BULLETIN 580 MAY, 1937

Cultural Systems for the Apple in Ohio

C. W. Ellenwood and J. H. Gourley

OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

CONTENTS

This page intentionally blank.

CULTURAL SYSTEMS FOR THE APPLE IN OHIO

C. W. ELLENWOOD AND J. H. GOURLEY

Various systems of orchard culture are in vogue in Ohio, and it is the purpose of this bulletin to examine the effects of some of these different methods of soil management upon the soil and trees. Topographical, soil, and economic conditions vary widely in the State, and it is obvious that no one system of soil management can be adapted to all. Moreover, it is not necessary and often not desirable to follow a single system throughout the life of an orchard. An orchard soil may be handled one way while the trees are young and in some other manner when the trees are mature.

Before an intelligent decision can be reached as to the best system to be used under a given set of conditions, the objectives of the soil management program should first be determined. Although not all the objectives are essential for each orchard, the principal ones may be listed as follows:

1. To provide for a favorable moisture supply.
2. To supply sufficient nutrients for maximum production.
3. To add at least sufficient organic matter to offset any loss due to decomposition, erosion, or other factors.
4. To prevent erosion.
5. To avoid serious compacting of the soil (i. e., to maintain a loose or friable condition).

The chief systems of soil management in use in Ohio are sod, tillage with cover crops, mulch, and intercropping. Various modifications and combinations of these systems are also used.

SELECTION OF THE CULTURAL SYSTEM

Before presenting the results of orchard experiments a general statement of the advantages and disadvantages of the more important cultural systems may be helpful to the prospective orchardist.

SOD

The most primitive system of orchard culture is that of maintaining the land in a permanent sod. The grass is pastured, cut and used for hay, left to lie where it falls, or raked under the branches of the trees as a partial mulch. There is often a tendency, however, to neglect the sod orchard; hence, it is in disrepute in many sections.

There are more commercial apple orchards in sod or some permanent cover in Ohio than under any other system of management. Much of the objection to this system can be obviated by the use of a mulch, fertilizers, lime, irrigation, occasional disking, or by use of such a tool as a "weed hog". The naturally occurring nitrates are low, with the result that the trees frequently exhibit typical nitrogen deficiency, such as small and light-colored leaves, short and slender growth, and excessive dropping of blossoms with a consequent low average yield. Often the soil moisture also is low. To what extent lack of free movement of air through a sod adversely affects the tree behavior has not been adequately studied but presumably the effect is unfavorable.

On the Station grounds there is a small but representative block of Stayman Winesap trees which were planted in 1916. The land has been in undisturbed bluegrass sod since it was planted. Although this block was not designed as an experiment, careful records and observations have been made. The trees which have not been fertilized have been very unproductive and at present only four out of eight are alive. The immediately adjoining trees which received fertilizer are in good condition and are producing satisfactory crops.

TABLE 1.—Stayman Winesap Production in Sod Land

1926-1935 (10 years)

	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total	Yearly tree av.
Row A—Normal nitrate in spring												
No. of trees....	5	5	5	5	5	5	5	5	4	3†	47	.....
Production*...	1678	505	836	564	1516	1707	1172	1216	1338	1550	12,082	257.1
Row G—No fertilizer												
No. of trees....	3	3	3	3	3	3	3	3	3	3	30	.....
Production*...	351	682	6	139	623	274	730	608	872	417	4,702	156.7
Row I—Normal nitrate October 1												
No. of trees....	5	5	5	5	5	5	5	5	4†	4	48	.....
Production*...	711	1227	562	247	1480	1181	1583	1692	1748	1722	12,153	253.2

*Measured in pounds.
†Others removed because of shading.

It will be noted from Table 1 that the untreated ones produced an average yield of 156 pounds; those treated with nitrate of soda at the rate of ¼ pound for each year of age have yielded 257 pounds; and those receiving the same amount of nitrate as a fall treatment have averaged 253 pounds per tree for the past 10 years. This illustrates to what extent nitrogen is the limiting factor in a sod orchard.

An examination of the nitrates in this and an adjacent orchard shows that they are lowest under sod, higher under tillage, and highest under mulch.

TABLE 2.—Nitrates in Orchard Soil

Treatment	1924-1926 3-year average
Beneath trees in sod	3.90
Beneath tilled trees	7.71
Beneath straw-mulched trees	8.39
Sod—between trees where competition is less	7.60
Tilled—between trees	14.90

It must be understood, of course, that the amounts of nitrates here shown represent only the differences between what the trees and grass have absorbed or what has been lost by leaching and the total amounts which occurred in the soil. However, there is another side to the case for sod. If the sod does not

seriously compete with the trees for water (which it may or may not do) and nitrogen is furnished as an annual treatment, the trees may be productive and long-lived, for such an orchard will not suffer soil erosion and the organic matter of the soil will not be depleted. If the sod near the trees is broken occasionally (once in 2 or 3 years) with a disk or "weed hog", the orchard may be about as profitable, particularly if the soil is deep and it is in a region of ample rainfall, as though it were under any other system. When the soil and moisture conditions are favorable, it is likely that the sod will eventually become too heavy and require breaking up more than where the soil is shallow or infertile. However, under some conditions it may require years to reestablish a good sod once it is torn up.

The practice of plowing, disking, or tearing up the sod every few years has come to be known in some quarters as the short-sod rotation.

TILLAGE

Another fundamental type of culture is that of tilling or cultivating the soil. A couple of decades or more ago some orchardists practiced what was known as "clean cultivation". No cover crop or weed crop was grown and the land was kept clean throughout the growing season. This system soon proved to be disastrous or at least undesirable from several standpoints and practically all orchardists in America who cultivate today grow some sort of a green crop to return to the land as green manure. The details of this program vary widely.

Tillage decreases competition of the trees with sod or other crops during the early part of the season when moisture and nitrates may be inadequate for both, and it makes possible the growing of a green manure crop. Nitrification is increased by the better aeration of the soil. This system may conserve moisture but this apparently varies on different soil types.

A modification of this system is the growing of cultivated crops which are to be harvested. Sweet corn, potatoes, tomatoes, melons, squashes, or pumpkins frequently add to the cash income of the farm during the period when the trees are small. Berries may also be used but do not lend themselves to an intercropping system as well because of spraying operations.

Tillage may be highly objectionable if soil erosion accompanies its use, but otherwise it gives excellent results in the young orchard.

Strip cultivation.—There are various modifications or combinations of this cultural system which are used to some extent. One is known as strip cultivation. This consists in keeping the orchard in sod but cultivating on either side of the rows of trees. This is particularly applicable to young orchards. The tillage may consist of plowing in the spring and cultivating with a spring-tooth or other type of cultivator during early summer, or a disk may be used first, followed by a cultivator. More recently, a type of spring-tooth cultivator, "weed hog", has been used once or more each season partially to destroy the grass (Fig. 1).

Such a system has certain advantages. It is more economical than all-over cultivation and results in less erosion because of the frequent barriers of grass land; yet it gives the results of a partial cultivation.

Alternate row cultivation.—Still another method of handling the orchard is to cultivate every other (second) "land", leaving the odd one in sod. The next year or two these cultivated areas are reversed. This plan has the advan-

tage of providing a better working surface for getting through the orchard with sprayers and wagons in early spring. On some soils the soft ground in the early season makes it almost impossible to work in the orchard.

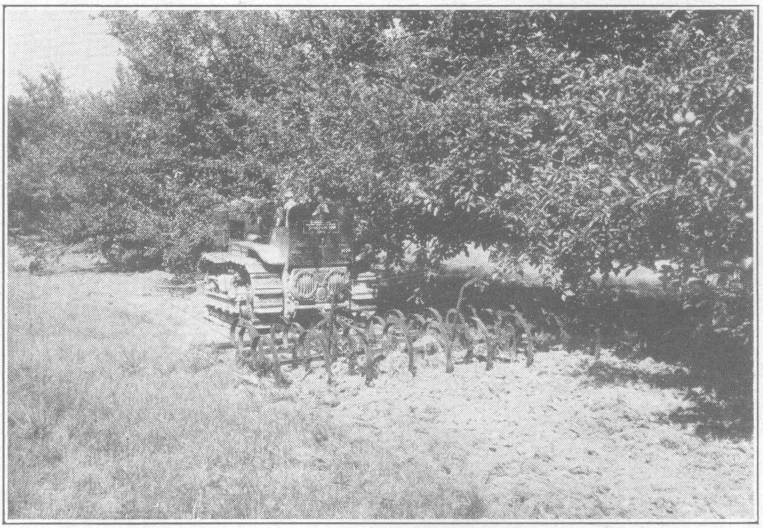

Fig. 1.—Cultivating tool known as a "weed hog" being used in strip cultivation

Half of each tree row is cultivated by this system, and, in addition, the danger from erosion is very much reduced provided the tilled areas are at right angles to the direction of the wash. It makes possible the turning in of cover crops or the production of intercrops.

MULCH

The term "mulch" as applied to the orchard has had a wide interpretation, so that anything from mowing a sparse grass and allowing it to lie where it falls to spreading straw or other material to a depth of several inches or a foot beneath the trees has been designated as mulch.

Certainly a true mulch system is as different from sod in its biological effect as sod is different from tillage. The fact that all the growth beneath the trees is destroyed or suppressed, together with other physical and biological results, places this system in a category by itself (Fig. 2).

This system of orchard culture was seriously criticized and questioned in the past because it was generally believed that all plants would do better if cultivated, because of the scarcity and expense of mulch material, and also because of certain hazards, such as mice, insect pests, and danger from fire. Moreover, mulching material should be obtainable at a price not to exceed $6 or $8 per ton.

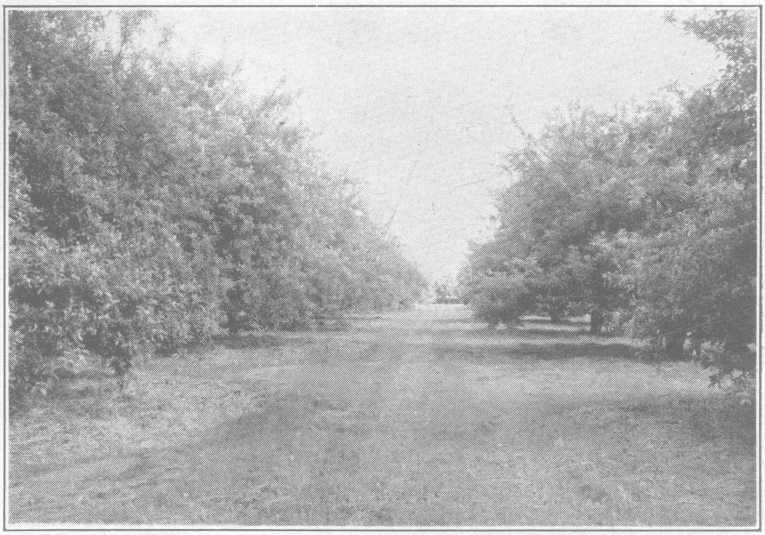

Fig. 2.—Orchard C, mulch plot. Straw mulch extending beyond branches

Some Advantages and Disadvantages of Mulch System of Orchard Culture

As compared with sod, a mulch of litter reduces the competition of the trees for water and soil nutrients. It increases the penetrability of water and prevents runoff. Evaporation of water from the soil is reduced to a minimum. The soil does not become compact, thus facilitating aeration of the soil. Additions of small amounts of potash and lime, as well as other inorganic nutrients, to the soil are made through decomposition of the litter.

Apart from these soil factors there are certain economic advantages and disadvantages of the mulch system that should be considered in placing an estimate upon this system as compared to cultivation for an orchard.

A mulched orchard can frequently be more economically sprayed than a cultivated one, particularly in the prebloom period when the soil is often very wet. It should be kept in mind that spraying, especially during the prebloom period, must be done on time. A delay of a day or two to allow a water-soaked soil to dry out may be sufficient time to permit an infection of apple scab. The necessity for spraying within definite time limits frequently results in serious packing of the soil from the weight of the heavy modern sprayer. The amount of damage caused in this way depends very largely on the type of soil. On loose, sandy soils which drain rapidly probably not much injury will result. On heavy, clay soils the physical condition of the soil may be affected for a season or more following the early spring spraying in a wet season.

Windfalls are cleaner from a sod than from a cultivated orchard. Mulch reduces the amount of bruising of the windfalls and fruit which falls during the picking operation.

Trees grown in sod, whether mulched or not, may be more subject to mice injury than those grown under cultivation. However, it should be stated that cultivation alone is no guarantee against mice injury, especially if a winter

cover crop is grown or litter is allowed to accumulate at the base of the tree, as demonstrated during the severe winter of 1935-1936. A mulch undoubtedly increases this hazard considerably. In areas known to be infested with mice, it should be an annual practice to clean all litter away from the base of the trees by late October. This should be done regardless of whether the trees are cultivated, in sod, or mulched. Poison mice bait, and wire tree protectors should be used as a part of the regular orchard practice where rodents are especially numerous.

The possibility of fire is greater in a sod orchard than in one which is cultivated. This hazard is increased appreciably where a mulch is maintained. During dry periods the owner of a mulched orchard should be on guard against fire. An occasional cultivated area in a mulched orchard to serve as a fire-break helps to reduce the hazard. During prolonged dry periods care should be taken to have a supply of water quickly available and the orchard sprayer easily accessible to assist in extinguishing a possible fire.

Certain claims have been made for the mulch system which seem to be exaggerated or unwarranted from the results of these orchard studies. The trees do not come into commercial bearing much, if any, earlier. The color of the fruit is not necessarily any better, nor is there any great building up of organic matter in the soil as a result of this surface mulch except in the first inch or two. It is not necessarily cheaper. Data on growth, yield, and general behavior are given later.

POISONED BAITS FOR MICE

Removing all weeds and grass from the area around the tree trunk in the fall is always advisable to guard against mouse injury. However, when mice are abundant, the use of poisoned baits is the only dependable method of protection.

The bait should be placed in poison stations which are set close to the base of the tree and lightly covered with vegetation or prunings. If mice are abundant, place one station under each tree. The stations should be on high ground to avoid standing water. They are preferably made of wood and may consist of pieces of board and lath nailed together to make a small mouse runway and also shelter the bait.

Drain tiles 1½ inches in diameter or larger or hollow building tile serve fairly well. Wide-mouth glass jars have been used successfully. The stations should be refilled with bait as required. Baiting should be done late in the fall and again during the winter or early spring if necessary.

The following formulas for preparing mouse bait are recommended by the Bureau of Biological Survey, U. S. Department of Agriculture:

Rolled-oats bait.—Mix together dry ⅛ ounce of powdered strychnine and ⅛ ounce of baking soda. Sift the strychnine-soda mixture over 1 quart of rolled oats, stirring constantly to insure an even distribution of the poison through the grain. Thoroughly warm the poisoned rolled oats in an oven and sprinkle over them 6 tablespoonfuls of a mixture of three parts of melted beef fat and one part of melted paraffin, mixing until the oats are evenly coated. When the grain is cool it is ready for use.

A teaspoonful of the bait should be placed in each poison station. This poison may also be placed inside the entrances of burrows. It should not be scattered in the open where birds will feed upon it.

Starch-coated grain bait.—Mix 1 tablespoonful of gloss starch in ½ teacup of cold water and stir into ¾ pint of boiling water to make a thin, clear paste. Mix 1 ounce of powdered strychnine with 1 ounce of baking soda and stir into the starch to a smooth, creamy mass free of lumps. Stir in ¼ pint of heavy corn sirup and 1 tablespoonful of glycerine. Apply to 12 quarts of wheat or to 20 quarts of steam-crushed whole oats and mix thoroughly to coat each kernel.

Steam-crushed whole oats are preferable as they may be scattered in the open without endangering bird life. This bait is prepared each summer at the Idaho Field Station of the U. S. Biological Survey and shipped at cost to local farm organizations which send in their orders. For information about this, growers should consult their county agent or state agricultural college.

EXPERIMENTAL DATA ON SOD, TILLAGE, AND MULCH SYSTEMS

RECORD OF A 43-YEAR-OLD MULCH ORCHARD, ORCHARD A

Orchard A at the Experiment Station at Wooster, embracing approximately 7 acres with the permanent trees set 33 feet apart, was planted in 1893. For 6 years the orchard was cultivated; then it was seeded down to grass. Since that time a mulch has been maintained around the trees. As the diameter of the heads of the trees increased in size, the width of the mulch was expanded, extending outward as far as the branches. Wheat straw has been used more extensively for mulch than any other material, although oats straw, damaged alfalfa, timothy, soybean threshings, sweet clover, grass clippings, and leaves have all been used to some extent. Sawdust and apple pomace have been tried in a limited way.

The purpose of the orchard was primarily for variety trials, and as such it was not suitable for cultural experiments. The behavior of the trees over this long period of time, 1893-1935, does furnish some evidence of the results which might be expected in an orchard maintained in mulch. In Table 3 are presented the yield records of 15 well-known varieties for a 26-year period. The average annual production for these 15 varieties for the 26-year period (1910-1935) was 15.5 bushels per tree. During the decade ending with the crop of 1935 the average annual production per acre for this entire variety orchard grown under the mulch system has been approximately 500 bushels. The location of the orchard is such that spring frost has not materially reduced the crop.

TABLE 3.—Average Annual Yield of 15 Varieties in Orchard A (Mulched)

26-year period, 1910-1935. Trees set, 1893

Variety	Av. annual yield	Variety	Av. annual yield
	Bu.		*Bu.*
Baldwin	15.4	Red Canada	14.4
Ben Davis	15.4	Rhode Island Greening	21.0
Grimes	19.0	Rome Beauty	17.5
Jonathan	16.8	Stark	13.2
McIntosh	16.1	Wealthy	8.4
Northern Spy	14.4	Yellow Transparent	12.3
Northwestern Greening	21.9	York Imperial	13.7
Oldenburg	13.1	Av. of all varieties	15.5

Mortality of trees in the orchard during the 43 years has not been above the normal amount.

Comparisons between this block of trees and others grown under different systems of soil management are not possible because no such orchards were available nearby for this length of time. It may be concluded, however, that the plan of soil management has been conducive to regular bearing and high production.

A small section of the orchard was plowed in 1928 and has been kept in clean cultivation since then. No detrimental effect on the trees has been noted as a result of the plowing and subsequent cultivation; neither has there been any improvement over the trees in the portion retained permanently in mulch.

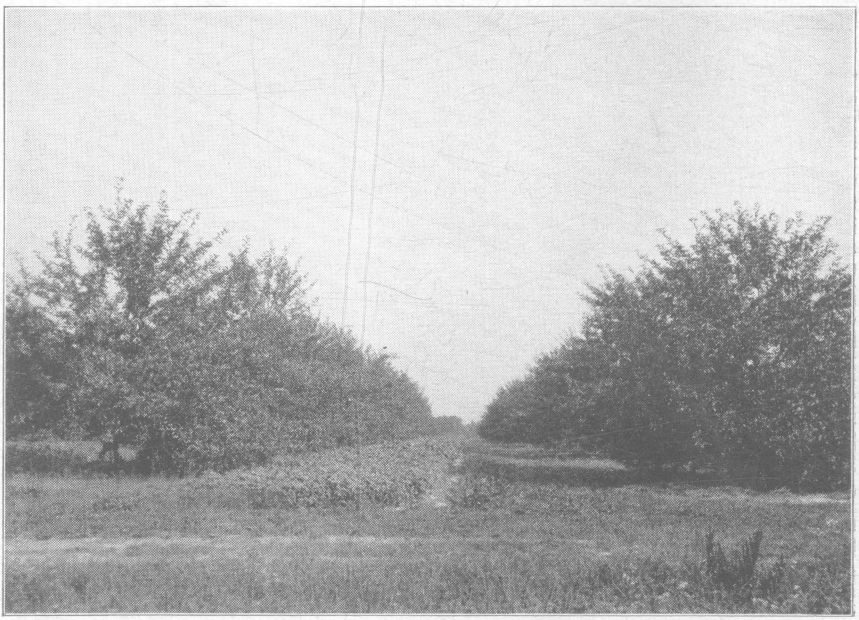

Fig. 3.—Orchard C, showing the division between cover crop and mulch plots. The cover crop is soybean.

A 20-YEAR COMPARISON OF MULCH AND TILLAGE, ORCHARD C

Orchard C was planted in 1915 and immediately placed in a cultural experiment. Only two varieties, Stayman and Delicious, are represented in the orchard. The trees were set 35 x 35 feet.

Previous to the planting of this orchard, the site had been a pasture field for many years and was covered with a heavy bluegrass sod. Half of the trees were planted in sod and mulched with straw. This portion of the orchard has been continuously maintained under the mulch system of culture. The annual rate of application of mulching material in Orchard C for the 6-year period ending with 1935 was 1 pound of dry material for an area of between 3 and 4

Fig. 4.—Disking under Sudan grass for green manure in an apple orchard

square feet. Rate of application was somewhat heavier the first few years of the life of the orchard. The other half of the orchard was plowed in the spring of 1915 and the ground was carefully fitted before the trees were planted. This section has been kept under cultivation from the time the trees were planted until the present. For several years it was the practice to grow soybeans in this block during the early summer and then disk them under and seed to rye. Rye continues to be the overwinter cover crop. However, because of the unsatisfactory growth, probably on account of shade and the competition with the trees for moisture, the soybeans were found to be unsatisfactory for a summer cover crop after about 15 years. Oats and Sudan grass have occasionally been substituted for soybeans during recent years.

Many of the data which were recorded in this orchard annually during the first 15 years were presented in Bulletin 456 (1). A part of these data together with some which have accumulated since Bulletin 456 was printed is given in Tables 4 to 10, inclusive.

Aside from the different methods of soil management, the two sections of orchard were given the same treatments. A moderate amount of annual pruning was given each plot; the spray treatment was in accord with good commercial practice; the same amount and kinds of fertilizers were applied; and commercial thinning was followed in the years when the trees were overloaded with apples.

A brief discussion and condensed tabular data showing the results of these two systems of soil management in this particular orchard follow. The principal indexes used for practical comparisons are yield, color, and size of fruit, growing costs, value of fruit, and tree growth.

INFLUENCE OF SOIL MANAGEMENT ON YIELD OF FRUIT

The average yield per tree from the time the first apples were produced in Orchard C (1921 for Stayman and 1922 for Delicious) to and including the crop of 1935 is presented in Table 4. The average yield of the Stayman trees on the cover crop plot at the end of 1935 was 677.4 pounds more than the average yield of the Stayman on the mulch plot. The average yield of the Delicious trees on the mulch plot exceeded the yield of the cover crop plot by 95.8 pounds.

TABLE 4.—Influence of Soil Management on Yield of Fruit

Orchard C, planted 1915. Total production per tree (including crop of 1935)

Plot	Variety	Average total production per tree
		Lb.
Cover crop	Stayman	6942.8
Cover crop	Delicious	5342.1
	Average	6142.5
Mulch	Stayman	6265.4
Mulch	Delicious	5437.9
	Average	5851.7

Space does not permit a tree by tree summary of the yield for the entire period. It may be stated, however, that individually the trees were remarkably uniform in production. No doubt the commercial thinning given these trees has tended to make the yield more uniform from year to year and from tree to tree. Of the 240 individual tree yields for the last 6 years of the record, only four were for less than 100 pounds per tree. Two of these were from the Stayman in the cover crop section and two, from the Delicious in the mulch plot. Yields above the average were uniformly distributed between the plots. The data seem to indicate that the two varieties have responded somewhat differently to these two types of soil management.

INFLUENCE OF CULTURE ON COLOR OF APPLES

From 1929 to the present the apples from Orchard C have been separated into three color grades. The color grade requirements established as U. S. Standards for apples have been used. During all the 6-year period the color has been remarkably uniform between plots for each variety. A summary of the color grades for the 6 years is presented in Table 5. The slight difference shown in the color grades of Delicious can hardly be rated as significant. In Orchards J and K, which embrace numerous fertilizer treatments, color grades have also been made over a period of several years. The data from these orchards show that varying fertilizer treatments as to date of application and combination of elements has had little or no effect upon the color of the fruit. Excessive applications of nitrogen have tended to result in fruit not quite so highly colored as that on the plots given a normal amount of nitrogen. Likewise, there has been slightly more scald on the fruit from the high nitrogen plots.

However, it may be safely concluded from the data here presented that the method of soil management followed has much less influence on color than such practices as pruning or thinning.

TABLE 5.—Influence of Culture on Color of Apples

Orchard C. 6-year period, 1930-1935

Variety	Plot	Color grade		
		U. S. Fancy*	U. S. No. 1†	Below U. S. No. 1
		Pct.	*Pct.*	*Pct.*
Stayman	Cover crop	80.6	15.3	4.1
Stayman	Mulch	79.8	13.6	6.6
Delicious	Cover crop	84.8	12.5	2.7
Delicious	Mulch	81.5	12.1	6.4

*U. S. Fancy color requirement—Stayman over 33⅓ per cent; Delicious over 50 per cent.

†U. S. No. 1 color requirement—Stayman over 15 per cent; Delicious over 25 per cent.

INFLUENCE OF CULTURE ON SIZE OF FRUIT

During the 6-year period, 1930-1935, the Stayman fruits grown on the mulch plot in Orchard C have been consistently larger than on the cover crop section. The Delicious fruits have also averaged a little larger on the mulch plot than on the cover crop plot. Three size grades have been made of both varieties: above 2¾ inches, 2¼ to 2¾ inches, and below 2¼ inches. It will be seen by reference to Table 6 that there was a much greater difference in size on Stayman than on Delicious for the two plots. It is possible that by using a different gradation of sizes from the one used there would be more variation between the Delicious from the two treatments. A rather high percentage of the Delicious graded well above 3 inches, and by breaking the crop into more grades it is likely that the slight size advantage shown for the mulch plot would have been increased. The difference in size of Stayman on the two plots was easily apparent nearly every year before the data were tabulated. Assuming a price range for Stayman for the different tree sizes of 1½, 1, and ½ cents per pound, respectively, the difference in the aggregate value of 100 pounds of apples from the two plots based on size alone would have been 10 cents, or approximately 4 cents per bushel. A higher price range or a greater differential between grades would of course make the difference in aggregate values more. With the apple prices prevailing the past few years, a difference of 4 cents in the aggregate value of a bushel of apples would frequently have been the margin between profit and loss.

TABLE 6.—Influence of Culture on Size of Fruit

Orchard C. 6-year average, 1930-1935

Variety	Soil treatment	Above 2¾ inches	2¼ to 2¾ inches	Below 2¼ inches
		Pct.	*Pct.*	*Pct.*
Stayman	Cover crop	66.8	31.0	2.2
Stayman	Mulch	84.8	14.6	0.6
Delicious	Cover crop	85.9	13.8	0.3
Delicious	Mulch	92.0	7.8	0.2

GROWING COSTS COMPARED

The growing costs of the cover crop plot for the 20-year period, 1915-1934, are presented in Table 8, and those for the mulch plot, in Table 7. The two varieties are grouped together for the data included in these tables. During

TABLE 7.—Twenty-year Record of Production Costs per Tree of Stayman and Delicious Apples under Mulch System. Orchard C. 1915-1934

Costs	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Man labor per hour	0.20	0.20	0.25	0.30	0.36	0.40	0.40	0.33	0.35	0.35
Team labor per hour	.20	.20	.30	.30	.36	.40	.40	.33	.35	.35
Tractor per hour										
Tractor operator per hour										
Tree	.10									
Planting tree	.05									
Mowing—man and team	.025	.033	.063	.017	.054	.092	.042	.065	.08	.068
Miscellaneous hand labor	.021	.046	.016	.04	.008	.058	.008	.041	.00	.044
Pruning and disposing of brush		.008	.005		.022	.025	.038	.038	.088	.056
Tree guards		.10								
Mulch and application	.049	.017	.031		.023	.033	.033	.375	.032	.024
Number of spray applications		1.00	1.00	1.00	1.00	2.00	5.00	5.00	6.00	6.00
Spraying, including labor, machine, and material		.022	.018	.027	.062	.175	.182	.209	.58	.69
Fertilizer and application									.039	.039
Interest and taxes	.289	.352	.415	.415	.478	.548	.62	.685	.746	.756
Thinning										
Picking							.035	.073	.243	.172
Hauling to storage							.008	.016	.058	.041
Rental of crates and small tools	.01	.01	.01	.01	.01	.01	.046	.057	.095	.079
Grading							.017	.038	.125	.088
Supervision	.169	.169	.169	.194	.194	.194	.316	.316	.316	.316
Total cost per tree	.713	.757	.727	.703	.851	1.135	1.345	1.913	2.402	2.373
Average yield per tree in pounds							16.80	42.80	133.60	94.40
Cost of production per bushel (48 pounds*)							3.843	2.146	.863	1.207

TABLE 7.—Twenty-year Record of Production Costs per Tree of Stayman and Delicious Apples Under Mulch System. Orchard C. 1915-1934—Continued

Costs	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Man labor per hour	0.35	0.35	0.35	0.40	0.40	0.40	0.30	0.30	0.25	0.25
Team labor per hour	.35	.35	.35	.35	.35	.35	.30	.30	.25	.25
Tractor per hour	.....	.....	.....	.....	.....	.....	.85	.85	.85	.85
Tractor operator per hour	.....	.....	.....	.....	.....	.....	.40	.40	.40	.40
Tree	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Planting tree	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mowing—man and team	.064	.075	.076	.085	.05	.071	.041	.055	.026	.023
Miscellaneous hand labor	.024	.016	.04	.038	.033	.038	.041	.037	.034	.045
Pruning and disposing of brush	.115	.239	.366	.376	.335	.433	.365	.385	.614	.557
Tree guards	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mulch and application	.693	.016	.541	.516	.033	.866	.436	.657	.92	.....
Number of spray applications	6.00	5.00	7.00	6.00	6.00	6.00	6.00	6.00	8.00	7.00
Spraying, including labor, machine, and material	.961	.798	1.621	1.193	1.871	1.418	.956	1.219	1.686	1.284
Fertilizer and application	.039	.05	.05	.062	.062	.304	.053	.05	.043	.05
Interest and taxes	.754	.484	.29	.308	.318	.32	.309	.318	.313	.289
Thinning	.....	.....	.49	.189	.13	.229	.293	.365	.182	.591
Picking	.395	.519	.456	.339	.438	.649	.695	.541	.554	.695
Hauling to storage	.118	.187	.164	.078	.135	.224	.30	.233	.116	.25
Rental of crates and small tools	.153	.217	.196	.107	.156	.23	.368	.293	.255	.367
Grading	.254	.40	.352	.169	.293	.487	.667	.519	.392	.583
Supervision	.422	.422	.422	.422	.422	.482	.46	.46	.46	.46
Total cost per tree	3.992	3.423	5.064	3.882	4.276	5.75	4.99	5.13	5.64	5.19
Average yield per tree in pounds	271.00	427.50	375.50	163.00	280.80	467.00	800.70	622.70	519.20	800.00
Cost of production per bushel (48 pounds*)	.707	.384	.647	1.143	.731	.591	.299	.396	.510	.312

*At the outset of this experiment 48 pounds was the legal weight of a bushel of apples in Ohio; hence, this weight has been used throughout the experiment.

TABLE 8.—Twenty-year Record of Production Costs per Tree of Stayman and Delicious Apples under Cover Crop System. Orchard C. 1915-1934

Costs	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Man labor per hour	0.20	0.20	0.25	0.30	0.36	0.40	0.40	0.33	0.35	0.35
Team labor per hour	.20	.20	.30	.30	.36	.40	.40	.33	.35	.35
Tractor per hour										
Tractor operator per hour										
Tree	.10									
Planting tree	.033									
Cultivation—man and team	.223	.154	.333	.167	.262	.274	.40	.219	.213	.252
Cultivation—man and tractor										
Miscellaneous hand labor	.025	.162	.026					.048		.015
Pruning and disposing of brush		.004	.005		.022	.025	.038	.038	.084	.061
Tree guards		.10								
Cover crop seed and drilling	.164	.062	.042	.083	.135	.052	.146	.083	.087	.141
Number of spray applications		1.00	1.00	1.00	1.00	2.00	5.00	5.00	6.00	6.00
Spraying, including labor, machine, and material		.022	.018	.028	.062	.175	.182	.209	.58	.69
Fertilizer and application									.039	.039
Interest and taxes	.288	.352	.414	.478	.54	.635	.744	.810	.91	.919
Thinning										
Picking							.04	.082	.163	.224
Hauling to storage							.01	.02	.039	.067
Rental of small tools and crates	.01	.01	.01	.01	.01	.01	.042	.054	.071	.098
Grading							.02	.043	.084	.144
Supervision	.169	.169	.169	.194	.194	.194	.316	.316	.316	.316
Total cost per tree	1.012	1.035	1.017	.96	1.225	1.365	1.938	1.922	2.586	2.966
Average yield per tree in pounds							19.40	47.50	89.30	153.40
Cost of production per bushel (48 pounds*)							4.795	1.942	1.392	.926

TABLE 8.—Twenty-year Record of Production Costs per Tree of Stayman and Delicious Apples under Cover Crop System. Orchard C. 1915-1934—Continued

Costs	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Man labor per hour	0.35	0.35	0.35	0.40	0.40	0.40	0.30	0.30	0.25	0.25
Team labor per hour	.35	.35	.35	.35	.35	.35	.30	.30	.25	.25
Tractor per hour							.85	.85	.85	.85
Tractor operator per hour							.40	.40	.40	.40
Tree										
Planting tree										
Cultivation—man and team	.289	.198	.213	.588	.603	.054				
Cultivation—man and tractor							.217	.271	.171	.35
Miscellaneous hand labor				.609	.104	.174	.036	.136	.085	.227
Pruning and disposing of brush	.106	.243	.388	.343	.357	.52	.450	.331	.443	.523
Tree guards										
Cover crop seed and drilling	.217	.12	.098	.098	.124	.129	.057	.082	.093	.337
Number of spray applications	6.00	5.00	7.00	6.00	6.00	6.00	6.00	6.00	8.00	7.00
Spraying, including labor, machine, and material	.961	.798	1.621	1.193	1.871	1.418	.956	1.219	1.686	1.284
Fertilizer and application	.039	.05	.05	.062	.062	.281	.053	.05	.043	.05
Interest and taxes	.916	.462	.277	.282	.29	.293	.295	.318	.313	.289
Thinning			.502	.20	.113	.391	.269	.385	.255	.636
Picking	.397	.676	.596	.407	.511	.86	.64	.57	.54	.537
Hauling to storage	.143	.244	.214	.094	.159	.297	.277	.24	.162	.193
Rental of small tools and crates	.170	.266	.238	.116	.172	.29	.340	.303	.25	.292
Grading	.306	.522	.46	.204	.344	.645	.615	.538	.378	.451
Supervision	.422	.422	.422	.422	.422	.44	.44	.46	.46	.46
Total cost per tree	3.966	4.001	5.079	4.618	5.132	5.79	4.64	4.91	4.88	5.63
Average yield per tree in pounds	326.70	556.50	490.30	195.50	330.80	619.30	737.70	646.40	518.20	618.40
Cost of production per bushel (48 pounds*)	.581	.345	.499	1.133	.744	.449	.302	.365	.452	.437

*At the outset of this experiment 48 pounds was the legal weight of a bushel of apples in Ohio; hence, this weight has been used throughout the experiment.

the last 10 years of this period the growing costs including picking and grading have been 53 cents per bushel on the cover crop plot and 57 cents on the mulch plot. During the last 4 years of this period, 1931-1934, the comparative cost of production was 39 cents per bushel for the cover crop and 38 cents for the mulch.

The data show that there has been but little difference in growing costs per bushel between the two plots. Over the longer period, apples were produced more cheaply on the cover crop section than on the mulch section, mainly because of a larger yield per tree. During the latter years of the period the records of yield per tree have shown a slight difference in favor of the mulch plot and a correspondingly favorable advantage in growing costs per bushel.

It has been pointed out previously that the variety factor has apparently had an influence on the total yields of the two plots. However, for reasons well understood by fruit growers, it is not advisable to plant large numbers of trees of a single variety in a solid block. Moreover, it does not seem practical in an orchard containing several varieties to maintain a different type of soil management for each variety.

It seems logical to conclude that the inclusion of a larger number of varieties in each of these plots would not greatly have changed the relationship between the plots as regards yield.

Associated closely with growing costs per bushel and yield per tree is the aggregate value of the fruit per tree. Color and size both influence the value of the fruit per tree. The value of the fruit produced on the two plots for the 10-year period 1926-1935 is shown in Table 9.

TABLE 9.—Value of Fruit per Tree

1926-1935. Varieties Delicious and Stayman, planted 1915

Cultural treatment	1926	1927	1928	1929	1930	1931
Cover crop	$14.59*	$17.40	$7.45	$16.86	$24.98	$13.69
Mulch	11.21	13.23	6.20	14.25	19.15	15.21

Cultural treatment	1932	1933	1934	1935	Av. 1926-1935	Av. 1932-1935
Cover crop	$13.68	$11.53	$14.27	$14.26	$14.87	$13.44
Mulch	13.59	11.94	18.79	12.75	13.63	14.27

*Average value per tree.

Delicious and Stayman are grouped together in this table. The average value per tree of the apples on the cover crop plot for the 10-year period was $14.87 and for the mulch, $13.63. During the last 4 years of this 10-year period the value of the fruit per tree has been $13.44 for the cover crop plot and $14.27 for the mulch plot.

These data seem to indicate that the value of the fruit per tree is shifting from an earlier trend in favor of the cover crop plot towards the mulch section.

The higher percentage of Stayman in the larger size grade on the mulch plot in recent years has been one of the main factors in shifting the trend in the value of the fruit from the cover crop plot to the mulch.

INFLUENCE OF SOIL MANAGEMENT ON GROWTH AND SIZE OF TREES

Data on the size of the trees in Orchard C are presented in Table 10. These trees have been uniform in growth throughout the life of the orchard. Measurements taken at the end of the twentieth year of growth showed that there was practically no difference in the height or spread of the trees and that the circumference of the trunks of the trees on the mulch plot was only slightly greater than on the cultivated section. Taken individually or as a whole, the records show that the trees made good growth on both plots during the entire period and at the end of 20 years could be rated as medium to large trees. Considering the data progressively from the date the first measurements were taken to 1934, there is some slight suggestion at least that the growth records of the trees on the mulch section might be rated a little more satisfactory than on the cover crop section. It may also be stated that from a superficial observation of the trees, the mulch area seemed superior so far as color of foliage is an index of vigor, especially in the dry seasons of 1930, 1933, and 1934.

TABLE 10.—Influence of Soil Management on Growth and Size of Trees

Orchard C. Trees planted 1915

Variety	Plot	Diameter of head			Height of trees			Circumference of trunk 12 inches from ground			
		1923	1929	1934	1923	1929	1934	1916	1922	1929	1934
		Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*In.*
Stayman.....	Cover crop	19.32	22.22	27.6	15.27	17.95	19.8	3.50	16.62	30.41	36.6
Stayman.....	Mulch	18.40	20.55	27.8	14.70	17.25	20.4	3.53	16.41	31.56	38.1
Delicious.....	Cover crop	17.33	23.58	28.8	14.33	16.83	19.5	3.10	15.64	30.95	37.9
Delicious.....	Mulch	16.75	22.98	29.1	14.12	17.42	19.9	3.04	14.99	30.90	39.2

EFFECT OF CULTURAL METHODS UPON SOIL TEMPERATURES

The temperature of the surface soil is profoundly influenced by the cultural treatment used. This has been shown frequently elsewhere under soil treatments similar to those reported in this bulletin. As shown in Figure 5, bare, exposed soil or that where a cover crop is grown responds more quickly and to a greater extent to the air temperature than ground which is well covered (insulated) by a mulch or a sod. As shown in the smoothed curve at the lower right-hand side of Figure 5, the soil temperature is highest during summer and lowest during winter where the land is cultivated. The mulched area stands at the opposite extreme, with the sod land intermediate.

To what extent extremes of temperature are undesirable has not been investigated here. If extremely low temperatures occur when the ground is unprotected by snow or other insulating material, root killing will occur. If, on the other hand, the soil temperature becomes high during summer the rate of moisture loss is higher. The more equitable temperature, along with its resultant effects under the mulch, would seem to be most favorable for the trees.

The soil under the mulched trees in Orchard C did not freeze so deeply as that under the cultivated trees during the severe winters of 1933-1934 and 1935-1936. Measurements were taken at the end of the severe temperatures

Fig. 5.—Soil temperature

in early March, 1934 and twice during February, 1936 and are presented in Table 11. It is not suggested here that the deeper freezing of the soil in the cultivated area had an injurious effect on the trees in this particular orchard. However, these data do throw some light on the value of a straw mulch in preventing deep frost penetration.

TABLE 11.—Depth of Frost Penetration Under Different Soil Management Conditions

Soil treatment	Date of examination		
	March 3, 1934	Feb. 3, 1936	Feb. 26, 1936
	In.	*In.*	*In.*
Heavy straw mulch	3.0	3.0	9.0
Sod, not mulched	9.5	7.0	18.0
Cover crop	10.5	11.0	30.0
Clean cultivation	14.3	18.0	.....

INFLUENCE OF METHOD OF CULTURE ON DATE OF BLOOM

Mulching has sometimes been suggested as a means of retarding the development of fruit tree blossoms. This opinion is probably based on the common observation that blossoms of low-growing plants like strawberries may be delayed by means of a mulch.

Individual tree records have been taken of the date of full bloom in Orchard C each year. A summary of these data is presented in Table 12. The average date of full bloom for the Stayman was May 8 and for Delicious, May 9 on each plot.

It may safely be concluded that the normal development of the blossoms was not influenced by either method of culture. This experience in Orchard C is in conformity with observations made in other blocks of trees at the Station over an even longer period of time.

TABLE 12.—Date of Full Bloom

Orchard C. 1922-1935

Variety	Soil treatment	Date of full bloom Av. for 14 years
Stayman	Cover crop	May 8
Stayman	Mulch	May 8
Delicious	Cover crop	May 9
Delicious	Mulch	May 9

INFLUENCE OF CULTURAL SYSTEMS ON SOIL MOISTURE

Reference has already been made to the effect of sod, mulch, and tillage upon the occurrence of nitrates in the soil and also upon temperature, depth of freezing, and other factors. Since soil moisture is one of the important factors in the favorable growth and production of trees, it has been observed from time to time in these and other orchards.

Although there has been a considerable change in viewpoint regarding the amount of moisture necessary for the normal development of plants, it is not our purpose here to enter into a discussion of the moisture levels at which they will best develop. The reader may consult other sources for these data (3). During very dry seasons, such as 1930 and 1934, trees and fruit showed the effect of lack of moisture. The most noticeable of these effects were smaller and poorer colored fruit and even shriveling of fruit in extreme cases, shorter twig growth if the drouth occurred early in the season, and even death of trees in extreme cases.

In August of 1930, during a season of very low rainfall, moisture determinations were made in sod, mulched, and cultivated areas of Orchards A and C. The mulched trees were in the most favorable condition, followed about equally by the sod and tilled blocks of trees (Table 13). The fact that the mulched area contained about double the moisture of those which were close by but under sod or tilled culture is significant indeed. That this is not true in all sections is shown by Magness who states that "during periods of prolonged drouth, non-irrigated trees growing under heavy mulch in soil only 2 to 2½ feet deep, suffered very severely from lack of moisture".

TABLE 13.—Soil Moisture in Mulched, Sod, and Cultivated Areas, August, 1930

Date taken		Soil treatment			
		Mulch 181-186	Cover crop culture	Clean culture	Sod not mulched
		Pct.	*Pct.*	*Pct.*	*Pct.*
Aug. 2	Upper 6 inches	8.88	5.11	8.58	6.04
	Second 6 inches	7.35	7.65	8.57	6.02
	Av. for 12 inches	8.12	6.38	7.58	6.03
Aug. 4	Upper 6 inches	13.98	5.92	6.47	6.55
	Second 6 inches	10.88	6.49	7.17	6.67
	Av. for 12 inches	12.43	6.20	6.82	6.61
Aug. 6	Upper 6 inches	8.49	6.28	7.39	5.90
	Second 6 inches	7.13	6.80	7.19	6.24
	Av. for 12 inches	7.81	6.54	7.29	6.07

THE ROOT SYSTEMS OF APPLE TREES AS AFFECTED BY CULTURAL TREATMENTS

During the past few years emphasis has been placed upon the nature and depth of the rooting habit of fruit trees. Because of the ease of examination the aboveground parts have been mostly studied in the past, but these recent findings in regard to tree roots have shown the importance of a greater knowledge of the surface and subsoil conditions if trees are to reach their maximum efficiency.

Among the chief observations pertinent to these studies the following may be mentioned:

The most important single factor which affects root distribution is soil drainage and the consequent soil moisture and soil air supply. Optimum root development occurs when both are well provided.

A high water table, even for a portion of the year, limits the depth of root penetration; the roots in a water-logged area die and new ones fail to develop. Such trees are stunted, have shallow roots, and suffer in both dry and wet seasons.

Rock strata in the subsoil or "hard pan" or heavy, impervious layers in the B horizon may limit depth of penetration. Roots may extend to a depth of 20 feet or more in a deep, penetrable sand and have been traced as deep as 8 feet in a well-drained clay underlaid by sands (5).

The maximum concentration of roots occurs within the top foot and a half of soil. In an extensive survey in the State of New York it was found that over 60 per cent of the roots of the tree occurs within the top 16 inches (4).

Horizontal spread of roots may extend as far as 40 or more feet in the case of older apple trees. Thus, the roots may interlace over the entire orchard area.

In general, trees with deep and wide-spreading root systems are largest, longest lived, most regular in bearing, and most productive. This character of underground parts is partially varietal but it is largely a matter of soil type.

ROOT DEVELOPMENT UNDER MULCH AND TILLAGE

Much has been written regarding the tendency of the roots under a heavy mulch to occupy the surface soil and grow into the loose mulch. The inference has been that such trees are not as deep rooted as cultivated ones, and hence the trees would suffer in time of protracted drouths.

In order to determine the situation in an orchard which had been mulched for a number of years, trenches were dug in one of the Station orchards which had been in a heavy mulch for about 35 years. The trench extended from the base of the tree to a point half way to the opposite tree in the next row, a distance of about 17 feet. It was excavated as deep as roots were found and was 2 feet wide. One wall of the trench was marked off into square feet (Fig. 6) by means of string stretched between nails which were set in the trench wall. Then the various horizons and subhorizons were plotted on the map. The roots occupying the soil were then indicated on the map both as to horizon and the proper square foot position. The size of roots is indicated on the chart (Fig. 7).

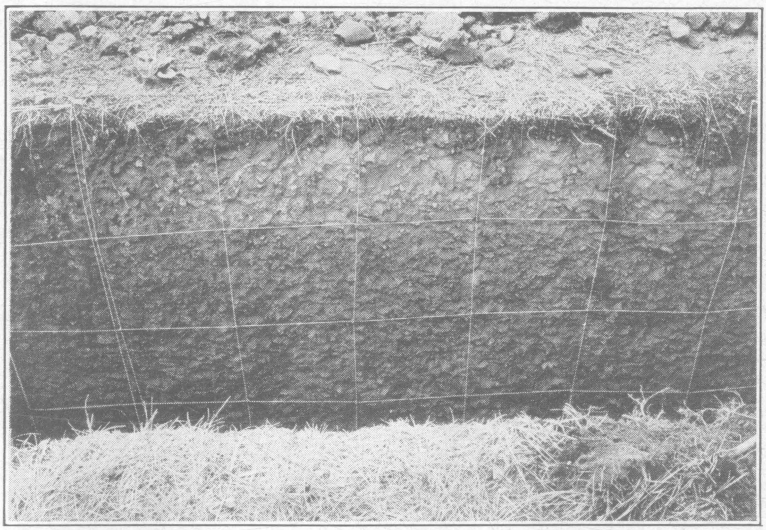

Fig. 6.—Trench used in plotting root development

Root distribution was studied with eight trees for comparison with the mulched one. Although they are of different ages and varieties, they illustrate the rooting habit under different cultural systems. The orchards are known by letters A, B, J, and K. Table 12 gives number of roots in percentage from the first to the sixth foot, inclusive. This figure includes all roots found from the base of the tree to the point halfway to the next tree row.

It will be noted that the mulched Ben Davis tree (197) has a somewhat greater root penetration than the Arkansas Black (301), which has been cultivated for the past 7 years, and that in both cases the main portion of the roots is in the first 2 to 3 feet. In the case of the younger trees from 86 to nearly 100 per cent of the roots is in the first 3 feet. In every case over 64 per cent of the roots, by number, occurs within 2 feet of the surface. Oskamp and Batjer, in their report on distribution of roots based on figures taken 8 to 10 feet from the trunk in a trench dug tangential to the trunk, report similar surface concentration throughout the Hilton area, New York.

It will be noted from a study of Table 14 and Figure 7 that there is no tendency in the mulched orchards toward shallow rooting. Both Trees 197 and 301 in Orchard A have a deep, uniform root penetration and were developed under 3 decades of continuous heavy mulch. The roots in the A or mulched horizon were not included in the count with Tree 197, because the root mass was so thick that a count was practically impossible. Probably at least 50 per cent of the total number of roots would have been in the upper foot of soil if these surface ones could have been included. With Tree 301, from which the mulch was removed 6 years prior to these observations, there has been no reduction in yield or vigor, even though a large portion of the roots was destroyed when the change in culture was made. This was typical of all the other trees in this tilled area.

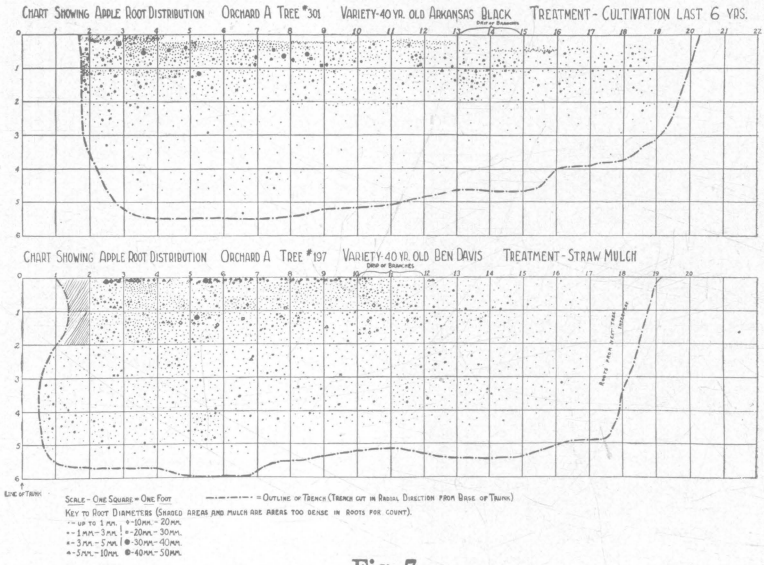

Fig. 7

Fig. 8.—A disk with an extension hitch being used to cultivate an apple orchard

It must therefore be concluded from this work that the mulch favors surface rooting but does not inhibit the development of deeply penetrating roots also, if the soil is favorable. It is also of interest to note that the cutting of the surface roots in a sod or mulch orchard by plowing does not seriously injure the tree. This has been noted under many other circumstances. One would

not argue that it is desirable to destroy these surface "feeding" roots, but, if there is reason for so doing, it is not likely to devitalize the trees unless the season is very dry.

Tree 3/14 was located on a slight knoll upon a very good Canfield[1] silt loam; Tree 3/18 was located in a slight depression with a poorly drained Volusia[1] silt loam profile; and, on a ridge on the other side of the depression, Tree 3/26 was located on a deep Canfield silt loam. The effect of the soil type upon depth of penetration of roots of these three McIntosh trees is very obvious from Table 14. The profile descriptions of the Volusia silt loam taken from the trench show a mottled gray horizon at a depth of 30 inches, which offered some mechanical resistance to developing roots and which held the water table up during part of the year, killing back new growth. The Canfield profiles showed a granular B horizon, with a reddish cast to the surface of the granules, composed of iron and manganese material. These trees were all 10 years of age, of comparable stock, and were products of similar cultural treatment.

TABLE 14.—Percentage of Roots at Various Soil Levels

Depth	Tree 197 Ben Davis Age, 40 yrs. Orchard A	Tree 301 Arkansas Black Age, 40 yrs. Orchard A	Tree 4/2 Stayman Winesap Age, 10 yrs. Orchard J	Tree 17/6 Stayman Winesap Age, 10 yrs. Orchard K	Tree 3/14 McIntosh Age, 10 yrs. Orchard K	Tree 3/18 McIntosh Age, 10 yrs. Orchard K	Tree 3/26 McIntosh Age, 10 yrs. Orchard K	Tree 4/20 Grimes Golden Age, 10 yrs. Orchard K
Ft.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0–1	36.6	55.1	53.0	76.1	54.7	52.3	39.9	65.1
1–2	27.6	32.4	20.8	22.3	23.2	34.7	26.2	30.3
2–3	13.0	6.6	19.2	1.5	9.6	12.6	20.4	4.6
3–4	13.5	3.0	5.5	.....	11.0	0.4	9.4	.....
4–5	8.2	2.7	1.5	....	1.5	.....	4.1	.....
5–6	1.0	0.2	.....	.....	.....	.....	.....	.....
Totals	99.9	100.0	100.0	99.9	100.0	100.0	100.0	100.0

Another mode of analysis may be based on the numerical count comparison in a vertical direction across the profile. With the same set of data a percentage of total count for each vertical foot of the trench wall away from the trunk is obtained. Table 14 is based on the total number of roots, but the original data show that roots of all sizes follow the same approximate figures.

Table 15 gives in a general way the trend of the root concentration away from the tree. In no case was the trench continued to the absolute limit of the rooting system. The mapping was stopped when roots from adjoining trees interfered with accurate recording. However, these data emphasize the wide general spread of the rooting system, particularly when it is remembered that there is a much larger area of ground included in a band 1 foot wide using a radius such as 12 feet from the trunk, than in a circle using a distance such as 4 feet from the trunk as a radius. The same situation may be cited with a Jonathan tree at the Farnsworth orchards at Waterville (Fig. 9).

It is thus seen that there is a downward and outward gradient of roots from the trunk of the tree and that the roots of even a comparatively young

[1]Canfield silt loam has a light brown surface soil and is mottled in the subsoil below 16 to 24 inches; whereas the Volusia has a grayish-brown surface soil and is mottled below 8 inches. The B horizon of the Volusia is commonly somewhat inferior to the similar horizon in the Canfield soil.

orchard extend over the entire orchard area. This suggests an all-over method of fertilization rather than the application of chemicals or manure in a narrow band beneath the drip of the branches.

TABLE 15.—Percentage of Apple Roots at 1-foot Intervals from Tree Trunks

Distance from trunk	Tree 197 Ben Davis Mulched	Tree 301 Arkansas Black Mulched	Tree 4/2 Stayman Sod	Tree 17/6 Stayman Sod	Tree 3/14 McIntosh Tilled	Tree 3/18 McIntosh Tilled	Tree 3/26 McIntosh Tilled	Tree 4/20 Grimes Tilled
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1st vertical foot...	.....	.....	.....	18.2	.....	.....	.....	.....
2nd vertical foot..	2.8	.....	24.5	10.5	13.8	11.7	.....	15.8
3rd vertical foot ..	8.0	6.9	18.8	19.3	15.9	11.9	9.9	23.5
4th vertical foot ..	13.1	11.8	11.3	16.5	9.8	9.1	14.1	13.2
5th vertical foot ..	11.0	8.9	14.9	7.5	8.7	10.6	17.7	10.3
6th vertical foot ..	8.6	8.6	9.8	9.9	9.5	7.9	12.7	10.9
7th vertical foot ..	6.9	9.2	2.7	8.4	6.8	7.1	12.1	7.8
8th vertical foot ..	7.3	5.9	3.6	4.9	6.8	4.9	11.7	6.9
9th vertical foot ..	7.5	6.4	3.7	3.0	6.5	7.1	8.8	5.9
10th vertical foot ..	6.3	6.0	1.5	1.7	7.9	4.6	6.3	3.8
11th vertical foot ..	7.4	6.0	0.9	.....	5.1	7.7	2.2	.....
12th vertical foot ..	6.9	6.4	1.3	.....	4.1	5.6	1.8	.....
13th vertical foot ..	4.3	4.4	3.6	.....	3.4	7.2	2.1	.....
14th vertical foot ..	3.8	5.0	1.8	.....	1.7	4.7	0.6	.....
15th vertical foot ..	2.7	3.9	1.6	.....	.....	.....	.....	.....
16th vertical foot ..	2.0	3.3	.....	.....	.....	.....	.....	.....
17th vertical foot ..	1.6	2.8	.....	.....	.....	.....	.....	.....
18th vertical foot ..	.....	2.2	.....	.....	.....	.....	.....	.....
19th vertical foot ..	.....	2.3	.....	.....	.....	.....	.....	.....
Totals.....	100.0	100.0	100.0	99.9	100.0	100.1	100.0	100.0

Before an orchard is planted the soil should be investigated to a depth of 5 or 6 feet and gray, mottled soil areas avoided if long-lived and productive orchards are to be secured.

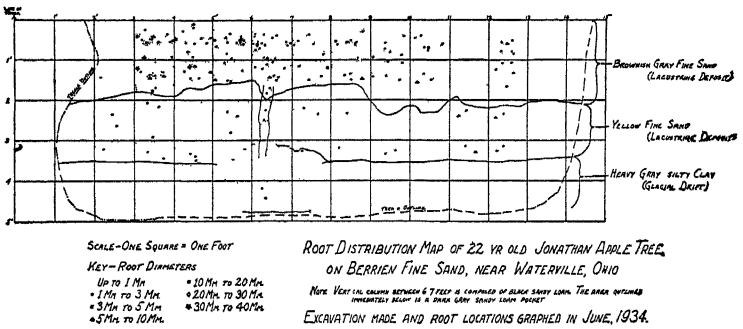

Fig. 9

SOME GENERAL CONSIDERATIONS AND SUGGESTED PRACTICES FOR OHIO ORCHARDS

There is no single system of orchard soil management which may be recommended for all conditions in Ohio. Even under a given set of conditions more than one method may be used successfully at the same time. Moreover,

as has been pointed out elsewhere in this bulletin, it is frequently feasible to shift from one system to some other. Special emphasis should be placed upon the importance of avoiding any system of tillage if erosion is likely to occur.

Closely associated with the choice of a soil management system are a number of secondary considerations which demand the attention of the orchardist. A brief discussion of a few of these phases of orchard culture based on experiences in the Station orchards follows.

TILE DRAINAGE

A well-drained soil is one of the essential requirements for tree growth. Inadequate drainage has frequently been responsible for excessive mortality and low vigor of trees. It is not unusual to find fairly well-drained strata of soil near the surface underlaid by a soggy subsoil. It must be kept in mind that roots of apple trees frequently penetrate soils to a depth of 6 or 8 feet or even more. High mortality of trees in poorly drained soils may result from suffocation of the tiny root hairs which are submerged in water over long periods, or excessive moisture in the soil may lead to winter injuries. An orchard may develop normally for a few years on poorly drained soil or until that time when the roots begin to penetrate into the lower region of the surface soil or the subsoil.

Orchard K at the Experiment Station, planted in 1922 on a tract of land presumably well drained, began to show evidences of "wet feet" about 8 years after planting or about the time the trees began to set fruit in commercial quantities, and a good many trees finally died. It was necessary to install another system of drainage in this orchard independent of the original drainage system which had apparently been sufficient to insure good crops of grain prior to the planting of the orchard. A detailed description of this drainage system was presented in 1933 (2) and is available for any Ohio orchardist interested in tile drainage.

Briefly, the system followed was to lay a line of tile midway between each two rows of trees. The rows in this orchard were 38 feet apart. These lateral tiles were 4 inches in diameter with a 6-inch main at the base of the orchard carrying the water to the main drainage system. In this particular orchard, because of the heavy character of the surface soil, a rather shallow placing of the tile was required; the depth was from 2 to 2½ feet. Under average conditions the tile in orchards should be from 3 to 3½ feet below the surface.

Even in orchards planted on rolling or hilly land there are frequently areas that require some artificial drainage. Unless the soil is properly drained, the beneficial effects of other cultural practices, such as fertilization, cultivation, spraying, and pruning, may be wholly or partly lost.

COVER CROPS FOR OHIO ORCHARDS

During the past decade or more, a good many different cover crops have been grown in the Station orchards. Brief notes on the time, methods, and rate of seeding, together with comments on the value of these several crops as orchard cover crops at Wooster, are included in this report. The selection of crops and rate of seeding have been governed in part by the experience and advice of the Department of Agronomy.[2]

[2]Credit is due L. E. Thatcher and C. J. Willard for advice on cover crops and methods of seeding.

For the purpose of this discussion the several crops grown are divided into two general groups: first, those crops suitable for spring or summer covers, and, second, those which are more commonly used for overwinter covers.

SUMMER COVER CROPS

Soybeans.—The rate of seeding recommended is 1½ to 2 bushels per acre. Any standard variety may be used; the price of seed is the determining factor. Soybeans should be seeded on a good seedbed June 1 to 15. The drill should not be set too deep. Soybeans are an ideal summer cover crop for improving the physical condition of the soil. They are better adapted to orchards under 15 years of age than to older ones. Soybeans are generally disked under late in the summer and followed by a winter cover crop. Soybeans leave the ground very loose, and unless the orchard is level a winter crop should follow to prevent erosion.

Cowpeas.—Cowpeas are another summer cover crop occasionally used in orchards. This crop is handled in much the same way as soybeans but the latter crop is to be preferred, except on very poor soils.

Millet.—Millet is sometimes used as a summer cover crop and will usually make good growth in an orchard. In dry years the competition with the trees for water makes its use a questionable practice. It is seeded at the rate of 40 to 50 pounds per acre. When combined with soybeans, the rate of seeding is 1 bushel of soybeans and 15 pounds of millet.

Sudan grass.—Sudan grass is another of the grasses sometimes used for an orchard cover crop. Like millet, it is objectionable in dry years. It is a good crop to use where mere tonnage of organic matter is a factor and is especially valuable where soil aeration is necessary. However, a rather heavy application of nitrogen fertilizer should accompany the use of either millet or Sudan grass. Sudan grass is seeded at the rate of 25 to 30 pounds per acre. This crop makes a very rapid growth and may sometimes be used where soybeans have failed to grow.

Buckwheat.—The chief use for buckwheat as an orchard cover crop is in young orchards not yet in bearing. It may be seeded in the summer as late as the last of July and still mature a seed crop. If left standing, it will provide sufficient ground cover over winter to prevent erosion except in hilly orchards.

The following spring the orchard can be cultivated for a few months, and after cultivation has ceased there will be sufficient volunteer buckwheat to provide a good cover crop for the late summer. This process may be repeated for another year, thus providing a cover crop for 3 successive years from one seeding. Buckwheat is also a valuable source of honey during the fall months, which makes it have an added value as an orchard cover crop. The rate of seeding for a cover crop is 6 pecks per acre.

Lespedeza.—Korean lespedeza in an orchard serves as a permanent crop. It is, however, an annual plant and should be seeded rather early in the spring to allow the plants to develop seed before freezing weather the following autumn. At Wooster the plant does not attain enough height to make it an ideal cover crop for an orchard. Farther south in the State the growth is better. An area in one of the Station orchards seeded to lespedeza continues to produce a thick ground covering 4 years after the original seeding.

Weeds frequently grow much taller than lespedeza at Wooster and necessitate a special mowing in midsummer. Owing to the thick stand this plant

must be rated as a good ground cover rather than a rank-growing cover crop. In the southern half of the State lespedeza no doubt has a place as an orchard cover crop.

WINTER COVER CROPS

Rye and wheat.—Rye and wheat serve about the same purpose as cover crops in an orchard. The price of seed is a determining factor in the choice between the two. Rye makes a faster growth in the spring, and this is at once its greatest advantage and disadvantage as compared with wheat. If plowed under at the proper time in the spring, rye is quite satisfactory; on the other hand, if the plowing is delayed a little too long, frequently a matter of only a few days, rye may be injurious to the trees because of the amount of moisture taken from the soil. Rye is an ideal winter cover, especially where erosion is a problem. Wheat makes nearly as good a ground cover for the winter and develops more slowly in the spring. Eight to 10 pecks of either rye or wheat are about the rate of seeding for an orchard cover crop.

Rye and vetch.—Rye has frequently been used in combination with vetch as a cover crop in orchards, and when a good stand of vetch is secured this combination generally produces a heavy tonnage of green material. Some growers have followed the practice of saving sufficient acreage of the combined rye and vetch to thresh for seed in periods when the price of vetch seed was high. The main difficulty encountered in this practice is that the mass of rye and vetch is apt to lodge before maturity and make harvesting difficult or impossible. The rate of seeding for this combination is 5 to 6 pecks of rye and 15 to 20 pounds of vetch per acre.

Hairy vetch.—Vetch may be rated as one of the best cover crops for over winter for an orchard when a good stand is secured: however, inoculation is necessary to secure a good stand. Given a good stand the quantity of organic matter resulting is not only above the average for winter cover crops but is very high in nitrogen, containing from 3 to 4 per cent of nitrogen up to June 10 (6 years' unpublished data). It may be seeded any time after August 15. Because of a rather slow development in the spring, vetch should not be plowed under until the latter part of May. Like buckwheat, vetch may be allowed to ripen and reseed itself. The seedbed for hairy vetch should be well fitted. Twenty-five to 30 pounds of seed per acre are required when vetch is seeded alone.

Oats.—Oats are of course not an overwintering crop. However, they are useful as a fall cover crop, and, if seeded by mid-August, will usually make enough growth to provide protection for the ground over winter. Oats have the advantage of eliminating any danger of too rank spring growth. Eight to 12 pecks of seed per acre are required.

Crimson clover.—Crimson clover has been none too successful as an orchard cover crop at Wooster. It usually dies out badly during severe winters. When it does succeed it develops into a very good cover crop. It has a tendency to grow in a matted condition but not as rank as vetch. This crop may also be combined with rye or wheat. Fifteen pounds per acre constitute the recommended rate of seeding. It should be seeded by August 1.

Sweet clover.—The chief value of sweet clover as an orchard cover crop in Ohio is in the early life of the orchard and, where large quantities of humus are desirable, in bearing orchards. Sweet clover should be sown early in the spring

and plowed under the following spring about May. For best results, it should not be cut in the seeding year. If left much later than May it is pretty apt to compete seriously with the trees for moisture. Fifteen to 20 pounds of seed per acre are recommended (Fig. 10).

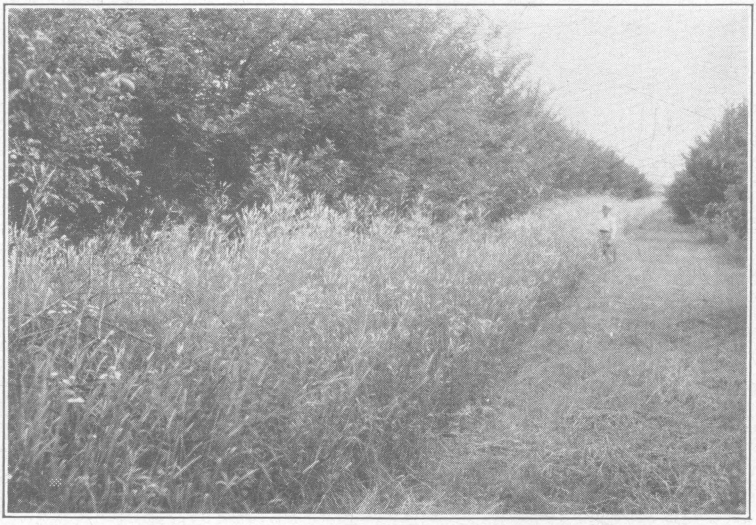

Fig. 10.—Sweet clover. Strip left for reseeding. Practice not advised except where irrigation is available

Alfalfa.—Alfalfa is not widely used in Ohio strictly as a cover crop. It is possible to use it much in the same manner as suggested for sweet clover and it would be preferable in every way except for seed cost. Generally the price of the seed has discouraged its use as an annual cover crop. It is more valuable either alone or as part of a mixture of other clovers and grasses for a permanent sod. Where alfalfa is used as a permanent cover crop a grower should be prepared to irrigate. Alfalfa may be seeded either early in the spring or early in August.

Clovers.—Red clover and alsike are both valuable crops to precede the planting of an orchard or to grow in the orchard during the early years. In bearing orchards these crops are useful mainly when grown in combination with other clovers and grasses and where the orchards are mown and the clippings used for mulch.

NEW ORCHARD COVER CROPS

Sesbania.—Sesbania is a native North American plant which has been used as a green manure crop in southern states. This is an annual and is seeded in the spring. Under favorable conditions it attains a height of 6 to 8 feet. The limited experience with this plant as an orchard cover crop at Wooster has not been very favorable. On muck soils in northern Ohio it has been more successfully grown than in the Station orchards. Wooster is too far north for Sesbania to succeed, and it is doubtful whether it can be recommended for even the southern part of the State.

Crotalaria.—The limited experience with Crotalaria as an orchard cover crop at the Station at Wooster indicates that this plant is not adapted to northern Ohio. Unfavorable weather conditions following the sowing of the seed may have partly accounted for a poor germination of seed. This plant is said to be grown successfully as a green manure crop in the southern states, and it has been grown with fair success in southeastern Ohio.

SEEDING FOR PERMANENT SOD

A great many grasses can be used successfully to secure a good permanent orchard sod. Orchard grass, timothy, bluegrass, red top, alfalfa, and the clovers may all be used for this purpose.

A mixture which has been used very successfully in the Station orchards in developing a permanent sod is 4 pounds of alfalfa, 4 pounds of red clover, 2 pounds of alsike, and 4 pounds of timothy. The addition of 3 or 4 pounds of bluegrass to the above combination is also recommended. This mixture should be sown by August 15 on a carefully prepared seedbed. Germination is better and more rapid if the seed is sown just following a shower.

TREATMENT OF SOIL IN PREPARATION FOR SEEDING COVER CROPS

A good seedbed is one of the main essentials in securing a good stand of any cover crop. A complete fertilizer at the rate commonly used in seeding wheat helps to secure a good stand (250 to 300 pounds of a 2-12-6 or a 2-14-4).

A detailed discussion of the adaptability of the cover crops in the foregoing list to different soil types is not possible here. It is of course assumed that the orchardist will not attempt to grow those crops which require soil having a near neutral reaction (such as alfalfa and sweet clover) on acid soils without first applying the required lime to produce the necessary reaction.

Many of the cover crops in the foregoing list require inoculation whether grown for orchard crops or for mulching purposes.

ORCHARD CULTIVATION IMPLEMENTS

The development of a number of cultivation implements during recent years has given the orchardist a wider selection of methods of soil management.

Tractors, especially of the track type, make it possible to use some of the larger disks and other cultural tools, as well as the larger sprayers, in most orchards.

Another implement which has more recently come into rather general use is a cultivator similar to an ordinary spring-tooth harrow but of much heavier construction. This harrow is built in sections and is popularly referred to as a "weed hog" (Fig. 1). The capacity of the power available determines the number of sections which may be used as a unit. This tool is especially adapted for the purpose of loosening up the soil in an orchard covered with a heavy sod and where complete destruction of the sod is not desirable. This tool is also particularly useful for strip cultivation in orchards where it is desirable to maintain a sod over part of the surface. An extension hitch may be used to permit the harrow to be driven well under the spread of the trees if this is desired. The surface of the soil is rather easily leveled by following this tool with a smoothing harrow or drag. The best time to use this tool is in early spring before the soil has packed or in late fall after the apple harvest.

There are a number of types of disk harrows available for use in orchards with a range of sizes to suit the power available (Fig. 1 and 8).

LAND-USE CLASSIFICATION

In its recent study of the soil conservation program, the Agricultural Adjustment Administration of the U. S. Department of Agriculture has attempted to classify the various uses of lands from the standpoint of conservation of the soil. Although orchards and vineyards are more complex than farm crops in their effect on the soil, such classification assists in clarifying the soil problem and may well be reviewed in this connection.

Practically all crops may be grouped under the three classes of (a) soil-depleting crops, (b) soil-conserving crops, and (c) soil-building crops. The first refers to all harvested crops that result in a net loss to the soil either because of opportunity for soil erosion or actual loss of organic matter, utilization of nutrients (chemical compounds) by the crop itself, and deterioration in soil tilth. Such crops are corn, potatoes, tobacco, sugar beets, oats, wheat, barley, rye, buckwheat, and soybeans used for hay. In the first class orchards and vineyards are likely to be included. The second refers to crops which neither exhaust the soil nor add to it, such as timothy and soybeans which are cut for seed and whose straw and leaves are left on the field. The third refers to such legumes as red and alsike clovers, alfalfa, and sweet clover (as a green manure).

Based on this concept of soil productivity, any soil program in the orchard which is definitely soil depleting, either through cropping or erosion or both, is a destructive one in the long run. Clean tillage (without cover crop), inadequate green manure crops, failure to fertilize and possibly lime would all fall in this category.

On the other hand, a system would be soil conserving or neutral if the orchard is kept in bluegrass or other nonleguminous sod and fertilized in such a way as to balance any normal loss of nutrients from the soil.

Lastly, a system should be classed as soil building only if there is a net gain in organic matter, soil tilth is bettered, and the common nutritive elements are replaced in an increasing ratio. Such a system would be tillage with luxuriant cover crops. This would usually mean the use of a complete fertilizer over the orchard area at least every 2 or 3 years, the use of lime on acid soils, and the additional use of nitrogen fertilizer or manure beneath the trees each year. Even with these precautions it is of doubtful value on hilly land where erosion occurs. Another system is sod mulch or grass mulch with the use of lime and chemical fertilizers or manures as needed.

These concepts have been considered in the earlier discussions of soil management methods for fruit production.

LITERATURE CITED

1. Ellenwood, C. W. 1930. The cost of developing an apple orchard. Ohio Agr. Exp. Sta. Bull. 456.
2. ———— and J. T. McClure. 1933. Tile drainage in the orchard. Ohio Agr. Exp. Sta. Bimo. Bull. 18: 163.
3. Magness, J. R. 1935. Soil moisture and irrigation investigations in eastern apple orchards. U. S. D. A. Tech. Bull. 491.
4. Oskamp, J. and L. P. Batjer. 1932. Soils in relation to fruit growing in New York. Part II. Size, production, and rooting habit of apple trees on different soil types in the Hilton and Morton areas, Monroe County. Cornell Univ. Agr. Exp. Sta. Bull. 550.
5. Partridge, N. L. and J. O. Veatch. 1931. The relationship between soil profile and root development of fruit trees. Mich. Agr. Exp. Sta. Quart. Bull. 14: No. 3, 200-207.
6. Salter, R. M., R. D. Lewis, and J. A. Slipher. 1936. Our heritage—the soil. Ohio Agr. Ext. Service Bull. 175.