LOCALIZATION OF CERTAIN FACTORS INFLUENCING THE SIZE OF APPLES

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Flood Shields Andrews

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THESIS

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Thesis

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THESIS

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Introduction

The demand for large fruit has long been recognized, but the relative importance of producing uniformly larger apples has been more seriously considered since the recent studies by Gaston (21) revealed the fact that small size is responsible for a large percent of the culling that is done in grading apples.

The cause for variation in the size of apples (within certain varieties) has been studied more or less from the standpoint of conditions affecting individual trees; consequently there is a considerable body of data on the influence of various environmental factors on the size of fruit borne by the tree as a whole. However, there is comparatively little information on the localization of factors within the parts of the tree to explain the variation in the size of the fruit borne on individual limbs, branches, or spurs. Obviously, any information as to how the factors influencing the size of the fruit can be localized, or segregated so that the response of the various units of the tree may be more uniform, thereby producing uniformly larger apples, would be of interest.

In these investigations a study was made of the localized and general responses of the tree to such environmental factors as (1) the application of water and nitrogen to certain roots, (2) root pruning, (3) trunk, limb, and spur girdling, (4) defoliation, and (5) shading, as might be indicated by the subsequent variation in the size of the fruit.

Review of Literature

Factors influencing tree as a whole

Nutrients, water, cultivation:

Hendrickson and Veihmeyer (30) in some experiments with irrigation water found that the size of peaches was increased about sixty percent by irrigation in the dry areas.

Batchelor, (cited by Gardner, Bradford and Hooker (18)) in reporting upon results of irrigation experiments with peaches, states no amount of water applied early in the season to a crop of peaches on a gravelly soil will compensate for the lack of water a month before harvest.

Ruth and Baker (50) gave data to show that the growth of the deeper roots was not materially affected by the distribution of water, where the trees are on a slope and the water table is relatively low. However, the length and character of the root system was found to be associated with soil differences.

Ralston (44) concludes that the size of apples may be increased by the early application of nitrogenous fertilizers, while the later applications had less influence on the size and yield of fruit.

Cooper (9) in working with apple trees, found that nitrogen is the most effective element in orchard fertilization and that the fruit matured somewhat later but was considerably larger in size when nitrogen was applied.

Bedford and Pickering (4) present data to show that sod reduces the size and weight of the leaves; decreases the depth of rooting; influences the color of fruit leaves and bark; and reduces the vigor of the tree.

Malpighe, (cited by Palladin) concluded that soil solutions move upward through the wood and that the organic substances move through the "cortex". His work was later substantiated by Pfeffer (41), Czapek (14), Palladin (40), Chandler (7), Rumbold (47), Auchter (2), Garner (18), and Curtis (12). The works of Curtis and Garner give evidence which conflicts with the views of Czapek wherein he stated that reserve plant food passes from the roots to the growing point through the xylem, and with the statement made by Atkins (1) that xylem tissue is essential for the upward translocation of foods. Curtis presents evidence to show that synthesized plant foods pass both upward and downward through the phloem, and Garner furnished further evidence that the movement of food is restricted to the phloem.

Eames and McDaniels (16) suggest that the younger xylem cells function in the conduction of nutrients while the older thick walled cells function only in water conduction.

Curtis (13) noted that girdling injured the xylem tissue and interfered with its function.

Girdling and pruning:

Marshall (40) found that the total yield of apples, in some cases even the total yield of large apples, was reduced by pruning (but there were relatively more large apples on the pruned than on the unpruned trees.)

Shading, leaf area, thinning:

Dorsey and McMunn (15) have shown that the size of the fruit on peach trees is larger when it has been thinned.

Lincoln (39) states: "It is evident that young pear trees may lose nearly as much nitrogen by shedding their leaves as the tree was able to take from the soil during the season."

Factors influencing the variation within different parts of the tree.

Cross transfer of water nutrients and plant foods:

Hartig (cited by Rankin (45)) introduced some colored solution into the growing stems of trees and found that the colored solution would be conducted to the tops of the trees, but only those vessels directly above the points of injection were colored.

Pfeffer (41)(translated by Ewart) "If two saw cuts are made one above the other on opposite sides of twigs of the oak or of the fir each passing the center of the stem, sufficient water will reach the leaves to keep them turgid." He states further that "Lateral connections in the vascular bundles allow water to pass along oblique paths."

Chandler (8) in some winter injury studies gave evidence to show that materials made by the foliage, which tend to mature and make the wood hardier are not uniformly distributed throughout the branches and trunk but are confined to the area directly beneath the limb bearing the foliage.

Heinicke (29) noted that when nitrate of soda was applied to one side of apple trees the limbs directly above retained their leaves longer in the fall.

Blake (5) cites a case where fertilizers applied to only one side of certain peach trees caused a greater variation in size of the fruit than upon the trees receiving full share of nitrogen on all sides.

Gile and Carrero (32) in some cultural experiments with corn showed that roots growing in a complete nutrient solution assimilated potassium and phosphorus at a greater rate than when the roots were divided into three incomplete solutions. In explanation of the results the authors state:"Probably the chief inhibition to translocation (the slowness of translocation which they claimed reduced assimilation) arises from the fact that nitrogen, phosphorus, and potassium were more or less scattered, as it were, in different parts of the plant, as a result of having been absorbed by different roots."

Crane (cited by Auchter (2)) in some pruning experiments, found that in general larger and more roots had developed directly under the larger limbs.

The top of one side of a tree which had been dwarfed by pruning had roots on that side smaller than those on the opposite side.

Auchter (3) in some experiments with woody plants, found that when roots were removed from one side of a tree and then nitrate applied to the ground evenly under the spread of all limbs, "the leaves on the side to which the roots had been pruned lost nitrogen". He also found that when nitrate was applied to one side of a tree and the other side is used as a check (1) the catalase activity on the nitrated side is much greater, (2) the leaves on the nitrated side did not have as high a sap concentration, (3) the rate of transpiration is higher on the nitrated side, (4) the foliage on the nitrated side became greener and somewhat larger.

When halves of certain trees were defoliated and the other half used as a check he found that the sap expressed from the bark of the roots directly under the undefoliated halves had a larger total concentration in every case than that expressed from the bark of the roots directly under the defoliated halves. Where nitrogen was applied to one side of the tree the moisture content of the leaves appeared to be the same on both sides of the tree. He suggests, however, that water may move through or around the tree without much difficulty.

Girdling and bending:

Curtis (11) in studying the influence of girdling and ringing on woody plants, concluded that defoliated stems from which a ring of tissue extending to the xylem is removed ceased to grow. If the leaves above a ring are not defoliated the leaves are able to supply sufficient food for considerable growth. When dormant stems are ringed the growth above the ring ceases soon after the starch supply is depleted. The greater the starch supply above the ring the longer growth will continue. "When a ring is made on that part of a stem from 5 to 15 or more years old or from 1 to 4 centimeters in diameter the growth above the ring approximates that of a normal stem, which fact indicates that upward movement of food from points below the ring is not essential for growth above the ring." When shoot growth is well started much of the food used for continuous growth may be produced by the leaves of that shoot, which fact indicates that considerable growth may take place where but little stored food is available.

Garner (19) in some ringing experiments with Bartlett pears found that ringing interfered with the passage of water due to injury of the xylem; bending, however, did not seem to interfere with the passage of water. He also states: "Ringing, bending, and heading back of shoots resulted in the growth of buds immediately below the ring."

Howard (33) states concerning the position of the limb which may influence growth: "The crude sap from the roots rises most rapidly in those branches and twigs which are nearest in a straight line upward from the ground."

Dorsey and McMunn (15) mentioned that limbs which are bent by heavy crops tend to grow slower and become weakened because of shading and crowding of lower limbs.

Pruning and other factors:

Cooper (9) found that pruning will change the performance of spurs, but that the effectsof pruning are limited to the areas in close proximity to the cut, and do not at all correspond to the size of the cut.

Harvey (27) supported the work of Cooper that the effect of pruning is rather localized and that individual limbs respond to pruning in the same way as do whole trees.

Hooker and Bradford (31) in a study of the individual behavior of spurs in fruit bud formation, report that the spur, or branch of the tree, act as units, but that the individual spurs are influenced by other portions of the tree.

Roberts (47) in studies concerning the individual behavior of spurs in fruit bud formation states: "Spurs act largely as individuals -- fruitfulness is related to spur length" and that pruning and biennial bearing both had influences on spur length.

Light, shading, leaf area and temperature:

Gourley and Nightingale (23) reported some interesting results from shading certain horticultural plants. They state: "The intensity of sunlight reof the plants treated responded in the same manner as if it had been a separate plant.

Coville (10) found that when certain portions of a plant were exposed to cold the response of the plant was generally localized.

From the evidence based on the observations and experiments of previous investigators the following statements seem warranted:

Such environmental factors as available plant nutrients and water, cultivation or sod, distance of planting and type of pruning, temperature, light, shading, and other factors may influence the tree as a whole or some of its individual parts.

There is some evidence of cross transfer of water in woody plants, but the amount of cross transfer in specific kinds of trees under different conditions has not been worked out. That there is little or no cross transfer of plant nutrients or elaborated plant food in an apple tree is fairly evident. The theory first advanced by Pfeiffer that water may pass through the lateral connections in the vascular bundles and thus through or around the stem is supported by the results of all subsequent investigators so far.

ceived by the plant had a marked influence on the type of growth, the size, structure and color of their leaves; their roots and upon the reproduction processes." (It may be noted here that the writers failed to mention the possible influence of the difference in the temperature and humidity of the shaded areas) They noted that the air temperature runs higher in the shaded areas than in the open, while the soil temperatures are cooler under the shade than in the open. They point out further that different species and horticultural varieties of species responded somewhat differently but in the same general direction. They also found that the leaf area was increased but the thickness was reduced by shading and that the leaves dropped several days earlier on the shaded portions.

Kraybill (33) suggests that shading is effective either by reducing carbon assimilation or by increasing nitrogen or by both actions. He points to the fact that shading decreases while ringing increases fruit bud formation.

Garner and Allard (20) in studying the influence of light on plants, report that each portion

Pruning has been found (by Marshall and others) to influence the size of the fruit, while other investigators (Cooper and Harvey) agreed in their findings that the influence of pruning is localized within close proximity to the cut made.

Investigators dealing with light, shading, and leaf area, present evidence to support the conclusion that any degree of shading or defoliation may have more influence on the variation in size of fruit than has been commonly believed.

The recent work of Dorsey and McMunn has confirmed the long accepted belief that thinning increases the size of fruit. The findings of Haller and Magness concerning the leaf area requirements of individual fruit may be accepted as a reliable criterion whereby the degree of thinning necessary for the normal development of fruit may be determined.

After reviewing the work of previous investigators the following questions arise:

(1) What causes the variation in the size of apples on the different trees within a variety; on different limbs or branches of the same tree?

(2) To what extent will environmental factors, affecting only specific roots or branches, influence

the size of fruits in close proximity to the treated areas, and to what extent, if any, will the fruit on remote parts of the tree be affected?

(3) Does the water, or the nutrients, absorbed on one side of an apple tree influence the size of the fruit on that side, only, or is there an appreciable transfer of water or mineral nutrients or plant food to the developing fruit on the other side?

(4) What effect will an excess of carbohydrates or an excess of available nitrogen in certain parts of the tree have on the size of apples, locally or generally throughout the tree?

(5) Does the removal of the older leaves from certain parts of a tree (such a condition as spray burn or insects may cause) influence the size of the fruit locally or generally?

(6) Is there a correlation between the number of leaves on a spur and the size of the fruit, or can the fruit draw freely for synthesized food materials from adjacent leaves?

(7) Does the fruit draw more of its food materials from the leaves near the growing points or from the base of the limbs? That is, from what direction does it come?

(8) What influence has the position of the limb (whether it be upright or lateral) on the size of fruit?

(9) What local or general influence on the size of apples has shading of small branches, large limbs, or the whole tree?

The purpose of this investigation was to obtain evidence that would at least partially answer some of these questions.

The experiments were conducted at the Graham Horticultural Experiment station, of the Michigan State College, located at Grand Rapids, Michigan.

Only those trees bearing a full crop of apples, evenly distributed on both sides of the tree, were selected for the experiments. The fruits on all trees, including the checks, were thinned to approximately six inches apart at the time the treatments were applied.

In some cases more apples were measured on one side than on the other side of a tree, due to the presence of such factors as certain limbs being bent, broken, or growing across from one side of the tree to the other, causing the fruit on those limbs to be discarded.

Presentation of data.

Experiments concerning translocation or cross transfer of water, nutrients and plant food.

The work of previous investigators, cited in the review of literature, has confirmed the long accepted view that water greatly influences the size of apples. Their conclusions also indicate that exact evenness in the application of irrigated water is unnecessary, and that the individual variations in size as we find them on the tree are not due to localized irregularities or variations in the water supply. One experiment was conducted in the course of this investigation that further information on this point might be obtained.

Water was applied, at the rate of 200 gallons per tree per week from June 13 to October 1, to the soil on one side of each of two trees, one Ontario and one Wealthy. On the opposite half of the tree the ground was made rain proof by the use of tar paper roofing covering an area of 10' x 20'. Around one whole tree the ground was made rain proof by tar paper roofing covering an area of 20' x 20'. To one whole tree water was applied at the rate of 400 gallons each week. Two trees were used as checks. At the time the roofing was put around the trees the soil contained a high percent of moisture due to the previous rains. The moisture content was determined on soil samples taken September 1 and October 17. These data are given in table 1.

The increase in the size of apples on the watered side of the trees, as compared with the dry side (shown in table 1), was very slight. The differences associated with differences in water application were greatly exceeded bythe individual tree variation. It appears from the results of this and previous experiments that water may pass through or around a limb, and when applied to one side of a tree will tend to be distributed to all parts of the tree in sufficient quantities to produce apples of practically the same size and weight on both sides. Since so few trees were included in this experiment, the results cannot be considered conclusive; however, they are in line with those of several investigators who have already been cited.

The large size of the apples on the supposedly "dry" tree was doubtless due to a deeper root system supplying necessary water from below, or to some soil variation not accounted for. The water supply in the first three feet of soil taken from the covered area ran well under the requirements for the normal development of the fruit, as shown by supplement sheet attached to table 1.

Table 1

The effects of water applied to the roots on one side of the tree, and to the roots of a whole tree, as indicated by differences in the size of the apples.

Variety Ontario	Treated June 13 to October 15	Measurements August 27		Measurements at harvest October 15			
Tree	Treatment	Number Apples	Average diam. cm.	Number apples	Average di. cm.	Probable Error	Ave. Wt. grams.
1.	Water whole tree	106	6.85	315	8.16	±.016	169.1
2.	Dry-covered whole tree	125	6.55	321	7.83	±.012	173.6
3.	Dry-covered one-half tree	104	6.48	189	7.73	±.018	166.8
	Water one-half tree	100	6.79	152	8.05	±.020	180.2
4.	Check tree	137	6.58	148	7.14	±.020	124.9
	"	138	5.81	116	7.58	±.016	159.2
	Variety--Wealthy						
1	Water one-half tree	103	6.35	156	6.60	±.018	107.7
	Cover one-half tree (dry)	117	5.97	158	6.36	±.022	96.6
2	Check			204	6.57	±.013	103.1

Moisture content of soil in water experiment

	Depth	Percent of total moisture September 1		October 17	
Tree #1 Entire tree watered	1 ft.	11.3		18.3	
	2 "	13.5		16.5	
	3 "	14.7		15.7	
Tree #2 Entire tree covered	1 "	9.8		7.1	
	2 "	9.2		7.6	
	3 "	8.9		8.4	
Check tree	1 "	15.4		14.0	
	2 "	15.0		12.9	
	3 "	14.0		11.2	
Wealthy	1 "	Watered side	: Dry side	Watered side	: Dry side
	1 "	12.8	11.8	15.8	7.6
	2 "	11.8	11.1	14.8	8.5
	3 "	10.4	9.8	12.2	9.0
Ontario	1 "	11.2	8.5	14.0	7.9
	2 "	10.3	9.1	13.7	8.7
	3 "	9.6	9.2	12.4	9.1

Precipitation by months during summer

May	3.81 inches	August	0.66 inches
June	1.45 "	September	4.55 "
July	1.43 "	Oct. 1 to 15,	3.01 inches

The soil on which the trees in this experiment grew was of a sandy loam type. According to Loughridge (cited by Gardner, Bradford and Hooker (18)) such a soil type requires from 11-14% total moisture for the development of the fruit.

Fertilizer applications:

Accepting the general view that apple trees respond to nitrates more readily than any other fertilizer, nitrates were the only fertilizers used. The nitrate experiment was conducted as follows:

1. Nitrate of soda at the rate of four pounds per half tree was applied to one side of three McIntosh trees June 10.
2. Nitrate of soda at the rate of four pounds per half tree was applied to three McIntosh trees June 10. The trunks of these trees were girdled June 23.
3. Nitrate of soda was applied at the same rate to one side of two Ontario trees June 6. On the opposite side of these trees the roots were pruned at the same time.
4. *Nitrate of soda was applied at the rate of eight pounds per tree to two McIntosh trees June 10.
5. Nitrogen was applied at the rate of eight pounds per tree to two McIntosh trees June 11. One side of these trees received root pruning.

*Where eight pounds of nitrates was applied it was distributed evenly to all parts of the ground beneath the tips of the limbs.

6. Nitrogen was applied at the rate of eight pounds per tree to one Ontario tree June 6.
7. Three Ontario trees received nitrogen at the rate of eight pounds per tree June 6, with certain limbs and branches girdled.
8. Two Ontario trees received eight pounds of nitrate of soda per tree June 6. These trees were trunk girdled at the same time.
9. Six McIntosh trees received an application of four pounds ammonium sulphate per half tree August 12.
10. Each of two McIntosh trees received eight pounds of ammonium sulphate August 12.

A study of the results given in table 2 reveals evidence which supports the findings of previous investigators wherein they concluded: (a) that nutrients applied to one side of a tree are used or stored mainly on that side; (b) that the mid-summer application of nitrogen has very little influence on the size of the fruit.

These data show a substantial increase in size of the apples on the nitrated side of the trees as compared with the check side, which evidence holds true for all trees receiving early application of nitrogen.

In combination with the other treatments the nitrated sides of the trees produced larger apples in every instance (that is, including where the limbs or branches were girdled and also where the opposite roots were pruned).

Cultivation vs sod:

Apples on both sides of two trees, one side of which had been in cultivation and the other in sod for several years were harvested and separately measured. These trees were on the check row between the cultivated and sod plots and had been so treated for several years. Results are shown in table 3. In each case the apples on the cultivated side were very much larger. This shows that the response to continuous cultivation or variation in the nutrient supply from year to year on one side of an apple tree where the opposite side receives a different treatment, continues to be localized, and that cross transfer of nutrients and plant food over a long period of time is negligible, though presumably the difference in water content of tissues between the two sides is negligible. Incidantally, when considered along with the other evidence that is presented in this report, it indicated clearly that the main influence of sod on the apple tree is through its effect on nutrient rather than water supply.

Table 2

The effect of nitrogen applied to the soil on one side of apple trees on the size of the fruit produced on that and also on the opposite side.

Variety McIntosh	Treated June 10 - 11	Measurements August 29		Measurements at harvest September 20			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable Error	Ave. Wt. grams
1	Nitrate of soda 4# ½ tree	87	6.05	132	6.81	±.034	109.1
	Check side	89	5.74	84	6.54	±.028	103.1
2	Nitrate of soda 4# ½ tree	79	5.50	67	----	----	114.8
	Check side	105	5.37	54	----	----	84.1
3.	Nitrate soda 8# whole tree	93	5.27	181	----	----	72.0
	Nitrate soda 8# whole tree	100	5.71	115	6.62	±.014	107.4
4	Check tree	72	5.98	119	6.63	±.018	105.4
5	Check tree	--	----	132	6.80	±.020	106.6
6	Check tree	176	[illegible].40	201	----	----	79.9
	McIntosh - treated June 27						
1	Ammonium Sulphate 4# ½ tr.	22	6.46	20	7.29	±.016	133.6
	Check side	43	6.43	31	7.15	±.014	132.8
2	Ammonium sulphate 4# ½ tr.	69	6.20	87	7.17	±.019	126.9
	Check side	62	6.18	113	6.98	±.016	123.3
	Ontario - treated June 6-7						
1	Nitrate soda 8# whole tree and trunk girdled	128	6.52	229	7.65	±.014	157.7
2	Nitrate soda 8# whole tree and trunk girdled	113	6.40	87	7.86	±.024	170.0

Table 3

Effects of late application of ammonium sulphate, and cultivation one-half tree vs sod one-half tree, on the size of apples.

Variety McIntosh	Treated August 12	Measurements August 27		Measurements at harvest October 15			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable Error	Ave. Wt. grams.
1	Ammonium sulphate 4# ½ tree	--	--	81	6.70	±.023	110.9
	Check side	--	--	66	5.84	±.020	107.5
2	Ammonium sulphate 4# ½ tree	--	--	169	6.78	±.028	111.4
	Check side	--	--	136	6.78	±.019	109.4
3	Ammonium sulphate 8# whole tree		--	70	7.15	±.023	130.9
	Ammonium sulphate 8# whole tree		--	105	----	----	126.1
4	Check tree	--	--	119	6.63	±.026	105.4
5	Check tree	--	--	132	6.80	±.024	106.6
	Cultivation vs Sod - Wolf River variety						
1	Cultivated side	--	--	106	8.78	±.032	223.7
	Sod side	--	--	71	8.26	±.030	199.3
2	Cultivated side	--	--	74	9.04	±.026	248.6
	Sod side	--	--	68	8.60	±.038	225.4

Root pruning:

The root pruning was performed on the McIntosh trees June 22 and on the Ontario trees June 9 and 10. All of the roots were cut on one side of each tree four feet from the outer circumference of the trunk by digging a trench 18" to 24" deep. To four trees nitrogen was applied to the side opposite that on which the roots were pruned. On two trees certain limbs and branches were girdled on the root pruned side to compare with girdled limbs and branches on the opposite side. Two trees had their trunks girdled in connection with root pruning, while two trees received no other treatment.

Table 4 indicates that the root pruning on one side of an apple tree influenced the size of apples on that side but did not influence the size of fruit to an appreciable extent on the opposite side of the tree, except where the trunk of the tree was twisted. In one case the trunk of the tree was decidedly twisted so that presumably the roots on one side of the tree did not supply the nutrients to the limbs above, in which case the apples on the root pruned side were larger. But generally apples on the check side of the trees were larger.

Where the roots were pruned on one side and nitrogen was applied to both sides of the tree, the apples tended to show less variation in size than where root pruning on one side alone was practiced. In one case the apples were larger on the root pruned side. There were not enough trees under this treatment for the results to be conclusive, but incidentally, Gardner, Bradford and Hooker (13) cites an analogous case where Rivers, one of the leading exponents of the root pruning practice, recommended cutting the roots around the tree, and filling the trench with manure in order for the tree to make "short and well ripened shoots and bear abundantly".

The data on the root pruning experiments show that the variation in size of the fruit grown on different trees is greater than the difference due to the treatments. Although the evidence is not conclusive, the results are interesting and show possibilities for future development.

Measurements, as given in table 5, indicate that trunk girdling does not materially affect the passage of nutrients, since the apples on the check side were consistently larger than those on the root pruned side. The results of this experiment were also substantiated by the experiments shown in table 5 wherein the trunks of certain trees were girdled, having nitrogen applied to the opposite side of the tree, the apples on the nitrated side being larger.

Table 4

Effects of pruning roots on one side of the tree on the size of apples on either side

Variety McIntosh	Treated June 22	Measurements August 29		Measurements at harvest September 22				
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di.cm.	Probable Error	Ave. Wt. grams	
1	Roots pruned ½ tree	65	5.06	178	5.65	±.014	68.6	
	Check side	75	5.29	152	6.00	±.012	75.5	
2	Roots pruned ½ tree	120	5.65	120	6.37	±.015	92.8	
	Check side	123	5.77	79	6.50	±.011	102.35	
*	Roots pruned ½ tree	92	5.79	172	6.64	±.016	113.6	
	Check side	63	5.82	86	6.72	±.015	116.1	
*	Roots pruned ½ tree	111	6.29	82	5.97	±.011	77.4	
	Check side	36	5.26	67	5.85	±.023	68.8	
Ontario variety - treated June 6-8								
1	Nitrogen 4# ½ tree	73	6.40	105	7.71	±.031	160.0	
	Roots pruned side	92	6.15	116	7.38	±.029	136.5	
2	Nitrogen 4# ½ tree	103	6.18	156	7.82	±.026	160.3)	twisted
	Roots pruned side	82	6.20	94	7.82	±.032	164.5)	trunk
3.	Nitrogen whole tree	131	6.12	320	7.50	±.018	139.6	
4	Check tree	138	6.58	116	7.58	±.021	159.1	
5	Check tree	138	5.81	148	7.14	±.020	139.9	

* 8 pounds of ammonium sulphate was added to these trees.

Girdling:

Seventeen McIntosh and four Ontario trees were used in the girdling experiments. The McIntos h trees were girdled June 23 to 27, the Ontario trees were girdled June 6.

Trunk girdling:

Two trees ringed or girdled at the trunk received no other treatment, while one tree receiving root pruning and three trees receiving nitrogen were girdled at the trunk. The trunk girdling was effected by the removal of a strip of bark extending to the cambium, one half inch wide around the trunk one foot from the ground.

Table 5 gives results of trunk girdling alone on certain trees, and where nitrogen was applied in connection with trunk girdling on other trees. This is another instance where the tree variation due to unknown factors was greater than the variation resulting from the treatment. There was no appreciable difference in size between the fruits on the trunk girdled trees and those borne by the checks. However, on trees where nitrogen was applied in connection with trunk girdling there was apparently an increase in size of fruit, while root pruning with trunk girdling gave smaller fruits on the root pruned side.

The results of the trunk girdling experiment indicate that the synthesized materials confined within the trunk by girdling is not confined within close proximity to the fruiting spurs available for use by the developing fruit, as was the case in the limb and branch girdling which were found to materially increase the size of apples.

Table 5

Effects of trunk girdling, trunk girdling with nitrogen, and trunk girdling with root pruning, on size of apples.

Variety McIntosh	Treated June 22-27	Measurements August 30		Measurements at harvest September 20			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable Error	Ave. Wt. grams
1	Trunk girdled	171	6.35	111	7.19	±.032	126.81
2	Trunk girdled	158	6.18	79	7.13	±.014	119.42
3	Check tree	46	6.36	63	7.95	±.020	139.63
4	Check tree	68	6.01	41	7.09	±.023	136.45
5	Check tree	--	----	129	7.11	±.019	136.07
6.	Trunk girdled 4# $NaNO_3$ one-half tree	129	5.84	81	7.37	±.020	148.40
	Check side(trunk gir.)	135	5.76	98	6.62	±.022	145.32
7	Trunk girdled roots pruned ½ tree	123	6.37	138	6.56	±.031	126.54
	Check side (trunk gir)	83	6.40	132	7.25	±.026	152.96
	Ontario variety - treated June 6						
1	Trunk girdled plus 8# nitrogen ($NaNO_3$)whole tree	113	6.52	229	7.65	±.020	157.70
2	Trunk girdled plus 8# nitrate soda whole tree	113	6.40	87	7.72	±.029	170.00
3	Check tree	138	6.58	116	7.58	±.024	159.10
4	Check tree	137	6.81	148	7.14	±.022	139.90

Limb girdling:

On five trees receiving no other treatment certain limbs, branches and spurs were girdled. On ten trees certain limbs were girdled in connection with other treatments.

In ringing limbs a strip of bark one quarter of an inch wide extending to the cambium around the limb was removed.

Tables 6 and 7 show a decided increase in the size of apples on girdled limbs. Where nitrogen was applied to the roots beneath the girdled limbs the fruit on the limbs above averaged larger than those under any other treatment. One may reasonably assume that the increase in the size of the apples on the girdled limbs is due to the fact that girdling stops the translocation of synthesized foods. Doubtless the girdled limbs had a relatively larger leaf area per fruit than did the girdled branches, while the relative amount of injury to the xylem tissue was less on the girdled limbs. This accounts for the difference in the size of the fruit on the girdled limbs and branches. (It may be noted here that limb girdling was performed in connection with the late application of nitrogen mentioned under "nitrogen application". The results of either treatment applied at this time, as shown in table 3, indicate that the size of fruit is not influenced to any appreciable degree by nitrogen application or limb girdling in mid season)

Limb girdling in case of apples or vine girdling in case of grapes has been a practice more or less in vogue for a number of years where increased size of the fruit at the expense of the tree or vine was desired. The evidence submitted from these experiments suggests that the practice may be of practical value on filler trees which are to be removed.

Branch girdling:

Branch girdling was performed on three trees receiving no other treatment; on two trees having the roots pruned on one side; and one tree receiving nitrogen. Each girdled branch was allowed to carry approximately the same number of apples.

The branch girdling was performed by, the removal of a strip of bark extending to the cambium, one eighth of an inch wide around the branch.

Apples on girdled branches were consistently larger than those on the check limbs (of same size and relative position on the tree) except where the branches were girdled above the pruned roots, in which case a reduction in size of apples occurred on the girdled branches, compared with the check side of tree.

A count was made of the number of blossoms and the number of fruit to set on certain branches which were girdled and on other branches which were not girdled. Out of 500 blossoms on the girdled branches 230 set fruit, while out of 500 on the ungirdled branches 81 set fruit.

Table 6

Influence of limb and branch girdling on size of apples

Variety McIntosh	Treated June 22-24	Measurements August 29-30		Measurements at harvest September 20			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable Error	Ave. Wt. grams.
1	Limbs girdled O check side	82	6.48	122	7.89	±.032	147.34
	Check limb - check side	69	6.10	80	6.74	±.016	110.51
	Branches gir. - check side	28	6.53	39	7.12	±.029	129.10
	Limbs gir.-roots pruned ½	107	6.22	86	7.62	±.015	112.22
	Check limb-roots pruned ½	114	5.65	71	6.59	±.014	104.44
	Small branches girdled- roots pruned ½ tree	76	6.03	83	6.40	±.019	103.75
2	Limbs gir.-check side	86	6.61	81	7.95	±.021	153.93
	Check limb - check side	70	6.08	106	6.96	±.012	122.87
	Bran. gir. - check side	75	5.55	43	----	----	135.52
	Limbs gir - roots pruned ½	90	6.22	73	7.34	±.018	139.38
	Check limb -roots pruned ½	45	5.82	55	6.72	±.028	115.73
	Small branches girdled - roots pruned ½ tree	88	5.83	61	6.54	±.033	104.29
3.	Small branches girdled	38	6.61	34	7.55	±.023	153.94
	Check branches	--	----	61	6.95	±.020	141.30
4	Small branches girdled	39	6.77	34	7.70	±.021	165.29
	Check branches	--	----	30	7.33	±.019	142.26

Table 7

Influence of limb girdling with nitrogen on size of fruit.

Variety Ontario	Treated June 6 - 7	Measurements August 27		Measurements at harvest October 15			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
1 *	Limbs girdled	91	6.62	202	7.43	±.041	147.36
	Check limbs	47	6.10	77	7.15	±.032	128.3
2 *	Limbs girdled	96	6.18	103	7.91	±.033	170.0
	Check limbs	70	6.39	68	7.60	±.027	159.4
3	Limbs girdled, 4# $NaNO_3$ ½	95	5.92	61	7.32	±.036	136.7
	Check limbs	75	5.89	.69	6.64	±.021	107.4
4	Check tree	72	5.98	119	6.63	±.027	105.0
5	Check tree	--	----	132	6.80	±.021	106.0
McIntosh variety - treated June 22 - 24							
1 *	Limbs girdled plus	93	6.48	125	----	----	164.56
	Check limbs	81	6.25	72	6.77	±.018	113.75
2 *	Small branches	70	6.27	43	7.40	±.022	143.95

* Nitrate of soda, 8 lbs. per tree, was added to whole tree.

Spur girdling:

On three trees spurs bearing from three to five leaves, other spurs bearing from five to fifteen leaves, and a third group bearing more than fifteen leaves, were girdled.

The spur girdling was performed by the removal of a strip of bark, approximately one sixteenth of an inch wide, extending to the cambium around the spur.

The data shown in table 8 illustrate the fact that apples borne on the girdled spurs were consistently smaller than those borne on girdled branches. The measurements show that the apples on the girdled spurs are in proportion in size to the number of leaves borne by the spur. These figures also point to the fact that the developing fruit depends on the synthesized food from the leaves of adjacent non-fruiting spurs or branches for its normal development. There was apparently no difference in the size of fruit on check spurs bearing three to five leaves as compared with check spurs bearing six to fifteen leaves provided adjacent leaves in close proximity to the fruiting spur are available.

Table 8

Influence of spur girdling and leaf area on size of apples.

Variety McIntosh	Treated June 22 - 24	Measurements August 29-30		Measurements at harvest September 20			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
1	Spurs girdled, 3-5 leaves	18	4.70	20	4.31	±.028	35.10
	Spurs girdled, 6-15 leaves	15	5.00	14	5.96	±.025	74.01
	Spurs girdled, over 15	48	5.50	41	6.72	±.029	114.50
	Check 3-5 leaves	65	6.10	60	7.14	±.021	142.56
	Check 6-15 leaves	32	6.01	29	7.11	±.024	135.72
	Check over 15 leaves	12	6.61	*10	7.09	±.026	132.86
2	Spurs girdled, 3-5 leaves	40	4.38	42	4.35	±.027	40.24
	Spurs girdled, 6-15 leaves	40	4.98	34	5.77	±.034	71.50
	Spurs girdled, over 15	15	5.89	*41	6.72	±.026	114.50
	Check 3-5 leaves	38	6.15	37	7.27	±.025	144.05
	Check 6-15 leaves	42	6.00	37	7.28	±.029	146.32
	Check at random	29	5.92	29	6.79	±.028	136.09
3	Spurs girdled, 3-5 leaves	--	----	29	4.28	±.021	33.86
	Spurs girdled, 6-15 leaves	--	----	43	5.67	±.023	69.10
	Check 3-5 leaves	--	----	34	7.32	±.023	135.23
	Check 6-15 leaves	--	----	42	7.39	±.028	142.37
	Check at random	--	----	63	6.95	±.027	141.30

* Mixed in moving, weights and measurements of all girdled over 15 leaves taken together.

Experiments relative to the local or general effects of defoliation and shading.

Defoliation:

The defoliation experiments were conducted to determine the direction, or areas, from which the developing fruit draws its food, and to determine the influence of defoliation on the defoliated areas, on the adjacent areas, and on the remote parts of the tree, as might be indicated by the differences in the size of the fruit. The defoliation in the cultivated plot was performed June 15, and in the sod plot July 5 to 8.

The defoliation experiments were conducted as follows:

1) Sod plot: From certain branches of three trees the old leaves, comprising approximately one half of the foliage, were removed.

2) Same as (1), plus nitrate of soda applied at the rate of eight pounds per tree July 8.

The data presented in table 9 give conclusive evidence to show that the removal of the leaves on certain limbs caused a reduction in the size of the fruit on the limbs that were defoliated. Nitrogen

applied July 8 (in this dry year) did not increase the size of the fruits on the defoliated limbs nor on the check limbs.

3) Sod Plot: (a) On certain limbs of three trees all leaves for a distance of ten inches above the fruiting spurs were removed, with the leaves on the fruiting spurs trimmed to approximately one half their normal area. (b) On certain limbs of three trees all leaves for a distance of ten inches below the fruiting spurs were removed, with the leaves on the fruiting spurs trimmed to approximately one half their normal area.

In each case the terminal halves of the spur leaves were trimmed away with scissors leaving the basal portion.

(c) On certain branches of three trees areas for ten inches above and ten inches below the fruiting spurs were completely defoliated, leaving the leaves on the fruiting spurs intact.

From the measurements shown in table 10 the reduction of the leaf area by trimming the leaves on the fruiting spurs had a greater effect on the size of the fruit borne threron than did the removal of a greater number of adjacent leaves either from above or below the spur.

Table 10

Effects of defoliation of areas above or below the fruiting spur

on the size of the fruit.

Variety Wolf River	Treated July 5-8	Measurements September 1		Measurements at harvest September 12-13			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
1	*Defoliated below	14	7.75	29	8.53	±.041	209.0
	Check	--	----	52	8.86	±.057	234.5
2	Defoliated below	63	8.03	97	8.76	±.033	207.9
	Check	15	8.44	37	9.23	±.037	254.9
3	Defoliated below	25	8.07	38	8.76	±.022	190.3
	Check	--	----	40	8.68	±.034	245.0
4	**Defoliated above	22	7.58	61	8.63	±.019	212.1
	Check	--	----	52	8.86	±.057	234.5
5	Defoliated above	34	8.07	38	8.79	±.066	223.8
	Check	15	8.44	37	9.23	±.037	254.9
6	Defoliated above	17	8.14	16	8.71	±.021	193.7
	Check	--	----	59	9.09	±.040	226.1
7	***Defol. above and below (not trimmed	17	8.03	61	8.66	±.036	224.5
	Check	38	8.24	61	8.78	±.027	223.6
8	Defol. above and below	41	8.40	41	(9.17	±.056	249.1) xf
	Check	39	8.45	48	----	----	(161.3) xf
9	Defol. above and below	13	8.28	20	8.48	±.081	211.2
	Check	--	----	59	9.09	±.040	226.1

*Fruiting spurs trimmed to one half area, all leaves removed for ten inches below the spur.

**Fruiting spurs trimmed to one half area, all leaves removed for ten inches above the spur

***All leaves removed for ten inches above and ten inches below the fruiting spur. Spurs not trimmed.

xf Thrown out on account other factors.

Table 9

Influence of defoliation of old leaves on size of apples

Variety Wolf River	Treated July 5 - 8	Measurements September 1		Measurements at harvest September 12-13			
Tree	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
1 *	Old leaves removed	31	7.67	37	8.06	±.082	186.3
	Check limb	19	7.77	36	8.61	±.116	203.3
2	Old leaves removed	53	7.36	59	8.12	±.028	195.9
	Check limb	36	8.03	45	8.54	±.030	205.4
3	Old leaves removed	31	8.09	23	8.19	±.050	186.9
	Check limb	32	8.80	24	8.62	±.067	211.3
**	)Old leaves removed	28	7.67	48	8.13	±.030	182.7
	)Check	15	7.95	39	8.57	±.035	204.7
	)Old leaves removed	42	8.28	38	8.91	±.113	229.7
	)Check	34	8.68	36	8.76	±.068	230.5
	)Old leaves removed	98	7.27	84	7.92	±.014	171.9
	)Check	68	7.97	71	8.17	±.013	179.3

* The older half of all the leaves om certain limbs were removed.

** $NaNO_3$ - 8 lbs. per tree - applied July 5

4) Cultivated Plot: (a) Certain limbs of three trees were partially defoliated by trimming approximately one third the area from the tips of all leaves, leaving two thirds of the basal area of all the leaves thereon. On three trees the leaves on certain limbs were in like manner trimmed back to one third their normal area. Most of these apples dropped from the tree and the measurements are not shown. (b) The fruiting spurs on the limbs of two trees were completely defoliated. (c) The terminal half of certain branches on three trees and the basal half on certain other branches was completely defoliated.

Measurements, as shown in table 11, were taken on treated and untreated portions of the trees in this experiment. Apples borne on the areas which were completely defoliated dropped worse than did the apples borne on the partially defoliated areas. The percent of dropping and the size of the fruit were apparently in proportion to the degree of defoliation in close proximity to the fruiting spur; yet fruit borne on the completely defoliated areas shows that the developing fruit is able to draw food from adjacent leaves at least within a certain distance. The apples on the basal portions of branches of which the tips had been defoliated were even larger than were those on the check branches.

Table 11

Influence of complete or partial defoliation of certain branches on the size of apples.

Variety Wolf River	Treated June 15	Measurements August 30		Measurements at harvest September 12			
Trees treated	Treatment	Number apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
3	1/3 defoliation	93	7.76	86	8.41	±.042	206.2
	Checks of same trees	93	8.06	126	8.63	±.038	230.52
3	Complete terminal defol.	37*	7.32	34	8.01	±.046	180.1
	Check same	92	8.35	121	8.77	±.031	225.4
2	Complete spur defoliation	37	7.90	21	8.35	±.045	195.48
	Check same	64	8.35	53	9.06	±.046	250.87
3	Undefol. base of branches (with tips defol)	70	8.58	83	9.58	±.047	264.7
	Check same	92	8.35	121	8.77	±.031	225.4
2	Basal defoliated	31	8.01	25	8.15	±.088	186.6
	Check same	90	8.38	85	8.85	±.035	230.2
2	Terminals undefoliated (complete basal defol)	101	----	105	9.00	±.042	241.6
	Check	80	8.38	82	8.85	±.031	230.2

1/3 area of all leaves on certain branches trimmed 1/3 area leaving 2/3 of area nearest base
All leaves removed from entire branch
Complete undefoliated basal half of branches (with tips completely defoliated)
Complete defoliated basal half of branches (tips undefoliated)

* 200 apples were treated in each case, the remainder had dropped in this case.
Branches under treatment were approximately $1\frac{1}{2}$ inches in diameter.

Shading:

The shading experiment was conducted on seven year old Golden Delicious apple trees. Heavy weight white muslin cloth was used. On three trees certain branches (about one-half inch in diameter) were enclosed in white cloth sacks. On three trees certain main limbs were likewise enclosed. One tree was entirely covered with the cloth stretched on a wooden frame built around the tree. Ventilation, temperature, and humidity were not taken into consideration since the purpose of the experiment was to determine the general and localized responses of the trees to the shading of its different parts.

Table 12 compares the effects of shading the whole tree with the effects of shading certain limbs and small branches. Where the whole tree was shaded the apples were considerably smaller than were the fruits on the check limbs and even smaller than those fruits where the limbs were shaded. The shaded smaller branches produced larger fruits than did the shaded limbs. The results showed that the effects of shading tend to be limited to the area which is shaded, and that the influence of shading in reducing the size of fruits is apparently in proportion to the area which is shaded. The fact that the apples on the shaded branches were larger than those on the shaded limbs or shaded tree may be readily associated with the fact that the developing fruit can draw food materials from unshaded leaves nearby, but not from areas a great distance away. The question of lower transpiration and higher temperature may have been factors conflicting with the influence of the reduction in the photosynthetic processes, if so, apparently the lack of photosynthesis is the vital factor in shading.

Table 12

Effects of shading certain small branches, limbs, and the whole tree, on the size of apples.

Variety Delicious Treatment	Treated July 9	Measurements at harvest October 15: Number Apples	Average diam. cm.	Probable error	Ave. Wt. grams
Whole tree shaded		170	5.99	±.024	76.08
Shaded limbs		154	6.16	±.062	101.91
Check limbs		64	6.65	±.016	138.00
Shaded limb		171	6.10	±.043	109.6
Check		144	6.60	±.019	131.6
Shaded limb		26	6.20	±.057	118.8
Check		36	6.80	±.014	143.61
Small branches shaded		41	6.59	±.038	136.82
Check		32	6.72	±.016	161.25
Small branches shaded		59	6.33	±.013	128.6
Check		64	6.65	±.017	138.0

Other Experiments

Position of Limbs:

Measurements were made of the fruits growing upon the lateral and the upright limbs of two Ontario and two McIntosh trees, in order to determine the variation in the size of the fruits as influenced by the position of the limb. These data are shown in table 13.

The apples growing on the upright limbs were consistently larger than those growing on the lateral limbs. Greater vigor has been recognized on the perpendicular limbs, due possibly to better water conduction and to the fact that tops of apple trees are more open and less shaded than the lateral limbs.

Pruning:

On four trees the apples on the stubs within one foot of the pruned end of cut back limbs were measured. Measurements were made only where there was a normal fruit set. The results presented in table 13 show a very decided increase in the size of the apples borne on the stub in close proximity to the cut. One may reasonably conclude that the same impulse which stimulates shoot growth under similar conditions may be responsible for the increase in the size of apples growing on the stubs of limbs pruned back during the summer.

Measurements were made on the apples growing on the north, the east, the west, and the south sides of several trees, up until September 1. No consistent differences were found in the size of the fruit borne on these various portions of the tree. These data are not presented.

Table 13

Influence of the position of the limb, and the effects of heading back

on size of apples

Variety Ontario	Treated	Measurements		Measurements at harvest			
Tree	Treatment	Number Apples	Average diam. cm.	Number apples	Average di. cm.	Probable error	Ave. Wt. grams
1	Lateral limb	73	6.38	138	7.19	±.021	129.6
	Upright limb	55	6.66	91	8.12	±.028	185.8
2	Lateral limb	63	6.45	72	7.12	±.028	128.3
	Upright limb	28	6.80	130	7.85	±.020	166.76
3	Lateral limb	32	4.47	50	7.00	±.027	132.0
	Upright limb gir.	34	6.85	50	7.90	±.082	170.6
	McIntosh variety						
1	Upright limbs	54	6.73	60	7.20	±.036	136.45
	Lower limbs	51	6.01	62	6.67	±.068	119.50
2	Upright limbs	55	6.59	69	7.00	±.021	113.45
	Lateral limbs	58	5.83	67	6.63	±.043	105.76
	Wolf River - treated July 6						
*	Apples on stubs	34	8.71	30	9.52	±.051	270.29
	Checks	89	8.13	68	8.72	±.053	227.7

*These apples were borne within ten inches of the wound made in pruning back the first of July.

Summary

1. Individual apple trees bear apples which show more variation in size than do other trees of the same variety, in the same orchard, which are the same age and about the same size and shape.

2. Certain trees bear apples which are consistently larger while other trees produce apples which average smaller than the fruit borne on a number of check trees.

3. The size of apples borne on certain limbs, branches, or spurs, is influenced by the factors affecting the tree as a whole, but factors affecting a certain component part of a tree apparently do not necessarily influence the response of the tree as a whole.

4. Factors affecting certain main roots may influence the size of the fruit on the area directly above, or on the limbs fed by these roots, with no apparent effect on the size of the fruit on the remote parts of the tree.

5. Nitrogen applied to one side of an apple tree had a greater influence on the size of the fruit

on that side of the tree than did water; while the apples borne on the watered side of a tree were slightly larger than those borne on the opposite side.

6. Shading within certain limits tends to reduce the size of apples in proportion to the area shaded, and the reduction in size is confined principally to the area shaded.

7. Defoliation of fruiting spurs and small branches tends to reduce the size of apples in proportion to the percent of defoliation. However, apples on the defoliated area are able to draw food material from nearby leaved areas within certain limits.

8. The defoliation of the terminal half of branches increased the size of apples on the undefoliated basal portions, while the defoliation of the basal portions did not increase the size of apples on the terminal halves.

9. When the ends of certain limbs were sawed off in July the apples in close proximity to the cut were very much larger than the checks.

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