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THE FIRST TWENTY YEARS RESULTS IN A MICHIGAN APPLE ORCHARD

CULTIVATION-COVERCROP vs. SOD-MULCH CULTURE

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Cultivation-Covercrop vs. Sod-Mulch Culture

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Considerable interest has developed among investigators and apple growers during the last two decades in the use of one or the other of the various systems of sod-culture in the apple orchard. This is particularly true in those areas where the annual precipitation provides sufficient moisture for profitable apple growing on the more favorable sites and soils. Observations in those areas indicated that the more or less universal practice of clean-culture in the orchard was seriously depleting the soil of fertility and organic matter. Water erosion likewise was becoming increasingly damaging on eroding sites. A protective soil covering such as sod, therefore, seemed to offer the greatest possibilities to reduce these undesirable soil losses to a minimum. However, sufficient evidence was not available to justify recommending sod-culture in Michigan apple orchards, although preliminary reports favorable to this system of orchard soil management were coming from other apple-producing states having climatic conditions somewhat similar to those in Michigan.

However, the use of any specific profitable soil cultural practices employed in one district may be less profitable or useless in another fruit-growing area having different climatic or soil conditions. Important limiting factors may exist in one territory but not in another. The amount and distribution of annual precipitation, type and fertility of the soil, and orchard site must be considered. Therefore, it is necessary that each locality must determine and employ those methods of growing the apple under their own conditions that will give the greatest acre-yield of marketable products at the lowest possible acre-cost of production and still conserve the soil resources.

In view of those facts, there remain, however, two fundamental factors for the successful growing of the apple that are important, regardless of the geographical location of the fruit growing area. These two factors over which the grower has some control, through the use of good cultural practices, are soil moisture and soil fertility. Apples cannot be successfully grown even on the best of sites and soils if soil moisture is a limiting factor. Likewise, the orchard will show a smaller margin of profit—or even a loss—where there is an abundance of soil moisture but where the fertility of the soil is inadequate. Therefore, it is important that fruit growers pay particular attention to the conservation of water and to the maintenance, or improvement, of soil fertility.

The amount of water lost by runoff on sloping land is largely influenced by the degree of the surface slope, the ground cover, the quantity and intensity of the rainfall, and the texture of the soil. The use of terraces, cover crops, or sod-culture in orchards, or the incorporation of large quantities of organic matter into the soil will materially reduce the amount of water lost by runoff and likewise reduce soil erosion losses.

However, much of the effort expended to conserve rain water for future use by the trees would be ineffective if the water reserve region, the subsoil, were so open or porous in structure as to permit soil water to penetrate freely to a depth beyond the reach of the tree roots. The subsoil must necessarily act as a source of reserve water during a period of drouth. The most valuable orchard soils are those whose subsoils are able to supply abundant moisture at such times. The texture should be fine enough to hold large quantities of water, but the structure should be open enough to permit tree roots to penetrate freely. Deep layers of clays or silts with a considerable admixture of sand or gravel are able to supply the needs of the trees under most conditions likely to occur in Michigan.

Much of the land planted to apple orchards in Michigan is more or less subject to the loss of water by runoff. The soil management practices employed in many apple orchards in this state have reduced water loss to a minimum, while in other orchards, handled under a different program, much rain water has found its way into nearby streams. Except for several intermittent seasons of near normal precipitation, most parts of Michigan suffered from a deficiency of summer rainfall during the last 10-year period covered by this report. The resulting detrimental drouth effects in the latter orchards during this period were manifest in considerable premature leaf-fall, restricted tree growth, and a larger percentage of undersized fruit at harvest time. These seasons of deficient summer precipitation have clearly indicated certain orchard practices that are particularly favorable for good tree production under adverse soil moisture conditions. Likewise, they have indicated which of the usual orchard soil management practices used were most valuable in reducing soil erosion and the loss of soil fertility. Of the various methods tried, none has been so favorably received by fruit men as has the sod-culture system—in particular, the sod-mulch system of soil management. Consequently, its adoption became more widespread in the principal apple-producing sections of the state.

PLAN OF EXPERIMENT

A block of apple trees growing on the Graham Experiment Station grounds near Grand Rapids, provided an excellent opportunity to compare the two most commonly used soil management practices in Michigan orchards—namely, cultivation-covercrop and sod-mulch—in regard to soil moisture, erosion, and general tree response. The trees in this block were planted at a spacing of 20 x 20 feet in the spring of 1919, and consisted of the Duchess, Grimes Golden, Baldwin, Stayman Winesap, and Northern Spy varieties. At the end of the 15-year period, diagonal rows of trees in both plots were removed to provide a spacing of 28 x 28 feet for the remaining trees. The soil in both plots is a silt loam of medium fertility, with a rather heavy clay subsoil. The land has a slight slope which does not exceed 5 per cent.

From the time of planting, one-half of the trees of each variety were maintained under the cultivation-covercrop system of soil management. These cultivated plots were thoroughly disked each spring, followed by dragging at two-week intervals until about the middle of July, at which time the ground was again disked and dragged in preparation for seeding the annual cover crop. The cover crops used were oats, rye, or rye and vetch; during the last five years, seedings of sudan grass, millet, or sorghum were made.

The remaining trees were put under a clover sod-straw mulch system in 1920. Owing to a poor "catch," this plot was reseeded to clover in the spring of 1921. During the following three years the clover was cut and removed from the plot. Following 1924, however, the clover was rapidly crowded out by bluegrass, which has since occupied the plot area. The bluegrass was mowed once or twice annually, raked up and placed under the trees as a mulch, until the last three years of this experiment when the grass was left in the swath because of the danger of injuring the trees with the hay rake. Additional mulching material, consisting of straw, damaged hay, or weeds, was placed under the trees from time to time in sufficient quantities to maintain a moderate mulch and keep down most of the grass growth under the spread

Fig. 1. A Duchess tree shortly after mulching. Note how the straw was kept away from the trunk to reduce danger of mouse injury. (Photograph taken March 28, 1939.)

of the tree branches. This required approximately two tons per acre annually. Wire guards were placed around the trees to protect them from mouse injury.

Annual applications of a nitrogenous fertilizer were made in equal amounts to the trees in both the cultivation-covercrop, and the sod-mulch plots. All other practices employed, such as pruning, spraying, and fruit thinning were the same under both systems of soil management.

Trunk circumference measurements were recorded annually for the 20-year period, while terminal shoot growth, fruit yields and size records were obtained after the trees came into bearing. Soil moisture determinations were made during the late summer and early fall of 1937, in both plots. The acre costs of soil maintenance under the two systems of soil management were calculated.

RESULTS

SOIL MOISTURE AS INFLUENCED BY CULTURAL PRACTICES

As previously stated, the predominantly dry summer weather experienced in Michigan during the last 10-year period covered by this report was particularly favorable for determining the merits of the two cultural practices in conserving snow and rain water. The results of the soil moisture determinations made are presented in Table 1. At the bottom of the table are shown the amounts of rainfall recorded during the same period by the United States Weather Bureau Station located in Grand Rapids. The latter records partially explain the moisture fluctuations of the soil for the different sampling dates.

The Duchess and Northern Spy plots were selected for these determinations because the former were the smallest trees in the project, while the latter were larger and apparently had the greatest leaf area of any of the trees under observation. Inasmuch as it was believed that transpiration might be roughly proportional to leaf area, these two varieties would probably show the widest extremes in moisture requirements.

Periodically, as shown by the dates in the table, five individual soil borings, each to a depth of 5 feet, were made in both of the Duchess plots, and likewise in the two Northern Spy plots. The figures given represent the average percentage of soil moisture, based on the dry weight of the five soil samples, at the depths indicated. The soil moisture differences between the Duchess and Northern Spy plots, under the same soil cultural systems, are only slightly in favor of the former, indicating that the larger Northern Spy trees required more moisture, possibly because of their greater size and leaf area.

The greater soil moisture in the sod-mulch plots can partially be attributed to the two soil coverings—namely, sod and mulch. These naturally slow down any movement of surface water, thereby increasing the time during which the water may penetrate the surface soil. Further, the soil under sod and protective mulches, is much more porous, which accelerates the movement of rain or snow water into the soil. In contrast, the clean-cultivated soil offers little or no resistance to the escape of precipitation water. Its less porous condition,

Table 1. The Percentage of Soil Moisture in Consecutive Foot Depths in the Clean Cultivated and Sod Plots from Aug. 2 to Oct. 18, 1937.

		August				September				October			
Date		2	3	16	18	4	4	17	20	1	2	15	18
Treatment		Sod	Cult.	Sod	Cult.	Sod	Cult.	Sod	Cult.	Sod	Cult.	Sod	Cult
	(feet)												
Duchess	0-1	9.0	5.5	13.9	8.9	12.5	4.8	12.4	7.1	13.5	8.5	14.4	13.3
	1-2	11.3	8.2	12.8	8.0	11.6	6.8	13.2	8.1	13.2	7.8	12.7	13.0
	2-3	12.8	6.9	12.4	9.0	12.3	7.2	13.6	7.8	13.3	7.8	12.7	11.2
	3-4	11.8	6.9	11.9	8.2	11.5	7.1	12.5	8.1	12.1	7.2	11.4	9.7
	4-5	11.7	7.3	12.5	8.0	11.6	6.9	12.3	6.5	11.8	7.3	11.3	8.6
	Per cent	11.3	7.0	12.7	8.4	11.9	6.6	12.8	7.5	12.8	7.7	12.5	11.2
		August				September				October			
		4	5	25	26	14	16	28	30	13	14		
Northern Spy	0-1	9.6	6.5	14.3	10.4	8.6	6.5	13.3	8.4	14.9	9.2		
	1-2	7.7	7.6	12.0	10.5	8.9	6.2	9.8	8.8	11.5	8.2		
	2-3	10.1	8.4	11.3	8.9	10.2	5.6	10.6	8.8	11.2	10.1		
	3-4	9.8	6.5	11.5	7.8	10.8	5.6	11.5	7.1	11.0	9.6		
	4-5	10.5	6.2	11.4	7.3	10.8	5.4	11.1	6.8	10.9	9.1		
	Per cent	9.5	7.0	12.1	9.0	9.9	5.9	11.3	8.0	11.9	9.2		

Rainfall	August		September		October	
		(inches)		*(inches)*		*(inches)*
	3-4	0.18	3-4	0.04	5	0.35
	7-8-9	.43	10	.28	9-10-11-12-14	.44
	11-12	1.03	14-15-16-17-18	.55	17-18	1.24
	17-19-20-21	2.47	24-25	1.54		
			30	.03		

brought about by a lower humus content, compacting by heavy orchard equipment, and the beating down and puddling of the surface by dashing rains greatly retards the free penetration of snow and rain water. Also, it has been observed that the soil in the cultivated plots froze at an earlier date and to a greater depth than it did under the protective covers of sod growth or mulch. Consequently, the longer period of frost in the soil of the cultivated plots would retard the free downward movement of water over a longer period of time than the less frozen soil in the sod-mulch plots.

The figures presented in Table 2 show the depth to which the soil was frozen on March 21, 1939. The determinations were made at equal distances from the tree trunk on the north and south sides of the trees, in the clean-culture plots and under the mulch in the sod plots. Additional frost-line depths were determined under the grass sod, the areas selected being the slight ridges and depressions on the less level

Table 2. Depth in Inches to Which the Soil was Frozen on March 21, 1939 in Clean-cultivated Soil, Under a Straw Mulch, and Under a Bluegrass Sod.

Location	Cultivated		Sod-Under Mulch		Grass Sod	
	North Side	South Side	North Side	South Side	High Spots	Low Spots
Frost depth	6.6	5.2	3.1	1.7	3.4	2.0
Average	5.9		2.4		2.7	

soil surface. Adjacent trees, under which a recent mulch to a depth of several inches was applied, showed the soil to be frost-free on the same date.

SOIL EROSION AS INFLUENCED BY CULTURAL PRACTICES

Emphasis has been placed during recent years on the prevention or reduction of soil erosion by various soil agencies, and it should also be given serious consideration by the fruit grower. The gradual removal of the fertile surface soil by wind and water from the orchard will manifest itself sooner or later in smaller tree yields and lower quality of fruit. Only fertile soils, with an adequate water supply, are capable of producing heavy crops of high quality apples at a low acre-cost.

Exposed tree roots as shown in Fig. 2 result from surface erosion, a condition that can be found in many cultivated commercial apple orchards in Michigan where the cultivation-covercrop system of soil management is followed. Such soil losses are notable evidence of the havoc erosion produces. Heavy soils of fine texture are less pervious to water penetration than are soils of coarse texture such as sands. In addition, these heavy soils when cultivated year after year offer greater resistance to water penetration owing to (a) their lower humus content, (b) the closing of the soil pores by heavy dashing rains, and (c) their compacting by heavy cultural and spray equipment. The result is that most of the water from such heavy rains flows down the slopes, taking with it valuable humus, soil particles, and fertility. Similarly, rains during late winter or early spring, when the unprotected surface soil of the cultivated orchard thaws to a depth of an inch or more, will often remove a large part of the unfrozen super-saturated soil, a loss which does not occur in the sod-protected orchard.

The protective influence of ground cover such as mulches, sod, or a heavy cover crop growth, will materially reduce the depth of freezing and surface erosion. Such a ground cover can be rather readily produced by the use of heavy-yielding cover crops in the young apple orchard under clean cultivation, until the trees become 10 or 15 years of age. Cover crops as German millet, sudan grass, amber sorghum, or a mixed seeding of these, have produced heavy protective growth when seeded during the first week in July. However, after the trees grow larger they offer increased competition to the cover crop for moisture,

Fig. 2. Stayman Winesap tree under clean cultivation showing effect of soil erosion. Such shallow roots are more subject to injury by cultural equipment and low winter temperatures.

fertility, and sunlight. In consequence, the growth of the cover crop gradually decreases to the point where it no longer adds any appreciable amount of organic matter, nor provides adequate protection to the soil. When this condition arises such supplementary soil management practices as covering the soil lightly with strawy manure, peat, hay, or straw during late fall, should be used to reinforce the protection supplied by the reduced cover crop, and keep the loss from erosion at a minimum.

TREE GROWTH AS INFLUENCED BY CULTURAL PRACTICES

The growth responses of the trees to the two cultural practices previously described, are presented in Table 3. The data present the average trunk circumferences of the trees at the ages of 10, 15 and 20 years. In addition, average terminal shoot growth measurements of the same trees are given for the years of 1928 to 1938 inclusive, the last 11 years of the 20-year period.

At the end of the tenth growing season the average trunk circumference of the trees grown in the cultivated soil were considerably larger than the average of those in the sod. The differences are shown in column 2, Table 3. However, examination of the annual trunk circumference measurements reveals that during the last few years of this first 10-year period the annual trunk circumference increases of

Table 3. Rate of Trunk Circumference and Terminal Shoot Growth Increases of the 20-year-old Apple Orchard.

(Measurements given in inches)

		Trunk Circumference							Terminal Shoot Growth Totals of Annual Averages		
		10 years (1919 to 1928)		15 years (1919 to 1933)		20 years (1919 to 1938)		Increase 1929 to 1938 Inclusive	Growth 1928 to 1933 Inclusive	Growth 1928 to 1938 Inclusive	Difference in 1938
		Trunk circumference	Difference	Trunk circumference	Difference	Trunk circumference	Difference				
Duchess	Cultivated	15.1	+3.4	20.7	+1.9	25.5	+1.1	10.4	49.	66.8	
	Sod-mulch	11.7		18.8		24.4		12.7	50.	73.5	+6.7
Grimes Golden	Cultivated	16.8	+2.4	23.3	+1.3	31.5	+1.6	14.7	54.3	82.2	
	Sod-mulch	14.4		22.0		29.9		15.5	55.5	84.1	+1.9
Baldwin	Cultivated	18.1	+2.8	24.7	+0.8	32.6		14.5	63.7	89.	
	Sod-mulch	15.3		23.9		33.9	+1.3	18.6	66.1	98.6	+9.6
Stayman	Cultivated	17.1	+1.7	23.9	+0.3	30.9		13.8	68.3	94.7	
	Sod-mulch	15.4		23.6		32.6	+1.7	17.2	72.1	102.7	+8.0
Northern Spy	Cultivated	17.7	+2.7	24.3	+1.1	32.4		14.7	50.	74.5	
	Sod-mulch	15.0		23.2		32.8	+0.4	17.8	52.7	81.9	+7.4

the trees in the sod had nearly equalled those of the trees in the cultivated plots. Nevertheless, it was not until the eleventh growing season that the sod trees took the lead, except for the Duchess variety which first showed greater growth for the sod trees the twelfth season. By the end of the fifteenth year the previously greater growth differences in favor of the cultivated trees had been reduced, inasmuch as the sod trees were now making the larger annual trunk circumference increases. Except for the Grimes Golden variety, the same holds true again for the end of the 20-year period, at which time the Baldwin, Stayman Winesap, and Northern Spy varieties in the sod plots, had a greater total trunk circumference than the same varieties in the cultivated plots. The figures in columns 7, Table 3, represent the average total trunk circumference growth made by all trees, for the years of 1929 to 1938, inclusive, under the two methods of soil management.

The total terminal shoot growth made by these same trees for the years indicated, are presented in columns 8 and 9, Table 3. The total differences for the 11-year period are shown in column 10, Table 3. Although the differences are not great, they nevertheless indicate a definite tree response in favor of the sod-mulch plots.

TREE YIELD IN RELATION TO CULTURAL PRACTICES

Individual tree yields were recorded during the 20-year period for all trees growing under both systems of soil management. The data obtained were converted to an acre-yield basis and are presented in Table 4. As in the case of the greater trunk circumference increases, the trees under clean cultivation also showed a greater yield for the first 10-year period than the trees growing in the sod-mulch plots. However, by the close of the 15-year period the total production for all varieties in the sod-mulch plots, except Duchess, was greater per acre than for the trees in the cultivated plots. This was also true of the 20-year period when all of the trees grown in the sod, including Duchess, showed heavier total production of fruit than the cultivated trees. On a percentage basis, the Duchess trees in the sod-mulch plots produced 7.4 per cent more fruit per acre during the period than the same variety under cultivation, the Grimes Golden 15 per cent more,

Table 4. Average Acre Yield in Bushels of the Five Apple Varieties at Different Age Periods.

		Duchess	Grimes Golden	Baldwin	Stayman Winesap	Northern Spy
Cultivated	10 years............	251	633	93	404	0
	15 years............	1218	1724	1104	1590	670
	20 years............	2271	4297	2566	3105	1979
Sod	10 years............	140	240	85	186	0
	15 years............	1153	2180	1259	1732	1353
	20 years............	2439	4944	3639	4106	3678

Baldwin 42 per cent, Stayman Winesap 32 per cent, and the Northern Spy 86 per cent more. The data giving total production per acre for the different periods, incidentally show which of these varieties may be expected to come into heavy production earlier in Michigan, on the soil type and with the cultural practices employed in this experiment.

INFLUENCE OF CULTURAL PRACTICES ON FRUIT SIZE

During the years 1931 to 1938 inclusive, fruit size records were obtained in all seasons when sufficiently large crops of apples were produced on each variety, in both plots, to provide adequate samples for this purpose. During this eight-year period the apples of the Duchess variety were size graded for four years, Grimes Golden eight years, Baldwin seven years, and the Stayman for five years. Due to the ease of bruising, the Northern Spy apples were not graded for size differences. The three different sizes into which the fruit was graded were, 2½ inches and larger, 2½ to 2¼ inches, and from 2¼ to 2 inches. The percentages of fruit falling below 2 inches in diameter were of minor significance, and are not included in the data. Likewise, the fruit size records obtained on all apples lying on the ground at harvest time are excluded from the total percentages tabulated in Table 5.

Table 5. Average Percentage of Fruit from the Clean-cultivated and Sod-mulch Plots Falling into the Various Sized Groups.

Grade Sizes		Duchess	Grimes Golden		Baldwin	Stayman Winesap	Average for all varieties
Cultivated	2½-+	53.2	21.7	53.8	51.4	25.	47.1
	2¼-2½	30.3	32.1		28.5	41.1	36.9
	2- 2¼	16.4	46.1		20.1	33.9	15.9
Sod	2½-+	88.5	45.8	80.	89.9	81.3	84.2
	2¼-2½	8.2	34.2		7.8	14.5	13.7
	2- 2¼	3.2	20.		2.3	4.2	2.0

With the exception of Grimes Golden, the Stayman trees in the cultivated plots produced the smallest percentage of fruit exceeding 2½ inches in size, while the Duchess and Baldwin varieties had about an equal percentage falling into this sized group. In the case of Grimes Golden, the former Michigan A grade size requirement was a minimum of 2¼ inches. The total of the percentages of fruit exceeding this minimum size for this variety, equals the percentages of the Duchess and Baldwin meeting their respective A grade size requirement. The percentage of fruit from the sod plots that grades into these same size groups is much larger than the former plots. On a percentage basis, the Duchess trees in the sod plots yielded 67 per cent more A grade fruit, the Grimes Golden 48 per cent, Baldwin 43 per cent, and the Stayman 224 per cent more than trees of the same varieties grown in the cultivated plots. The figures on the extreme right side of the table represent the average total percentages of all fruit graded for size, that fall into the various grade sizes formerly required for these varieties of apples in Michigan. A comparison of these figures reveals that approximately 79 per cent more total fruit meeting the A grade requirements was produced in the sod plots than in the cultivated plots.

INFLUENCE OF CULTURAL PRACTICES ON FRUIT COLOR

Although no data were obtained on the actual percentages of fruit that met the established color requirements for the several grades of varieties in question, frequent observations indicated that the fruits produced in the sod plots, except Grimes Golden, had slightly more of their total area covered with a somewhat brighter red color than those in the cultivated plots. The fruit from the former plots also had a better finish and was more attractive in appearance.

ACRE-COST OF SOIL MAINTENANCE

The annual soil maintenance cost of another block of trees on the station grounds, handled under the same system of soil management as these apple trees, amounted to $10.60 per acre for the cultivation-covercrop area. This includes the disking and dragging of the soil, as previously described, and the cost of the annual cover crop seed and its planting. The annual cost for the sod-mulch area totaled $4.50 per acre, which included the expense of mowing, raking and spreading of the grass under the trees. However, additional material such as straw, weeds, or damaged hay was added from time to time and spread under the trees, inasmuch as the material grown in the orchard was not sufficient to maintain an adequate mulch. This additional cost, over the second 10-year period, amounted to approximately $5.75 per acre annually, and included the value of the mulch material, its hauling and spreading. The total of these two expenditures was $10.25, only slightly less than the annual acre maintenance cost of the cultivation-covercrop system. The figures presented do not include the cost of the nitrogen fertilizer applied annually, nor the cost of application since the trees under both systems of soil management received equal amounts. Any increase in the purchase price of mulching material, or heavier annual mulching of the trees than was practiced in this experiment, would automatically increase the acre maintenance cost of the sod-mulch system over that of the cultivation-covercrop system.

GENERAL OBSERVATIONS ON THE TWO SYSTEMS OF SOIL MANAGEMENT

During the progress of this experiment several observations, not covered by specific data, were made which provide some additional information on conditions that can be expected to prevail in apple orchards growing under the two systems of soil management, under conditions similar to those in this experiment.

During the last few years of this experiment the leaves on the trees in the cultivated plots were somewhat smaller in size, and had

Fig. 3. Baldwin tree under clean cultivation, showing effect of soil erosion. Such shallow roots are more subject to injury by cultural equipment and low winter temperatures.

a slightly yellowish cast, while the leaves on the trees in the sod-mulch plots were larger with a darker green color. It was also observed during this same period, that foliage injury caused by spray materials, was more severe on the trees in the former plots, and a consistently earlier leaf fall was more or less an annual occurrence.

The ability of a mulch to absorb water and retard its runoff was demonstrated at this station with a representative 15-year-old Baldwin tree having a limb spread of 22 feet. The mulch under this tree was only moderately heavy, and extended to the outer spread of the branches. Over a period of one hour, 700 gallons of water were applied to the mulch before any water emerged from beneath its outer edge. In addition, because approximately one-half of the total area in the sod plots is covered by mulching material, it is reasonable to assume that a water absorbing mulch of this type would greatly reduce the amount of possible runoff water, even from an exceptionally heavy and rapid rainfall. This would likewise be of considerable additional importance in orchards growing on steep slopes where some surface water loss might occur on soil covered only by a sod growth. Such protective soil covering is also very valuable in reducing soil water losses by evaporation, especially during periods of intense heat or drying winds.

The frequency with which additional mulching material should be applied or the depth to which the mulch should be maintained, depends on several factors, such as, availability, kind, and cost of the material applied in the orchard. The maintenance of a comparatively light mulch, but sufficiently heavy to retard most of the grass growth under the spread of the tree branches, will be of material aid in reducing the competition of the grass for moisture and the reduction of the loss of water by evaporation and runoff. Examination of heavy mulches following a rain which was of sufficient amount to penetrate to tree roots in cultivated soil, revealed that in many cases the rain failed to wet the heavy mulch to the soil below. This would indicate that trees growing under these conditions may receive but little benefit from all but the heavier rains, and would be compelled to obtain the necessary moisture for tree and crop development from the lower soil layers. It is therefore believed that light applications more frequently applied are probably preferable to less frequent heavy applications. When to mulch the trees will be largely determined by the amount of available time the grower has at his disposal and the period the mulching material is available. Observations indicate that fall or winter mulching is most desirable.

DISCUSSION

Commercial apple growers, almost exclusively, follow the practice of maintaining their newly set orchards under the cultivation-cover-crop system of soil management, until such time that it appears the trees are sufficiently well established to withstand the competitive influence of a grass sod. Opinions of these growers however, differ as to when this period has been reached. Some hesitate to change over to the sod-mulch system before the trees reach the age of 20 or 25 years, while others seed their orchard to grass at an earlier age. In view of the data presented on the growth and yield of the trees in this experiment, it appears entirely feasible that the sod can be estab-

Fig. 4. Apple trees in sod which received an additional mulch approximating 2½ tons per acre a few months previously. Trees are set 28 x 28 feet. (Photograph taken March 28, 1939.)

lished at a much earlier stage than was formerly thought advisable, without appreciably changing the rate of tree growth and fruit production. It is believed that the value of the somewhat greater growth and yields obtained in the young orchard under the clean culture system, by delaying the change-over to the sod-mulch system, will not equal the value of the additional soil and fertility lost during the same period by erosion, particularly on erosive soils and steep slopes. Tree growth can be increased, in a large measure, by applications of the necessary fertilizer elements, but the cost of replacing the lost soil with its humus and fertility in the orchard, will much exceed the value of any extra fruit produced. The more erosive the soil type and the steeper the slope, the earlier is the date at which the cultivated orchard should be seeded down to grass.

Several disadvantages are also associated with the use of mulches in the sod orchard. The presence of a mulch under the trees provides attractive winter quarters for mice from surrounding areas, frequently resulting in heavy mouse concentrations with the constant danger of subsequent girdling of unprotected tree trunks. Protective devices must be maintained around the trunks and an intensive poisoning program followed during the late fall and winter months to keep rodents under control. Possibly owing to the comparative absence of protective material during the winter in the cultivated plots mouse injury to the trees has been less severe. Further, the danger of fire damage to the trees is increased in the sod-mulch area during dry periods. However, the probability of serious losses from this source can be reduced by the maintenance of cultivated strips or fire lines running through the orchard at frequent intervals. These fire lines should be made to cross the slopes following the contour of the land, otherwise they may lead to serious gully formation owing to their bare and unprotected surface.

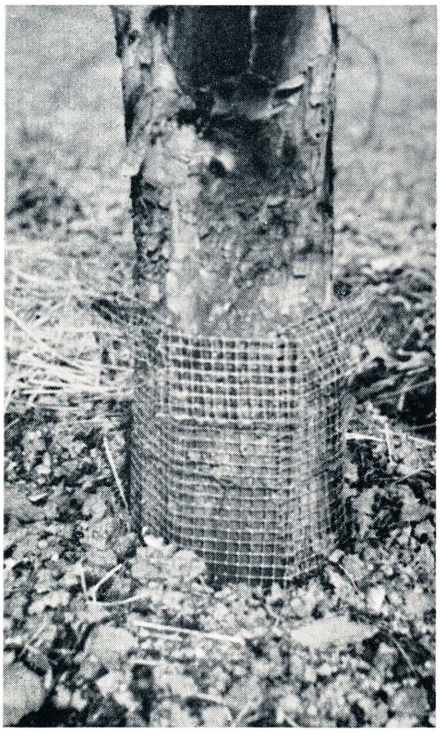

Fig. 5. An apple tree protected against mouse injury in the sod-mulch plots. Cinders and wire mesh extend to a depth of 8 inches below the soil surface.

Materials most frequently used in Michigan for mulching apple trees are straw, alfalfa, sudan grass, corn stalks and peat. These materials, with the exception of alfalfa, have a rather high-carbon and a low-nitrogen content, and consequently decomposition takes place at a slower rate in the absence of an additional nitrogen supply. On the contrary, alfalfa decomposes very rapidly because it is higher in nitrogen and lower in carbon and quickly releases most of the nitrogen and other plant nutrients stored within its structure. Apple growers who have been applying green or partially dry alfalfa direct from the field as an orchard mulch during late June or early July, frequently complain of the poor color of their fruit in the fall. The additional nitrogen made available to the trees from the decomposition of the alfalfa mulch, acts as an additional application of a nitrogen fertilizer during the summer season, a practice which is not generally accepted or recommended as a desirable procedure by Michigan apple growers.

At harvest time the soft spongy condition of the mulch acts as a cushion for the fruit that drops from the trees, thus greatly reducing bruising, and thereby permitting the salvaging and sale of additional apples after the harvesting operations are completed. This is particularly true of McIntosh and other varieties which tend to drop rather severely during hot or windy periods.

From the foregoing discussion and data it should not be inferred that the sod-mulch system of soil management can be employed indiscriminately in all Michigan apple orchards with any assurance of greatly increased yields and profits. The type, fertility, and depth of soil, also the slope of the land, will individually or collectively, determine whether this method of handling the orchard soil may be used to advantage in any given apple orchard. Orchards planted on the lighter types of sandy soils lacking in water-holding capacity, no doubt may suffer severely during dry seasons from moisture deficiency aggravated by the demands of the grass growth for moisture. In contrast, soils of medium to heavy loam types, underlain by a water-retaining sub-soil of good depth, are capable of supporting grass growth without materially affecting satisfactory tree performance. Where such soils are found, the data presented prove the sod-mulch system to be an economical and profitable method of management.

SUMMARY

As observed under the conditions of this experiment both systems of soil management have their merits and faults. The cultivation-covercrop method consistently favored the loss of a large part of the water resulting from rapidly melting snow and dashing rains by surface runoff, while the very effective soil cover in the sod-mulch plots virtually prevented all such water loss, permitting the water to penetrate and be stored in the soil. Soil moisture determinations made to a depth of 5 feet, from August 2 to October 18 in 1937, showed that the soil in the sod-mulch plots contained an average total of 47 per cent more moisture during this period than the soil in the cultivation-covercrop plots. Erosion of the soil is likewise becoming serious in the latter plots as evidenced by the exposure of many tree roots, and the lighter color of the surface soil. No erosion can be detected in the sod-mulch plots.

The cultivation-covercrop method can be expected to grow larger and more vigorous apple trees during the early life of the orchard. During the first 10-year period the trees under clean culture had the

larger trunk circumferences and produced more fruit per acre, but at the end of the 20-year period the trees in the sod-mulch plots showed the larger tree measurements and produced the greater total acre yield. The fruit from the latter plots had slightly more color of a brighter shade, and graded out approximately 79 per cent more A grade size than did the fruit from the cultivated plots.

The annual acre maintenance costs for the two systems of soil management, as used in this experiment, were only slightly less for the sod-mulch plots. However, any increase in the cost, or the amount of mulch material applied per acre over that here discussed would equal or exceed the acre maintenance cost of the cultivation-covercrop system of soil management.

The advantages of the cultivation-covercrop system are not of sufficient magnitude to warrant its further use after the apple trees become well-established in those orchards having conditions which compare favorably with those prevalent in this experiment. The better tree performance in the sod-mulch plots indicate that this method of soil management should also prove the more profitable in many other similar Michigan orchards now being grown under the clean cultural system.