ORCHARD CULTURE.

A COMPARISON OF DIFFERENT METHODS AS APPLIED IN THE CARE OF THE APPLE ORCHARD.

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Agricultural Experiment Station.

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 171. MARCH, 1906.

ORCHARD CULTURE.

BY W. J. GREEN AND F. H. BALLOU.

A COMPARISON OF DIFFERENT METHODS AS APPLIED IN THE CARE OF THE APPLE ORCHARD.

The subject of orchard culture, within quite recent years, has come to be one in which all thoughtful growers of tree fruits are greatly interested. That this is true is indicative that our new century shall be marked by substantial progress in horticulture. The deeper study of the principles of economic soil culture cannot but impress the practical student that conservatism is the basis of true progress. Abundant yields of fruit are, of course, to be earnestly desired and persistently striven for, but the careful culturist is becoming more and more insistent that the cultural plan adopted in bringing about a fruitful reward, shall be such as will not only maintain, but increase and improve, the fertility and physical character of the soil upon which such crops are grown. This he owes not only to himself and to his soil, but to those who are co-dependent and to posterity.

Individual culturists, laboring under widely varying conditions and circumstances, as might naturally be supposed, have not developed a generally accepted or universal idea or standard of what good culture, in a literal sense, should be. Upon one hand, it has ever been that our careful orchardists, favorably situated, have

taken a justifiable pride in keeping their methods above the reproach of equally scrupulous neighbors. Thus, with naturally fertile, level land upon which to pursue these ideal methods of persistent (may we not truly, in some instances, say merciless?) soil stirring, without any special concern as to the maintenance of fertility or the addition of vegetable matter in any form, unintentional, friendly rivalry has led to extremes, the sequel of which has already become apparent, in certain sections, in lifeless soil, diminished productiveness, even dead and dying trees and orchards.

Upon the other hand, orchardists who are situated in the hilly sections of our state, and in which is located some of our most excellent orchard land, know by short, sharp, bitter experience that annual plowing and cultivation of their steep, orchard land is absolutely impracticable—a method of culture not to be considered for an instant by the conservative fruit-grower of the hills—as flooding rains annually carry away hundreds and thousands of tons of soil that can never be replaced by any known cultural means. Indeed, the seasons are sometimes such that the soil is carried away by washing almost as fast as it is broken up and mellowed by the cultivator.

It is to be deeply regretted that the orchardists of our own and adjoining states, and of the country at large, who are favored in following out their ideals in orchard culture and management by level land, where plowing and cultivation may be done with labor-saving tools and with comparative ease and safety, do not comprehend nor appreciate the conditions under which the orchardists of the hilly sections labor, nor the obstacles and difficulties to be met and overcome where Nature has left a more rugged impress of her hand. And it is too often with a disposition to consider that the slothful has been unduly rewarded, that the radical clean-culturist finds himself compelled to acknowledge the orchardist from the hills as a worthy competitor in the great fruit markets of our country.

Without further discussion of the attitudes of believers in and followers of seemingly opposed methods of culture which, when consistently and conservatively applied, bring about practically the same results, let us hope that less and less in evidence will become the spirit of prejudice which heretofore may have been entertained concerning particular ways and means which failed to win our personal approbation. Rather let us avail ourselves of the present day opportunities and necessity of considering these vitally important questions broadly, generously and sympathetically.

The problem of orchard management leads directly into the earnest study of the better and safer methods and practices of soil culture as adapted to orchard work; and this study, if it be impartially pursued in connection with practical experimental and investigational field work, cannot but impress the student with the truth that *good culture*, in the broadest meaning of the term, does not necessarily imply a continuous turning and stirring of the soil mechanically; rather does it mean the bestowal of such care and the application of such methods as, under widely varying conditions and circumstances, will bring about the greatest results in crop production with the least possible loss of the essential constituents and necessary physical characteristics of the soil.

It is generally well known that fertile soil of good character or texture embraces two substances—organic and inorganic. The organic substance, of which nitrogen is the most important plant food element, is derived from decaying vegetable matter. The inorganic substance, of which potassium and phosphorus are the most important plant food constituents, is derived from mineral sources—chiefly from disintegrating rocks which originally composed the earth's crust. So long as these vegetable and mineral elements are maintained within the soil in undiminished supply, either by *natural* or *artificial* means, the soil will retain its original fertility and good physical condition. The retention or perpetuation of these necessary elements and characteristics of the soil by natural means—by the plan of Nature—demands that the soil remain unbroken; that vegetation continue to luxuriate, die, fall, decay and return to the soil. That this *natural* means of maintaining the fertility and original physical character of the soil is practicable and consistent with *high culture* of fruiting trees, plants and vines, is affirmed by one class of culturists and opposed by another.

Upon the other hand, in order to retain the fertility and good physical condition of the soil under regularly repeated plowing and cultivation, *artificial* measures must be employed. For not only will the organic, vegetable or nitrogenous matter be, in time, exhausted through the "burning out" process of decomposition incident to and hastened by continuous, clean cultivation, but the store of inorganic substances—phosphorus and potassium—will become lowered by repeated cropping under a method which does not especially favor the gradual unlocking and rendering available of the mineral plant food which is liberated by the decomposition of the store of vegetable fiber which should continally be replenished, and which is *not* replenished by continuous, clean culture.

season after season. The retention of fertility and a good physical condition of the soil by *artificial* means properly suggests that short, early, annual periods of clean culture be followed by the sowing of some crop—preferably of leguminous plants such as the clovers, vetches, cow peas or Soy beans—which will make a good growth during late summer and early autumn, cover the surface of the ground in winter and be plowed under the following spring, to be, in turn, followed by the recurring period of cultivation and later, again, by the sowing of the annual cover-crop.

Therefore *consistent* care and management of the orchard soil is invariably planned to provide for the restoration to the soil of the elements of fertility taken away by cropping, and to perpetuate the peculiar and necessary soil texture that is only to be found where decomposed vegetable matter is present in ample proportion.

The awakening interest in these phases of orchard management received an impetus and was brought to an issue when, within the past ten years, certain prominent and successful orchardists of New York and Ohio, namely, Grant Hitchings and F. P. Vergon, came boldly and almost simultaneously to the front as champions of the so-called "sod-mulch" or "grass-mulch" methods of apple orchard culture. The idea was regarded by life-long believers in and advocates and teachers of scrupulous, clean cultivation as "cultural secession"—pure and simple. However, so ardently and practically did the gentlemen referred to support their claims for *mulching* by quite regularly producing and exhibiting apples of the highest degree of perfection in color and quality that others, who were unprejudiced, foresaw the possibilities for adapting such a plan to particular situations where annual plowing and cultivation are difficult, or even an utter impossibility; became interested and were willing to systematically investigate the matter for the public good.

Thus it came about that, after noting the success of Mr. F. P. Vergon, of Delaware County, Ohio, the Ohio Experiment Station instituted the apple orchard culture test plots which, in the year 1905, furnished notes and photographic illustrations for the following preliminary report which is designed to be *suggestive* rather than *conclusive*.

THE EXPERIMENT STATION'S ORCHARD CULTURE TEST PLOTS.

In the Spring of 1900 was planted a block of one hundred and sixty apple trees—eight rows of trees with twenty trees in each row. Of these there were two rows each of Jonathan and Grimes Golden, extending the entire length of the plot, which, in this report,

are the only varieties considered, as the other sorts, which it was desired to plant, could not be obtained at the time, hence trees for top working were set, and these have not yet come into bearing. This block of trees was divided, crosswise, into four plots of forty trees each. Each individual plot, therefore, is an exact duplicate of the other as to varieties and the order in which they stand. The soil upon which these trees are growing is quite uniform as to fertility and general character. The surface of the ground slopes gently to the west, affording good, natural drainage. In Fig. 1, which follows, is shown the plan of the block or area devoted to culture work, its disposition into plots, and the distribution of varieties.

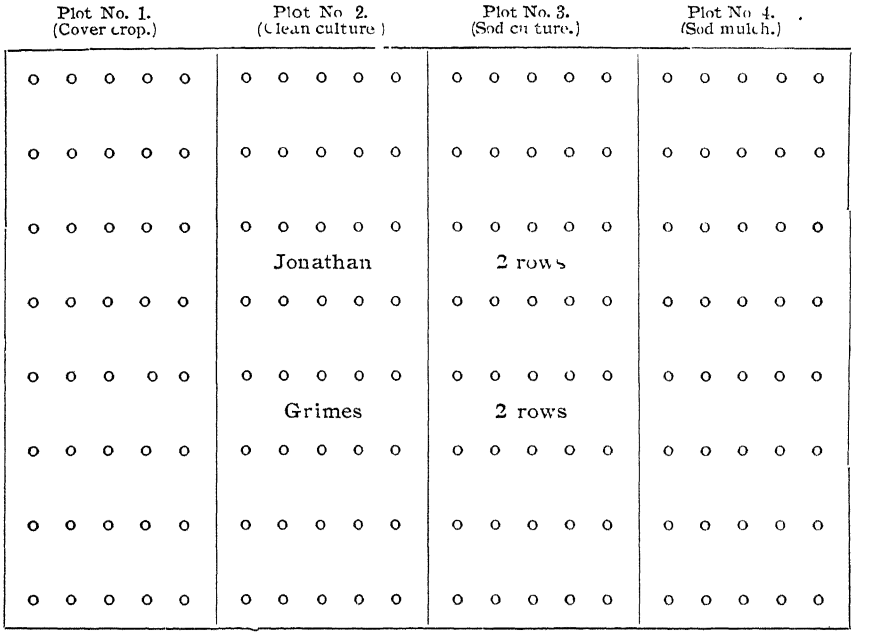


FIG. 1.

Briefly stated, plot No. 1 is the "Cover-crop plot." No. 2 is the "Continuous clean culture plot." No. 3 is the "Sod-culture plot", while No. 4 is the "Sod-mulch" or "Grass-mulch plot."

THE DIFFERENT METHODS OF APPLE ORCHARD CULTURE IN DETAIL.

THE COVER-CROP METHOD.

This method is safe, practicable and excellent while the orchard is young, where the ground is level or comparatively so, or even upon a surface that is quite sloping or irregular, providing the soil be not of such a character as to wash readily by flooding rains. In de-

tail, the cover-crop culture of orchards consists in plowing or, preferably, disking the ground as early in the spring as the soil is in condition to be easily worked. When plowing is practiced it is well to annually reverse the order of breaking the ground, throwing the soil toward the trees one year and away from them the next. This tends to keep the general surface from becoming irregular much longer than when the same order of plowing is followed year after year. As plowing close up to the bodies of the trees cannot be safely done through danger of injury by the traces bruising and mutilating them, it is almost necessary to have a one-horse breaking-plow to finish up the rows.

Following the plowing or disking,the surface is kept clean and mellow with a spring-tooth harrow, fine-tooth cultivator or weeder. Cultivation is continued until the middle of July or the first to the middle of August, when some cover-crop should be sown and allowed to take possession of the soil during the balance of the season.

For cover-crop purposes a number of different plants have been successfully used. Mammoth and Crimson, or even Medium Red clover, have been used and are recommended by some orchardists: also winter vetch and cow peas. Soy beans do well even in the northernmost parts of Ohio, and are generally conceded to be superior to cow peas for the purpose of a cover-crop. A combination of oats and Canada field peas also makes a good winter covering for the soil. The cow peas and Soy beans are usually sown in drills two feet apart and at the rate of three-fourths to one bushel per acre. The young plants are then cultivated once or twice to give them a vigorous start. A mixture of rye and vetch is sometimes broad-casted among the cow peas and Soy beans immediately preceding the last cultivation in early autumn. This combination affords a dense carpeting during winter and makes an early, heavy growth the following spring by the time the ground should be plowed again. All of the plants mentioned provide humus for the soil, and the legumes, such as the clovers, peas, beans and vetch deposit, through the agency of their peculiar root nodules, considerable nitrogen gathered from the atmosphere.

A good cover-crop will hold the leaves and snow, thereby lessening the depth of alternate freezing and thawing. The turning under of a few such crops will make the soil spongy and friable, increase its moisture holding capacity and render it more able to resist drought. The cover-crop plan is probably the nearest approach to absolutely clean cultivation of orchards, that the orchardist can safely make. It meets not only the requirements of those

who delight in keeping their orchards in a neat and sightly condition, but it provides generously for the needs, present and future, of the trees and orchard, by the gradual accumulation of a surplus of plant food and vegetable fiber in the soil. In Fig. 2 is presented a view in the cover-crop section of the Station's culture test plot. The plants shown in the engraving are Soy beans, between the rows of which were sown rye and winter vetch, at the rate of one bushel of rye and fifteen pounds of vetch per acre.

THE CONTINUOUS CLEAN CULTURE METHOD.

While this plan of culture has long been followed in certain favored localities in the northern part of Ohio, and in other states as well, in many cases without apparently serious results, it is safely applicable only where the soil is level, fertile, and naturally well supplied with humus. Even under these favorable conditions, the vegetable matter in the soil is sure, in time, to become depleted. For Ohio upland soils where the surface is sloping, steep or broken, it would be a serious mistake to recommend continuous, clean cultivation of the orchard.

Plot No. 2, in the Station culture test, was designed to be kept under continuous, clean culture without cover-crops or the addition of fertility or vegetable matter in any form—the same conditions under which many orchards in Ohio and elsewhere are existing. In detail the ground was to be plowed in the spring, the surface leveled with the harrow or cultivator and kept mellow and free from weed growth throughout the growing season, or until early autumn, when cultivation was to cease, and the soil to lie undisturbed and uncovered until the next spring, when the same program was to be repeated.

It will no doubt be observed that operations in plot No. 2 are mentioned in the past tense. It is advisedly that this is done. After four seasons' trial, continuous clean culture was abandoned as a practice not to be considered in connection with careful orchard culture. After many tons of soil had been swept away by the rains, exposing the roots of the trees in numerous places, and the surface cut, here and there, by great, yawning gullies in which many loads of brush, prunings and other coarse matter were necessary to fill the ditches so that a team might pass over, the method was discontinued in alarm and the plot thereafter included in the cover-crop area where, it is to be hoped, the loss and injury may be repaired in some degree. The great loss of soil, however, can never be recovered.

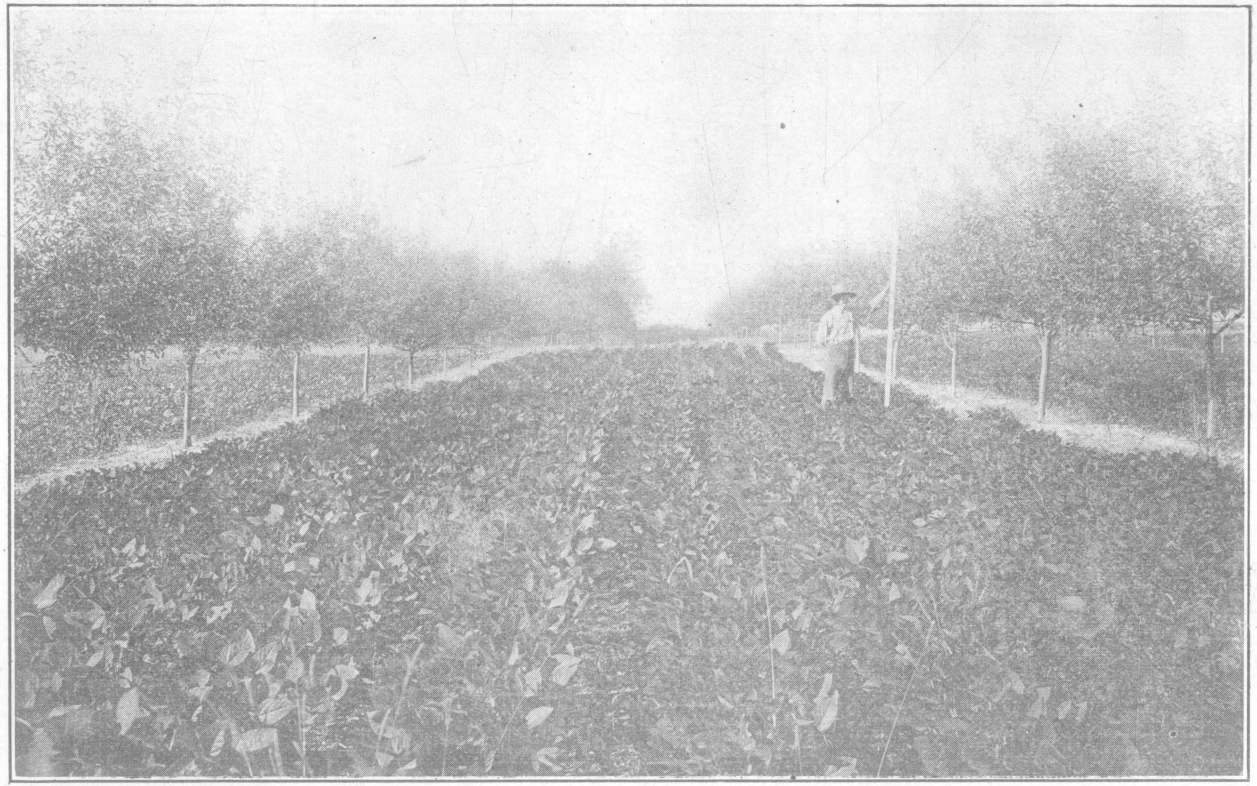


FIG. 2. Cover-crop plot. (Plot No. 1.) *Photo by Ballou.*

FIG. 3. Sod-culture plot. (Plot No. 3.) *Photo by Ballou.*

THE SOD-CULTURE METHOD.

In plot No. 3 the apple trees were planted in generous excavations, directly in the sod. Immediately following the planting of the trees a circular area of ground, three or four feet in diameter, was spaded or dug about each tree, and the spaces have annually been kept clean and mellow by frequent use of hoe or rake, throughout the growing seasons. The grass upon this plot has been cut three or four times each season since the trees have been planted, keeping the surface smooth and sightly in appearance. The grass, as cut, is allowed to lie where it falls, thereby adding a mulch to the entire surface, through which the new growth pushes up with increasing vigor. No fertility has been added to the circular, cultivated spaces, which are gradually enlarged to correspond with and to equal the diameter of the head of the respective trees.

This method was not designed to meet the requirement of the commercial grower whose considerable areas of ground are easily and safely tillable under the cover-crop method, or even for the grower whose land may be easily mown over with the machine, and to whom material for regular and heavy mulching of the trees is available. The sod-culture method is the most expensive and laborious plan of culture of the four tested at the Station and described in this report. It may be utilized to advantage upon small, very rough or stony areas where mulching material is not available. It also fully meets the requirements of those who desire to grow tree fruits about the home grounds, where the presence of poultry would render mulching undesirable, and where the utmost neatness and sightliness of the grounds and lawn are considered of equal importance with good care of the trees. A view of a section of plot No. 3 is given in Fig. 3, which is very suggestive of the plan of culture just described.

THE SOD-MULCH METHOD.

In plot No. 4, as in plot No. 3, the trees were planted in sod. Instead of spading and cultivating circular areas about each tree these spaces, of similar size, were at once heavily mulched with straw. The stems of the trees were enclosed with fine-meshed, wire-screen cylinders, to prevent injury by mice or other rodents. The grass in plot No. 4 is also mown three or four times each season; but, instead of allowing it to lie where it falls, as in plot No. 3, it is raked up, divided, and used to maintain the mulch about the trees.

FIG. 4. Sod-mulch plot. (Plot No. 4.) *Photo by Ballou.*

This method is admirably adapted to orchards on sloping or steep ground where cultivation cannot be easily or safely performed. It is no less well suited for well drained, level land, and has certain advantages wherever it may be employed. There is no system of orchard culture that will permit of keeping the orchard area in so sightly a condition if the program of culture be fulfilled. Orchard operations, such as pruning, hauling out brush, spraying, gathering and hauling out fruit etc., may be done at any time in the season, even when a very rainy season prevails, or immediately following a soaking rain. Horses, tools, wagons and men alike escape the inconvenience of soft ground and mud. In Fig. 4 is shown a view in the Station's "sod-mulch" test plot.

RESULTS OF DIFFERENT METHODS OF ORCHARD CULTURE COMPARED.

As has already been explained, Plot No. 2, or the continuous clean culture plot, is debarred from consideration in the comparison of orchard culture methods. So swiftly was it overtaken by disaster that it was unfitted for participating experimentally except in a class by itself—which class would present the problem of the restoration of "departed and depleted" orchard soil. Therefore only plots No. 1, 3 and 4 are included in the consideration of the results as obtained at the close of the sixth season's observation and study of the different methods of culture.

As a most fitting, suggestive and self explanatory introduction to this statement of results obtained, it is desirable that Figs. 5, 6 and 7 be referred to by the reader and a careful comparison made.

The individual trees shown in these pictures which represent the cover-crop (Fig. 5), the sod-culture (Fig. 6), and the sod-mulch (Fig. 7) plots respectively, were carefully selected for photographing through a desire to picture, as nearly as might be, a tree of average size and growth in each plot.

Soil conditions in the cover-crop plot, as observed at the close of the sixth year, are excellent. The annual turning under of a growth of leguminous plants produced each autumn, has materially increased fertility and filled the soil with humus. The trees have made very satisfactory annual growths, much better than in plot No. 3 (sod-culture), but not so heavy nor uniform a growth as the trees in plot No. 4 (sod-mulch).

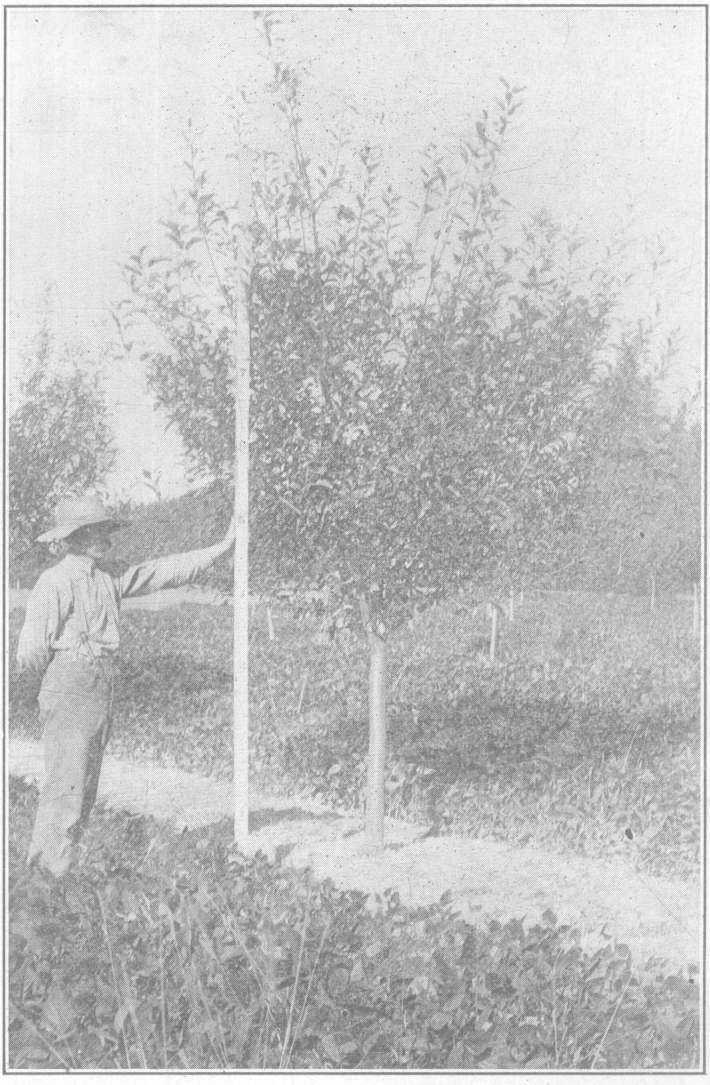


FIG. 5. Average-size tree in cover-crop plot. (Plot No. 5) *Photo by Ballou*

While the ground is but slightly sloping in the Station orchard, there has been experienced some difficulty in keeping the surface from ridging or terracing, even with care in alternating the order of plowing each season. This may or may not be an objection, depending wholly upon the individual culturist. The terracing of a hill-side by annual plowing and the cultivation with cover-crops gradually prepares a comparatively level road-bed between each two rows of trees, that may be utilized to advantage in getting about with spraying outfit and fruit wagon, although a uniformly smooth, regular, unbroken surface is much more sightly in appearance.

During the first two or three seasons subsequent to planting, the growth of the trees in plot No. 3 (sod-culture) was uniformly good—almost equaling that of the trees in Nos. 1 and 4. The past two seasons, however, has shown a remarkable falling behind in growth. This is not at all surprising when the fact is considered that the soil in this plot has been kept scrupulously clean about each tree as far out as the branches extend, that no fertility or vegetable matter whatever has been added to the areas within which the greater portion of the feeding rootlets of the trees are situated.

FIG. 6. Average-size tree in sod-culture plot. (Plot No. 3) *Photo by Ballou*

The general surface of this plot is smooth and lawnlike in appearance; but if there has been any improvement in soil conditions generally it has been slight, and has come about solely through the resting of the soil from cultivation and the return to the soil of the vegetable matter or humus derived from the grass which has been grown, cut and allowed to lie and decay upon the surface.

Unless the orchard soil be naturally fertile and abounding in humus, it is not difficult to perceive that the "sod-culture" method subjects young trees to a systematic course of semi-starvation. This discouraging period will, no doubt, be passed through in time as the feeding rootlets extend farther out beneath the area that has been under gradual improvement by lying at rest and receiving a light mulching of fallen grass annually.

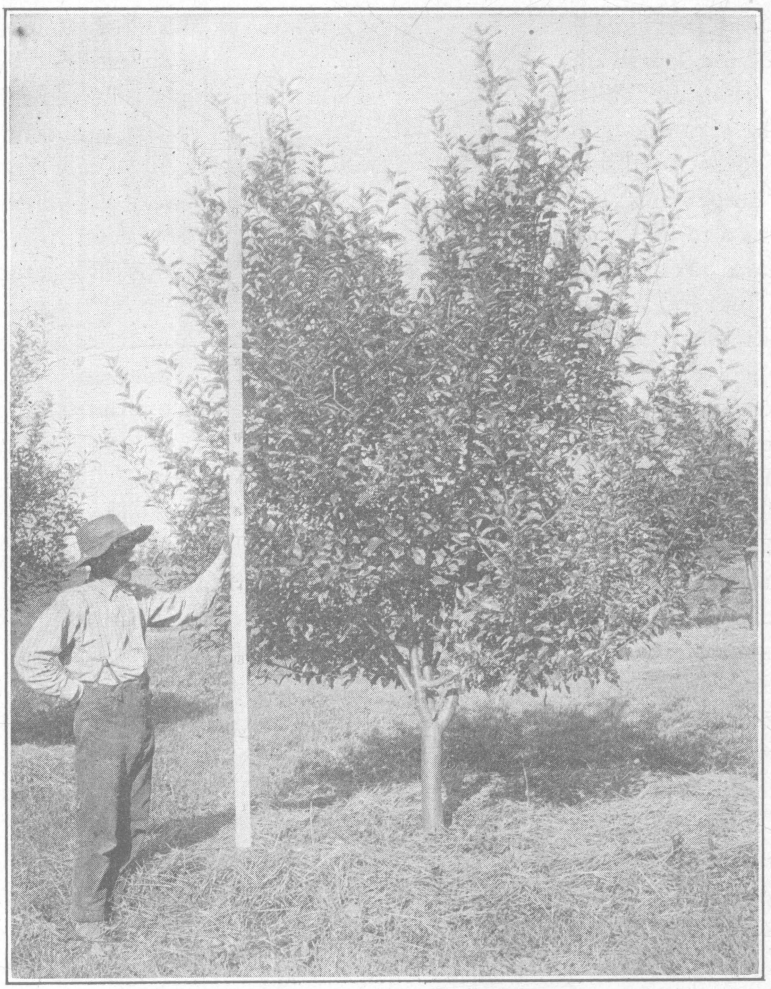


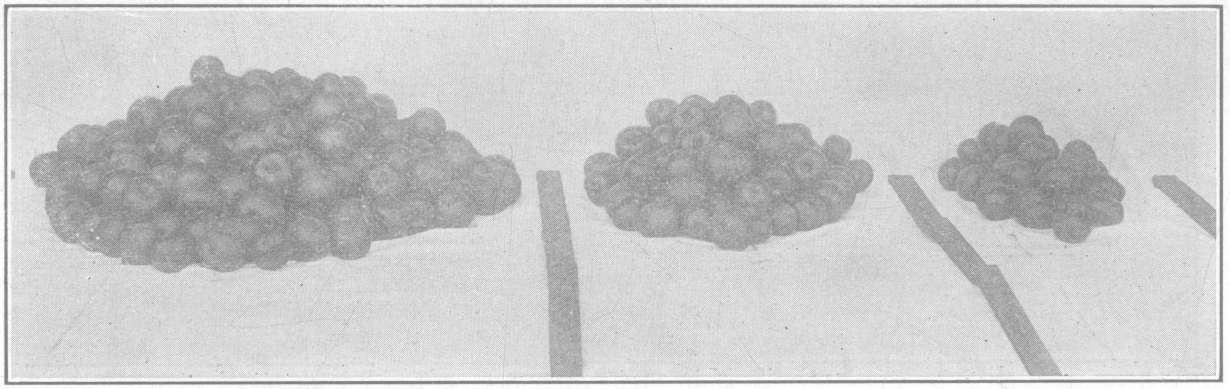
FIG. 7. Average-size tree in sod-mulch plot. (Plot No. 4) *Photo by Ballou*

In plot No. 4 (sod-mulch) the growth of the trees has been vigorous, sturdy, uniform and uninterrupted from the time of planting until the present. This method is one of concentration of plant food upon particular, circumscribed areas where it will be most easily available to the feeding-root system of the growing trees.

The first effect of a heavy mulch is the conservation of moisture by the prevention of evaporation of water from the soil of the area mulched. The surface of the soil is kept comparatively moist, and the rapid decay of the vegetable matter, which lies in contact with this moist surface soil, not only provides accumulating humus and plant food, but the chemical and bacterial action in the soil beneath, favored by the soil covering and its decomposition, results in the liberation of mineral elements of plant food and the formation of nitrates that otherwise would not occur, or would be so slow as to be of much less immediate benefit to the growing trees.

The soil conditions of the sod-mulch plot, as a whole, exclusive of the circumscribed areas about each tree where the vegetation of the entire plot has been continuously concentrated, are evidently not improving as materially as in plot No. 3, where vegetation is allowed to lie upon the surface of the soil that produced it. The general area of plot No. 4 is annually producing crops of vegetation, which crops are promptly removed, divided, and applied as a mulch about the young trees. No fertility or vegetable matter has been applied to this plot in the six years that it has been in orchard. The effect is substantially the same as upon any other like area from which annual crops of grass are removed without employing some way to restore the consequent loss of fertility. Only as the mulched circular areas about the trees are enlarged to correspond with the constantly increasing areas covered by the spread of the branches of the growing trees, will this gradual expenditure of fertility from the general orchard area be restored. And so slowly does this extension proceed that unless the orchard soil, taken as a whole, be naturally and unusually fertile and well stored with vegetable matter at the outset, it is evident that the time will come when it will not produce sufficient vegetation to maintain the mulch on the ever increasing circular areas about the trees. But, if material for maintaining the mulch about the trees can be secured from other and outside sources, and the annual growth of vegetation produced upon the orchard be cut and allowed to lie where it falls, there cannot but be a gradual improvement in soil conditions over the entire orchard area. This plan is feasible in most agricultural districts of our state where straw is procurable for mulching purposes, and was followed the past season in the Station's orchard test plot work. Likewise, as the general, bearing apple orchards at the Station are under the sod-mulch system of culture, the material for mulching was purchased of neighboring farmers to whom the Station can well afford, even from an economic point of view, to pay a fair price for the straw.

FIG. 8. First fruits from different culture plots. Variety, Jonathan.

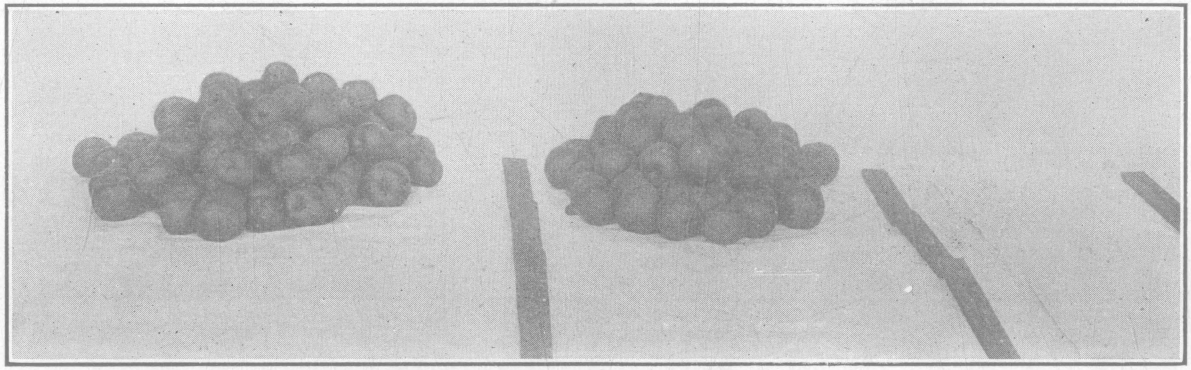


Product of sod-mulch plot.
172 apples. Weight —55.5 lbs.
Average weight of each specimen 5 .16+ ozs.

Product of cover-crop plot.
70 apples, Weight 21 lbs.
Average weight of each specimen 4.8 ozs.

Product of sod-culture plot.
29 apples. Weight 7 lbs.
Average weight of
each specimen 3.86+ ozs.

FIG. 9. First fruits from different culture plots. Variety, Grimes Golden.



Product of sod-mulch plot.
82 apples. Weight —30.5 lbs.
Average weight of each specimen 5.95+ ozs.

Product of cover-crop plot.
59 apples. Weight 23 ,bs.
Average weight of each specimen 6.23+ ozs.

Sod-culture plot.
No fruit.

In Figs. 8 and 9 are illustrated, from photographs, the actual products of first fruits from the different culture plots at the Experiment Station. The necessary explanations accompany the engravings.

COMPARISON OF TREE GIRTHS IN DIFFERENT CULTURE PLOTS.

Measurment taken twelve inches above ground.

Average girth of trees in cover-crop plot (No. 1).. ... . 9.71 in.+
" " " " " sod-culture " (. o. 3)..... 8.55 in.+
" " " " " sod-mulch " (No. 4).. ..... 10.56 in.+

COMPARISON OF FIRST YIELD OF FRUIT FROM DIFFERENT CULTURE PLOTS.

Variety	Method of culture	Number of apples	Total weight of apples	Average weight of each specimen
Jonathan	Cover-crop	70	21 lbs	4 8 ozs.
"	Sod-culture	29	7 lbs.	3.86+ ozs.
"	Sod-mulch	172	55 1-2 lbs.	5.16+ ozs.
Grimes	Cover-crop	59	23 lbs.	6.23+ ozs.
"	Sod-culture	..	..	.....
"	Sod-mulch	82	30 1-2 lbs.	5.95+ ozs.

THE EFFECT OF DIFFERENT METHODS OF CULTURE UPON THE ROOT SYSTEM OF THE APPLE TREE.

The great interest at present manifested in orchard culture has brought out many questions relative to the economic management of orchard soil and the influence of different methods of culture upon the root growth of fruit trees. It is frequently urged that by annual plowing and clean cultivation *it is possible to keep the root system of the trees at a greater depth—at a lower level in the soil—where they will be less likely to suffer from extremes of drought, heat and cold.* The adherents to the practice of clean culture furthermore urge the point that the system of mulching results in *alluring the entire root system—and especially the feeding rootlets of the trees—dangerously near to the surface of the ground and that through failure to continue the practice of mulching after having adopted and followed it for a period of time, the trees will be sure to suffer from the effects of drought, heat and cold.*

As a result of this interest, inquiry and discussion pertaining to soil culture and management, and the effects produced by seemingly opposed systems upon the root development of fruit trees, a careful investigation of the position and distribution of the roots of apple trees under different methods of culture, was conducted in the Station orchard culture plots. The results of these investigations,

aside from being of much interest to culturists generally, revealed a few surprises, and tend toward a refutation of the claims of the devotees of regular, annual plowing and clean cultivation of orchards, as cited above.

The results of investigations, herein recorded, were secured under conditions prevailing at the Experiment Station orchards alone, and it is expressly desired that this record of results be accepted as *suggestive* rather than *conclusive*, and as a stimulus to individual fruit growers to pursue this line of study under local and necessarily widely different conditions.

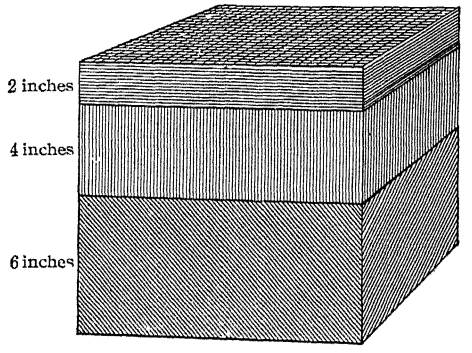


FIG. 10. Drawing representing a cubic-foot block of soil as removed from beneath the trees in the different culture plots.

Many cubic-foot blocks of soil (Fig. 10) were carefully removed at uniform distances from the stems of the trees and just beneath the extremities of their branches, where the greater number of the feeding rootlets are supposed to lie. These cubic-foot blocks of soil, from about the mulched trees, were removed by measuring and cutting out a square-foot block of the mulch down to the surface of the soil beneath. All of the rootlets, even to the minutest, were separated, by hand, from the decomposing substance composed of a six years' accumulation of vegetable matter provided by mulching. A layer of surface soil one foot square and two inches deep, with the rootlets contained, would next be removed; likewise the succeeding four inches of soil beneath and, lastly, the succeeding six inches of soil or subsoil, which completed the removal, in three sections, of one cubic foot of soil with roots and rootlets included.

The different sections of soil, containing roots and rootlets, were then placed, separately, upon a fine meshed wire screen and every particle of soil washed out with water from a hose, leaving the respective lots of roots and rootlets clean and in good condition for photographing. (See Figs. 11, 12, 13, 14, 15, 16, 17 and 18.)

The investigation was rendered of greater value by a duplication of experiments and work throughout and, moreover, by further careful examination of conditions existing beneath the surface of the soil to ascertain whether the results being obtained were reasonably dependable, which they proved, without doubt, to be.

Without taking up space to make elaborate comparisons that would only suggest that both those who believe in clean culture and those who defend the mulch-method have been somewhat mistaken in their ideas as to the general effect of their chosen methods upon the root systems of their orchards, the following summary of results of the root work is submitted:

1—The main root systems, of apple trees, under the different methods of culture, were found to be at a surprisingly uniform depth —the greater portion of the roots, both large and minute, being removed with the upper six inches of soil. It is desirable that the reader refer to and carefully study the engravings which follow and which are arranged in consecutive order and accompanied by brief explanations.

2—The fibrous or feeding-root system of a tree under annual plowing and clean culture with cover-crops, practically renews itself annually—pushing up thousands of succulent, fibrous rootlets to the very surface of the soil where they they actually meet with the steel hoes or spikes of the cultivator or harrow, especially in seasons when moisture is abundant. Apparently but a small percentage of these rootlets penetrate the lower, more compact, colder soil, but they come to the surface soil in countless thousands of thread-like extensions, to feed where warmth and air and moisture combine to provide the necessary conditions for root pasturage. As a matter of fact, these feeding rootlets are cleanly pruned away by the plowshare each succeeding year, and without apparent injury to the trees or crops; but they have succeeded in performing their function, and their places are occupied, the succeeding season, by a new generation.

3—The presence of a net-work or mass of fibrous rootlets upon the surface of the soil beneath a heavy mulch, and in the heavier portions of the mulch itself, is no indication whatever of the lack or absence of feeding rootlets in the upper soil; and the partial or even total destruction of these surface feeders, which occurs during the hotter, dryer months of summer and during the severe cold of winter, does not cause the trees to suffer in the least degree, as there was invariably found to be a wonderfully dense network of rootlets occupying not only the upper two inches of soil, but also the succeeding four inches of soil below the upper two inches.

4—Inasmuch as the surface rootlets, in or beneath a heavy mulch, do not increase disproportionately to those beneath the surface soil, it becomes evident that the removal of the mulch, or even a change from heavy mulching to the clean-culture-cover-crop plan, would not be as disastrous as has been generally supposed.

5—Under the "sod-mulch system" of culture the trees have uniformly made a heavier, more vigorous growth than under any other system of culture. This is no doubt due to the certainty and uniformity of the generous store of fertility right at hand—the concentration of an abundance of plant food where it is most available and the consequent presentation of conditions, beneath the mulch of vegetable matter, especially favorable to a healthy, unstinted, continuous nourishment of the trees.

The engravings from photographs, which follow, tell a story of much tedious and painstaking work, and show the character of roots and rootlets of the apple, found at various depths in the soil in the cover-crop and sod-mulch plots which are representative of the extremes in orchard culture methods. In the study of these engravings compare Fig. 11 with Fig. 16; Fig. 12 with Fig. 17; Fig. 13 with Fig. 18. In the comparison of Fig. 11 with Fig. 16 it should be borne in mind that the rootlets shown in Fig. 16 are a cumulative mass— the growth of several seasons—while those in Fig. 11 are the growth of but a single season—the preceding seasons' growth having been annually cut off and turned under by the breaking-plow in the early-spring plowings. The fibrous rootlets shown in Fig. 15, from the substance of the mulch, are also a cumulative growth, the feeding-root system renewing itself, in a great measure, annually.

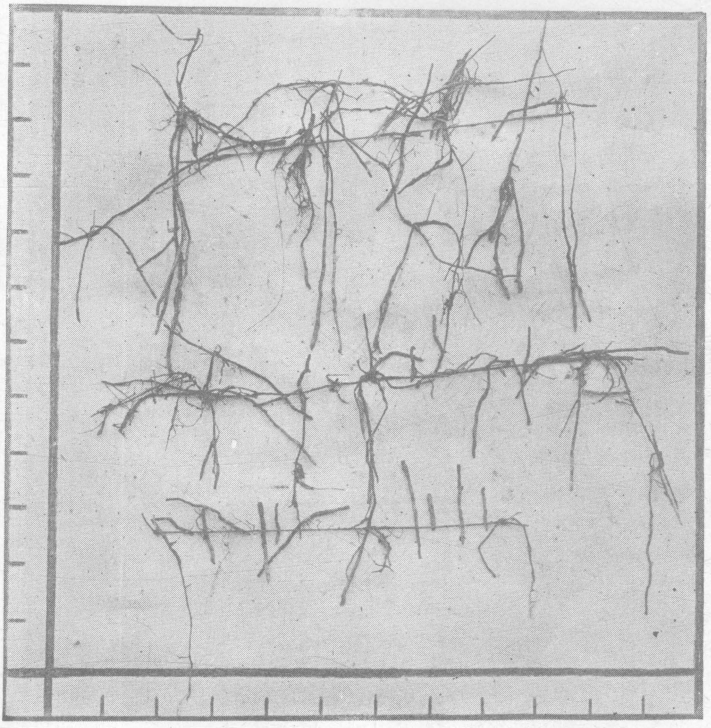


FIG. 11. New, white, succulent, fibrous or feeding rootlets of the apple, found in a square-foot section of surface soil two inches deep, in cover-crop plot.

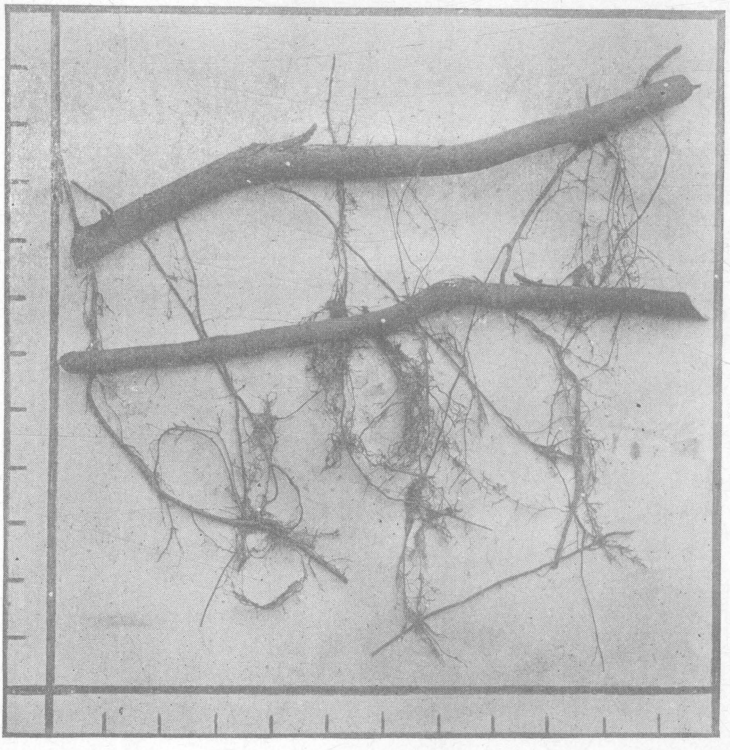


FIG. 12. Roots and rootlets of the apple found in a square-foot section of soil four inches deep, between the depths of two inches and six inches, in cover-crop plot. *Photos by Ballou.*

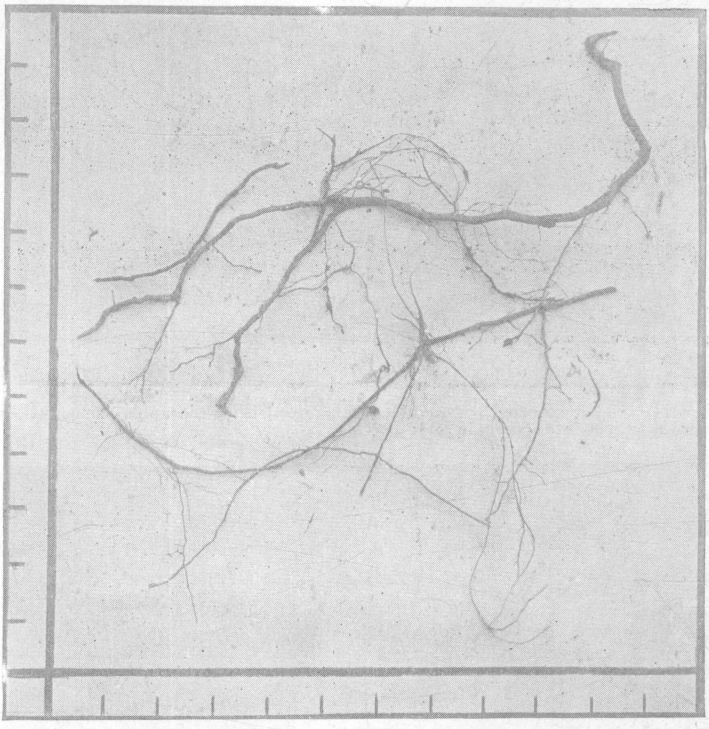


FIG. 13. Roots and rootlets of the apple found in a square-foot section of soil six inches deep, between the depths of six inches and twelve inches, in cover-crop plot. *Photo by Ballou.*

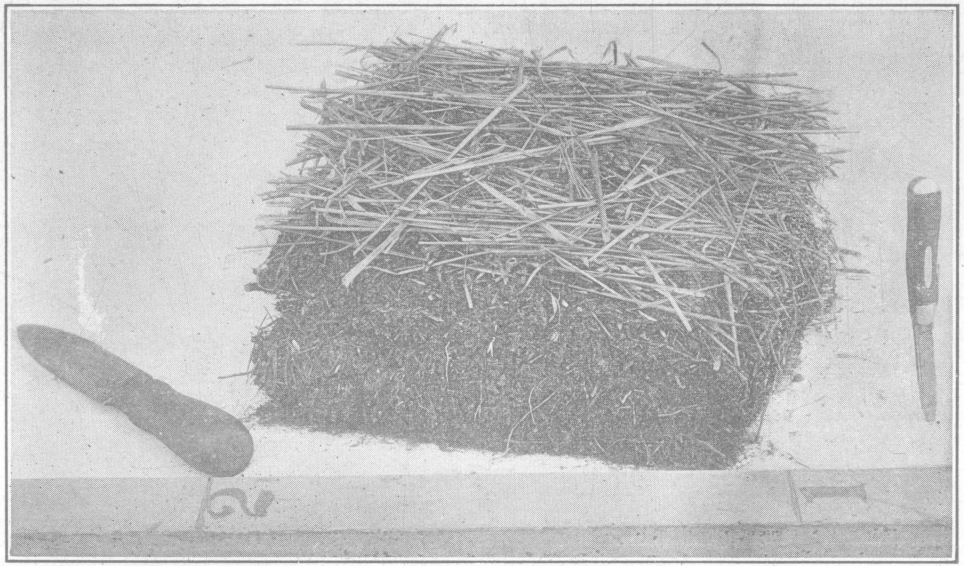


FIG. 14. Square-foot section of mulch, carefully cut out and removed from beneath an apple tree in the sod-mulch plot, showing (in depth) the accumulation of organic (vegetable) matter from six seasons' mulching. Sod-mulch plot. *Photo by Ballou.*

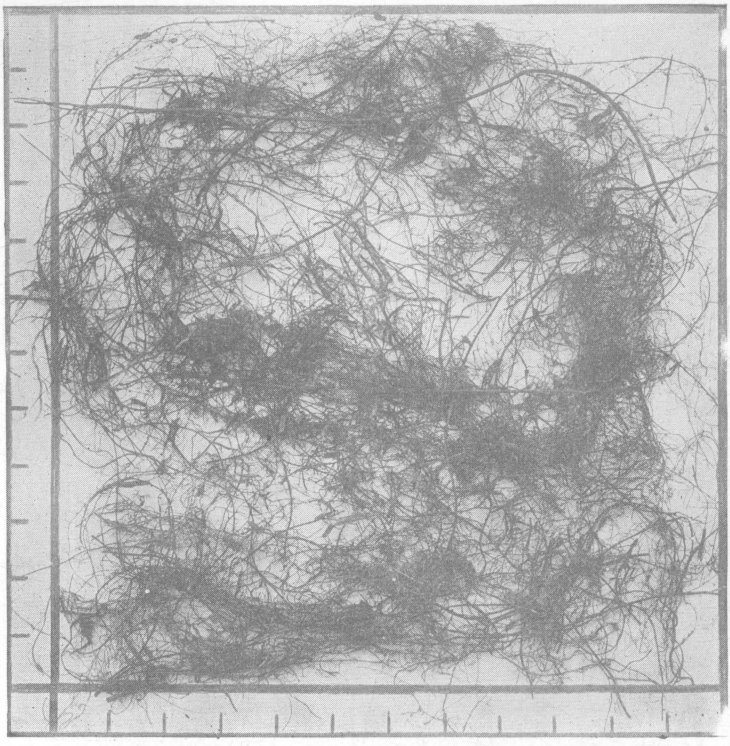


FIG. 15. Fibrous or feeding rootlets of the apple found above the surface of the ground and within the decayed and decaying substance of the square-foot block of mulch shown in Fig. 14. Sod-mulch plot.

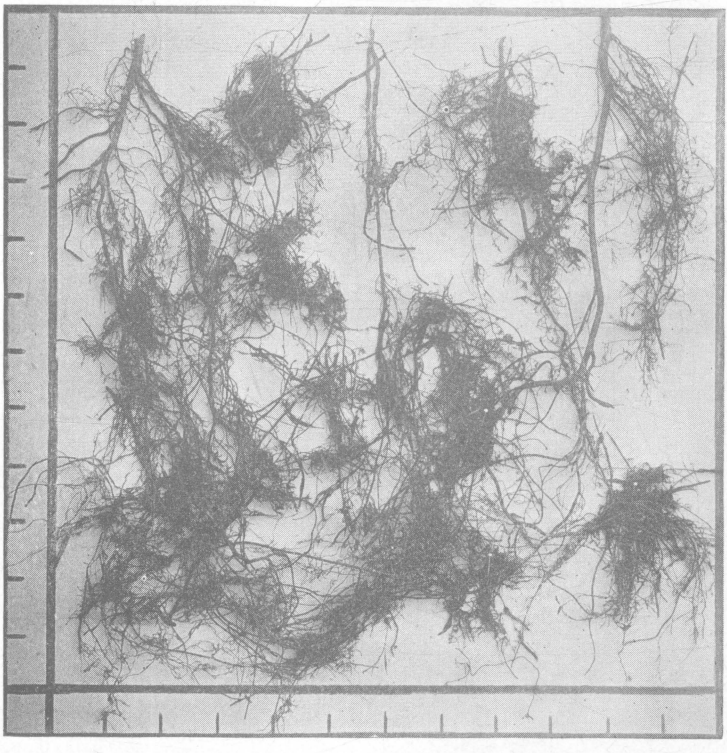


FIG. 16. Roots and fibrous rootlets of the apple found in a section of surface soil one foot square and two inches deep, beneath a square, foot block of mulch, such as is shown in Fig. 14. Sod-mulch plot.

Photos by Ballou

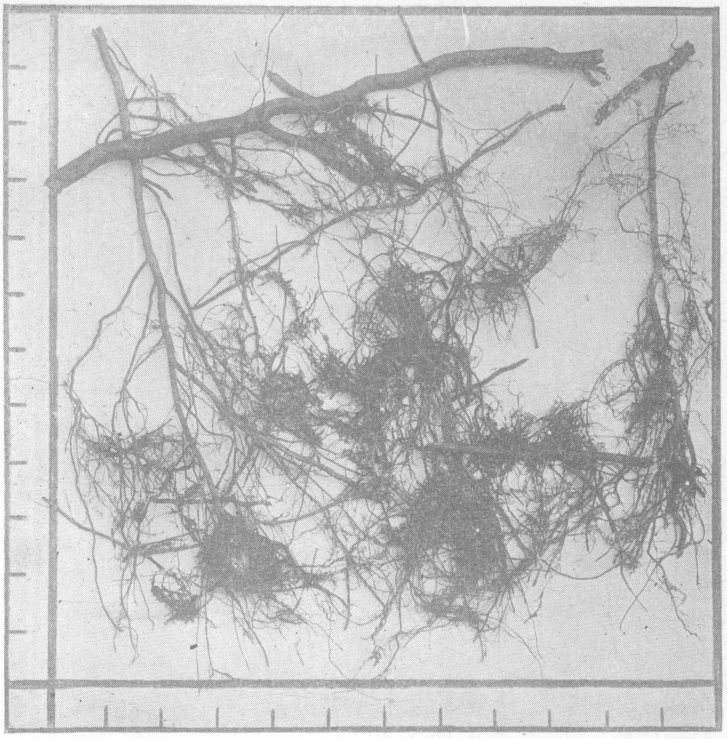


FIG. 17 Roots and fibrous rootlets of the apple found in a square-foot section of soil four inches deep, between the depths of two inches and six inches. Sod-mulch plot.

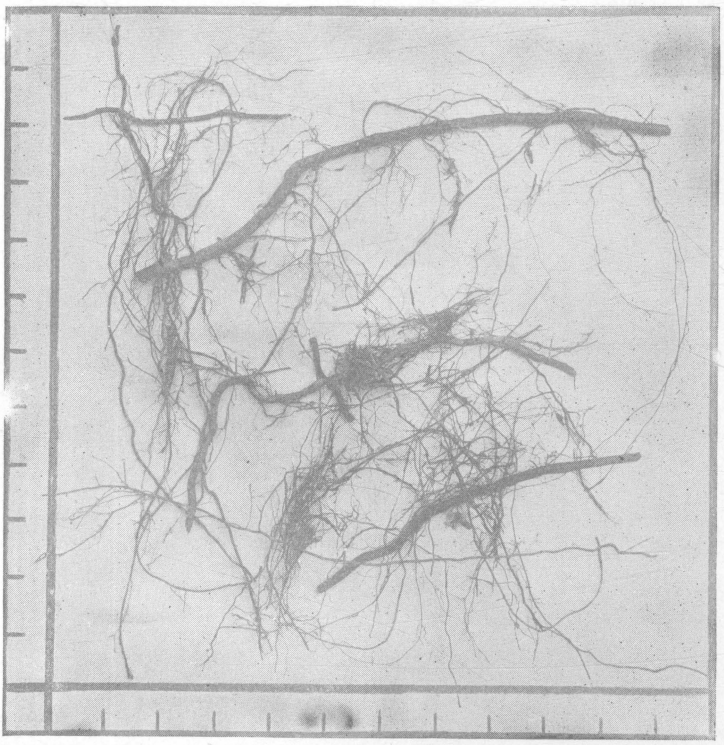


FIG. 18 Roots and rootlets of the apple, found in a square-foot section of soil six inches deep, between the depths of six inches and twelve inches. Sod-mulch plot. *Photos by Ballou*

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