plentiful nutrient supply.

**METHODS OF APPLICATION**

The fact that soils with appreciable clay will fix in their surface phosphorus and potassium, preventing their leaching downward to the roots of trees, is too well known to require elaboration here. This fact, together with considerations of labor involved and efficiency of results, has led to experimentation with newer methods of applying fertilizers.

There are a number of methods which would naturally be thought of in getting fertilizer nutrients into the tree, including the following:

1. **Direct broadcast application to the soil surface.** This is by far the most common method. It is quite satisfactory providing sufficient time is allowed for the material, which must be soluble in water, to dissolve and be carried downward, and also providing it is not firmly fixed by the superficial layer of soil.

2. **Drilling the fertilizer into the soil surface with fertilizer machinery.** This method is used some and gives good uniformity of application. Most fertilizer machinery, however, would not place the material sufficiently deep to contact the tree roots.

3. **Deep drilling or other method of deep placement of the fertilizer.** Methods of this kind, either hand or machine, are extensively used with shade trees and on the Pacific Coast, at least to some extent, with fruit trees. Such methods place the material down where the roots can get it. The objection to such methods is the labor required when used on a large scale.

4. **Direct injection of the nutrients into the tissue of the tree.** On first thought this method would seem to offer some real advantages in directness of method, economy of materials, quickness of action, and prevention of soil fixation. In practice, however, it has been found by this Station that it is injurious to the tree when borings are made frequently and many nutrient materials are themselves injurious unless used in very low concentration. This method would be somewhat laborious and time consuming.

5. **Spraying the nutrient material on the active foliage during the growing season.** It is well known that leaves will absorb small amounts of many soluble materials. Direct spraying of the nutrients in solution would have the advantage of almost
perfect and all-over distribution without toxic concentration in one spot as in injection into trunk or limbs. It should also give quick effects on the tree. Repeated doses could be given thru the season without much trouble, especially if the nutrients could be combined with the usual spray mixtures. Altho this method was contemplated when the injection experiments were begun some years ago, it was not tried, facilities being lacking at the time. Such a method is worth a trial, altho it is a question if growers would go to the trouble if many doses had to be used when one soil application easily and simply applied answers the purpose. Such a method might also eliminate some carriers of nitrogen unsuitable for direct foliage application but entirely suitable for soil application. It might have advantages, however, if potassium or phosphorus were required. The method has been used to some extent in the correction of minor element deficiencies.

There is still another method of application used especially in western United States which consists of adding the fertilizers to the irrigation water. Liquid ammonia is the material most used and when added in proper amount is carried to all parts of the orchard and has proved quite effective.

DEEP PLACEMENT OF FERTILIZERS

The negative results with phosphorus and potassium applications to orchards in New York has greatly interested this Station for some years. Lysimeter results secured over a period of years from 1914 to the present time have shown that even in a silty clay loam soil potassium, at least, does penetrate after repeated applications. This is shown by its appearance in the drainage water. In fact, this Station's lysimeter results show that fairly large amounts of soluble potassium are found in the drainage water from tanks receiving potassium fertilizers.

Phosphorus, on the other hand, has never been found in the lysimeter drainage in amounts worthy of analytical determination. For some years now a Dunkirk fine sand has occupied one half of the tanks, yet only a trace of phosphorus has been detected in the drainage. For the past 5 years one tank on both heavy and light soil has been well fertilized with soluble phosphorus and potassium and, in addition, has received heavy applications of cane sugar. The thought here was that soluble carbonaceous matter would greatly stimulate the multiplication of soil organisms which, in turn, would build up some of the phosphorus and potassium applied into organic
form. When such carbon supply was exhausted and many of such organisms decomposed, the organic phosphorus and potassium might escape fixation and more of these elements appear in the drainage water. Up to the present time such results with phosphorus, at least, have not been realized.

In the fall of 1934 some experimental work on deep fertilizer placement was begun in a bearing McIntosh orchard not far from the Station. The trees were young with trunks averaging 7 or 8 inches in diameter. The soil is a fairly heavy loam with a compact layer some 20 inches from the surface. Surface drainage at least is good. Thruout the period of experiment the orchard was in a fair alfalfa sod. Fruit yields had never been very satisfactory, partly due perhaps to insufficient pollination.

The orchard consisted of McIntosh interplanted in every other row with Baldwin. After 2 years the Baldwins were removed, having been rather severely affected by the hard winter of 1933–34.

Some 200 trees were divided into nine blocks and 14 different treatments assigned each block by random. Buffer trees were left thruout on each side of the treated trees. These buffer trees received a standard broadcast nitrogen application applied well up under the branches.

The treatments were as follows:

1. 6 pounds nitrate of potash broadcast in spring.
2. 7 pounds Ammo Phos (11–48–0) broadcast in spring.
3. 5 pounds Nitrophoska (15–30–15) broadcast in spring.
4. 6 pounds nitrate of potash in fall. 20 holes were made with an iron bar some 20 inches deep in a circle near the ends of the outer branches and the fertilizer dropped in equal amount in the 20 holes.
5. 7 pounds of Ammo Phos in fall in 20 holes as in 4.
6. 5 pounds of Nitrophoska in fall in 20 holes as in 4.
7. 12 pounds nitrate of potash and 20 pounds superphosphate in fall. Four large post holes about a foot square and 24 inches deep were dug equidistant around the tree near the ends of the outer branches and in these holes the fertilizer was equally divided and mixed with the soil from the hole so that the soil-fertilizer mixture rested from 12 to 24 inches below the surface.
8. Eight similar holes as in 7 were dug equidistant around the tree and the soil of each hole mixed with barnyard manure (fairly fresh), ½ pound nitrate of potash, and 2 pounds superphosphate. The mixture was then tightly packed into the holes.
9. 6 pounds nitrate of potash and 10 pounds superphosphate broadcast in fall.
10. 4 pounds sulfate of ammonia broadcast in fall.
11. No fertilizer.
12. 4 pounds sulfate of ammonia broadcast in spring. In addition, when the alfalfa was cut each spring, a good application of it was raked up around the trees as a mulch.
13. Manure mulch applied in fall.
14. 4 pounds ammonium nitrate-lime broadcast in spring.

All the fall applications were first made in 1934, the others the following spring. Each fall for the succeeding two years new holes were made and the applications repeated. After the second manure mulch was given treatment 13, it was discontinued because fire blight was bad in the orchard and was considerably worse on treatment 13.

Unfortunately, due to conditions over which the author had no control, the work had to be terminated after 3 years. A final observational check-up was made in the fall of 1938. Fall applications were made in early November, spring applications late in March.

From time to time the large holes were examined by removing the soil and replacing after examination. Althro there was some concentration of tree roots around the manure and fertilizer mixtures and some roots even penetrated the mixtures, it was not as pronounced as might have been expected. In some cases roots would develop near the edge of the holes and bunch up without really penetrating the mixture except superficially, indicating that the concentration of fertilizer in the holes was too high for much root penetration. It was also interesting to note that considerable fertilizer persisted in recognizable form in the lower part of the large holes throughout a 3-year period.

Table 1 presents the yields of the treatments for the 3-year period. The totals are corrected also for size of trees. When it is considered that each figure for yield represents the total bushels for nine replicate trees, it can be seen that yields in the orchard have been small for the size of the trees. In fact, this orchard has never been a very productive one.

Statistical analysis shows that none of the differences between treatments are significant, nor have fertilizers generally increased yields. The orchard is on good soil and the alfalfa sod has undoubtedly supplied some nitrogen. Sub-surface applications of phosphorus
and potassium have given no benefits over surface applications, nor are they inferior to surface applications, at least under conditions in this orchard. Apparently these trees secured enough of all three fertilizer elements from the unfertilized soil to make them independent of additional applications regardless of how applied. No differences of any significance could be found in growth, vigor, or color of foliage which could be correlated with treatment.

Probably in order to get any positive results on this question of sub-surface placement of fertilizers an orchard on soil which definitely responds to phosphorus or potassium, or both, would have to

<table>
<thead>
<tr>
<th>Year</th>
<th>Potash Nitrate; B.* Spring</th>
<th>Ammonium Nitrate; Superphosphate; 8 Holes</th>
<th>Sulfate of Ammonia; B. Fall</th>
<th>No Fertilizer</th>
<th>Sul fate of Ammonia; Hay Mulch; B. Spring</th>
<th>Potash Nitrate; Superphosphate; 4 Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>29.2</td>
<td>32.4</td>
<td>32.3</td>
<td>28.0</td>
<td>26.7</td>
<td>31.6</td>
</tr>
<tr>
<td>1936</td>
<td>15.0</td>
<td>15.3</td>
<td>16.0</td>
<td>16.5</td>
<td>14.5</td>
<td>14.0</td>
</tr>
<tr>
<td>1937</td>
<td>46.0</td>
<td>42.0</td>
<td>54.0</td>
<td>42.0</td>
<td>49.0</td>
<td>45.0</td>
</tr>
<tr>
<td>Total</td>
<td>90.2</td>
<td>89.7</td>
<td>102.3</td>
<td>86.5</td>
<td>90.2</td>
<td>90.6</td>
</tr>
<tr>
<td>Total corrected</td>
<td>91.8</td>
<td>93.2</td>
<td>100.7</td>
<td>88.5</td>
<td>92.6</td>
<td>91.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Potash Nitrate; B.* Spring</th>
<th>Ammonium Nitrate; Superphosphate; 8 Holes</th>
<th>Sulfate of Ammonia; B. Fall</th>
<th>No Fertilizer</th>
<th>Sul fate of Ammonia; Hay Mulch; B. Spring</th>
<th>Potash Nitrate; Superphosphate; 4 Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>25.4</td>
<td>37.4</td>
<td>38.6</td>
<td>37.4</td>
<td>35.3</td>
<td>41.4</td>
</tr>
<tr>
<td>1936</td>
<td>13.3</td>
<td>12.8</td>
<td>15.3</td>
<td>16.0</td>
<td>18.3</td>
<td>19.0</td>
</tr>
<tr>
<td>1937</td>
<td>43.0</td>
<td>45.0</td>
<td>45.0</td>
<td>51.0</td>
<td>44.0</td>
<td>44.0</td>
</tr>
<tr>
<td>Total</td>
<td>81.7</td>
<td>95.2</td>
<td>98.9</td>
<td>104.4</td>
<td>97.6</td>
<td>104.4</td>
</tr>
<tr>
<td>Total corrected</td>
<td>81.7</td>
<td>96.3</td>
<td>98.3</td>
<td>98.8</td>
<td>96.8</td>
<td>100.2</td>
</tr>
</tbody>
</table>

*B = Broadcast.
†Yields corrected for variations in tree size.
be found and the work started at an early age of the trees before they had developed a large root system tapping a large volume of soil.

An interesting fact came to light in this 3-year experiment in regard to the statistical set-up of the work in the orchard. The use of randomized blocks, each of which contains all treatments once, is supposed to show thru the block yields something of soil variation or heterogeneity in the lay-out. The arrangement of blocks and randomization of treatments within each block is supposed to minimize soil variation and the subsequent statistical procedure compares the yields with the soil factor eliminated.

In the block arrangement here one restriction was imposed, namely, that besides the nine square blocks into which the trees were divided, within each block randomization was imposed in such a way that nine quite different blocks were available. The square blocks measured soil differences east to west, while the other blocks, which were long and narrow, measured differences north to south. The yields of the blocks for 1935 will show these differences, which were in the same order all 3 years. For square blocks the three on the west gave yields of 80.4, 77.7, and 73.0 bushels, the three middle blocks gave yields of 46.8, 46.3, and 60.7 bushels, while the three blocks on the east gave yields of 22.1, 21.0, and 26.7 bushels. This shows a progressive soil difference from west to east with a secondary variation in the southeast corner of the orchard. The yields for the long narrow blocks were as follows from north to south: 49.9, 48.3, 51.1, 44.4, 51.7, 51.5, 49.5, 55.6, and 52.7 bushels. These are quite uniform for block yields. The compact blocks have thus shown a major and minor soil variation which would not have been suspected by any simple inspection of the other block arrangement. Compact blocks such as the square ones used here are recognized as superior in experimental design to long narrow ones. It happens that the west side of this block of trees is on fairly level ground, while beginning about the center of the block it slopes toward the east. There has undoubtedly been some soil erosion in the eastern half of the block in former years which has rendered it less productive. The growth of trees as measured by trunk diameters does not follow the same order as the yields, in fact the trees are as large on the east as on the west side of the block. In other words, soil variation has affected yields without affecting tree size.

In drawing conclusions from this work in sub-surface application
of fertilizers and from work elsewhere, it would seem that much more positive results from phosphorus and potassium in orchards than have been secured up to date in New York State will have to be demonstrated before any expensive and laborious method of getting them below the soil surface will be accepted by growers.

**VARIELTAL DIFFERENCES IN FERTILIZER RESPONSE**

This is a subject about which there is comparatively little known at present. Books on fruit growing sometimes state soil preferences of different apple and other fruit varieties. Occasionally, also, one hears the statement that a certain variety is believed to respond to higher fertilization than some other variety. This point can not be proved definitely without careful experimentation with a large enough number of trees to overcome variations in individuals. Individual trees are subject to variations in response due to soil differences and also to the variability of their seedling roots. In the Rome orchard at this Station which was under experiment for so many years differences in individual tree performance were so large that if the trees had been of different varieties, erroneous conclusions could easily have been drawn as to fertilizer preferences.

It is common observation that Greening, for example, will show dark green foliage much longer under a level of nitrogen supply which would mean shortage for some other varieties like McIntosh or Baldwin.

For the past several years the author has observed a block of alternately planted McIntosh and Cortland on an unusually uniform soil which has received uniform nitrogen application for 7 or 8 years. The Cortlands do not show the fine foliage characteristics of the McIntosh. In 1939 this was especially striking, the McIntosh trees showing good foliage while the Cortlands had the appearance of no nitrogen trees, with yellow sparse leaves and highly colored, not too abundant fruit. The nitrogen carrier was changed in 1939 which may account for the difference, or it may be a matter of soil preference. The soil is a medium gravelly sandy loam. Some work on these points in this orchard is contemplated.

Some years ago this problem of varietal differences in fertilizer response interested the writer and some experiments were set up in the greenhouse. Large steel containers were available made of boiler plate and holding over 500 pounds of moisture-free soil. These were filled with a Dunkirk fine sand low in nutrients and very responsive
to nutrient additions. In this soil were set trees of four varieties, namely, Baldwin, Spy, Delicious, and McIntosh, all budded on Doucin No. 2 semi-dwarfing stock originally propagated from the same source. Doors and ventilators were left open thruout the growing season and heat was turned off the greenhouse in Decem-
ber, January, and February to give the trees a dormant period. These
trees were fertilized for several seasons uniformly, then variations
introduced such as concentration or amount of nutrients per tree and
deficiencies as well as different ratios of the various nutrient ele-
ments. A full outline and description of the experiments will not be
given here as the whole project is to be written up at a later date.
Any differences in varieties noted here refer entirely to vegetative
characters as the trees have not yet been allowed to fruit.

For similar treatments Delicious showed the best colored foliage
and kept its fine green color later in the growing period.altho blos-
soms were removed each year, bloom was at first confined to McIn-
tosh and Delicious and later appeared on all four varieties.

When given adverse nutrient ratios, Spy showed the effects first
and most markedly; Baldwin and McIntosh next and about equally;
while Delicious showed the effects last. In fact, this characteristic
of Delicious was quite marked. It is interesting, however, that
growth increment as measured by trunk caliper, was greatest gener-
ally for McIntosh. Baldwin and Spy were next and about equal,
while Delicious made the smallest trunk diameter gains.

Under uniform treatment Delicious took up considerably more
calcium as measured by leaf analysis than any of the four varieties
and Spy the least. Baldwin and McIntosh were almost identical. At
first this difference between Spy and Delicious averaged over 30 per
cent more calcium for Delicious, while among individual trees the
difference was in some cases double this percentage. As the trees
got older the difference decreased, but calcium has always been
appreciably higher for Delicious. In a young bearing variety orchard
on the Station farm, leaves from Delicious trees have not always
been higher in calcium than all the other three varieties, altho Spy
has generally had the least calcium. Since calcium has been found
to be antagonistic to certain adverse nutrient relations in plants,
this may be the reason why Delicious was the last to show effects
of adverse conditions in its foliage, while Spy with the least calcium
intake showed effects of adverse nutrient conditions first, as indi-
cated by leaf mottling, scorch, and dropping. It is interesting in this
connection that Delicious has been reported to be less fruitful in soils of high acidity, increasing production strikingly when the soil is limed. There were other differences in nutrient relations among the four varieties which will be brought out in a later publication. What has been presented will serve to show that there seem to be some real differences in varietal responses, at least in young trees of these four varieties. These differences are of sufficient importance to justify more experimental work on this subject.

NITROGEN APPLICATION AND FRUIT COLOR

Many growers seem to think that lack of color on red varieties is almost entirely a matter of nitrogen applications. As a matter of fact, there are a number of other factors involved which are just as important. Too much pruning leading to over stimulation or too little pruning leading to a dense tree will also adversely affect color. Weather conditions also are very important, such as temperatures or temperature fluctuations, during the ripening process, rainfall thru the season, and sunshine. Methods of culture also are important. If red varieties could be left on the trees long enough before harvest and dropping prevented, they would acquire high color, better flavor, and probably better keeping quality.

As regards nitrogen application, there must be sufficient nitrogen for satisfactory production without seriously affecting color. Just where this happy medium lies in a particular orchard is quite difficult to say and may not be the same for two successive years. Undoubtedly at the present time many growers are using too much nitrogen for best color. Growers have raised the question as to which would be more profitable, to produce fewer apples of high color and higher market value, or more apples of less fancy grade and lower in value? In the first place it would be very difficult to know in different seasons just what treatment would effect this end since no nitrogen might in some cases mean very few apples. It has to be kept in mind also that insufficient nitrogen affects tree size increase and this in turn affects total yield per tree. It is perhaps best to apply a moderate amount of nitrogen for good production watching color closely and increasing or decreasing the application based on these observations but meanwhile paying attention to other matters of orchard care such as spraying, pruning, and other matters of soil management.

Generally speaking, when nitrogen lasts too late in the growing
season the tendency is to prevent color formation and increase drop. From this standpoint there should be an ample supply early in the season and a low supply late in the summer when fruit size has largely been attained and when color development is wanted. In theory at least this ideal should be furthered by fall or very early spring nitrogen application, while from the same viewpoint late season cultivation, legumes grown in the orchard, application of manure which furnishes nitrogen over a long period, and also mulch materials which continue decomposition throughout the season should tend to reduce color formation.

**MULCHING**

Altho mulching orchard trees has been done in a small way for many years, it is only in the last few years that there has developed an important trend in this direction. Dry seasons, federal payments for soil building practices, and soil erosion prevention have turned growers minds in this direction in recent years. It is intended here to discuss mulching mainly from the standpoint of its relation to fertilizer practice. A mulch of organic matter has value not only in holding moisture and preventing evaporation but also as a source of nutrients. Its value in this direction depends on its original composition and its rate of decay. To be of maximum value the mulch should decay rather readily. This decomposition process itself is valuable in providing soil aeration and good biological conditions and in making available nutrients from the soil minerals as well as from the mulch itself. This process also undoubtedly plays an important part in promoting deeper penetration of such nutrients as potassium and phosphorus.

Since mulch materials are expensive in the amounts required for best results, it is important to know if some material can be found which will make a good mulch and still have better lasting qualities. For some years this Station has been using German peat moss as a mulch. On first thought the reader will say such a material is impractical on account of cost. This is true if its lasting quality is no better than other more common mulch materials and, further, if its use must be confined to the rather expensive imported product. For some years this material has been used as a mulch on two of the lysimeters at the Station and on some other small experimental plots. It is also being tried on a small scale as an orchard mulch in the Hudson Valley.
At the Station it has been found that the peat disappears practically as fast as a good straw mulch which was something of a surprise. Peat supposedly has undergone preparation over a long period of years and therefore might be expected to have long lasting properties. This is true if the material is packed tightly and air is excluded, but when the material is removed, broken up, and allowed free access to air, moisture, and fertilizer applications, its lasting quality is disappointing. Altho lasting properties are desirable from the standpoint of expense, it is questionable if a mulch material which remains inert over a period of years has all the properties desirable in a mulch. A material which decomposes fairly rapidly not only gives up its contained nutrients but promotes very desirable biological changes in soil which are related to availability of the soil nutrients, water retention, and soil structure. Farm manures, for example, may to outward appearance disappear quickly, but their effects on a soil are observed over many years. Some rotation plots at Geneva were manured for a number of years then got no further manure, yet 12 to 15 years after manure was discontinued, the manured plats could be picked out readily when the field was seeded to a uniform crop. Instances of much longer effects than this are recorded. In the Jensen McIntosh orchard at New Paltz, New York, the trees have been mulched for over 30 years yet when the surface soil is examined, there is surprisingly little accumulated mulch and observationally at least its effect over this period seems to be confined to a very superficial soil layer.

In a small volume of “Field Notes on Apple Culture” published in 1886, Dr. L. H. Bailey makes the following interesting statement: “Straw is also one of the most desirable mulches. I have known a straw mulch a foot thick to decay and to pass almost out of sight in one year. Fallen leaves, ** * * * * sedge, and weeds which grow in bogs if mowed early before the seeds are ripe may be used to advantage; also brakes, fine brush, sawdust, coarse horse manure—in fact, any material which can be spread over the surface to sufficient depth to keep the sod loose and which will decay speedily is to be recommended”. This statement indicates not only that the value of mulch materials was early recognized but likewise the value of their speedy decay.

Since peat moss disappears so readily, its present cost could not be justified as an orchard mulch. However, there is some probability of developing an American peat industry and, if so, such material
should be produced at considerably less cost than those which have to be imported from abroad. New York State itself has available deposits of good peat. It is rather surprising that they have never been more extensively developed; but when this happens, such material may be available at a cost justifying its use as an orchard mulch.

MULCHING AND FERTILIZER PRACTICE

For the past 5 years this Station has conducted a fertilizer experiment on a mulched McIntosh orchard in Wayne County. The trees are large and on a stony sandy loam of the Worth series. A real mulch has been maintained thruout and added to fairly regularly so that practically all weed and grass growth are eliminated from the trunks of the trees to several feet beyond the branch spread. The remainder of the soil has a fairly good orchard grass cover. The mulching material is marsh hay and other marsh growth, also other kinds of hay and straw.

Only the relation of mulch to the application of nitrogenous fertilizers will be touched on here. The use of mulch around the tree raises the question of the rate of nitrogen application, if any, which is advisable. In 1935 and 1936, while the mulch was comparatively new, the trees received nitrogen on the basis of 5 pounds of sulfate of ammonia per tree. This application did not seem excessive from the standpoint of production, altho color was none too good. There was a light crop (5 to 10 bushels per tree) in 1935, while in 1936 a freeze in May reduced the yield greatly (0 to 8 bushels per tree).

In 1937 nitrogen was increased to the equivalent of 6 pounds of sulfate of ammonia per tree. That year the crop was only fair (10 to 20 bushels per tree) with heavy drop but with color no worse than that of the lighter crops of the two previous years. The same application was repeated in 1938, a year of good rainfall. The fruit was large, drop heavy, and color poor. Production, however, was large (30 to 48 bushels per tree).

Since less nitrogen seemed advisable, in 1939 the orchard was divided into three sections. Three of the 10 replicates received no nitrogen at all, 4 received the equivalent of 2 pounds of sulfate of ammonia, while the remaining 3 replicates received the equivalent of 4 pounds of the same. A medium-sized crop followed (20 to 30 bushels per tree), with a medium drop but poor color. In spite of the fact that the 1939 season was excessively dry, there was good mois-
ture under the mulch and the fruit was of good size. There was no reduction in yield in the section receiving no fertilizer or in that receiving the smaller quantity, nor was there any detectable difference in color of fruit among the three sections. Either there was enough carry over effect of the nitrogen applied the preceding years in spite of the heaviest crop on record in 1938, or the mulch carried the crop without reduction in yield. Undoubtedly, also, larger nitrate accumulation under mulch during a dry season when there could be little leaching contributed to this result. The same plan will continue to be followed until a reduction of yield is observed, thus determining if the mulch will adequately carry the trees for high yield. It will be interesting to know how long mulch without additional nitrogen will maintain production and also if drop and color will be influenced at the same time. Up to the present time the extra moisture and nitrates under the mulch late in the season have increased drop and decreased color.

In some cases legume mulches are used and here it would probably be quite easy to overdo nitrogen fertilization. An example of this came to the writer's attention in some blueberry mulching experiments at the Station recently. Cultivated blueberry bushes from 2 to 2½ feet high were quite heavily fertilized in the spring of 1939. The year previous one half of them had been mulched with sawdust, the other half with bean vines. Under bean vine mulch the bushes yellowed, lost their leaves, and one or two died. The bushes under sawdust mulch showed none of these effects, in fact were exceptionally thrifty and made excellent growth. Altho various explanations are possible, the most probable one is that the rapid decomposition of the legume mulch raised the soluble nutrient concentration too high for the bushes. Sawdust is relatively inert and what did decompose undoubtedly reduced rather than increased the soluble nitrogen.

Whether a mulch will carry trees without some addition of fertilizer nitrogen depends very largely therefore on the mulch itself, its composition, amount, and frequency of application and its rate of decay, as well as the original soil supply when mulching began.

COVER CROPS

There is no more difficult point in orchard soil management for the grower to decide than what constitutes the best soil cover under his conditions, unless he pays no attention to cover. It is becoming increasingly evident, however, that this latter is a short-sighted
policy and may cause difficulty later on in decreased yields, lower quality of fruit, and difficulty handled soils due to poor tilth, poor biological conditions, and possible erosion. Altho considerable work has been done on the use of various orchard covers much of it fails to take into consideration some of the less evident tho just as important factors which make for a satisfactory cover. There are quite a number of such considerations to which it may be well to call attention. It is taken for granted here that part of the value of a cover crop is in the organic matter it furnishes to an orchard soil, hence the cover and green manuring values of the various crops are considered here as inseparable.

It should be remembered, too, that there probably is no ideal cover crop, that is, one which furnishes the best cover, the largest amount, and best quality green manure and which is ideal from the soil erosion and snow retention standpoints. Some crops have some best points and other crops different ones. Following are characteristics which should be taken into account in selecting a cover crop for the orchard:

1. The ease with which a good stand of the cover can be secured is no unimportant consideration. Some cover crops are quite difficult to establish, especially if the character of the soil, its preparation, freedom from weeds, or moisture supply are not at their best. It is very seldom that these factors are at their best, so that a newly sown cover usually has to compete under one or more of these handicaps.

2. Rapidity of growth is also important as upon it depends the development of a cover quickly, especially if an annual cover seeded rather late. Upon it also depends the establishment of a root system which will withstand dry weather conditions if spring-seeded and will get ahead of the weeds. Some crops such as buckwheat serve as smother crops for weeds because they develop and occupy the ground quickly.

3. Persistence of a cover when left down for a considerable period is also of importance. Some covers are easily crowded out by other plants, injured by the passage of orchard machinery, and fail completely after a time. Delicate soil adjustments which may be difficult to maintain are sometimes required to give a crop this property of persistence. Self-seeding of the crop is also concerned here.

4. The loss of soil moisture thru the transpiration of the cover is very important when such a cover surrounds growing trees. This matter may become critical during periods of drought, especially if the cover is seeded too close to young trees which
have not yet rooted widely and deeply. The writer has seen young apple trees stunted and almost killed by a close-growing crop of alfalfa during a dry summer.

5. The production or tonage of material furnished by the cover is also important if green manuring is one of the objects in growing it. The production of organic matter for the orchard soil is one of the main objectives in having a cover. Crops grown for this purpose vary markedly in their proportion of roots to tops and in total dry matter produced.

6. Crops used as orchard covers vary greatly not only in the quantity of dry matter produced per acre but also in the quality of their organic matter. Some types of crops and crop residues decompose readily and quickly; others much more slowly. They may also contain much or little of certain components such as lignin, for example, which resist complete decomposition and are thought to contribute to the basic humus of a soil. Just how important this contribution to basic humus is or whether the biological process of decomposition of the more easily and completely broken down ingredients is the factor of prime importance, is still a matter of conjecture. This point, together with the question of the significance of and the changes which take place in this comparatively static portion of basic soil humus, is a most interesting and fundamental one, but one on which the cover crop work reported here unfortunately will throw very little light. It is hoped in a later publication, however, to present some of the soil nitrogen and organic matter changes caused by the cover crops.

It may be well at this point to emphasize the fact that under a system of cultivation and the consistent use of annual cover crops, it is practically impossible to build up or, in many cases, even to maintain the organic matter of an orchard soil. The decomposition of the annual cover crop with its good effects on soil biology and structure may maintain tree production and fruit quality but at the expense of the ultimate organic matter content of the soil. There is even some indication that under certain conditions the biological transformations of the added organic matter with its great stimulation of soil organisms may even hasten the decomposition of the more stable and basic humus of a soil. These reasons are sufficient to justify the adoption of a system of orchard soil management which will involve a minimum of cultivation and a maximum use of permanent or semi-permanent covers.

7. The effect of the cover on the trees is also a consideration. Besides the competition for moisture already noted, a cover may affect trees in other ways. It was once thought, for example, that grass was actually toxic to trees and much work was done on this subject. A legume may furnish nitrogen to the
trees, while some other covers may compete for the soil or fertilizer nitrogen. Some nonlegume crops of high fiber content if allowed to mature may temporarily compete seriously with trees for soil nitrogen when plowed down. The time of year for plowing under a cover crop and its stage of maturity may thus become of importance.

8. On orchard land subject to soil erosion the cover crop becomes of importance in control and crops vary considerably in their erosion control value.

9. In northern climates a snow cover may be an important factor in winter protection of trees as well as a source of moisture in spring and early summer. It is important, therefore, to know if various crops used as winter covers differ in this property of retaining snow against drifting and blowing off.

10. One further property of a cover is its ability to grow in partial shade. This was not tested here since all covers were grown on open plats without proximity of trees. This point may make it necessary to change radically the kind of covers as the trees get larger and shade more and more of the ground. Many times if a permanent cover such as grass or alfalfa is used and is well established before the trees get too large, such cover may persist for many years longer than would be the case if the attempt is made to establish it after the trees cast heavy shade.

EXPERIMENTS ON COVER CROPS

In the spring of 1932 a little over an acre of Ontario loam soil on the Station farm at Geneva was divided into 32 plats, each of 1/30 acre. The purpose was to grow on the plats various crops to determine their adaptability as orchard covers. Many of these crops were ones already used in orchards but more information was wanted concerning their requirements and the best methods of handling them. The lay-out of the plats and crops is given in Table 2.

It should be noted here that this cropping plan was not strictly adhered to throughout the period. Sometimes when a crop failed, another one not in the plan would be tried.

For several years the whole piece was fertilized uniformly in early spring with 200 pounds of nitrate of soda and 400 pounds of 20 per cent superphosphate. Later, an all over application of a 4–12–4 or a 5–10–5 was given. In no case have crops been removed. Where continuous crops such as alfalfa, clovers, and grass have needed mowing, this has been done and the crop left as it falls. For the past 4 years plats 11 to 16 in the north series have been used by the United States Soil Conservation Service in testing erosion control
Table 2.—Crops and Method of Management in Orchard Cover Experiment.

<table>
<thead>
<tr>
<th>Plat No.</th>
<th>Crop</th>
<th>Seeded</th>
<th>How managed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South Series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Soybeans</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>2</td>
<td>Oats and sweetclover</td>
<td>Together in spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>3</td>
<td>Clean cultivated</td>
<td>Weeds allowed late</td>
<td>Fall plowed</td>
</tr>
<tr>
<td>4</td>
<td>Sweet clover</td>
<td>Spring</td>
<td>Fall plowed</td>
</tr>
<tr>
<td>5</td>
<td>Rye and vetch</td>
<td>Fall</td>
<td>Left over winter</td>
</tr>
<tr>
<td>6</td>
<td>Oats</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>7</td>
<td>Oats</td>
<td>Spring</td>
<td>Fall plowed</td>
</tr>
<tr>
<td>8</td>
<td>Buckwheat</td>
<td>Summer</td>
<td>Fall plowed</td>
</tr>
<tr>
<td>9</td>
<td>Vetch</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>10</td>
<td>Alsike clover</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>11</td>
<td>Bluegrass</td>
<td>Spring</td>
<td>Left 3 years</td>
</tr>
<tr>
<td>12</td>
<td>Bluegrass</td>
<td>Spring</td>
<td>Continuous</td>
</tr>
<tr>
<td>13</td>
<td>Sweet clover</td>
<td>Spring</td>
<td>Continuous</td>
</tr>
<tr>
<td>14</td>
<td>Sweet clover</td>
<td>Spring</td>
<td>Left 3 years</td>
</tr>
<tr>
<td>15</td>
<td>Alfalfa</td>
<td>Spring</td>
<td>Left 3 years</td>
</tr>
<tr>
<td>16</td>
<td>Alfalfa</td>
<td>Spring</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>North Series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Millet</td>
<td>June</td>
<td>Left over winter</td>
</tr>
<tr>
<td>2</td>
<td>Clean cultivated</td>
<td>No weeds</td>
<td>Plowed each spring</td>
</tr>
<tr>
<td>3</td>
<td>Rye and soybeans</td>
<td>Rye in fall; soybeans in June</td>
<td>Rye over winter</td>
</tr>
<tr>
<td>4</td>
<td>Millet</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>5</td>
<td>Rye</td>
<td>Fall</td>
<td>Left over winter</td>
</tr>
<tr>
<td>6</td>
<td>Millet</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>7</td>
<td>Soybeans</td>
<td>Spring</td>
<td>Plowed in fall</td>
</tr>
<tr>
<td>8</td>
<td>Rape</td>
<td>Spring</td>
<td>Fall plowed</td>
</tr>
<tr>
<td>9</td>
<td>Sweet clover</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>10</td>
<td>Red clover</td>
<td>Spring</td>
<td>Left over winter</td>
</tr>
<tr>
<td>11</td>
<td>Bluegrass</td>
<td>Spring</td>
<td>Left 5 years</td>
</tr>
<tr>
<td>12</td>
<td>Red top</td>
<td>Spring</td>
<td>Continuous</td>
</tr>
<tr>
<td>13</td>
<td>Alsike clover</td>
<td>Spring</td>
<td>Left as long as good</td>
</tr>
<tr>
<td>14</td>
<td>Alsike clover</td>
<td>Spring</td>
<td>Left 2 years</td>
</tr>
<tr>
<td>15</td>
<td>Red clover</td>
<td>Spring</td>
<td>Left as long as good</td>
</tr>
<tr>
<td>16</td>
<td>Red clover</td>
<td>Spring</td>
<td>Left as long as good</td>
</tr>
</tbody>
</table>

Of some of the covers, so have been retired as far as the other studies are concerned.

In the following section the various crops in the test are separately discussed from the standpoint of some of the 10 essentials already enumerated. It should be stressed here that these crops were not grown for show or demonstration so were not pampered in any way. Thus the soil preparation for seeding was only average and probably not as good as some fruit growers would attain. No hand work was done on the plats such as pulling weeds for better plat appearance. The purpose was to place all crops under conditions
they would meet on the average fruit farm. The main difference was that no trees occupied the plats, so to this extent they had the advantage of removal of tree competition. For young orchards this would not be serious, in fact the young tree usually suffers first in such competition. In old orchards it is always a question what cover can be grown and usually no cover is very successful. The time to build up the organic matter content of orchard soil with cover and green manure crops is while the trees are young. A reserve established then helps to carry the trees in later years. Old orchards on soils deficient in organic matter or on erosive slopes on which covers can no longer be successfully grown should be mulched.

It should further be kept in mind here that what is said in the following section refers specifically to what was found during the 7 years of this experiment at Geneva, where the crops were compared under the same conditions of soil, climate, and fertilization.

Tests of dry matter production were made by letting drop an iron ring in various parts of the plat and cutting the crop within the ring. This was done when the crop seemed to have attained about maximum growth. Since the ring was only about 18 inches in diameter, 10 replications were combined and the crop from these 10 small areas oven-dried and weighed.

The effectiveness of the covers in holding snow was tested as follows: In February or early March, depending on amount of snowfall and especially after there had been winter winds to cause blowing off of snow and drifting, surface observations were first made as to snow retention on each plat then a yard stick was thrust down thru the snow to the soil surface in a number of places over the plat and the average snow depth measured. These results are given in tabular form under soybeans below.

**COMPARISON OF COVER AND GREEN MANURING CROPS**

**Alfalfa** is used in orchards to some extent as a permanent or semi-permanent cover. Altho the seed is small there has been no particular difficulty in securing a stand and no real seeding failures have been experienced. It has been decidedly superior in this respect to sweet clover, red clover, ladino, and alsike. For a small-seeded legume it is a rapid grower and, altho weeds may come in after seeding, sometimes seriously, the alfalfa usually gets the better of them, especially the second year. Ontario Varigated has been used thruout and, with the exception of Kentucky bluegrass, has shown
the greatest persistence and purest stand of any of the continuous or semi-permanent covers. Its most serious competitor has been quack grass and this became so prevalent after 4 years that the continuous plat was plowed under, summer fallowed, and reseeded.

A serious objection to alfalfa is that its season of rapid growth coincides with that of the tree, its water requirements are high, and further, it takes water not only from the surface but also from the subsoil where tree roots are also located. In dry periods a deep-rooting plant of this kind keeps on using subsoil moisture when shallower rooted ones almost cease growth and go into semidormancy.

Owing to the fact that cutting seems to be stimulating to alfalfa and since it grows up again quickly, dry matter production is high. At the first cutting dry matter ran about 3,200 pounds per acre, the second cutting somewhat less. It was usually mown only once per season, occasionally twice. Total seasonal dry matter ran around 3 or 3½ tons per acre. In addition to this, the percentage of stubble and roots, which latter go to considerable depths, would be proportionately high, which is an important consideration in organic matter production, effect on soil structure, and the formation of channels for water absorption.

Being a legume with a narrow carbon-nitrogen ratio, alfalfa decomposes rapidly, its nutrients coming back into the soil-plant cycle quickly without nitrogen competition with the trees. Alfalfa is relatively high in minerals so when it decomposes the mineral turn-over is considerable.

For snow retention value, see under soybeans.

Alsike clover proved in this test to be a poor cover crop. Considerable difficulty in getting a satisfactory seeding was experienced, it was a poor weed competitor and its persistence was poor. Repeatedly the plats had to be worked up and a reseeding attempted.

Ladino clover was also tried twice. The first trial failed completely, dry weather and weeds ruining the seeding. The second trial was in the late spring of 1939. Altho this year was an unusually dry one at Geneva a rain just after seeding brought the Ladino plants up well. Dry weather later caused very slow growth so that weeds came in badly. These weeds were mown twice and there is still considerable Ladino left. It remains to be seen what it will look like in 1940. This clover, which is larger growing than wild white or Kentish white, has promise as a permanent legume orchard cover.
It is quite probable that if greater care had been used as to weed eradication and soil preparation, both Alsike and Ladino clovers would have made a much better showing, but this was not the specific purpose of the tests, as has before been noted.

**Kentucky bluegrass**, when once established, has made an unusually satisfactory cover in these tests. Apparently at the beginning of the tests when the bluegrass was first seeded, soil and moisture conditions were right and a good seeding was obtained. Since that time one or two other attempts have been part failures. Altho some weeds came in at first, the bluegrass gradually took care of them so that for the past 4 years both plats on the south series have had a perfect stand. No weeds whatever have since gained any foothold. On account of the difficulty in securing a stand when conditions are not good both plats were left unplowed, but one of them was gone over with a disk repeatedly each spring for several years breaking up the heavy sod. In a short time in each case the grass filled in again to a perfect sod. This grass is so matted down in fact that it is very difficult and really not necessary to cut with a mower. This heavy matted mass of old grass near the soil surface must act as a good insulator against moisture evaporation and temperature changes. A heavy sod like this not only conserves soil organic matter but also builds it up since working soil thru methods of cultivation is a humus-destroying process.

Bluegrass has another moisture relation which makes it valuable as an orchard cover. During periods of hot dry weather unlike many plants, the grass becomes yellow, ceases growth, and becomes almost dormant, thus reducing greatly transpiration and therefore moisture competition. When rain comes it revives and makes growth. It is true that light summer showers are largely absorbed by the grass in an orchard but many of these showers even without the sod cover scarcely reach tree roots.

It is the observation on these grass plats that in a few years the accumulated mass of old grass becomes so pronounced that less new growth is put out each season. In 1935 around 1½ tons of dry matter per acre, sometimes a little more, was produced but at the present time less than half this amount of new growth is produced. Besides maintaining itself with very little trouble or expense, at present the sod has much the appearance of a heavy matted mulch. It is questionable if such a sod could be established and maintained in an orchard, but if so it could well take the place of mulch material
drawn into the orchard from outside. It seems to be an ideal covering except perhaps for its absorption of the nitrogen or other fertilizer applied. The fact that no such perfect grass sod has been present in experimental orchards used by the writer in fertilizer experiments probably accounts for the fact that no difficulty has been experienced from the grass absorbing most of the nitrogen, as has been reported elsewhere.

What was once thought to be an actual toxic effect of grass sod when growing around trees has been shown to be a nitrogen relation. Hundreds of successful orchards are now in sod but of course the trees' nitrogen needs are carefully met. In fact grass is one of the most stable soil covers from the standpoint of holding soil in place and conserving its best chemical and structural features. It is inferior to many other covers in snow retention which matter is discussed under soybeans.

**Buckwheat** has a number of good points to recommend it as a cover crop. No seeding failure has ever occurred. The seed is inexpensive, germinates quickly, grows fast, and the plants cover the ground quickly. It therefore competes with weeds very successfully. Altho buckwheat can be put in in late spring, it is usually seeded in midsummer or later. It is shallow-rooted and quite succulent so, altho dry matter production was 2½ to almost 4 tons per acre, little is left of it after a year. Organic matter build-up with it is slow, altho mineral turn-over is unusually high for a nonlegume.

Buckwheat is not considered an especially good soil erosion control crop. Its snow retention property was not tested since the one plat available is plowed each fall. It is widely used on account of its cheapness and almost certain growth. It leaves soil in good physical condition.

**Millet** used in these tests has been mainly the Japanese, altho Hungarian was grown in 1939. It has not always been entirely satisfactory in stand due to unfavorable weather causing slow growth and weed competition. The plats some seasons have been quite weedy and the plants have not always covered the ground well. The Hungarian type was more satisfactory in these respects. Millets are shallow-rooted and take considerable moisture from the soil on account of their large rapid growth. From 4 to as much as 5 tons of dry matter per acre have been produced in these tests.

Millet's are used to some extent as orchard covers apparently without any injury to trees and give good soil protection. Some of
the better-growing ones should make good orchard mulch material. When it stands upright, millet is a fair snow retention cover.

**Sudan grass** was grown in 1939, a dry year, and gave an extremely good growth. It was also satisfactory from some other standpoints. Altho an annual, after cutting some growth was made before frost. This crop deserves more consideration as a green manure, as a protective cover, and as a source of mulch material.

**Oats** in these tests, altho presenting no difficulties in seeding, were much restricted in growth by dry or hot weather. They have occupied the ground well and quickly but dry matter production has been small, amounting to about 2 tons per acre and less than 3 tons when grown with sweet clover. Like the other cereals they are shallow-rooted and organic matter build-up is slow. When left on the land as a cover they go down readily and the seed many times comes up and forms a secondary crop in the fall. For this reason they do not retain snow very well. They are sometimes used as an early fall cover but of course are killed by the winter.

**Rape** has been a very unsatisfactory green manure crop in these tests. Stands have not been too satisfactory, but it has stood weed competition well. Altho shallow-rooted, it uses considerable water. Despite the fact that a large amount of green material is produced, its water content is high so that in cases where it is left on the land, killed by frost, and then dried out there appears to be very little organic matter left. Its snow retention has not been tested.

**Red clover** was grown for several years on plats 15 and 16 of the north series before they were given over to soil erosion studies. Seedings have not been too satisfactory and weeds have been bad. Persistence has been poor and self-seeding unsatisfactory. It has been quite inferior to both alfalfa and sweet clover. Dry matter production has been disappointing due partly to imperfect stand. From one-quarter to one-third the total plant is in the roots, which is a desirable feature in an orchard cover.

**Rye** has been an old stand-by as a green manure and cover crop for many years. In these tests it has in all cases been used entirely as a winter cover, seeded in the fall, and plowed or disked in the spring preparatory to seeding some other crop. Its real value lies in this method of handling. It is more valuable preceding a rather late-seeded spring crop such as soybeans, millet, or sudan grass, as then more growth is secured. Seeding is easy, sure, and at a time of year when weeds bother very little. Used in the way described, its
water use is of little consequence as far as the trees are concerned. If allowed to mature, this factor is of more importance. Its organic matter build-up used in this way is of course slow, as it is incorporated while the plants are young and succulent. It is shallow-rooted like other cereals. Some growers think rye when allowed to mature is hard on trees, especially peaches, but this has not been verified. It is questionable if it is more so than other nonlegumes. In spite of incorporation while still immature, as much as 2½ tons of dry matter have been produced in the above-ground portions. Its snow retention is poor due to its small growth before cold weather.

**Soybeans** have made an excellent annual cover in these tests. The only seeding failure was in 1935 when the matured crop from the previous year which had stood over winter was lightly plowed with self-seeding in view. The plowing proved too deep and the beans gave only a scattered appearance above ground. The plot was immediately reseeded and gave a good stand. This self-seeding was tried, however, the succeeding three years with good success. The method was to disk lightly the standing plants as soon as the weather warmed up in spring so the beans were not buried too deep. A variety should be chosen which produces mature seed where it is grown, and if a good seed crop is produced the fall previous and pheasants or other birds do not exact too heavy a toll during the winter, a good stand should be gotten. One of the three years it was tried, the stand was almost too heavy. If this can be done, cost of seed is greatly reduced. A good stand of soybeans resists weed competition well and is fast growing. Soybeans are shallow-rooted, the roots making up only about one-eighth of the total plant compared with one-third for alfalfa and red clover. It is a less serious tree competitor therefore than if it were deeper and more extensively rooted. Dry matter production with large growing varieties ran as high as 3¼ tons per acre, smaller growing varieties only about one-half to two-thirds as much. Like other legumes the plants rot down quickly, even the apparently rather coarse stems resisting decomposition a comparatively short time. The mineral turn-over is considerably less than with alfalfa. The erosion control value of the crop is much less than that of alfalfa and the clovers as it has a loosening effect on soil.

Soybeans have been found in these tests to have unusual snow retention properties exceeding any of the other crops studied. The results for all the crops studied is presented in Table 3.
It should be noted that the plats have a 6 to 7 per cent slope to the north and are exposed to north and west winds which may cause considerable snow drifting. There is a young orchard to the west which is allowed to grow up to weeds each year. This is a constant source of new weeds to the plats, altho this very fact has given a severe test to the covers as to their ability to compete with weeds. It has, however, made it much more difficult to secure pure seedings of some crops.

**Table 3.—Depth of Snow Covering on Cover Crop Plats in Inches.**

<table>
<thead>
<tr>
<th>Crop or Treatment</th>
<th>Feb. 1, 1935</th>
<th>Feb. 4, 1936</th>
<th>Mar. 4, 1936</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>3, uniform</td>
<td>5–8, uniform</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Alskie clover</td>
<td>2–3, uniform</td>
<td>5–8, uniform, plowed</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Bluegrass</td>
<td>4, uniform</td>
<td>5–8, uniform</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Millet</td>
<td>4–8, variable</td>
<td>6–10, uniform</td>
<td>Bare to 6</td>
</tr>
<tr>
<td>Oats</td>
<td>5–8, uniform</td>
<td>5–8, uniform</td>
<td>Bare to 2</td>
</tr>
<tr>
<td>Red top</td>
<td>2–3, uniform</td>
<td>5–8, uniform, plowed</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Red clover</td>
<td>2–3, uniform</td>
<td>5–8, uniform, plowed</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Rye, new</td>
<td>1–3, uniform</td>
<td>5–8, uniform</td>
<td>Bare</td>
</tr>
<tr>
<td>Soybeans</td>
<td>12–16, uniform</td>
<td>14–20, uniform</td>
<td>8–12, uniform</td>
</tr>
<tr>
<td>Sweet clover</td>
<td>3, uniform</td>
<td>10–14, uniform</td>
<td>4–8, uniform</td>
</tr>
<tr>
<td>Vetch</td>
<td>3, uniform</td>
<td>5–8, uniform, plowed</td>
<td>Almost bare</td>
</tr>
<tr>
<td>Weeds</td>
<td>3–4, uniform</td>
<td>5–8, uniform</td>
<td>2, uniform</td>
</tr>
<tr>
<td>Plowed</td>
<td>Bare to 2</td>
<td>3–6, uniform</td>
<td>Bare</td>
</tr>
<tr>
<td>Disked</td>
<td>Bare to 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On March 18, 1937, some further observations were made on snow covering. These were made after the only heavy snow of the winter and after a heavy west wind had drifted the snow badly. Those plats which had the most erect covers held the most snow. The soybean plat in 1937 had the thinnest stand of the 7-year period so the snow covering was only slightly better than that for other plats with equally erect growth. Erectness of growth is a very important factor since this feature acts as a wind break. This is very evident in the case of the heavy bluegrass plats. Here the growth is extremely thick but so matted down that it presents an almost smooth surface to the wind. The rougher the ground even when without crop, the better the snow cover. Thus the fall-plowed plats, which are always left in the furrow, had a better covering than the disked plats. The character of the snow cover on such crops as alfalfa, the clovers, oats, rye, millet, and others depends very largely on such factors as the thickness of the stand, but much more on the height of the material left over the winter and especially on its erectness of
growth. The soybean is a crop which has stiff stems which remain erect almost all winter unless broken down by heavy snow. Even the profusion of stiff hairs on the plant helps in snow gathering as was sometimes noted in the extra 2 to 3 inch cones of snow directly adhering to the stems above the general snow level.

Sometimes after drifting the plats to leeward of the better covers also had more snow, the better covers acting as a windbreak for the plat to leeward. The data in Table 3 for February 4, 1936, is for a snowfall which had drifted some but had not yet settled or melted, while that taken a month later was after settling and thawing had occurred. The soybeans at both periods carried much the most snow.

Just how important these differences in snow retention by cover crops may be is difficult to say, but it would seem that a heavy snow cover should have an important bearing on moisture relations the following spring, should furnish better root protection to trees during severe winters, and should even modify air and soil temperatures for a short time in early spring.

It will be noted that on plat 3, north series (Table 2), a combination of rye and soybeans is grown. The soybeans are plowed in the fall and rye seeded, left over the winter, and plowed just in time to sow soybeans. This furnishes two crops a year and has worked out well. It has the further advantage that the nonlegume can utilize the nitrogen liberated from the legume. With some extra expense vetch could be sown with the rye. In these tests, however, vetch has not given enough growth to justify the extra cost. It probably would if the rye-vetch mixture could be left longer in the spring to gain more growth.

**Sweet clover** has not fulfilled the expectations which its apparently wide popularity had justified. No great difficulty was met in securing good strands, altho in this feature it has been inferior to alfalfa. Altho good for two years, persistence longer than this has been poor. Weeds and quack grass have come in rather badly. Then when mown the whole crop may be killed especially if the weather is hot and dry or if mown too close. The second year, when the plants get large and spreading, it is difficult to handle and self-seeding has been disappointing. Perhaps if the ground had been gone over lightly with a disk after seed was mature a self-seeding would have been secured. Altho shallower rooted than alfalfa, sweet clover competes considerably with trees for moisture since it has been found to have a high transpiration rate. Even dry matter pro-
duction has been rather disappointing, a little over $2\frac{1}{2}$ tons being produced. Second growth after cutting has been rather poor when not entirely killed. This crop does furnish much nitrogen to soil and compares with alfalfa in this respect. It is generally considered a good soil-building crop. If desired as a permanent orchard cover it would either have to be reseeded every two years or great care used in getting it to self-seed. It remains more erect in winter than alfalfa so its snow retention properties are somewhat better.

**Vetch**, altho considered in some regions to be an excellent cover and green manure crop, has not been very satisfactory in these experiments. Germination was usually good, but the plants grew so slowly that not until late in the season would they make much showing. During this time weeds had an excellent opportunity of getting the lead. Cutting in one or two cases killed the stand. Persistence was poor and self-seeding still poorer. This was true whether seeded alone or with rye, in fact better results were secured when seeded alone. Altho no dry matter yields were taken the production was not high.

Vetch is a shallow-rooted legume which grows better than some on soils not too well supplied with lime. Perhaps on a different soil it would have made a better showing. Its snow retention was not determined, but its weak stems and habit of matting down would probably prevent its showing any marked results in this regard.

**Weeds** may make, under favorable conditions, a very satisfactory cover. Satisfactory conditions consist in plenty of weed seed being present, lack of competition with a seeded cover, and favorable moisture conditions. In these experiments, the close proximity of very weedy land amply fulfilled the first requirement. Plowing and clean cultivation early in the season, altho discouraging early season weeds, provided good tilth and moisture conditions for midseason and late season weeds. This early cultivation has discouraged quack grass and encouraged weeds like fox tail grass. In some seasons the stand has consisted almost entirely of this latter weed and has covered the ground as thickly as a seeded cover. In 1935 as much as 4 to $4\frac{1}{2}$ tons of dry matter per acre were produced. This particular crop was not especially good in snow retention as it lost its erect character early in the winter. Nothing very specific can be said here since weed growth under various conditions probably would be quite different in species and in stand.

One naturally hesitates to allow land deliberately to be taken over
by weeds, especially those which cause trouble and expense in eradication on other cultivated land. There are some annual weeds, however, which if they can be depended upon, cause little trouble elsewhere and will furnish a fairly good orchard cover. In some orchards quack grass is the main cover and this grass is greatly encouraged by nitrogen fertilization. It also grows well under shade. It lacks some of the desirable characters mentioned under bluegrass and further is difficult to eradicate near the trees without hand labor. Quack has been found to have a higher water requirement than bluegrass and to the same degree at least lacks the desirable character of greatly reducing its transpiration rate during dry weather.

Kent white clover was seeded one year on one of the plats, but weather conditions were such that the seeding was a practical failure. On smaller plats, however, this spreading, low-growing, perennial clover has proved a very excellent permanent cover. It has completely occupied the ground with a vigorous, thick, persistent growth. The comparatively low form of this clover would interfere very little with harvest or other orchard operations.

For some reason better success has resulted with this clover than with common wild white clover under the same conditions. The former has had better persistence and has come out of the winters in better condition. It would be interesting to try both of these clovers in orchards on a larger scale to determine their adaptability to shade, hard usage, and other conditions.

There are other small-growing, perennial legumes which might, on trial, prove very satisfactory as permanent covers in orchards. For example, the newly found Birdsfoot trefoil should have value under some orchard conditions in New York State. There are others worthy of trial which may possess characters peculiarly fitting them for some specific orchard conditions. Many of these more or less unusual or little-known crops should be thoroly tested from the standpoint of adaptability to orchard conditions.

**DISCUSSION OF COVER CROPS**

In general, it seems wise to favor mulches and permanent covers for orchards in New York State. The tendency to replace cultivation and annual cover crops with other systems of soil management has a reliable basis both in theory and practice. In many orchards such a change would be profitable from the standpoint of soil erosion alone not to mention a distinct gain in organic matter build-up. It is a
question in orchards on slopes subject to erosion which causes the greater loss of soil organic matter, decomposition thru cultivation or soil erosion. Prolonged cultivation may accentuate the loss from both causes.

Many growers, however, still wish to cultivate so the annual crops as well as those suitable for permanent and semi-permanent covers have been included in these studies. If cultivation is used, it is well to stress the necessity of good annual covers consistently used if high production of high-quality fruit is to be maintained over a long period of years. The best cover for the purpose can only be determined by trial under a grower's conditions. It may be advisable to vary the cover from year to year and even to make use of two covers a year or a mixed cover. Combinations of legumes and nonlegumes or legumes followed the same year by a winter nonlegume may work out satisfactorily. A large production of organic matter will greatly help to justify the cost of seed and labor involved in soil preparation and subsequent incorporation. Fertilizers should be used if they will insure better covers, lime and phosphorus especially for legumes and nitrogen or even complete fertilizers for nonlegumes.

It has been reported that in some cases a permanent cover of grass sod has absorbed practically all the fertilizer nitrogen applied for the trees. This is probably true if the sod is quite heavy and no precautions taken to prevent it. In such a case the nitrogen can be confined to a narrower band around the tree, or the application made either in late fall or early spring when grass growth is suspended or before it has begun. The writer has seen few orchards in the State with grass sod heavy enough to cause much difficulty from such a source. One should try all methods before destroying a first-class sod which many times may be very difficult to re-establish in an orchard. There are a number of compensations for the withdrawal of moisture by a heavy grass sod. In times of moisture shortage grass takes on a semi-dormancy, as has already been noted. It also acts as a cooling agent, a shade, and a buffer against evaporation. Further, its organic matter build-up enables the soil to absorb a larger proportion of the rainfall with less run-off, and finally, it improves water retention properties of the soil thru erosion prevention.

If under grass sod with normal nitrogen applications, nitrogen shortage is experienced, some method of breaking up the sod without destroying it should be used such as heavily diskig or plowing
alternate very narrow strips. This still allows the grass to re-establish itself without the necessity of complete reseeding which may be difficult. A permanent or at least long time legume crop in the orchard may obviate the above difficulty with grass sod. A perennial legume would be most suitable for such purpose, such as alfalfa or probably even better, a shallower rooted, thicker, and lower growing crop such as wild white or Kent white clover, Ladino clover, Birdsfoot trefoil, or other perennial, spreading, and low-growing legume.

Considerable valuable work could also be done on a study of grass mixtures for orchard sod. Grasses may have some specific properties such as growth under varying soil reaction, persistence under specific conditions, ability to stand hard usage such as the passage of motor machinery and spray outfits, etc. For this reason it is advisable, unless the orchard soil conditions are known very intimately, to use a mixture of grasses rather than a single one. Survival will then indicate what species are best adapted.

With perennial legumes in the orchard there is the question of the legume furnishing all or part of the nitrogen for the trees. It must be remembered that when legumes are making their active growth soil nitrogen may be about as effectively utilized as with nonlegume crops. If such crops, however, are not removed from the soil, considerable nitrogen may in time become available. Just as much care should be used in watching tree performance as to growth, foliage characters, fruit production, and color, making these characters an index of the tree’s nitrogen status, as if no legumes were grown.

Finally, the trend toward using mulches should be carefully watched. Heavy mulch, by keeping moisture and nitrates at a high level late in the growing season, may cause greater dropping of fruit and also may injuriously affect fruit color. Under a mulch system of culture the rate of nitrogen application becomes especially important. This relation is affected by season, both moisture and temperature, so al tho it is impossible to predict these conditions, it is best to use nitrogen sparingly.