THE INFLUENCE OF CERTAIN CULTURAL FACTORS ON SIZE OF APPLES

THESIS FOR THE DEGREE OF M. S.

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CULTURAL FACTORS ON SIZE OF APPLES

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THESIS

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Introduction

As the apple industry has developed, the size of fruit has come to be the most important single factor in selling the crop at a profitable price. A moderate crop of large apples brings better net returns to the grower than a large crop of small fruit. Gaston (34) has shown that small size is the most common cause for apples being placed in the cull grade in Michigan. Methods of producing large apples have been reported on by various research workers throughout the country. The recommendations for increasing the size of apples involve a number of treatments. It was to evaluate certain of these cultural factors, under one set of soil and climatic conditions, that the study herein reported was undertaken.

REVIEW OF LITERATURE

Murneek (9) reports that thinning will increase the size, grade and quality of fruit. By reducing the number of defective specimens, it will also decrease the cost of handling. Systematic fruit thinning will reduce the breakage of limbs and preserve the vigor of a tree but it may not prevent biennial bearing. As a rule not more than one apple per spur should be left and these should not be closer than 4 to 6 inches apart.

Herrick (10) concludes that thinning of mature Winesap trees pays the first year. Winesap responds to thinning by increased size and better color even when thinned as late as July 20. The best results were obtained in thinning old Winesap trees by leaving the apples 9 to 10 inches apart.

Ballou (15) states that in every case the percentage of "first grade" fruit was materially increased by thinning. For example a well thinned orchard of 63 trees produced but 21 pounds of apples under 2 inches in diameter, while a single unthinned tree of the same age and variety produced 28 pounds under 2 inches. He also relates that pruning out crowded branches and twigs, while helpful, will not prove a substitute for thorough thinning of the fruit on individual branches and twigs.

Auchter (12) states that where apple trees are bearing a medium to a heavy crop of fruit, the removal of part of the fruit by thinning is a very profitable practice. Under certain conditions, however, such as light crops, with fertile soils and vigorous trees, thinning may not pay. In all cases where trees had a good crop, thinning increased the size of the fruit. He says, "Thinning does not influence subsequent crops nor cause trees, naturally biennial in bearing habit, to bear a crop each year. Winter varieties should be thinned in West Virginia from June 20th to July 5th. In the case of summer or early autumn varieties it will probably pay to delay thinning until the fruit is large enough to use, and then several thinnings should be made as the fruit sizes up".

Beach (13) says that where thinning is judiciously carried out, it does not materially reduce yields. In fact, in the case of over loaded trees it often increases the yield of large marketable fruit.

Batchelor (11) remarks, much of the so-called habit of "alternate bearing" in apple trees is directly traceable to the fact that they overbear one year and recover from this strain by bearing a very light crop the following year. Many broken limbs in the orchard could be prevented by proper thinning and much time and money saved in propping the branches.

Aldrich (6) found heavy thinning increased, in all cases, the size and color of the fruit, as compared to no thinning. In nearly all cases the thinned trees set more blossoms the spring following the thinning, than unthinned trees. The response to thinning was greater on vigorous trees. On non-vigorous trees increased fruit bud formation did not occur.

Rollins (8) working with Baldwin found that the percentage of total yield in pounds in the 2½ to 3 inch and over 3-inch groups is greatly increased by thinning. In this case increasing the size was accomplished at the cost of a rather serious reduction in yield per tree. The average thinned tree produced 498 pounds while the average unthinned tree produced 682 pounds of fruit.

Weinberger (5) working with peaches states that thinning reduces the total volume of fruit and the heavier the thinning the greater the reduction. Under Maryland conditions it seems that 30 to 40 leaves per fruit are desirable.

Haller (4) concludes that practically no difference in the size of the fruit occurred when no leaves were nearer than 4½ to 10 feet from the fruit as compared with fruit grown with the leaves adjacent. Apples are able to obtain foods as easily from leaves that are above, below, or on separate branches as from leaves that are adjacent. The size of the fruit at the end of the season is correlated with the size of the fruit early in the season.

Cummings, Jenkins and Dunning (14) found that small sized fruit is one of the common causes for apples being placed in the cull grade. Varieties which are naturally small or those trees are liable to overset, are most likely to respond well to thinning. A tree heavily loaded in one quadrant may need thinning in that region, even though sparsely set in its other quadrants. Each branch seems to be largely independent of conditions existing in other branches. There is very little mutuality or cross influence. Apparently leaf size and possibly depth of color may be more important than number of leaves. Thinning is worth while to eliminate culls, even though no good fruit is taken off. Invariably the larger apples contained more good seed than the small fruit. Hence a partial remedy for small apples is to be found in the more perfect fertilization of the blossoms. Six seeds per apple is enough to insure development if no other factors inhibit.

Discussing the relation of growth on ringed and unringed branches, Magness, Overley and Luce (1), state that on unringed branches the accumulation of carbohydrate materials would be free to move out of the branch and in considerable part, contribute to trunk and root growth, whereas, on ringed branches it tended to be stored, at least in part, in the fruit. They further report, that under Washington conditions from 40 to 50 leaves per fruit are needed with varieties such as Delicious, Winesap, and Rome Beauty to obtain large size fruit and at the same time enable the trees to bear regularly. Twenty to 30 leaves gave fruit of good commercial size, but the extra leaves are required to produce fruit buds for the next year's crop.

Ellenwood (7) concludes that thinning materially increased the percentage of fruit 2½ inches in diameter and reduced the total weight of harvested fruit. He also makes the following statements, "Size of leaves may vary greatly under different conditions and leaf area is more important than number of leaves. In spite of obvious disadvantages, distance of thinning probably remains the most accurate basis for recommendations to fruit growers."

Magness (9) says "It is true of course, that water shortage will result in small size in fruit regardless of leaf area. However, with ample water supply the leaf area seems largely to limit the size and quality of the fruit."

Furr and Magness (5) report that the soil moisture content of most of the root zone of apple trees must be above the wilting percentage (5.5 per cent, on dry weight basis, measured by growing millet) if the leaves are to function and the fruit to grow at the maximum rate during periods of warm, dry weather. On the irrigated plots the highest moisture content was always found in the surface 6 inches and the same was true of the dry plots during rainy periods, but during extreme droughts the highest moisture content on the dry plots was found in the second foot below the surface. Fruit harvested from Rome trees in the dry plots was about two times larger than that of the corresponding irrigated plots.

Working with peaches, Hendrickson and Veihmeyer (35) report a 40 per cent increase in size of fruit from the "wet" plot as compared to the "dry" plot.

Stewart (31), working with apples and studying the effect of fertilizers upon size of fruit, revealed that size depends a great deal upon the soil moisture content.

Using a tar paper roof to prevent rain water from entering the soil Osmann (30) picked 136 apples, measuring three-fourths of a bushel, from the covered plot and 160 apples, measuring one bushel, from the check plot, denoting little difference in size. He added that the method used did not give the results hoped for but suggested removing the paper between periods of rain, thus permitting the usual loss of water by evaporation.

Loughridge (cited by Gardner, Bradford and Hooker) (32), states that 5 per cent hydroscopic moisture and 8 to 9 per cent free water is just above the minimum soil moisture requirements for apples growing on certain loam soils.

Ballou (15) infers that no results of value would occur from orchard fertilization experiments on fertile soil--soil that already contains a sufficient supply, the elements necessary to vigorous growth and prolific fruiting of the trees. In his experiments all trees receiving nitrogenous fertilizer required thinning while unfertilized trees did not set heavy enough to require thinning.

Stewart (16) states that the plant food influence upon fruit size will always be secondary to moisture conservation and proper thinning.

Alderman (17) and Reimer (22) secured evidence that nitrogen increased the size of fruit.

Evidence that applications of nitrogen fertilizers are likely to result in some decrease in size of fruit has been submitted by Chandler (18), Crane (20), and McCue (21).

Cooper and Wiggans (19) working with peaches found that the number of fruits on the tree influenced the size of fruit more than the fertilizers used.

Cooper (23) studying the effects of fertilizers on the performance of apple trees observed that fertilizers did not increase the size of the fruit. He adds that fruit size is governed by the number of fruits on the tree, the size decreasing as numbers increased.

Knowlton (25) experimenting with fertilizers reports that the limbs on the fertilized side of the tree received more of the nitrogen than did the other unfertilized side, as shown by the length of terminal growth.

Andrews (33), studying the various factors which influence size in apples, found that the fruits picked from the nitrated side of the trees were larger in size than those from the unfertilized side of the trees.

Dutton (24), studying spray injury, did not secure a consistant difference in size of fruit when lime sulphur and bordeaux mixture were compared. Only two years out of four did the Jonathan apples, from trees sprayed with lime sulphur, average larger than the apples from trees sprayed with bordeaux.

Fisher (26), working with sweet cherries, concluded that any alkaline spray had a tendency to reduce the size of the fruit. It was suggested that this influence was produced through the action of the spray material in destroying the bloom on the fruit, thereby increasing transpiration.

Duggar and Cooley (27) reported that potato plants sprayed with bordeaux mixture transpired more water than plants sprayed with lime sulphur or unsprayed.

Wells (28), working with sour cherries, found that spraying materials reduced the size of fruit. For example, cherries picked from trees sprayed with bordeaux mixture averaged 181 fruits per pound while those sprayed with lime sulphur averaged 133 per pound, sulphur dust 119 per pound and unsprayed 114 fruits per pound.

Dutton (29) observed that by combining a small amount of ferrous sulphate with lime sulphur and lead arsenate, foliage injury was reduced, which resulted in brighter color and larger size of apples.

Andrews (33), studying the effect of root pruning on fruit size, relates that the apples were smaller on the root pruned side than on the opposite side (roots not pruned) of the same trees, except where the tree trunk was twisted. Applying a nitrogen-carrying-fertilizer tended to off-set the injury caused by root pruning.

Andrews (33) picked and sized apples from trees, half of whose roots were in sod and half in cultivation, and his records show that the apples from the cultivated side averaged about 0.4 centimeter larger in diameter.

Tonjes (36) reports that over a period of years several varieties of apples grown under sod mulch since setting, have consistently produced larger apples than trees of the same varieties and age grown under clean cultivation.

Partridge and Veatch (38) state that in both sod and cultivated orchards, the most dense root development is usually from six to eight inches below the surface. Fruit trees growing on a good loam soil produce an upper and lower root system. The latter taps a more permanent water supply and supplies the tree with water during periods of drought. In some instances, the roots reach a depth of 20 feet or more.

OBJECT OF THIS STUDY

The experiments herein reported were performed to isolate some of the factors which influence the size of fruit in apples and to determine the value of each contributing factor. Specific data to answer the following questions were sought:

(1) How does fruit thinning affect the size of the apple?

(2) Will irrigation under Michigan conditions increase size of apple and if so to what extent?

(3) Will the application of nitrogen-carrying-fertilizers result in large apples?

(4) How does spraying affect the size of fruit?

(5) What is the effect on fruit size if part of the tree's roots are removed?

METHODS EMPLOYED

The experiments reported herein were carried on at the Graham Horticultural Experiment Station, located near Grand Rapids, during the seasons of 1927 and 1928. The soil according to the soil survey (40) is classified as Isabella loam. The trees used were about ten years old and included the varieties, Wealthy, King David, Grimes Golden and Stayman Winesap. All trees were growing in sod mulch except the King David and part of the Stayman Winesap and were in a good state of vigor at the time the experiments were conducted.

Each treatment included from one to four trees. To eliminate individual tree variations as many treatments as possible were applied on the same tree.

At harvest time a steel caliper, having long lips, was used to measure the diameter of each apple and the measurements were recorded in centimeters. The average weight per apple was obtained by weighing the whole lot and then dividing that weight by the number of apples. The results were recorded in grams in 1927 and in pounds in 1928.

PRESENTATION OF DATA

Thinning

Two uniformly moderately to heavily loaded Wealthy trees were selected for a thinning experiment. As the trees were adjacent to each other any variation in soil was eliminated. One tree was thinned soon after the "June drop" to six inches between apples. At harvest time the apples were picked from each tree and were measured through the largest diameter. The results are presented in table I.

Table - I Effect of Thinning on Size of Fruit

Treatment	Number of Apples	Average Diameter (cm)	Average Weight (gr)
Whole Tree Thinned	847	6.71	94.6
Whole Tree Unthinned	948	5.65	62.6
Difference		1.06	32.0

It will be noted that thinning resulted in about a 16 per cent increase in diameter, but in weight per apple the increase was about 34 per cent. Possibly the most important reason for such an increase is that the unthinned tree was overloaded. By thinning, the load was reduced, thus the amount of leaf area, moisture, and other constituents which go to make up the apple were increased for each remaining apple.

In the fall of 1927, apples were picked at random from three moderately loaded Wealthy trees to show the size of fruit borne by spurs and terminal shoots. Apples were picked from spurs bearing one fruit, from terminals shoots bearing one fruit, and from terminals shoots bearing two fruits. The results are shown in table 2.

Table 2 - Size of Fruit Borne by Spurs and Terminals Shoots.

Treatment	Number of Apples	Average Diameter(cm)	Average Weight(gm)
One Apple per Spur	207	6.85	100.3
One Apple per Terminal Shoot	198	6.65	97.4
Two Apples per Terminal Shoot	160	5.87	80.5

It will be observed that apples borne by spurs were slightly ~~the~~ larger than those borne by terminal shoots. When the terminals shoots bore only one fruit, the size was about 16 per cent larger than when two fruits were borne. These data suggest that in thinning only one fruit should be allowed to remain per spur or terminal.

To eliminate variation in different trees, uniform pairs of branches which ranged in diameter from $\frac{1}{4}$ to $\frac{3}{4}$ inches were selected on a Wealthy tree. One branch of each pair was thinned soon after the "June drop", and the apples were spaced about 6 inches apart. Following the thinning about one half of the pairs of branches (thinned and unthinned) were girdled by removing a 1/8 inch strip of bark. Care was taken not to injure the cambium layer. To prevent drying out of the exposed cambium, nurserymen's tape was placed over the girdle. The results of these treatments are shown in table 3.

Table 3 - Effect of Thinning and Girdling on Fruit Size

Treatment	Number of Apples	Average Diameter (cm)	Average Weight (gm)
Thinned - Ungirdled	41	6.42	93.2
Unthinned - Ungirdled	29	6.27	89.8
Difference		.25	3.4
Thinned - Girdled	59	6.61	104.6
Unthinned - Girdled	44	6.34	94.3
Difference		.27	10.3

When ungirdled, thinned and unthinned branches are compared it will be observed that the apples picked from the thinned branches average about 4 per cent heavier. The reason for such a small contrast in size is due to the fact that the elaborated carbohydrates could be transferred from the thinned to the unthinned branches. To prevent this translocation of plant foods, certain pairs of branches were girdled. Where thinning was practiced on girdled branches the increase in size was about 10 per cent or twice as much as on ungirdled branches. In summing up the thinning experiments it appears that where the tree is overloaded the fruit may be small in size. Apparently thinning is a practical method of producing large apples.

Moisture

To determine the effect of soil moisture on fruit size, three uniform ten-year-old King David apple trees were selected. The apples were thinned to about 6 inches apart. These trees were located on a well drained loam soil, having a gentle slope. One tree was watered at the rate of 300 gallons per week. A dirt retainer was constructed around the tree just under the drip of the branches to prevent any run-off. Around an adjoining tree a tar paper roof was constructed covering an area of 20 x 20 feet. This roof was placed 6 to 10 inches above the ground, depending on the elevation of the ground. This permitted free circulation of air under the roof and normal evaporation was not greatly decreased. Roots extending beyond this roof were severed by digging a trench two feet deep. On the side adjoining the watered tree a trench 2½ feet deep was dug and the roofing paper was extended from the top of the roof to the bottom of the trench. The trench was then refilled with dirt and packed firmly. Two openings in the form of boxes with close fitting removable covers, were built in the roof under the drip of the branches. The purpose of the openings was to permit taking samples of the soil for moisture determinations. A third tree which received the natural rainfall was used as a check.

Soil moisture determinations were made at monthly intervals at one, two, and three feet depths to determine the relationship between soil moisture and fruit size. The soil samples were taken about the middle of each month. A soil auger was used for securing the samples. In September and October it was necessary to use a post-hole digger of the life type to secure samples of the soil from the dry plot because the soil was so dry it could not be lifted with a soil auger. The total moisture of the soil was determined by placing the samples in an oven at a temperature of 100° centigrade for a period of 36 hours. The per cent was expressed on the wet weight basis. Table 4 presents these data.

Table 4 - Soil Moisture Content and Precipitation

Treatment	Depth	May	June	July	Aug.	Sept.	Oct.	Average
Dry	1	-----	13.3	8.2	5.9	6.52	6.70	8.12
"	2	-----	10.6	12.2	8.6	9.92	11.15	10.53
"	3	-----	14.7	15.6	12.6	10.82	10.82	12.91
Check	1	10.61	12.6	10.0	8.51	11.85	14.10	11.41
"	2	10.95	13.2	17.0	9.92	11.45	11.40	12.59
"	3	-----	16.3	10.7	10.30	12.15	9.90	11.67
*Precipitation (In.)		3.09	6.03	0.81	4.46	3.14	3.27	
Water	1	-----	14.3	12.8	12.10	14.10	14.50	13.56
"	2	-----	18.2	16.8	16.10	17.35	16.35	17.36
"	3	-----	16.2	16.8	17.50	17.20	16.95	17.73

* By United States Weather Bureau.

It will be observed that at all times during the growing season the soil under the watered tree ran the highest in moisture content, and that the soil under the roof ran the lowest with the check plot falling in between. Under all three treatments the highest average moisture content was found at the three foot depth, and the lowest in the surface foot. This is apparently due to the fact that the majority of the feeding roots were located in the surface foot of soil. The deficiency of moisture in the surface foot may explain why the apples harvested from the tree with the roof under it were smallest in size. (See table 5)

Table 5 - Effect of Soil Moisture on Fruit Size

Treatment	Number of Apples	Average Diameter(cm)	Average Weight(lbs)
Dry (covered by roof)	596	6.20	.192
Check (received rainfall)	601	6.42	.220
Watered	869	6.33	.225

The largest apples were picked from the watered tree. More apples were picked from the watered tree than from either of the other two treatments. The apples showing the largest average diameter were picked from the check tree which received the natural rainfall. The principal difference in size was between the fruit harvested from the dry plot and the watered plot. Apples from the watered plot weighed 14 per cent more than those from the dry plot. As measured by diameter the check plot bore apples 3 per cent larger than those borne by the dry plot. These data indicate that the size of the fruit does vary with the moisture content of the soil.

While picking the apples from these various plots the writer observed that the basket containing 150 apples picked from the dry tree weighed 27[illegible] pounds, and the same basket not quite completely filled with 120 apples from the watered tree weighed 27[illegible] pounds. After the above observation was made samples of fruit from the watered and dry plots were collected for moisture determinations. The method of determining the moisture content of the fruit is as follows: A random sample of 100 fruits was selected from each treatment and by making two radial longitudinal cuts a triangular slice was secured from each apple. These slices were cut into five pieces, and placed on an oilcloth before an electric fan for 30 hours. Then they were placed in an oven at a temperature of 80 degrees centigrade for 30 hours. The per cent of moisture was expressed on the wet weight basis, and these data are shown in table 6.

Table 6 - Relation of Soil Moisture to Size and Water Content of Fruit

Treatment	Soil Moisture Per cent*	Water in fruit Per cent	Size of Fruit Ave. Wt. lbs.
Dry	10.52	80.98	.192
Check	11.89	82.86	.220
Watered	16.22	83.33	.225

*Average moisture content for growing season to the depth of three feet. Based on Table 4.

The apples picked from the watered plot contained the highest per cent of water, and the apples from the dry plot, the lowest water content. The weight per apple, moisture content of the fruit and soil moisture content are all positively correlated. The fruit harvested from the check and watered plots averaged about 2 per cent higher in water content than fruit from the dry plot. These data somewhat explain why the fruit from the watered plot was slightly larger by weight, yet slightly smaller by diameter than fruit from the check plot, because there was over one-half of one per cent difference in moisture content of the fruit in favor of the watered plot.

Nitrogen Fertilization

Early in the Spring of 1928, eight nine-year-old Stayman trees, carrying a moderate crop of fruit buds, were selected for a nitrogen-carrying-fertilizer experiment. Due to a rather heavy drop in June, only a light crop was borne on these trees. Five of these trees were given five pounds of nitrate of soda (15% nitrogen) on one side of each tree, the other half of the same tree remained untreated. The fertilizer was applied under the drip of the outer branches on May 22nd. To one whole tree was applied 10 pounds of nitrate of soda. Two trees were untreated and were used as checks. At harvest time fruits from each treatment were picked, counted and weighed. When there was any question as to which side of the tree supplied the apples with soil nutrients such fruits were not picked by the experimentor. The results are recorded in table 7.

Table 7 - Effect of Nitrogen-Fertilization on Size of Fruit

Treatment	Number of Trees	Number of Apples	Average Diameter(cm)	Average Weight(lb)
½ tree Fertilized	5	234	7.17	.329
½ tree Untreated	5	182	7.72	.338
Whole Tree Fertilized	1	240	7.26	.324
Whole Tree Untreated	2	429	6.85	.291

When one-half of each tree was fertilized with a nitrogen-carrying-fertilizer the fruit from that half was of smaller size. The difference probably was due to the fact that the nitrogen fertilizer prevented some of the fruits from dropping at the time of the "June drop"; thus, the fertilized side bore more apples than the unfertilized side. With the unfertilized side carrying a lighter load, more moisture was available per apple than on the fertilized side. When a whole tree was fertilized, the apples harvested from it were larger than those picked from trees which were not fertilized. The only explanation of this lies in tree variation. In general the trees were uniform, but possibly the fertilized tree originally had more vigor and vitality than the untreated trees. In summarizing this nitrogen fertilizer experiment it might be stated that the results are not consistent, and of course, are not conclusive.

Spraying Materials

Standard Spraying Materials:

In the spring of 1927, 14 ten-year-old heavily loaded Wealthy trees were selected for testing the effect of standard spraying materials on fruit size. These trees were thinned to one apple about every 6 inches. Two trees were used in each plot. The following treatments were applied: sulphur dust (80-10-10); bordeaux mixture (8-8-100): liquid lime sulphur ($2\frac{1}{2}$ gallons per 100 gallons of spraying solution); one-half of each tree sprayed with lime sulphur at the above concentration, and the opposite half dusted; one-half of each tree sprayed with lime sulphur and the other half sprayed with bordeaux mixture: one-half of each tree was sprayed with bordeaux mixture, and the opposite half dusted. Two trees were left unsprayed and were used as checks. The time and number of applications were made according to the Michigan Experiment Station Spraying Calendar which is as follows: Delayed Dorment, Pre-Pink, Pink, Petal-Fall, Two Weeks, and Second Brood Application. The same materials were used in each application. A regular orchard sprayer, having a three cylinder pump, and a 200 gallon tank was used in making the applications. A hand powered duster was used in applying the dust. The method used to cover the various parts of the trees was as follows: a canvas 20 ft. x 20 ft. was pulled over the portion of the tree to be treated; then spray material or dust was applied to all the parts covered by the canvas. Good commercial control of diseases and insects was obtained with all the materials used. The results are presented in table 8.

Table 8 - Effect of Standard Spraying Materials on Size of Fruit-Twaltny 1927

Material	Number of Apples	Diameter (cm)	Weight (gm)
Three Materials Per Tree			
Lime Sulphur	67	6.72	125.2
Sulphur Dust	77	6.72	110.0
Bordeaux	131	6.50	107.2

(Table 8 - continued on next page)

Material	Number of Apples	Diameter (cm)	Weight (gr)
Two Materials Per Tree			
Lime Sulphur	671	6.51	105.5
Sulphur Dust	990	6.45	104.8
Bordeaux	821	6.82	112.4
One Material Per Tree			
Lime Sulphur	1437	6.88	101.9
Sulphur Dust	1397	6.71	101.9
Bordeaux	1632	6.30	91.0
Average			
Lime Sulphur	2175	6.74	110.2
Sulphur Dust	2464	6.63	105.6
Bordeaux	2784	6.44	103.5
Unsprayed	1123	6.12	83.1

On the variety Wealthy in 1927, with three materials on the same tree, the lime sulphur sprayed apples were the largest, sulphur dust next, and bordeaux mixture the smallest. When only two materials were applied on each tree the largest apples were picked from the portion sprayed with bordeaux mixture, and the next in size from the lime sulphur portion, and the smallest fruit from the dusted parts. When the whole tree was sprayed with one material, the largest apples were harvested from the trees sprayed with lime sulphur, and the next in size from the dusted trees, and the third from the bordeaux trees, and by far the smallest from the unsprayed trees. The reason that the unsprayed apples were much smaller than any of the sprayed apples is because 100% of them showed scab spots, and were badly deformed.

Also, the leaves on the unsprayed trees were deformed by the scab lesions. Considering all the spraying treatments in 1927, apples sprayed with lime sulphur were the largest, on the average, with dust next, and bordeaux sprayed apples the smallest.

In 1928 the experiment on testing of standard spraying materials was repeated. Grimes Golden was the variety used. These trees carried only a moderate load of fruit, and did not require thinning. The methods and time of applications were the same as in 1927. Considerable foliage dropped from the trees sprayed with lime sulphur and bordeaux mixture. The dropping apparently was caused by spray injury. No foliage injury or dropping was observed on the trees or portion of the trees dusted. Table 9 reveals the results of this spraying experiment.

Table 9 - Effect of Standard Spraying Materials on Size of Fruit - Grimes - 1928

Material	Number of Apples	Diameter (cm)	Weight (lbs)
Three Materials Per Tree			
Sulphur Dust	15	6.53	.285
Bordeaux	31	6.77	.307
Lime Sulphur	49	6.44	.259
Two Materials Per Tree			
Sulphur Dust	988	6.39	.251
Bordeaux	228	6.36	.244
Lime Sulphur	244	5.85	.226
One Material Per Tree			
Sulphur Dust	185	6.55	.269
Bordeaux	312	6.31	.242
Lime Sulphur	356	6.33	.230
Average			
Sulphur Dust	1188	6.49	.268
Bordeaux	571	6.48	.264
Lime Sulphur	649	[illegible]	[illegible]

When three spraying materials, were applied on different portions of the same Grimes trees, the bordeaux portion bore the largest apples, while apples from the dusted parts were second in size, and lime sulphur the smallest. Where two materials were applied on each tree the largest apples were picked from the dusted area, and the second size from bordeaux and the smallest from lime sulphur division. When only one spraying material was applied on the tree, the apples dusted were the largest, bordeaux second, and lime sulphur the smallest. Taking all the treatments as a whole on Grimes, the apples from the dusted portions were the largest, with bordeaux second, and lime sulphur the smallest.

In summarizing these spraying experiments with standard spraying materials it may be readily seen that the results are not consistent. Apples sprayed in 1927 with lime sulphur were larger than any others. In 1928 apples sprayed with lime sulphur were the smallest of the three standard spraying materials tested. Probably the difference in size in 1928, was partially due to spray injury. Dropping of the leaves on the lime sulphur and bordeaux sprayed trees undoubtedly influenced the size of fruit.

Standard Spraying Materials plus Copperas and Tobacco Dust:

In this experiment standard spraying materials were used with the addition of copperas and tobacco dust for the purpose of reducing spray injury. If spray injury is reduced, theoretically the fruit should show an increase in size.

Professor Dutton, of the Department of Horticulture, Michigan State College, outlined the experiment and recorded the spray injury, and the writer recorded the size of fruit. Each plot consisted of six rows, which included the following varieties: Duchess, Grimes, Baldwin, Stayman, Northern Spy, and R. I. Greening. The materials were used at the following concentrations: liquid lime sulphur, 2½ gallons per 100 gallons of spraying solution; bordeaux mixture, 2-2-100; tobacco dust, five pounds per 100 gallons of spraying solution; and Copperas, 1½ pounds per 100 gallons. The plots were given the following treatments: plot one, liquid lime sulphur was used in all five applications: Plot two, lime sulphur plus copperas was used in applications one, two, three, and four, with bordeaux mixture being substituted in application number five; Plot three, bordeaux mixture was used in applications one and five, lime sulphur plus copperas in applications two, three, and four; Plot four, lime sulphur was used in application one, lime sulphur plus tobacco dust in applications two, three, four, and five. The schedule followed was the same as recommended in the Michigan Experiment Spraying Calendar, see page 20. The sprayer tank was always thoroughly cleaned before a different mixture was used. Each row or plot was sprayed as a unit; thus there was no delay in waiting for the wind to change directions. Good control of insect pests, and fungus diseases was secured with all spraying materials. At harvest time a representative sample of fruit was picked from each tree. The fruits were counted and weighed, and the average weight per fruit was determined. (See table 10)

Table 10 - Effect of Standard Spraying Materials plus Copperas and Tobacco Dust on Size of Fruit

Treatment	Grimes		Stayman	
	No of Apples	Average Weight (lbs)	No of Apples	Average Weight (lbs)
Lime Sulphur 2½ gal. per 100 All appl.	95	.260	111	.313
L.S. 2½ in 100 Copperas 1½ lb - 5th App. Bord. 2-2-100	126	.269	169	.282
1st & 5th App. Bord. 2-2-100 L.S. Coperas in 2, 3 & 4th App.	185	.277	165	.316
L.S. 2½ in 100 1st App. Other applications L.S. + Tobacco Dust 5 lb-100	80	.289	195	.310

Trees of the variety Grimes sprayed with lime sulphur plus tobacco dust produced the largest apples, but on Stayman, bordeaux mixture in the first and fifth applications, lime sulphur plus copperas in the other applications resulted in the largest apples. The smallest Grimes were picked from the plot receiving only lime sulphur. The smallest Stayman were picked from the plot receiving lime sulphur plus copperas in all the applications except the fifth, when bordeaux was substituted. It is observed that these data are inconsistent; thus are not to be considered conclusive. It may be added that no severe foliage injury was caused by any of the spraying materials used.

Experimental Fungicides

These experiments were carried on in cooperation with Professor Dutton, of the Horticultural Department, Michigan State College, who outlined the experiments and recorded the spray injury, while the writer recorded the size of the fruit. Four nine-year-old trees of each variety, Grimes and Stayman, were sprayed with each of the following materials; copper carbonate, 1 pound per 100 gallons of spraying solution; corona 50% plus, 1 pound per 100 gallons of spraying solution; bordeaux mixture, 2-2-100; Wet Dow Basic Sulphate, 2 pounds per 100 gallons of spraying solution; Pure Basic Sulphate, 1 pound per 100 gallons of spraying solution; Liquid Lime Sulphur 2½ gallons per 100 gallons of spraying solution, and four unsprayed Stayman trees were used as a check. All of these experimental spraying materials are copper fungicides and, at the concentration used, were supposed to have the same fungicidal value. These are not common spraying materials, but were being tested as fungicides. The regular spraying schedule as recommended by the Michigan Experiment Station was followed. See page 20. At harvest time all the fruits from each plot were counted and the weight recorded in pounds. Table 11 presents the results obtained.

Table 11 - Effect of Experimental Fungicides on Fruit Size

Treatment	Grimes		Stayman	
	No of Apples	Average Weight (lb)	No of Apples	Average Weight (lb)
Pure Basic Sulphate 1 pound in 100 gal.	108	.264	215	.273

(Table 11 - continued on next page)

Treatment	No of Apples	Average Weight (lb)	No of Apples	Average Weight (lb)
Let Down Basic Sulphate 2 lb in 100	137	.255	214	.304
Corona 50% plus 1 lb. in 100 gal.	114	.251	199	.328
Copper Carb. 1 lb. in 100 gal.	57	.260	215	.301
Lime Sulphur 2- 100 gal.	411	.237	118	.278
Bordeaux 2-2-100	407	.240	222	.296
Unsprayed			211	.339

Grimes trees sprayed with copper carbonate bore the largest apples of any of the treatments. The pure basic sulphate sprayed apples were next in order of large size. The lime sulphur sprayed plot produced the smallest apples. On Stayman the unsprayed trees bore the largest apples, with corona 50% plus next in order of size, and the pure basic sulphate plot bearing the smallest apples, but the size of the fruit from the latter plot was only slightly smaller than the apples coming from the plot sprayed with lime sulphur. In general the experimental fungicides, when used on Grimes and Stayman trees, resulted in larger apples than when the same varieties were sprayed with the standard lime sulphur. The difference in fruit size is probably due to the fact that the lime sulphur plot showed more foliage injury than any other of the plots, although a small amount of foliage injury was present in all of the plots. These data further indicate that if it were possible to produce apples free from insects and diseases, without spraying, they would be larger than any of the fruits now sprayed with standard spraying materials. The fruit of the unsprayed plot showed better color and finish than any of the sprayed fruit.

Root Pruning

Six Stayman trees, carrying a moderate to light crop, were used to determine the effect of root pruning on fruit size. The roots were pruned by digging a circular trench 18 inches deep and three feet from the trunk of the trees. The trench was left open all summer. In digging the trench many roots ranging in diameter from 1/8 to 1/2 inch were severed, which indicates that the feeding roots of the trees were greatly reduced by this treatment. Two trees were used for each of the following treatments: (1) roots pruned on one side of the trees and the opposite side being untreated; and (2) roots pruned around the entire trees. Two whole trees were untreated and used as a check. At harvest time all the apples were weighed and counted. The results are depicted in table 12.

Table 12 - Effect of Root Pruning on Fruit Size

Treatment	No of Apples	Average Diameter (cm)	Average Weight (lbs)
Root Pruned on one side	93	6.79	.286
Untreated side	109	6.92	.288
Roots Pruned around whole tree	126	6.82	.291
Whole Tree untreated	429	6.85	.291

When roots were pruned on one side of the trees, the apples picked from that portion of the trees were only slightly smaller than from the opposite side of the trees, and the same is true when roots were pruned around the whole trees. This difference is probably not significant.

Cultivation vs Sod

Twelve uniform moderately loaded Stayman trees were used to determine the effect of cultivation and grass sod on fruit size. Six trees were growing in grass sod, and six trees were growing under clean cultivation. On the cleanly cultivated plot a cover crop was always sown in the fall of the year. At harvest time representative samples of fruits were picked from each tree, weighed and counted, and the tabulated data are shown in table 13.

Table 13 - Effect of Cultivation and Sod on Size of Fruit

Treatment	Number of Apples	Average Weight (lb)
Sod	638	.305
Cultivated	1030	.252
Difference		.053

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SUMMARY

1. Apples picked from thinned trees averaged 16 per cent larger in diameter and about 54 per cent heavier than those from unthinned trees.

2. When terminal bearing shoots bore only one fruit, the size was 13 per cent larger than when two fruits were borne.

3. Thinning experiments on small adjoining branches resulted in a four per cent increase of fruit size. When the same experiment was repeated on girdled branches, the increase was 10 per cent, indicating that carbohydrates are translocated.

4. Fruit harvested from a King David tree which had 500 gallons of water per week in addition to the natural rainfall were 14 per cent heavier than fruit picked from a tree which did not receive any surface water during the growing season. The difference in fruit size between the watered tree and the tree receiving the natural rainfall was insignificant.

5. Under all treatments (dry, check, and watered) the soil

moisture averaged the lowest in the surface foot and the highest in the third foot below the surface.

6. The water content of the fruits picked from the "watered" and "check" plots was over two per cent higher than that of the "dry" plot.

7. The influence of nitrogen-fertilizer on fruit size was found to be insignificant.

8. The results of different spraying materials on fruit size are inconsistent. In 1927, the largest apples were picked from trees sprayed with lime sulphur and in 1928 the smallest apples were picked from trees sprayed with lime sulphur.

9. The addition of copperas or tobacco dust to lime sulphur did not consistently increase the size of fruit.

10. Apples sprayed with experimental fungicides were not materially larger than fruit sprayed with standard fungicides.

11. Fruits harvested from trees or part trees having their roots pruned were only slightly smaller than fruits from untreated trees. Root pruning reduced yield.

12. Fruits borne by trees growing in a June grass sod were larger than those borne by trees growing in cleanly cultivated soil.

Apples picked from the trees growing in sod were larger than those picked from trees growing under clean cultivation. Possibly there were two reasons for this difference; (1) trees growing in the cultivated soil bore a heavier crop and (2) the trees growing in sod were stimulated to send their roots deeper in the earlier stages of their lives: thus, a more permanent water supply was quicker obtained.

DISCUSSION

None of these data presented in this paper should be considered as conclusive, because they were obtained in one, and in some cases, two years. These results probably are not of great experimental value, but they offer food for thought, and the information herein recorded may be of value as leads for further research on the all-important subject of fruit size.

The results indicate that thinning is a practical method of increasing the size of fruit. These results are substantiated by such research workers as: Batchelor (11), Auchter (12), Brock (13), Ballou (15), and Cooper (23). A certain amount of water, carbohydrates and other constituents are required to produce a given sized apple. A tree can only produce a certain number of apples of a given size. For example, if a tree were capable of manufacturing enough food to grow 100 apples to three inches in diameter, and the tree carried 200 apples, it is readily understandable why the harvested fruit might be somewhat smaller. If it is decided advisable to thin the trees, the results secured with Wealthy in 1927, as reported in this paper, indicate that not more than one fruit should be allowed to remain per terminal shoot or spur, which agrees with the results reported by Murneek (9). If one of two, nearby small branches, was overloaded and the other carried only a light crop, these data suggest that the heavily loaded branch would not need to be thinned as severely as if each branch carried an equally heavy load, because the carbohydrates may be translocated to balance the difference in load. These data agree with the findings of Haller (4).

Because apples contain a high per cent of water, it is not hard to understand that soil moisture might be a limiting factor under certain soil and climatic conditions in the production of large apples. The data presented in this paper indicate that with trees carrying a uniform load, the size of the fruit does vary with the moisture content of the soil. The findings of Furr, and Magness (3) Hendrickson, and Veihmeyer (35) and Stewart (31) are in accord with these data.

The results obtained with a nitrogen-carrying-fertilizer on fruit size are conflicting, but so are the results of other similar experiments. The data show that fruits picked from the unfertilized one-half of the trees were larger than the fruit picked from the opposite fertilized half of the same trees, which agree with the results obtained by Chandler (18) Crane (20) McCue (21) and Cooper (23). When a whole tree was fertilized the fruits harvested from it were larger than those from the adjoining unfertilized trees, which is in accord with the work of Alderman (17) Reimer (22) and Andrews (33).

Spraying materials affect fruit size indirectly. The effect is one of reduction, and is in proportion to the decrease of photosynthetic activities caused by the spraying materials. The results with unsprayed Stayman trees shown in table 11 indicate that the above statement is true. Diseases and insects attack the leaves and fruit of the apple tree; therefore the trees must be sprayed. In an epidemic scab year, like 1927, the loss on unsprayed trees, as measured by fruit size on the variety Wealthy (See table 8), was far in excess as compared to any of the standard spraying materials used. Consequently, the selection of spraying materials must be based on their ability to control insects and diseases with the minimum injury of leaves and fruit.

The effect of root pruning on fruit size is a question that arises when a sod orchard is plowed, and many of the roots are broken. The data contained in this paper indicate that root pruning does reduce fruit size, but only to a small amount, the principle effect being a decrease in yield.

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