STATISTICAL DETERMINATION OF THE RESPONSE OF APPLE TREES TO CULTURAL METHODS

by

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INTRODUCTION

Within recent years the subject of orchard tillage has come to be one of much interest to the fruit grower. It is only within the last few decades that tillage has been regarded as important. This may seem the more remarkable when we consider that other horticultural practices such as pruning, propagation, etc., reached a high degree of development some centuries ago. The improvement of varieties, too, has been developing for scores of years.

During the many years that the above methods of pruning, dwarfing, etc., were being developed, the orchard was habitually grown in sod. The apple tree, like a forest tree, was considered capable of making a satisfactory growth and development without tillage. Perhaps this conclusion was drawn since the apple tree is a strong perennial, reaches large size and vegetatively, at least, is capable of competing successfully with the small annuals, such as grass, weeds, and other plants which might be growing in the orchard.

The recent impetus to orchard tillage had its beginning in the west, particularly in the last two or three decades. In the newer agricultural regions, especially in the sections of sparse rainfall where dry farming methods are practiced, tillage became an established practice in conserving soil moisture. In general, tillage of the orchards throughout the west gave such favorable results that the practice rapidly spread to the more eastern and even older agricultural areas. This growth was particularly marked from 1890 to 1910.

During the last few years observations have proved that orchards, which have been tilled for many years, are low in humus. The humus and plant fiber have been burned out, the soil washes badly, crusts after a rain, and is less drought resistant. To use an orchardist's expression, such constantly tilled soils become "dead" as opposed to the "live" condition exhibited by soils which contain sufficient organic matter. At present the question is shaping itself as to whether orchard tillage may not have been overemphasized. May not the orchard lose more from lack of humus and plant fiber than it gains from tillage? Is it not possible that the best method of tillage may lie somewhere between the two extremes of constant clean culture on the one hand and permanent sod on the other? May it not be feasible to use a short season legume for a cover crop? In this case there is not such strong competition as is found between grass and the trees. Such a crop would supply the elements furnished by sod and yet retain the beneficial effects of tillage.

Whether to employ tillage or some sort of crop is a question which has been attacked very recently. No records of comparison are available where trees have been grown throughout their life history under different methods of tillage.

The Missouri Station planted an apple orchard with the view of testing several methods of orchard soil management. The different plots represent conditions ranging from permanent sod on the one hand to continuous clean culture on the other. In the intermediate plots tillage and cover crops are alternated. These trees are just now reaching bearing age, so the time is opportune to observe the effects of tillage on the fruitfulness and growth of the trees.

RESUME OF LITERATURE

With the advent of tillage in the apple orchard, the fruit growers have also realized the possibilities of this practice in its influence upon fruitfulness. Clean tillage or tillage and cover crop stimulates wood growth. This delays fruiting and prolongs the life of the tree. On the other hand, fruiting may be hastened by sowing the orchard to some crop which will form a sod; thus checking vigorous vegetative growth. This may possibly reduce the longevity of the tree.

It is evident that various horticultural practices favor or oppose fruitfulness by checking or by stimulating vigorous growth of the tree. Among these methods the following seem to be of the most practical importance:

Girdling, Ringing, and Notching. These methods are among the most effective known means of bringing trees into fruiting. By applying either of these practices storage of plant food reserve to a greater or less degree is apparently brought about in the parts above the wound. The phloem is restricted; thus preventing the usual downward movement of the elaborated food, while the upward passage of water and minerals is unmolested. Winkler (60) showed that girdled tomato plants took up practically the same quantities of water as plants that were not girdled. There must, then, be an increase of organic substances above the wound. This being the case, Winkler states that the, "Increased fruitfulness due to these practices must be attributed either to the greater quantity of reserve food, or to the relative increase of carbohydrates as compared with mineral matter, or perhaps to both of these factors."

May (37) secured, by girdling, an increase in yield of eight and one-half bushels of apples per tree from trees that had been practically barren for eight years. Whitten and Howard (58) and Howe (30) found that trees girdled in early June set a higher percentage of fruit buds than untreated trees of the same variety under similar conditions.

Spraying. The practice of spraying, aside from its main purpose, namely, that of combating insects and diseases, has long been regarded as a means by which fruitfulness and wood growth are controlled to a limited degree. However, within recent years both blooming and pollination have been influenced by the application of certain nutrient sprays during the dormant season. Ballard and Volch (2) secured an increase of 40 per cent in the production of fruit by applying nitrate of soda as a winter spray. After continuing the experiment another period of four years, Volch (52) confirmed the above results, and stated that there had been a very noticable improvement in the color, abundance, and vigor of the foliage. It seems possible that this spray may be a valuable substitute for nitrogen in ordinary fertilizer applications for obtaining quick results.

Grafting. This practice has been employed for many years by horticulturists, not alone for the perpetuation of varieties, but also to obtain dwarfed trees of an early bearing age. The graft union as shown by Chandler (7) inteferes with the rise of mineral salts absorbed by the roots, and it is quite probable that the obstruction to the descent of elaborated food is much greater. Thus, Sablon (43) found that the sap from a pear tree grafted upon the quince stock contains a much higher per cent of carbohydrates than sap from a tree grafted on its own stock. Cole (8) observed that, by dwarfing, the time of fruiting was hastened, and the yield was greatly increased.

Moisture. Other factors being favorable, an excessive supply of moisture indues a luxuriant wood growth and retards fruiting, while a lack of water seems to stimulate fruitfulness. Sorauer (45), in speaking of flowering plants, stated that, "As soon as the shoots are developed and the formation of flower buds is expected, the watering may be decreased. The formation of flower buds is best initiated by preserving a rest period, and the latter is favored by a diminished water supply".

In experiments on a number of cereal crops Mayer (38) found that the production of grain varies in inverse ratio to the moisture content of the soil, provided the amount of water available is sufficient for seed development. These results, as well as very similar ones obtained by Seelhorst and Freckmann (44), agree with Hilgard's (28) statement that: "Within certain limits production is almost directly proportional to the water supply during the period of active vegetation". Paddock's (39) deductions from Gourley's (22) results indicate that the amount of moisture present in the soil at the time of bud differentiation is of prime importance.

Root Pruning. This practice of checking vegetative growth and stimulating fruitfulness has been utilized for many years by orchardists. Barry (3) found that the removal of some of the roots from a tree lessens its food supply from the soil, checks growth, causes the sap to move more slowly in its channels, and stimulates the buds to assume a fruitful character. Field (17) says: "It has long been known that an obstinate variety growing on the pear stock might be hastened in its fruiting by separating some of the roots, thus cutting off the abundant supply of nutriment that increases wood growth at the expense of fruit bud formation". Walker (53) showed that trees which were growing too vigorously to bear satisfactorily could be checked in growth and stimulated to greater fruitfulness by root pruning.

Drinkard (14) found a very marked stimulation in fruit bud formation occured when root pruning was done after the foliage was fully developed, and when the fruit buds began to become differentiated.

It is evident that root pruning done when the leaves are fully developed, reduces the water supply of the entire tree. Thus a combination of factors may be responsible for the fruit bud formation. A lack of water in the plant checks wood growth and causes a more concentrated sap, condusive to fruitfulness, to be formed.

Dormant Pruning. The beneficial effects of dormant pruning are first realized in the shaping of the trees. Batchelor (4) observed that if the branches are annually thinned to a certain limit, thus allowing the sunlight to enter the trees, fruit will be distributed more evenly, will be produced in a much greater quantity, and will be of better quality. Wiggans (55), at the Missouri Station, found that at three years of age trees pruned to a low head had produced approximately twice as many short branches (potential fruit spurs) as similar trees pruned to a high head.

Another phase of dormant pruning is the rejuvenation of old or dying trees which fail to develop adequate new wood.

It is evident that some branch and twig

growth is essential to fruit production. The cutting back of the tree favors wood growth, and subsequently new and vigorous fruiting wood will be produced. Jarvis [31] found that the severity of heading-in is governed largely by the vigor of the tree. He concluded that the cutting back should be more severe with the weakest trees and decrease in severity for the other trees in proportion to the increase in vigor. In the latter case there is a danger of producing a rank growth of water sprouts. Alderman [1] and Downing [15] confirmed the above conclusion in their experiments on pruning.

Summer Pruning. This system of inducing fruitfulness is one of the most practical horticultural methods employed by fruit growers to obtain better yields. In general, this practice may be considered as the converse of winter pruning, the important difference lying in the physiological effect.

Whitten [57] and Drinkard [14] indicated the proper time to prune when they stated that summer pruning should be done the latter part of June. This checks the growth just at the time when the fruit buds begin to show differentiation, and it is too late for the development of secondary shoots which rarely produce fruit buds.

Dickens [13] stated that: "Trees pruned in summer have grown fewer water-sprouts than those of similar age, and grown in a similar soil, pruned in winter or early spring." An explanation of this is found in Jost's[33] statement in which he brings out the fact that summer pruning retards root growth. Consequently, the superabundance of water and mineral salts is greatly reduced.

Keffer[35] well stated the object of summer pruning when he said: "It is to enable the tree to develop fruiting wood on the main and lateral branches, which are usually bare". Judson,[34] Jarvis,[32] and Howard[29] found that summer pruning checks wood growth, thus directing the energies of the tree to the production of fruit buds.

During a fime year period Vincent[51] obtained an increase in yield of 111 per cent for Wagener, 52.8 per cent for Grimes, and 2.4 per cent for Jonathan as a result of summer pruning of apples. At the Oregon Station[19] it was clearly shown that summer pruned trees have a better system of fruit spurs than winter pruned trees.

In the light of the above statements, unless the peculiar results are attributed to climatic conditions, it is difficult to explain Batchelor and Goodspeed's[5] statement that in each case summer pruning was injurious.

Fertilization. Among fruit growers in general, there is a great diversity of opinion as to the value and necessity of commercial fertilizer application in the apple orchard. The average orchardist is of the opinion that apple trees should bear good crops without fertilizers.

Possibly this is due to the fact that the apple tree is deep rooted and has a long growing season, together with a long preparatory stage before fruiting.

However, at the Pennsylvania (46) (47) (50) and Massachusetts (6) stations it was shown that the fertilization of an orchard may have a most important effect on its production. Great differences in yield were obtained by varying the amount of fertilizer applied. Remy (42), in his fertilizer experiments, concluded that the application of a certain amount of nitrogen is necessary for the abundant development of fruit buds.

Wiggans (55), in working with three year old dwarf apple trees, obtained a marked increase over the check plot in the formation of fruit buds where nitrogen was applied as a fertilizer. Potassium and phosphorus failed to give noticeable results, both when applied alone and when applied in combination with nitrogen.

On the other hand, negative results in the application of fertilizers have been obtained at various stations. Hedrick (25) stated that: "The fertilizers applied to apple orchards have had no sensible effects upon the yield of fruit, and the trees would have been practically as well off had not an ounce of fertilizer been applied to them". After an annual application of fertilizers for a period of fourteen years, no appreciable effects on the yield have been obtained in the orchards on the Woburn (40) Experimental Fruit Farm. Similar results were obtained during a four year period by Woods.[61] By personal correspondence the work at the New Hampshire Station was summarized by J. H. Gourley,* for the past seven years, as follows: "Mature apple trees under a good system of cultivation respond slowly to the use of fertilizers, and perhaps it will be twelve or fifteen years before we have sufficient increase in yield from the plots to make the application of fertilizers pay in dollars and cents, while trees growing in grass or grass mulch will respond at once to nitrogenous fertilizers".

Thus it would seem that there is still some question as to the value of fertilizers in the apple orchard, especially with reference to increasing the yield. However, at the present stage of the work, this difference of opinion as to the value of fertilizers may be largely due to the fact that the soils on which the experiments were conducted vary widely. Then, too, this difference may be partially explained by the relatively unimportant role that inorganic salts, as compared with organic salts, play in reproduction. Nevertheless, the application of fertilizers may be of great importance, for it is highly essential that the trees produce a certain amount of branch and twig growth each year. This point, however, will be stressed more particularly in the next section of this paper.

* Letter dated November 7, 1917, Durham, N. H.

<u>Tillage.</u> Since the practice of orchard tillage is relatively new, the literature bearing upon this subject is of necessity somewhat scant. Nevertheless, some conclusive experimental data with reference to the merits and demerits of permanent sod and continuous clean tillage have been collected.

With the advance of cultural methods, it is becoming more and more evident that unless soil and other environmental conditions are especially favorable, the apple tree can not remain permanently in dense sod and still continue to be thrifty and productive. At the Cornell Station (9) (10) it was found that, even on the best apple soils of New York, sod culture is proving less profitable than cultivation. The orchards observed were all well cared for, receiving some fertilizer, and were sprayed, yet cultivation as compared with sod tillage showed an increase of 61 per cent in the average return during a five year period. It is evident that the lack of production in the sod orchards was largely due to an insufficient amount of wood growth. Gourley (23) observed that an average annual twig growth of 4.81 inches for eight years was not sufficient to keep the sod plot trees in a productive state. Whitten (56) gathered similar data on the difference in the rate of growth of cultivated trees as compared with trees grown in sod. His figures, though collected some years ago, show very strikingly the insufficient growth of the trees under sod tillage. Vigorous growth was observed in each case where cultivation was practiced. Hedrick (26) makes the rather far reaching statement that: "Grass makes apple trees sterile and paralyzes their growth".

On the other hand, within the last few years it has also been observed that orchards which have been tilled for many years are becoming less productive. This is possibly explained by the fact that continuous clean tillage burns out the humus and plant fiber, thus leaving the soil in a dead and water-logged condition.

Waters (54) found that on large areas of the Ozark fruit soils continuous clean tillage was detrimental. The soil soon lost all of its humus; became hard, baked after rains, and cultivation was next to impossible. Fletcher (18) obtained similar results in his observations of the apple orchards of Virginia.

Through personal conversation * with a representative of one of the large Citrus Growers' Associations of California, it was ascertained that this company had received good returns from alfalfa that they had plowed under during one season in their citrus orchards which had been clean tilled for many years. The representative also stated that they were profitably spending large sums each year in plowing alfalfa into the soils which had become unmanageable

* Reported by Dr. J. C. Whitten

and unproductive through continuous tillage.

The good results obtained by tillage in New York, as reported by the Cornell Station (9) (10), should not be considered as the result of tillage alone, since a heavy sod was broken up when these orchards were placed under tillage. The rotting of the sod might be expected to give rise to a great amount of humus, which has kept the soil open and porous, so that the air circulated freely. In addition, the decay of organic matter and the increaaed bacterial activity probably liberated a large quantity of carbonic acid gas, which was very effective in making plant food available. Thus, for the few years that these orchards have been in tillage, it is possible the increased production has been due largely to the addition of humus. It is a question as to whether these orchards will continue to be highly productive under prolonged clean tillage, since it seems only logical to suppose that the yields may decrease with the exhaustion of the original supply of humus. This assumption is supported by Gourley's (23) statement that: "Clean tillage alone greatly stimulated growth at first, but in recent years it has not maintained the growth of the first few years".

Within recent years experiments have been conducted at several of the Experiment Stations with the view of testing the various systems of tillage most generally employed in the apple orchard.

In an experiment at the Ohio Station, the (20) investigators leave the inference that the apple trees thrive better under a sod and mulch method of management than under clean tillage and a cover crop. Since these conclusions were based on general observation alone, their value is somewhat doubtful. Possibly their results were also influenced by the rolling lands of this Station, where tillage and cover crop is a "dangerous practice" on account of erosion.

In West Virginia, Dacy (11) reached the following conclusions: sod-culture is the least desirable of all methods of treatment for the young orchard; the sod-mulch system, in which the grass is mowed and piled about the trees, is little better than sod-culture; the mulching system, in which organic materials such as straw, manure, weeds, etc., from outside the orchard are piled around the trees, is well adapted to locations where cultivation is impractical; and clean tillage with a cover crop wherever possible is without exception the best system of culture for the orchardist to follow.

(48)(49)(50) Stewart, at the Pennsylvania Station, found that in mature orchards the tillage and cover crop system of culture gave double the growth and 36 per cent greater yield than the mulch system. In the young orchard just coming into bearing, however, the sod and sod-mulch systems of culture gave better results than the clean tillage or tillage and cover crops. Clean tillage ranked lower than tillage and a cover crop in the case of the young orchards.

Thus Stewart's results indicate that the relative values of the various systems of culture may depend to a considerable extent upon the age of the trees under observation. Nevertheless, in the application of cultural methods to young, middle aged, and mature orchards, the above investigator found that the mulching method has generally proven to be best, and sod-culture alone has been the poorest. The other systems range between these extremes with varying degrees of merit in orchards of different stages of maturity.

From experiments conducted at the New York (Geneva) Station, Hedrick [(24)(26)(27)] concludes that sod culture has no place in apple orchards in that state. He also states that the clean tillage system is unquestionably the best method of careing for the majority of apple orchards. However, it is possible that this investigator has failed to distinguish between the effect of tillage and that of a rotting sod which is a result of placing a sod orchard in tillage. This practice is one which has been employed in many of the New York orchards. He further found that there are peculiar locations, soils, and economic conditions under which the method of sod-mulching the apple orchard may be used advantageously. The Hitching's Orchard is an admirable example of an orchard where this system has proven to be a success.

Emerson (16), at the Nebraska Station, found the best general method of culture for the young orchard to be thorough cultivation in early summer, followed by a cover crop in fall. The mulch system unduly increases the winter injury by prolonging the growth in autumn and inducing a shallow root development which may be disastrous in severe climates.

Pickett (41), in experiments on orchard culture at the New Hampshire Station, found that the trees under clean tillage produced three times as much fruit as those in sod, and that the trees receiving tillage with a cover crop yielded one-fourth more than the trees under clean tillage. These results were confirmed by Gourley (21) in a later report in which he especially emphasizes the fact that the growth of the trees on the sod plot is not sufficient to keep them in a vigorous and productive condition. Gourley also stated that the growth of the trees under clean tillage is now considerably less than it was when the experiment was first started. This, in time, will undoubtedly reduce the yield of this plot.

With the amount of experimental data available at present, it still remains a question as to which system of tillage, if any one, can generally be recommended for all conditions.

HISTORY AND PLAN OF THE EXPERIMENT.

In the spring of 1911, the Department of Horticulture of the Missouri Agricultural Experiment Station, planted an apple orchard on the University Fruit Farm. This orchard contains 711 trees of the following varieties: Jonathan, Ben Davis, Grimes, King David, York, Delicious, Stayman Winesap, Ingram, Wealthy, Benoni, and Duchess. It is located on loess soil, a deep rich loam, known to be well suited to apple orchards.

The cropping records of the orchard land extend back a few years beyond the time at which the first planting was made. Since the effects of tillage methods may extend over several years, these systems of cultivation will be briefly noted. During the years 1908 and 1909 the entire plot was in timothy sod. The following two years, 1910 and 1911, a system of clean tillage was employed. For 1912 and 1913, the present tillage and cover crop plot (Plot 1) together with two-fifths of the present clean tillage plot (Plot 2) was under a system of tillage and cover crop. The remainder of the orchard was alternated between clean tillage one year and tillage with a cover crop the next.

The schedule of tillage considered in this investigation was started in the spring of 1914. The following scheme has been employed with regard to the individual plots:

Plot 1. - Cultivation and cover crop.
This plot is plowed each spring and cultivated to maintain a mulch and keep the weeds down until the middle of June. It is then seeded to an annual leguminous cover crop - usually cowpeas.

Plot 2. - Continuous clean tillage.
This plot is plowed about the middle of March and put into condition for corn. After the corn is planted, a dust mulch is maintained and the weeds are destroyed until late summer. In the strict sense of the word, this is not clean tillage. However, as carried out in this experiment, it virtually amounts to constant clean culture.

Plot 3. - Clover sod.
This plot is plowed in the spring of the odd years and seeded to clover, thus remaining in sod two years.

Plot 4. - Alfalfa sod.

This plot was seeded to alfalfa in the spring of 1914, to remain in permanent sod. However, the blue grass had so completely crowded the alfalfa out that it has had to be re-seeded twice.

Plot 5. - Timothy sod.

This plot was seeded to timothy in the spring of 1914, to remain in permanent sod.

THE PROBLEM

The primary object of the above experiment is to determine the effects of tillage methods upon the size, vigor, and fruitfulness of apple trees. However, the purpose of this paper must, of necessity, be limited to much more specific phases of the problem. The object here is to collect and correlate all present available data which may tend to throw light on the effects of the tillage methods described above. The specific points to be considered, then, are to determine the effects of these tillage methods upon:

1. - The time of fruiting as indicated by the blossom clusters in the spring of 1918.
2. - Growth and vigor as indicated by the diameter increase and the weights of prunings.
3. - The storage of reserve foods as indicated by:
    - (a) Sap density - determined by the freezing point method.
    - (b) The storage of carbohydrates - determined by chemical analyses.
    - (c) The storage of starch - determined by microscopic preparations.

4. - The size of the individual leaves, and the leaf area of the individual spurs.
5. - The time of leaf fall, and of leaf bud opening.
6. - The tree mortality.

In order to ascertain the effects of the tillage methods upon the trees determinations were made, both in the orchard and in the laboratory. The methods used are briefly outlined in the discussion of each phase of the work. In connection with this, the results are represented in Tables 1 - 11.

EXPERIMENTAL DATA

The Effect of Tillage Methods Upon the Time of Fruiting.

Since the chief object of all our endeavors in the orchard is to make it fruitful, it becomes of interest to observe the effect of tillage methods upon fruiting. However, a determination of the relation of tillage methods to production would require an investigation extending over a number of years for the data to be conclusive. Thus in a single year's work, in this orchard at its present stage of development, it is only possible to obtain figures on the effect of tillage methods upon the time of fruiting.

Data upon the time of fruiting was obtained by counting the number of blossom clusters produced by the trees of the same age and variety under the different treatments. The averages were computed and these figures used as the number of blossom clusters per tree. The varieties represented in Table 1 were the only ones blossoming in the spring of 1918.

<u>Note.</u> - In referring to the individual plots in the tables that follow they will be considered as "cowpea", "corn", "clover", "alfalfa", and "timothy" respectively. This sums up, in a single word, the treatment received by the different plots, thus rendering each table self-explanatory.

Table 1. The Effect of Tillage Methods Upon the Time of Fruiting.

Varieties	Blossom Clusters per Tree in the Various Plots*				
	cowpea	corn	clover	alfalfa	timothy
Jonathan	8	2	14	36	4
King David	14	11	23	32	8
Ben Davis	0	0	2	4	0
Rome Beauty	0	0	3	7	2
Grimes	0	3	0	2	4
Average	4.4	3.2	8.4	16.2	3.6

* See note on page 25

The data of Table 1, although meager in amount, would seem to indicate that the trees on the sod plots, as a whole, begin fruiting earlier than those on the clean tillage or tillage and cover crop plots.

The Effect of Tillage Methods Upon the Growth and Vigor of the Trees.

Along with the development of tillage methods the American pomologists have generally accepted the idea that growth and yield of apple trees are not entirely antagonistic. A well developed branch system and a vigorous tree are desirable when the trees reach bearing age.

Thus it becomes of interest, in a problem concerned with various systems of soil tillage, to determine which system may bring about the most favorable amount of growth. However, an investigation to determine the relation of growth to production must, of necessity, extend over a number of years before definite conclusions may be drawn. Therefore, in the orchard considered in this paper nothing more than a probable relation may be indicated. These factors may be measured with a fair degree of accuracy by making records of the diameter increase and the weights of the prunings.

To obtain data upon the diameter increase the trunks of the trees were measured six inches from the surface of the ground. This avoids the irregularity due to the spreading of the crown. The east-and-west diameter was measured.

Records on diameter increase have been kept by the Horticultural Department since 1914. By compiling these data the results represented in Tables 2 and 3 were obtained. The figures in Table 2 represent the averages of the trees of all varieties and of all ages.

Table 2. The Effects of Tillage Methods Upon the Average Diameter Increase (inches)

Plots*	1914 Diameter	1918 Diameter	Total Increase	1915 Increase	1916 Increase	1917 Increase	Average Increase
Cowpea	.914	2.577	1.663	.569	.604	.490	.551
Corn	.839	2.163	1.324	.435	.498	.391	.441
Clover	.784	1.780	.996	.337	.388	.271	.332
Alfalfa	.699	1.452	.753	.257	.297	.199	.248
Timothy	.669	1.598	.929	.292	.328	.309	.319

*See note on page 25

The figures of Table 2 show that the total diameter increase of the cowpea plot trees was 20.4 per cent more than that of the corn plot trees; 40.1 per cent more than that of the clover plot trees; 42.5 per cent more than that of the timothy plot trees, and 55.3 per cent more than that of the trees on the alfalfa plot.

The above relation was also borne out with but few exceptions in cases of the individual varieties. This is definitely brought out by the data representing the results with respect to several of the more important commercial varieties in Table 3.

Table 3. Diameter Increase (inches), as Affected by Tillage Methods, for Some of the More Important Commercial Varieties.

Varieties	Plots*	1914 Diameter	1915 Gain	1916 Gain	1917 Gain	Average Gain
Ben Davis	cowpea	.919	.616	.617	.509	.581
	corn	1.088	.538	.529	.42	.496
	clover	.792	.35	.458	.325	.378
	alfalfa	.823	.263	.385	.213	.287
	timothy	.633	.338	.378	.288	.335
Jonathan	cowpea	1.136	.642	.671	.521	.578
	corn	.97	.43	.572	.438	.48
	clover	.903	.419	.381	.298	.366
	alfalfa	.749	.27	.37	.189	.276
	timothy	.768	.374	.382	.354	.370
Grimes	cowpea	.918	.581	.669	.519	.589
	corn	.702	.336	.554	.373	.421
	clover	.734	.45	.386	.355	.397
	alfalfa	.718	.416	.449	.239	.368
	timothy	.640	.211	.283	.25	.248
King David	cowpea	1.002	.718	.658	.507	.628
	corn	.979	.590	.628	.461	.559
	clover	.717	.399	.466	.333	.399
	alfalfa	.742	.271	.422	.242	.278
	timothy	.711	.386	.440	.393	.406
Delicious	cowpea	.922	.617	.607	.493	.572
	corn	1.060	.580	.540	.480	.533
	clover	1.050	.633	.450	.450	.511
	alfalfa	.833	.350	.312	.212	.291
	timothy	.730	.563	.490	.303	.485

* See note on page 25

Records of the weights of prunings were made by collecting and weighing the prunings for the individual trees immediately after the prunings had been removed. These records, too, have been kept by the Horticultural Department since the spring of 1916. The compiled results of these records are represented in Table 4.

These data, although relative, are included as of secondary importance. The pruning of the entire orchard was done by the same men each year; hence it would seem logical to conclude that the amount of wood removed from the individual trees was in harmony with their vigor.

Table 4. Weights of Prunings as an Indication of the Effect of Tillage Methods Upon Vigor. Trees Seven Years of Age.

Varieties	Seasons	Weights of Prunings for the Various Plots*				
		cowpea	corn	clover	alfalfa	timothy
Grimes	1916	1350	458	440	293	630
	1917	2700	1025	675	189	625
	1918	1310	448	445	243	391
	total	5360	1931	1560	725	1646
King David	1916	2105	1523	1310	1275	1200
	1917	2307	2495	1520	1180	1900
	1918	1200	898	598	585	785
	total	5612	4916	3428	3038	3885
Jonathan	1916	975	591	611	323	312
	1917	2165	1655	636	350	693
	1918	768	790	311	283	307
	total	4908	3036	1558	956	1312
Rome Beauty	1916	652	182	300	410	205
	1917	970	542	423	465	381
	1918	442	260	20	85	227
	total	2064	984	743	955	813
Average		4486	2717	1822	1418	1914

* See note on page 25

Table 4.(Con.) Weights of Prunings as an Indicator of the Effects of Tillage Methods Upon Vigor. Trees Six Years of Age.

Varieties	Seasons	Weights of Prunings for the Various Plots*				
		cowpea	corn	clover	alfalfa	timothy
Benoni	1916	380	250	192	90	115
	1917	901	550	495	130	300
	1918	512	360	235	150	60
	total	1793	1160	886	370	465
Ben Davis	1916	1301	1005	476	421	595
	1917	2612	1742	923	671	1110
	1918	1460	805	385	357	375
	total	5373	3552	1784	1449	2080
Rome Beauty	1916	987	375	717	475	255
	1917	2054	693	772	490	335
	1918	805	727	385	245	145
	total	3846	1795	1874	1210	732
Average		3670	2169	1515	1009	1092

* See note on page 25

Table 4. (Con.) Weights of Prunings as an Indicator of the Effect of Tillage Methods Upon Vigor. Trees Five Years of Age.

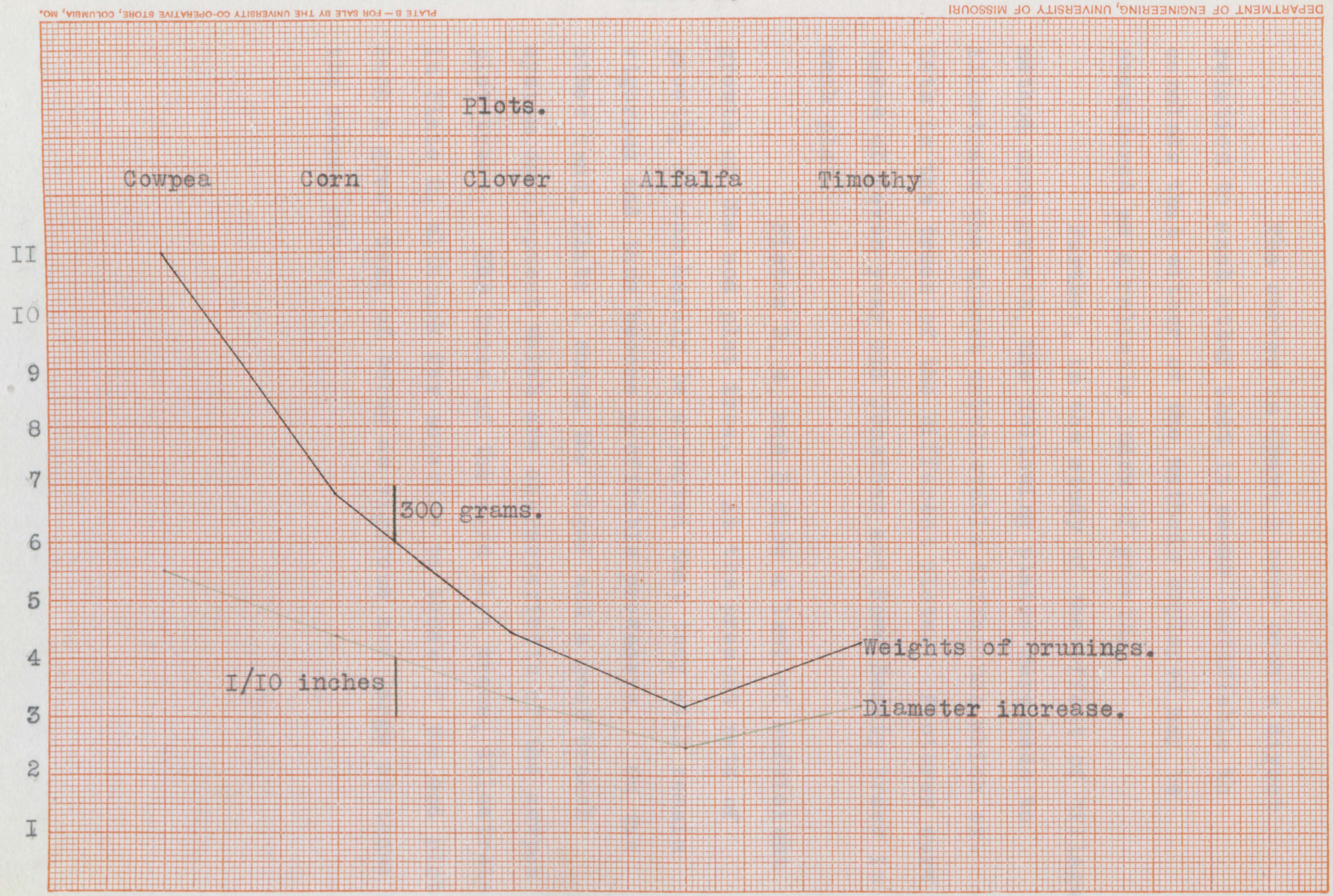
Varieties	Seasons	Weights of Prunings for the Various Plots*				
		cowpea	corn	clover	alfalfa	timothy
Grimes	1916	712	115	112	105	132
	1917	943	855	412.	222	352
	1918	885	492	305	85	375
	Total	2540	1462	829	412	859
King David	1916	248	150	185	52	210
	1917	348	485	401	98	450
	1918	488	305	180	253	167
	Total	1074	940	766	403	827
Average		1807	1201	798	407	843

* See note on page 25

Calculations of the data of Table 4 show that the weights of prunings of the cowpea plot trees were 38.9 per cent greater than those of the corn plot trees; 58.5 per cent greater than those of the clover plot trees; 61.4 per cent greater than those of the timothy plot trees, and 71.6 per cent greater than those of the trees on the alfalfa plot.

It now becomes of interest to observe the correlation which exists between the data in Tables 2 and 4; that is, the average diameter increase and the average weights of prunings. Chart 1 brings out this relation in a very striking manner. In this chart the average weights of prunings for the five, six, and seven year old trees, and the average yearly diameter increase were platted.

Chart I.



The Relation of Average Diameter Increase to Weights of Prunings.

The curves in Chart 1 bear such a direct relation to each other that it seems justifiable to conclude that either of the methods employed may be considered as a reliable index of growth.

Further, in the study of the effect of tillage method upon growth, the following plates were made to illustrate the almost unbelievable difference which exists in the trees of the different plots. Pictures were taken of seven year old Jonathan and Rome Beauty trees in each plot.

Plates 3, 4, and 5 show a lack of sufficient growth of the sod plot tree. At the present rate of growth, it can hardly be expected that they will remain vigorous and thus become profitable producers. On the other hand, Plate 1 shows the vigor and a good branch system development which are characteristic of the cowpea plot trees. The trees of the corn plot trees, illustrated in Plate 2, although far superior to those of the sod plots, lack a great deal of being as vigorous and large as those on the cowpea plot.

Rome Beauty Plate 1. Jonathan.

Pictures of Seven Year Old Trees on the Cowpea Plot.

Rome Beauty

Jonathan

Plate 2.

Pictures of Seven Year Old Trees on the Corn Plot.

Rome Beauty

Jonathan

Plate 3.

Pictures of Seven Year Old Trees on the Clover Plot.

Rome Beauty Plate 4. Jonathan

Pictures of Seven Year Old Trees on the Alfalfa Plot.

Rome Beauty Plate 5. Jonathan

Pictures of Seven Year Old Trees on the Timothy Plot.

The figures in Tables 2 and 4, together with the relative size of the trees for the different plots, as illustrated in Plates 1 to 5, seem to warrant the conclusion that apple trees fail to make sufficient growth in the sod plots in order to have a vigorous and well developed branch system when they reach bearing age. The conclusion that a system of tillage with a cover crop is the best treatment for the young orchard in this section of the state also seems justifiable.

The Effect of Tillage Methods Upon the Storage of Reserve Foods.

With the advance in horticultural science the idea, which had its origin some centuries ago,-that a sap bearing a large quantity of elaborated foods is conducive to fruitfulness, while a sap containing only a meager amount of these foods induces wood growth - is coming to be recognized more and more as a fact. At present some rather conclusive experimental data relative to this relation has been collected. However, the view of the majority of horticultural writers is voiced by Winkler's (60) statement: "That in all cases those operations which stimulate reproduction increase the sap density, while the converse is true of operations which stimulate vegetative activities".

In view of the importance of the amount of stored foods, three methods were employed to ascertain the relation of tillage methods to the reserve food supply in the sap and twigs of the apple tree.

The determination of the sap density is possibly the simplest, and yet a very accurate, method of obtaining an index of the reserve foods of a plant. The density of the sap was obtained by determining the depression of its freezing point below the freezing point of distilled water, by the use of a Beckmann apparatus. All necessary precautions for accuracy were observed in the use of this apparatus. In each case enough sap was secured for duplicates, thus checking the results.

For the freezing point depression determinations twigs were cut from similar positions on trees of the same age and variety under each of the different treatments. The cortex was then scraped from the twigs, finely ground in a food chopper, and the sap expressed. The latter was accomplished by wrapping the cortex in squares of a light grade of muslin and then subjecting it to heavy pressure.

Table 5. Effects of Tillage Methods on the Freezing Point Depression of Twig Sap.

Date	Varieties	Depression in the Various Plots *				
		cowpea	corn	clover	alfalfa	timothy
3-11-16**	Jonathan	2.193	2.230	2.275	2.435	2.325
"	Benoni	2.220	1.980	1.980	2.395	2.350
"	Delicious	1.675	1.525	1.655	1.675	1.510
4-10-17**	Jonathan	1.685	1.765	1.655	1.695	1.760
11-16-17	King David	1.755	1.716	1.931	1.973	1.822
"	Ben Davis	1.398	1.454	1.604	1.687	1.543
3-22-18	King David	1.216	1.339	1.482	1.517	1.439
"	Rome Beauty	1.361	1.349	1.426	1.453	1.407
Average		1.687	1.669	1.750	1.853	1.759

* See note on page 25

** Unpublished data of the Horticultural Department.

The figures of Table 5 show that the sap of the alfalfa plot trees was the most concentrated, while that of the trees on the corn plot was lowest in reserve foods. The sap of the twigs from the timothy, clover, and cowpea plots vary in concentrations ranging between the alfalfa and corn plots, in the order named.

By making a chemical analysis of twigs from similar positions on representative trees under the different systems of tillage, the exact effect of tillage method upon the amount of stored carbohydrates is obtained. Also, the relation of the carbohydrates to one another can be determined.

The method used in these analyses was, with some slight modifications, that devised by Davis and Daish (12) for the estimation of carbohydrates in plant extracts. From the weighings of cuprous oxide obtained by the above analyses the percentages of reducing sugar, total sugars, starch, and total carbohydrates were determined by consulting the tables published by the Association of Official Agricultural Chemists (59).

The percentages of carbohydrates in Table 6 represent the per cent of these foods contained in the alcoholic extract of a 15 gram sample of twig material.

Table 6. Effect of Tillage Methods Upon the Percentage of Reducing Sugar, Total Sugars, Starch, and Total Carbohydrates in Apple Twigs.

Date of Analyses	Plots*	Per Cent in Alcoholic Extract of the Twigs			
		Sugars			Total
		Reducing	Total	Starch	Carbohydrates
12-21-17	cowpea	.48	1.00	.92	1.92
"	corn	.52	.95	.88	1.83
"	clover	.61	1.19	1.11	2.30
"	alfalfa	.67	1.40	1.13	2.53
"	timothy	.51	.97	1.11	2.08
3-4-18	cowpea	.87	1.00	.96	1.96
"	corn	.90	1.06	.94	2.00
"	clover	1.12	1.33	1.18	2.51
"	alfalfa	1.13	1.44	1.16	2.60
"	timothy	.96	1.21	.97	2.18

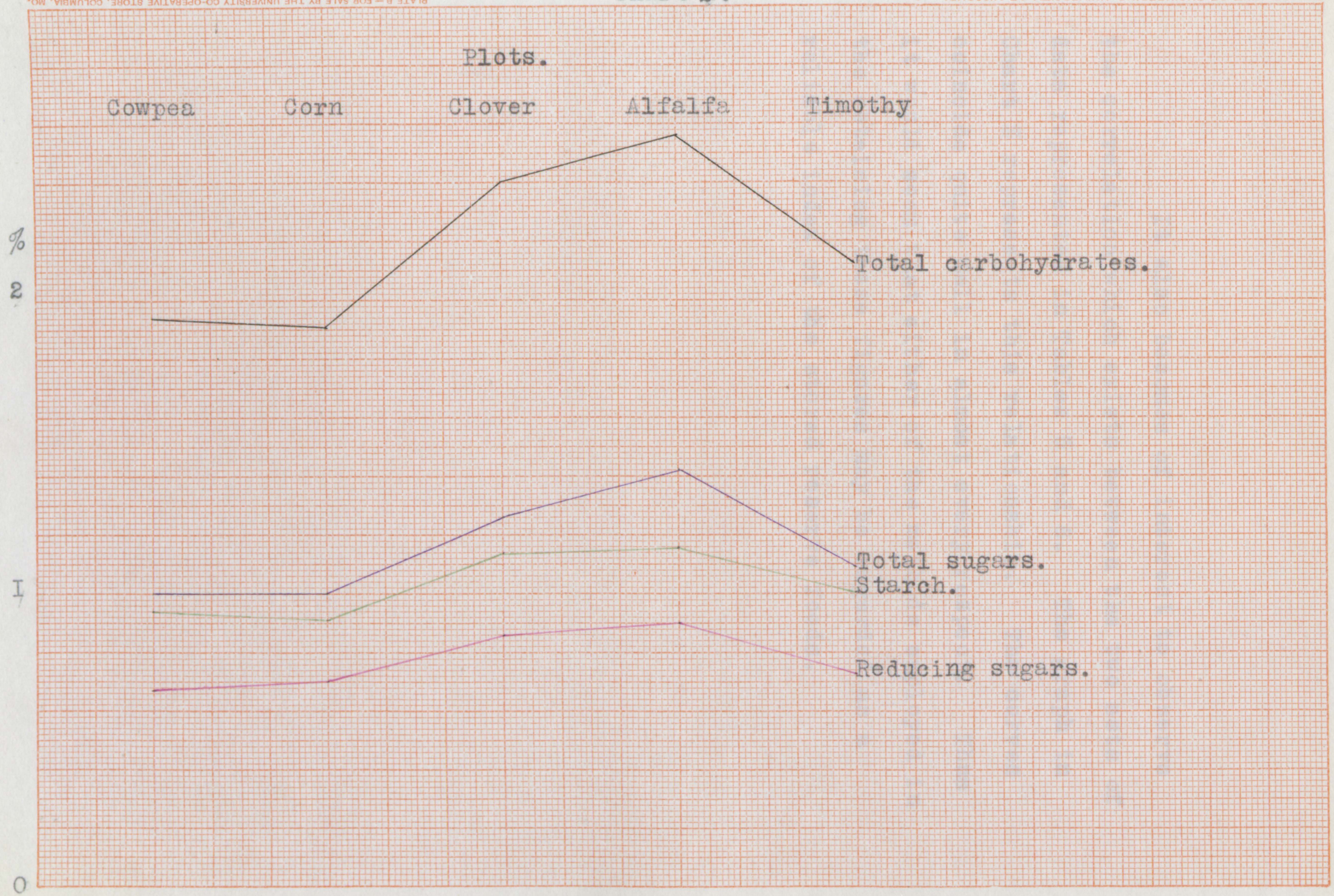
* See note on page 25

By observing the figures with respect to the total carbohydrates in Table 6, it becomes evident that the twigs of the alfalfa plot trees contain the largest storage of these foods, while those of the trees on the corn plot contain the smallest amounts. The clover, timothy, and cowpea plot twigs range intermediate in carbohydrates. In these three the twigs of the clover plot trees were highest in carbohydrates, those of the timothy plot trees next, while those of the cowpea plot trees were lowest.

The above relation also holds true, with but two exceptions, for the individual carbohydrates considered.

The effects of the different treatments upon the storage of reserve food, and the relation of the individual carbohydrates considered is brought out very strikingly by Chart 2.

Chart 2.

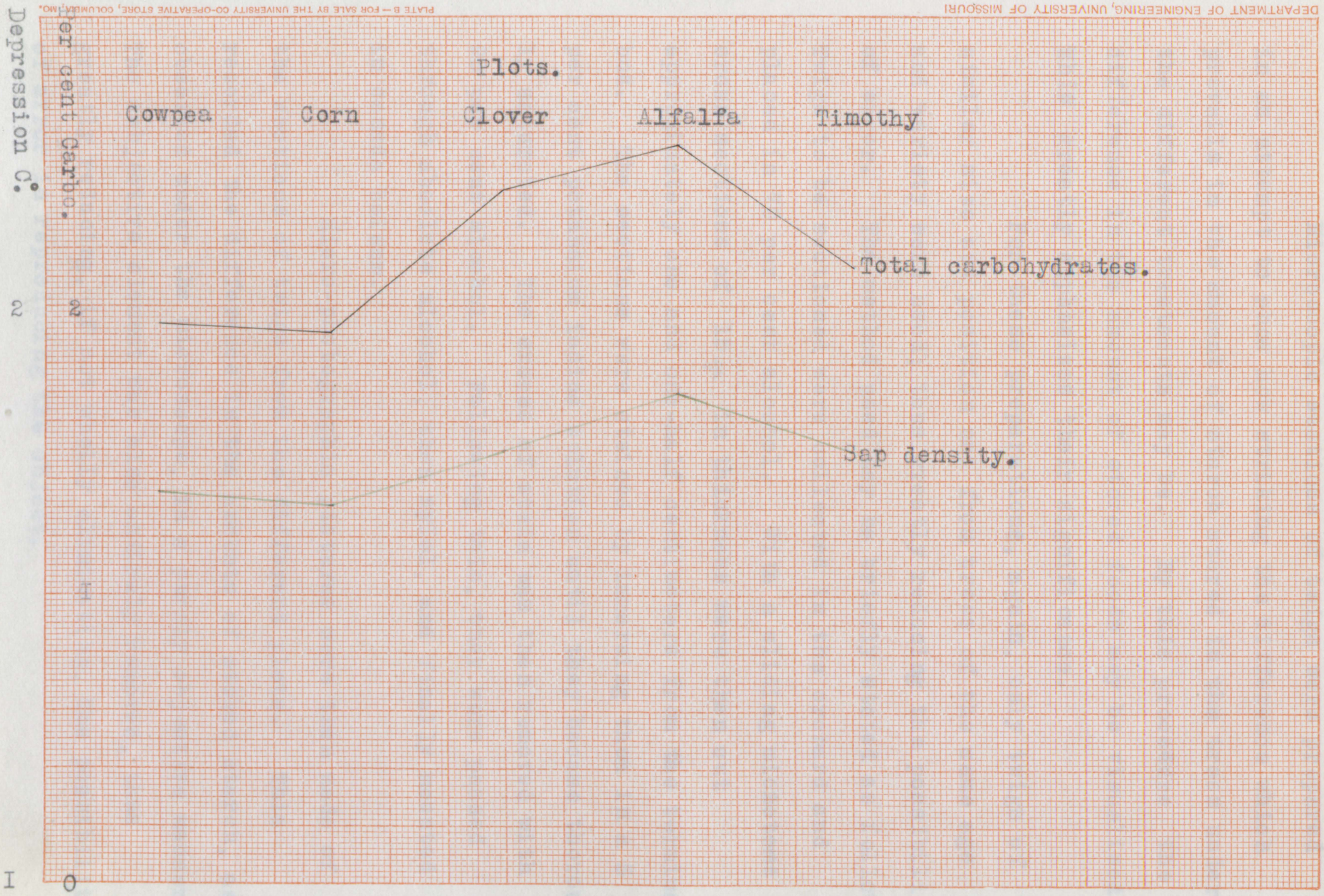


The Effects of Tillage Methods Upon the Amounts of

Reserve Carbohydrates.

It also becomes of interest to observe the correlation which exists between the two sets of data represented in Tables 5 and 6. The graph in Chart 3 represents this relationship. The curves coincide quite well in almost every respect. Thus it would seem that either of the methods employed in the obtaining these figures may be regarded as a reliable index of the stored reserve foods.

Chart 3.



The Relation Between Sap Density and the Total

Carbohydrate Storage.

Microscopic sections of twigs were prepared in an attempt to show how striking the difference which prevails in the amount of starch stored in the trees under the different treatments may be. By this procedure the difference in the amount of stored foods may be visualized, This greatly emphasizes their significance.

For these preparations, again, only twigs of similar size and position and from trees of the same age and variety were used; thus greatly reducing the possibility of error. The method used may be briefly stated as follows: Twigs to be sectioned were collected in the orchard and placed in 70 per cent alcohol. With a sliding microtome cross sections of 15 μ in thickness were then cut approximately one and one-half centimeters from the terminal bud. The sections were stained by immersing them in a 5 per cent potassium iodine solution until they became thoroughly saturated. The excess of stain was then removed with 95 per cent alcohol. Following this, they were passed through absolute alcohol, then xylol, and finally mounted in canada balsam.

Micro-photographic pictures were then made of the sections of twigs from the different plots. This recorded the difference in the amounts of stored starch, as observed under the microscope, in a purely objective manner. The subjective element was also entirely removed, thus greatly reducing, if not wholly eliminating, the possibility of error in reproducing the object.

Plates 6 to 10 illustrate in a clear cut manner the effects of tillage treatments upon the storage of starch. The starch grains are found in the greatest abundance in the cells at and near the margin of the pith. The most abundant storage of starch in the twigs was observed to be approximately one-half centimeter behind the bud. Where the starch appears in great quantities the majority of the pith and medullary ray cells are full of grains. However, by cutting the sections one and one-half centimeters from the base of the bud a more or less open field, that is, an area in which many of the cells were devoid of starch, was obtained about the middle of the pith. No starch was observed at the base of the bud, even though it is thought by some horticulturists that this is the main region of storage.

Some of the central pith cells contained starch in the case of the sections from each plot, there being more in the sections from some plots than from others. In the photographs the starch grains, though clearly distinguishable under the microscope, show up as dark areas. Thus the width of the darkened ring about the margin of the pith, together with the dark cells in the central region of the pith, serve as a basis of comparison.

The sections illustrated in the following plates were cut from twigs of the Ben Davis variety.

Based upon the above method of comparison, it becomes evident that the section represented in Plate 6 contains the smallest amount of starch, and the one represented in Plate 10, the largest amount. The sections representing the other three plots are represented in Plates 7, 8, and 9. They range intermediate to the other two in the amount of starch stored in the order of their arrangement.

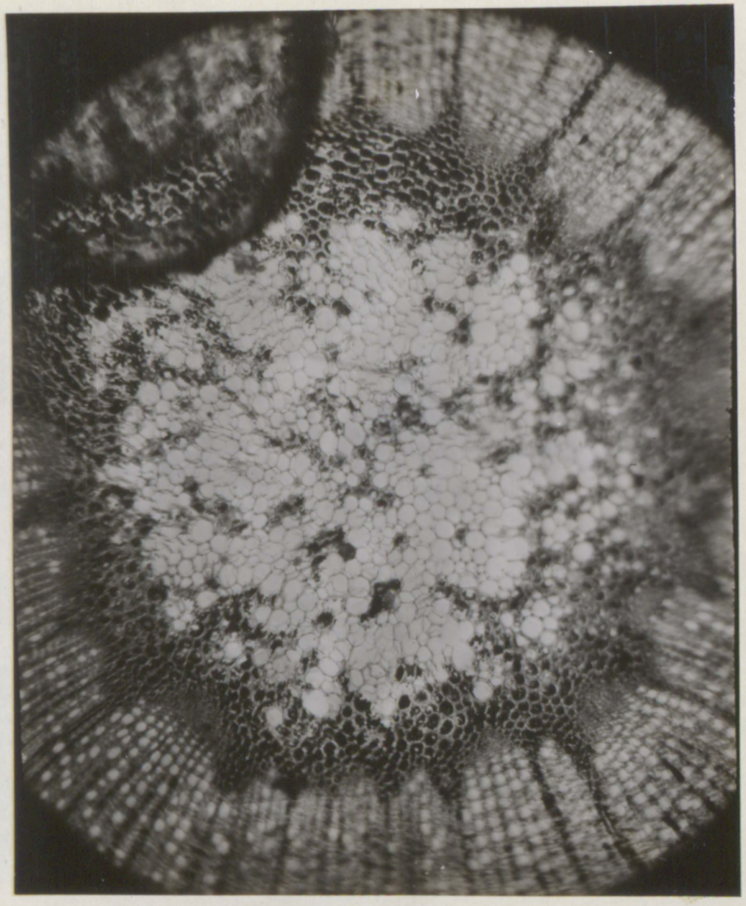


Plate 6.

Micro-photograph of Cross Section

Of a Twig From the Cow pea Plot.

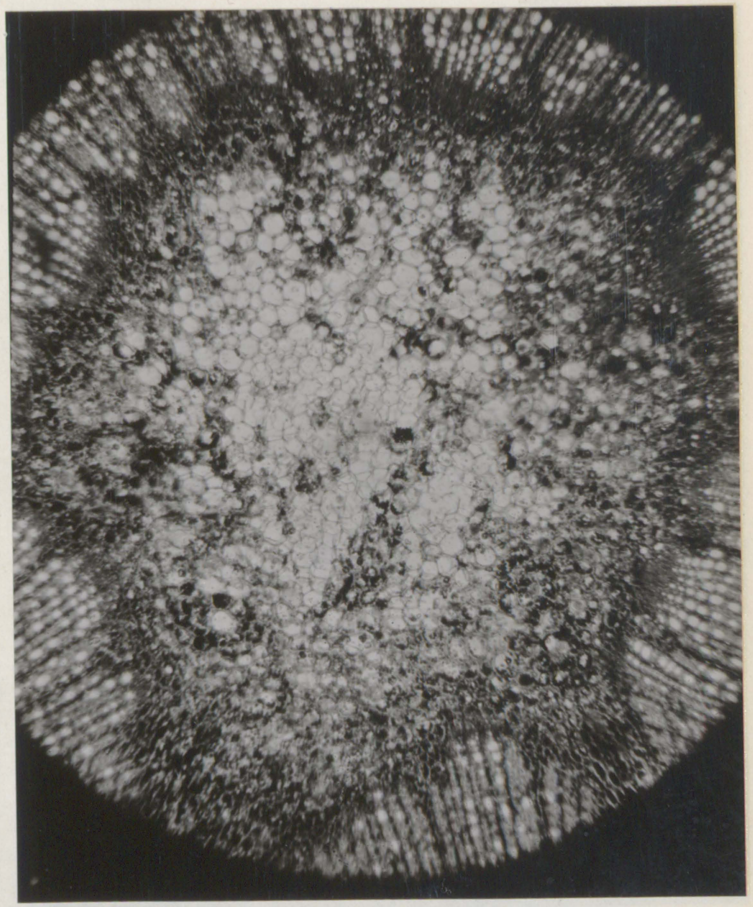


Plate 7..

Micro-photograph of Cross Section

of a Twig From the Corn Plot.

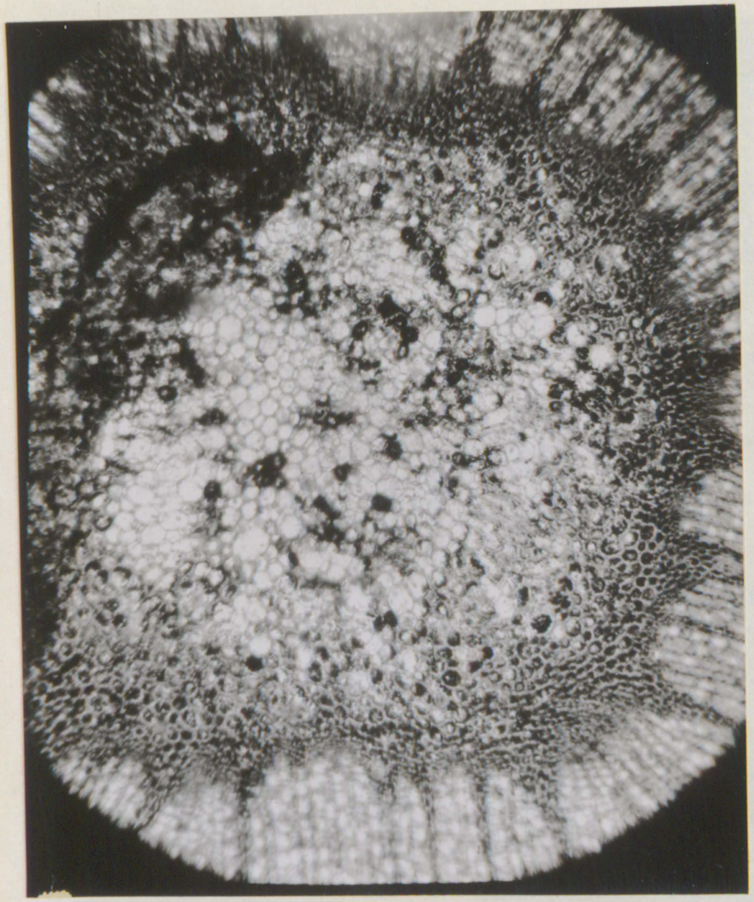


Plate 8.

Micro-photograph of Cross Section of a Twig From the Timothy Plot.

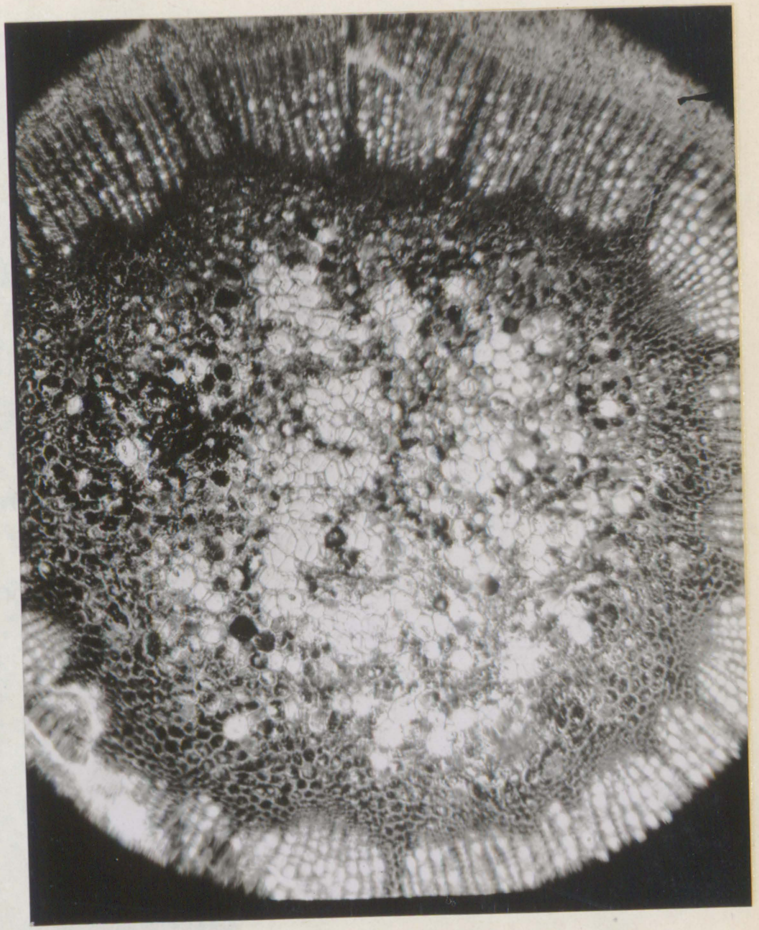


Plate 9.

Micro-photograph of Cross Section of a Twig From the Clover Plot.

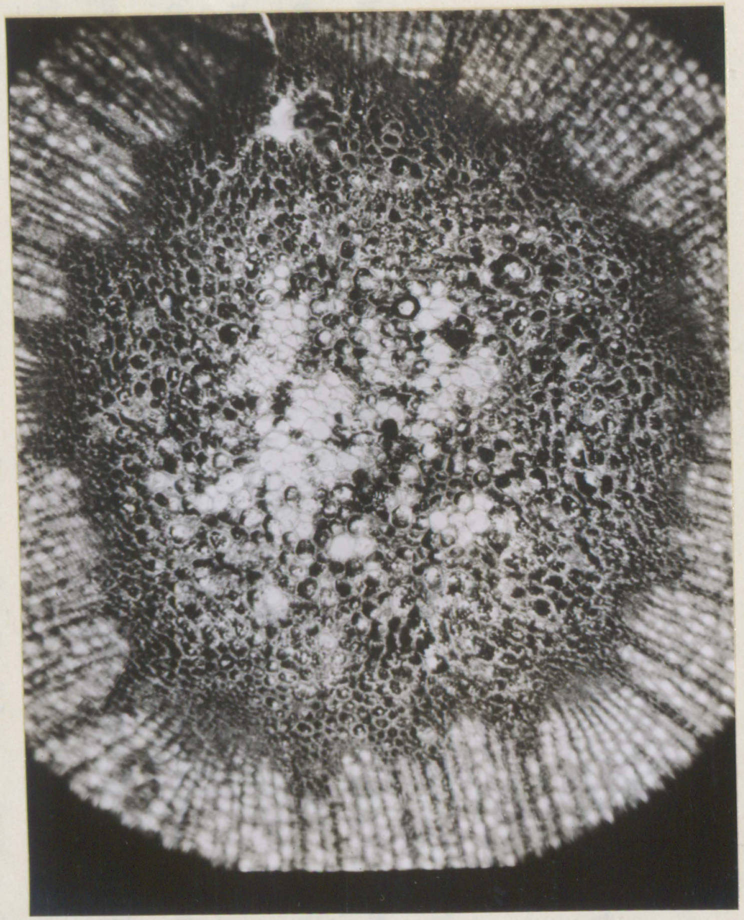


Plate 10.

Micro-photograph of Cross Section of a Twig From the Alfalfa Plot.

Then, by considering the figures in Tables 5 and 6, in conjunction with the storage of starch as illustrated in Plates 6 - 10, it seemingly becomes logical to conclude that tillage treatments influence the storage of reserve foods.

The Effect of Tillage Methods Upon the Size of the Leaves and the Leaf Area of the Spurs.

The present understanding of the functions of the leaves has brought their value, as a factor in production, very vividly before the minds of the orchardist. Since fruiting seems to depend directly upon the amount of reserve foods stored, the role of the leaves, as laboratories for the manufacture of elaborated foods becomes of great importance. Thus it becomes probable that the number and size of the leaves, other conditions being favorable, give a fair index of the manufacture of elaborated food in the individual trees. By a more direct application of the above deduction, the logical conclusion is reached that an apple tree with large leaves should produce a better yield than another tree of the same variety with relatively the same number of small leaves. With the above facts in mind, it becomes of interest to note the effects of tillage methods upon the size of the individual leaves.

In order to secure data upon the size, ten representative leaves were taken from trees of the same age and variety under each of the different treatments. Care was taken in collecting the leaves to remove them from relatively similar positions. In an attempt to secure more regularity in maturity, five or six of the leaves next to the end of the slender branches were omitted. The area of the leaves was determined with a polar planimeter, and the average computed. The leaf area is represented in the following table, the variety with the largest leaves being listed first.

Table 7. The Effect of Tillage Methods Upon the Size of the Leaves

Varieties	Leaf Size in the Various Plots *				
	cowpea	corn	clover	alfalfa	timothy
	sq.in.	sq.in.	sq.in.	sq.in.	sq.in.
Ben Davis	4.305	4.505	4.465	3.985	3.775
Delicious	4.305	4.175	3.605	3.900	3.745
York	4.035	4.215	3.865	3.885	3.720
Grimes	3.975	3.655	3.300	3.195	3.320
Ingram	4.070	3.300	3.300	-----	3.210
Jonathan	3.740	3.270	2.510	2.860	3.185
Average	4.071	3.853	3.607	3.565	3.642

* See note on page 25

This table shows that the leaves of the trees on the cowpea plot are 5.4 per cent larger than those of the corn plot trees; 10.6 per cent larger than those of the timothy plot trees; 11.4 per cent larger than those of the clover plot trees; and 12.5 per cent larger than those of the alfalfa plot trees.

The matter of leaf area and yield probably finds even a closer relation in the total leaf area of the individual fruiting branches. Here the potential fruit spur is considered. If Magness' (36) conclusion, that the elaborated foods are stored in the immediate vicinity of their manufacture, is true, it is only logical to assume that a spur with a large leaf area will store more food than a similar spur with a smaller elaborating surface. It also seems probable that bud differentiation into wood or fruit buds is controlled largely by the amount of stored reserve foods. Thus the trees bearing spurs with a large leaf area should be more productive than similar trees of the same variety bearing spurs with a small elaborating surface.

To determine the effects of cultural methods upon the elaborating surface of the spurs, three representative spurs were collected from trees of the same age and variety under the different systems of tillage. The leaf area of the spur was obtained by measuring the individual leaves with a polar planimeter. The average for the three spurs was then computed and this figure used as the leaf area of the individual spurs.

Table 8. The Effect of Tillage Methods Upon the Number and Size of the Leaves of the Individual Spur.

Varieties	Number and Area of Leaves for spurs in the Various Plots*									
	Cowpea		Corn		Clover		Alfalfa		Timothy	
	Leaves per spur	Area in sq.in.	Leaves per spur	Area in sq. in.	Leaves per spur	Area in sq.in.	Leaves per spur	Area in sq. in.	Leaves per spur	Area in sq.in.
Delicious	7.66	12.92	7.00	12.50	6.33	11.32	6.66	10.48	6.66	10.86
Jonathan	7.33	12.40	7.00	12.65	5.00	10.05	6.33	10.88	6.33	11.75
Ingram	7.33	12.31	7.33	11.55	5.33	7.85			5.33	8.44
Grimes	7.00	11.13	7.00	9.42	5.66	8.32	5.66	9.77	6.33	9.68
Ben Davis	5.33	9.28	6.33	10.52	4.66	7.89	4.33	7.62	6.33	10.20
York	6.00	9.26	5.66	8.68			4.66	7.48	5.00	8.70
Average	6.77	11.21	6.66	10.88	5.39	9.08	5.53	9.44	5.98	9.93

* See note on page 25

The above table shows that the elaborating surface of the spurs of the trees on the cowpea plot is 2.1 per cent greater than that of the corn plot trees; 11.4 per cent greater than that of the timothy plot trees; 15.8 per cent greater than that of the alfalfa plot trees; and 19 per cent greater than that of the clover plot trees.

An identical correlation to the one just stated for the leaf area of the spur also holds true for the number of leaves per spur. That is, the cowpea plot trees bear the most leaves per spur, and this number decreases in the corn, timothy, alfalfa, and clover plot spurs in the order named.

By comparing Tables 7 and 8, a direct relation between the size of the individual leaves and the leaf area of the spur is suggested. It is believed by the author that this relation might be established if data bearing upon this point were collected for a number of years.

The figures in Table 7 and 8 also seem to warrant the conclusion that leaf size may be influenced to a certain degree by tillage methods.

The Effect of Tillage Methods Upon the Time of Leaf Fall and Leaf Bud Opening.

The importance of a knowledge of the time of leaf fall becomes apparent when the direct association of this phenomonon with the ripening of the wood for the dormant season is considered. In the semi-severe winter climates, as that of Missouri, the fruit growers have for many years regarded the time of leaf shedding as of considerable importance. A late growth in autumn is undesirable for the trees enter the dormant period with immature wood and are liable to have their twigs injured or even sometimes killed during the winter months.

The figures in Table 9 were obtained with respect to the time of leaf fall in the orchard considered in this investigation. To obtain these figures the relative per cent of leaves that had fallen were estimated at the dates indicated in the Table.

Table 9. The Effect of Tillage Methods Upon the Time of Leaf Fall.

Date	Varieties	Leaf Fall in the Various Plots * cowpea %	corn %	clover %	alfalfa %	timothy %
10-11-17	Ben Davis	5	5	10	20	10
"	Delicious	0	0	5	5	5
"	York	0	5	35	5	10
"	Grimes	0	0	15	5	5
"	Jonathan	0	0	20	5	5
	Average	1	2	17	8	7
10-20-17	Ben Davis	30	30	40	50	35
"	Delicious	10	20	20	15	25
"	York	10	15	75	15	25
"	Grimes	0	20	40	10	20
"	Jonathan	0	5	30	10	15
	Average	10	18	41	20	25
10-30-17	Ben Davis	60	70	85	80	75
"	Delicious	40	60	60	40	65
"	York	30	35	85	30	30
"	Grimes	5	45	65	30	40
"	Jonathan	10	30	50	35	30
	Average	29	48	69	43	48

* See note on page 25

The figures in this table show that the trees in the clover plot shed their leaves earlier than those on the other plots. The leaves of the trees on the timothy and corn plots fell approximately at the same time. This was considerably later than the leaf fall of the clover plot trees. Those of the alfalfa plot trees follow slightly later, while the trees retaining their leaves longest were the ones growing in the cowpea plot.

The varieties represented in Table 9 are listed in the order of the time of leaf fall. It becomes evident that there is a striking varietal difference in the time at which the leaves are dropped. Ben Davis sheds its leaves considerably in advance of any of the other varieties. Jonathan retained its leaves longest. The Delicious, York, and Grimes, in the order named, range between these two extremes.

In a climate like that of Missouri the fruit crop depends also to a certain degree upon the time of leaf bud opening. The importance of the time of leafing out becomes evident when we consider the fact that blossom bud opening occurs almost simultaneously with leafing out. It sometimes happens that the crop on the trees which leaf out early is seriously injured by late spring frosts, while that on the other trees, which, due to tillage treatments or for some other cause, leaf out later, matures successfully.

To secure figures on the time of leafing out the per cent of unfolding of the buds was estimated. Since, in some cases, there is a marked difference in the time of unfolding of the terminal and axillary buds, they were considered separately.

Table 10. The Effect of Tillage Methods Upon The Time of Opening of (1) the Terminal and (2) the Axillary Leaf Buds

Dates	Varieties	Buds	Leaf Bud Opening in the Various Plots* cowpea %	corn %	clover %	alfalfa %	timothy %
4- 8-18.	Jonathan	1	15	15	40	15	15
		2	0	0	15	5	5
"	Ben Davis	1	10	5	30	15	5
		2	0	0	5	5	0
"	King David	1	5	5	40	5	10
		2	0	0	10	0	5
"	York	1	0	0	30	5	15
		2	0	0	10	0	0
"	Grimes	1	0	0	5	5	10
		2	0	0	0	0	0
	Average	1	7	4	29	9	11
		2	0	0	8	2	2
4-16-18.	Jonathan	1	50	50	100	80	85
		2	5	5	70	35	60
"	Ben Davis	1	60	30	100	90	60
		2	10	10	50	30	30
"	King David	1	20	30	100	30	50
		2	15	15	50	10	35
"	York	1	15	15	100	55	85
		2	0	0	50	10	30
"	Grimes	1	0	10	30	40	50
		2	0	5	10	10	10
	Average	1	29	27	86	54	66
		2	6	7	44	19	33
4-23-18.	Jonathan	1	100	100	100	100	100
		2	90	90	100	100	100
"	Ben Davis	1	100	100	100	100	100
		2	75	65	100	70	50
"	King David	1	40	60	100	90	100
		2	30	50	90	50	70
"	York	1	75	80	100	100	100
		2	50	60	80	90	60
"	Grimes	1	35	50	85	80	90
		2	15	20	60	40	50
	Average	1	70	78	97	94	98
		2	52	57	86	68	66

* See note on page 25

The figures of Table 10 show that the trees on the clover plot were first to leaf out, those on the timothy plot second, those on the alfalfa plot third, those on the corn plot fourth, while those on the cowpea plot were slowest to begin leaf growth. There was very little difference in the time of leaf bud opening in case of the corn and cowpea plot trees.

It also became evident that the individual varieties leaf out in the following order: Jonathan, Ben Davis, King David, York, and Grimes.

It is also indicated by the data of Table 10 that the terminal leaf buds open approximately 33 per cent earlier than the axillary buds.

By comparing the results in Tables 9 and 10 it is observed that there is a correlation in the different plots between the time of leaf fall and leafing out. The clover plot trees shed their leaves first, and were also first to open their leaf buds. Similarly, in each case, the trees on the timothy plot were second to shed their leaves and second to leaf out. The cowpea plot trees were latest both in dropping their leaves and in resuming vigorous growth in spring. However, the trees on the corn plot leafed out next latest, even though they shed their leaves approximately at the same time with the timothy plot trees, and, the alfalfa plot trees, although second latest in the time of leaf fall, were third in the time of leafing out.

The above figures also show that Jonathan, although shedding its leaves latest, was the first variety to leaf out. Ben Davis shed its leaves considerably in advance of any of the other varieties, and yet it leafed out later than the Jonathan. The other varieties shed their leaves and leafed out in the same order. These results seem to show that a variety dropping its leaves first need not necessarily be expected to open its leaf buds earliest.

The above data seem to justify the conclusion that the time of leaf fall and the time of leafing out within the various varieties may be influenced by soil treatment.

In addition to the above data photographs were made of the trees and the plots where leaf bud opening was earliest and latest. The pictures emphasize the difference in the time of leafing out as affected by cultural methods. Plates 11 and 12, which show the time of leafing out on the cowpea and clover plots respectively, were made from seven year old Jonathan trees. The trees of the other plots range between these extremes with respect to leaf bud opening in the following order: timothy, alfalfa, and corn.

Plate 11.
Tree on Cowpea Plot.

Plate 12.
Tree on Clover Plot.

The Effects of Tillage Methods Upon the Time of Leaf Bud Opening.

The Effect of Tillage Methods Upon the Tree Mortality.

Both good orchard lands and nursery stock have advanced enormously in value with the last decade; therefore it becomes of great importance to plant the trees successfully in order to obtain the earliest possible returns. It is poor economy to set trees under conditions where a large per cent of them die and must be replaced. Replanting not only increases the initial outlay of an orchard, but it also delays the time when profitable returns are received.

Figures regarding the effect of soil treatment upon the number of trees that had to be replaced in the orchard under consideration were obtained from unpublished records of the Horticultural Department. By compiling these data in tabular form the figures in Table 11 were secured.

Table 11. Effect of Tillage Methods Upon the Tree Mortality.

Plots *	Number of trees planted	Number of trees dying	Per cent of tree mortality
cowpea	200	3	1.5
corn	103	5	4.8
clover	74	12	11.4
alfalfa	122	31	24.8
timothy	212	71	32.2

* See note on page 25

The figures of this table warrant the conclusion that it is not economy to set apple trees in sod, regardless of whether the sod be that of a biennial legume or that of a dense rooted perennial grass. Furthermore, the data seem to justify the conclusion that it is more economical to set trees in a soil under a tillage and cover crop treatment than in a soil receiving clean tillage alone.

SUMMARY AND CONCLUSIONS

The present available data, although limited in amount, with respect to the effects of tillage methods in the orchard under consideration have brought out the following points:

The amount of bloom in 1918 indicates that the trees on the sod plots may begin fruiting earlier than those on the clean tillage or tillage and cover crop plots.

The cowpea plot trees show the most favorable growth and vigor. In the other plots these factors become less favorable in the following order: corn, clover, timothy, and alfalfa.

The storage of reserve foods, as indicated by sap density and chemical analyses, is greatest in the alfalfa plot trees and smallest in the trees on the corn plot. The clover, timothy, and cowpea plot trees range intermediate in foods stored to the alfalfa and corn plots in the order named.

The size of the individual leaf and the total area of the leaves on the spurs are greatest in the cowpea plot trees, and decreases in case of the trees of the other plots as follows: corn, timothy, clover, and alfalfa.

The number of leaves per spur bears a direct correlation to the leaf area of the spurs.

The trees of all varieties drop their leaves and leaf out on the different plots in the following order: clover, timothy, corn, alfalfa, and cowpea. Thus it would seem that the treatment which causes early leaf fall also induces early leaf bud opening.

There is no varietal correlation between the time of dropping the leaves in autumn and leaf bud opening in spring. Thus, a variety dropping its leaves earliest need not necessarily leaf out first.

Tree mortality is greatest in the timothy plot and decreases in the other plots as follows: alfalfa, clover, corn, cowpea.

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