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UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

APPLE PRUNING INVESTIGATIONS

I. Comparison of Fall, Winter, and Spring Pruning
II. Renovation
III. Wound Healing

W. G. BRIERLEY
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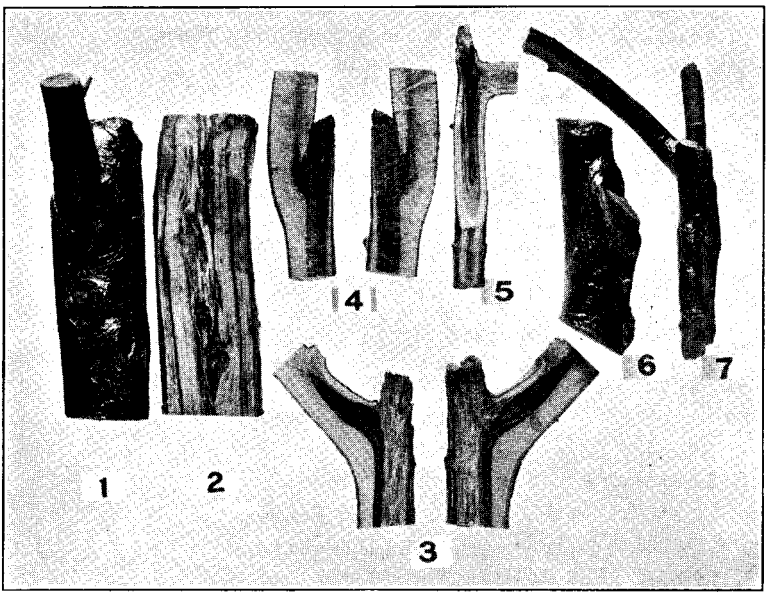

STUBS LEFT BY POOR PRUNING, SECTIONED TO SHOW DECAY OF THE HEART WOOD

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APPLE PRUNING INVESTIGATIONS

By W. G. Brierley

INTRODUCTION

The history of orcharding in Minnesota is a story of early failures with tender, unadapted varieties followed by the introduction of Russian varieties in the hope that some would prove hardy. From the earliest attempts at apple growing until the present, a very large number of seedlings have been grown by individuals who were and are deeply interested in producing varieties adapted to Minnesota conditions. The Wealthy and other less widely known varieties originated during this development period, are tributes to the patience and perseverance of the pioneer apple growers.

During this period of development the practice of pruning seems to have been on a very uncertain basis. Many apple growers were in doubt about what to do, while others firmly believed that pruning was injurious. Conflicting opinions of growers can be found scattered through the reports of the Minnesota State Horticultural Society. In these reports, especially the earlier ones, statements appear to the effect that trees in Minnesota will not stand pruning as well as trees grown in the east, or that trees in this state were killed by winter pruning. Some advised against pruning at any season while others recommended it in June or July. Such opinions and beliefs are still commonly held. It is very evident from extensive observations in Minnesota orchards that injuries resulting from disease, lack of vigor, unfavorable sites, or the effects of severe winters, have all been attributed to pruning.

In view of the fact that pruning is an essential orchard practice in all sections where the winters are less severe than in Minnesota, it appeared desirable to carry on some pruning studies in this state to determine if the common methods of pruning could be used with safety. This work was begun in the fall of 1913 and has been continued to the present time. Without presenting evidence in detail, it has been obvious that well-managed pruning has given the usual benefits. Few injuries which could be attributed to pruning have resulted, in orchards regularly and moderately pruned. Where trees have been of unhardy varieties, in poor vigor, badly crowded, located on unfavorable sites, butchered in pruning; or where soil management has been faulty, injuries have been noted, but in none of these cases can pruning be singled out as the cause of injury.

During the course of these investigations data have been obtained on the effects of pruning at different times within the dormant season, on renovation, and on the healing of wounds. The results of these studies are here presented.

1. COMPARISON OF FALL, WINTER, AND SPRING PRUNING OF APPLE TREES IN MINNESOTA

Fall and winter pruning, as well as spring pruning, are more or less standard practices in large orchards in eastern and central states, and on the Pacific Coast. Pruning at a time when other work is not pressing has been considered advantageous. In large orchards the work must be started in late fall in order to be completed before spring work begins. In Minnesota in November and early December pleasant weather suitable for pruning is usual; in March or April stormy weather may often interfere with pruning or the spring may "break" so quickly that in the rush of spring work pruning is neglected. Investigators have shown that in regions where they were working there was no appreciable difference in the response of the plant to pruning at different times within the dormant season. Bedford and Pickering[1], reporting in 1905 on pruning work at the Woburn Experimental Fruit Farm, in England, stated that they found no appreciable advantage in pruning at one period of the dormant season in preference to any other. Chandler[2] reports for New York conditions that generally no injuries resulted from fall and winter pruning, but that very heavy pruning sometimes resulted in injury. He states that at the Missouri experiment station no difference in injury had been noted on peach and other fruits from severe fall and winter pruning, even when the pruning was done while the wood was frozen hard.

Work on this phase of the problem was carried on at the Minnesota station from the fall of 1913 until the spring of 1923. Preliminary studies were conducted from 1913 to 1918 in an orchard not well suited for the work. The trees were badly crowded, of mixed varieties and seedlings, 8 to 10 years of age, and were interplanted very thickly with plum seedlings. The number of trees per row was variable, ranging from 5 to 10. The soil was a sandy loam and cultivated each year. At the beginning the work was largely in the nature of thinning out the trees and renovating the remaining ones. The renovation necessitated severe pruning, as the trees had not been pruned for at least five years. In the following years the pruning generally was the

[1] The Duke of Bedford and Spencer U. Pickering. "Pruning at different times (in the dormant season)." Woburn Experiment Fruit Farm. 5th Report pp. 37-8. 1905.

[2] Chandler, W. H. "Results of some experiments in pruning fruit trees." N. Y. (Cornell) Bul. 415, p. 41-3. 1923.

necessary follow-up of the renovation, but was less severe in each succeeding year. All trees were treated in the same manner except for the time when the pruning was done.

In 1913-14, winter pruning was done in December and spring pruning in March. In 1914-15, owing to weather conditions, winter pruning had to be postponed until early in January and spring pruning until early in April. The data covering the work of these two years show no appreciable differences between the winter- and spring-pruned blocks in regard to winter injury, vigor of growth, and maturity of growth the following fall.

In 1915-16 and 1916-17, the three rows which had been winter pruned were pruned one in November, one in December, and one in January. One row of the spring-pruned block was pruned each month from February to June, the work being done as near the middle of the month as the weather permitted.

Pruning during winter months frequently was done in zero weather while the wood was frozen hard. Sometimes the trees were coated with ice after sleet storms. The pruning at other times was done under normal conditions.

Notes made during the growing seasons of 1914 and 1915 show that there was very little difference in the behavior of the two blocks. The differences between individual trees were as marked as any differences between the winter- and spring-pruned blocks. No appreciable differences appeared between the rows pruned each month from November to June in 1915-16 and 1916-17. Because of the apparent uniformity of growth, some way roughly to indicate any lack of vigor was sought. In this preliminary study, particularly in view of the make-up of the orchard, it was not considered desirable to make extensive measurements. The longest shoot growth of the season taken at random along each row was finally determined upon as a rough method of showing lack of vigor. This method would not be satisfactory under ordinary orchard conditions. However, so many variables were involved under the conditions of this preliminary work that the method was as reliable as any other would have been.

The shoots selected at the end of the 1916 growing season are shown in Figure 1; those selected at the end of the 1917 season are shown in Figure 2. Table 1 gives the length and diameter of these shoots.

From the table and Figure 1, it will be noted that the best growth resulted from pruning in February, March, and April, with November, December, and January not far behind and of about equal rank. The shoot length and diameter for May pruning fell off noticeably, and for June pruning even more sharply. This decline in vigor of shoot growth was characteristic of the entire rows pruned in those two

months. In 1915-16 the trees were given the last general heading back. The rows pruned in May and June were pushing new growth rapidly, much of which was at the tips. This new growth was removed to a large extent by the heading back, and the buds lower down on the shoots were forced into growth. Evidently the food reserves were somewhat depleted by the time of pruning and the new shoots which were forced out had a shorter season in which to make their growth and to mature. Because of these handicaps they were shorter than normal shoots, not so well matured, and showed more wood and pith browning from winter injury. This was the only instance in the investigations in which appreciable differences in growth resulted from the time of pruning. As the pruning in May and June was done in the early part of the growing season and the trees were no longer dormant, this injury should be considered as arising from early summer pruning and not from dormant pruning. The shoot growth of 1917, shown in Figure 2 and in Table I, shows slightly more vigor in the shoots from the rows pruned in November, December, January, and February, but the other rows produced shoots of good length so no

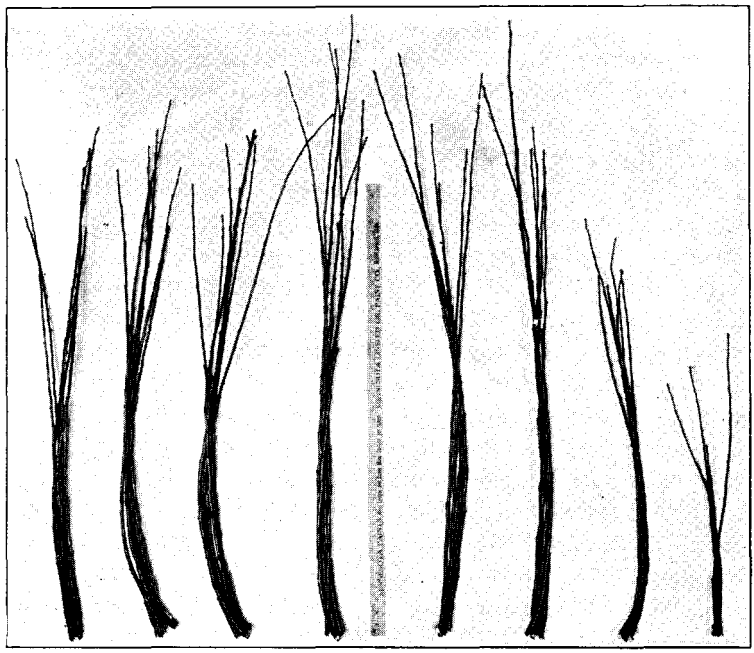

Fig. 1. Longest Shoot Growth of 1916 Selected at Random from Rows Pruned Each Month from November (left) to June (right) 1915-16

The shorter growth in May and June was due to heading back after growth had started. The new shoot growth which was developing rapidly near the tips of the old shoots was largely removed in the heading back, causing buds below the cut to be forced into growth later than normal and with a shorter growing season in which to develop and mature.

weakening effect was apparent. As the work of 1916-17 was largely thinning, there was no loss of new shoots in the rows pruned in May and June, and the shoots grew to approximately equal lengths with those from rows pruned in March and April.

TABLE I

COMPARATIVE LENGTH AND BUTT DIAMETER OF LONGEST SHOOTS FROM THE MONTH-ROWS*

Month	Growth of 1916 Trees pruned 1915-16 Average of 6 longest shoots		Growth of 1917 Trees pruned 1916-17 Average of 10 longest shoots	
	Length	Diameter	Length	Diameter
	cm.	mm.	cm.	mm.
November	95.4	7.9	93.6	8.9
December	98.3	8.2	101.5	9.3
January	99.9	8.9	105.7	9.0
February	115.1	8.9	98.8	8.8
March	106.3	7.9	83.3	8.4
April	104.0	8.7	91.0	9.9
May	76.8	6.8	81.1	8.7
June	44.3	4.8	89.0	8.3

* Diameter taken one cm. above old bud scars, avoiding buds.

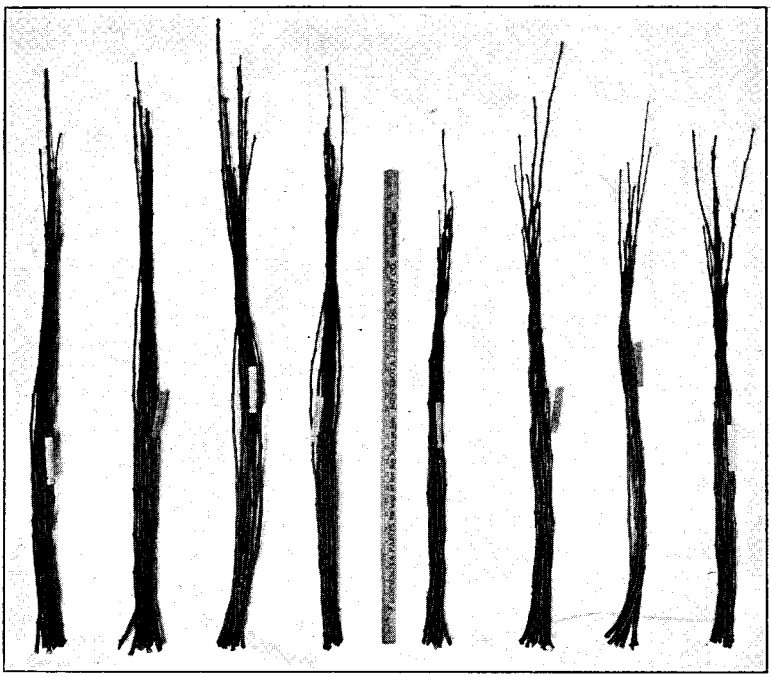

Fig. 2. Longest Shoot Growth of 1917 Selected at Random from Rows Pruned Each Month from November (left) to June (right) 1916-17

With no heading-back practiced, the shoot growth was approximately the same for each month.

Except for the behavior of the shoots on the rows pruned in May and June in 1915-16, no difference was noted in the maturity. If the trees held their leaves, they did so uniformly. If the shoots showed browning of the wood and pith at the tips this, too, was uniform for all the rows. In the healing of the wounds no differences could be detected which could be charged to seasonal effects. When the wood was frozen hard the use of lopping shears often produced a splintered wound or more bark would be slipped and crushed than was the case when the wood was not frozen. When saws were used, the cuts were the same on frozen wood as when it was not frozen. Hand shears were used with greater difficulty in the frozen wood, but little injury resulted in the shoots from their use. The drying back at the tips of the shoots was not appreciably greater at any one time, as seen in Figure 3.

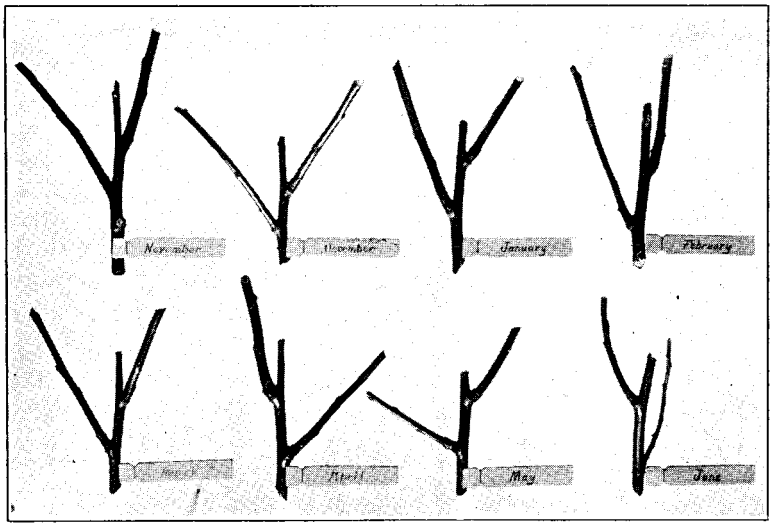

Fig. 3. Greatest Amount of Drying Back at the Tips in Rows Pruned Each Month from November (top at left) to June (bottom at right)

The opportunity was presented in 1919 to continue these studies in four representative young orchards in which were growing Wealthy, Oldenburg (Duchess), Patten, and other hardy varieties commonly grown in Minnesota. These were an orchard at University Farm, the J. V. Bailey orchard at Newport, the J. P. West orchard at Rockford, and the state hospital orchard at Willmar. The University Farm orchard contained 180 trees planted in 1916. The soil was a heavy loam and the site nearly level. The Bailey orchard contained 236 permanent trees planted in 1916 on hilly land, the soil being a light loam. The permanent trees were of Virginia Crab stock, budded

or grafted to the common varieties. There were also about 170 fillers of the common varieties. The West orchard contained about 40 trees planted in 1913 and 158 trees planted in 1915. Of the 1915 block, 52 trees were Hibenal top-worked with Wealthy. The soil was a clay loam and the site gently sloping to the northeast and southwest. The orchard at Willmar contained 576 trees planted, one fourth in 1914 and the rest in 1915 on clay loam soil on a practically level site. These orchards were each divided into blocks according to variety and age. One half was pruned in late fall after the trees were well matured, the work generally being done late in October or in November. The other half of each block in each orchard was pruned in April. Opportunity was thus afforded to compare the effects of pruning at both extremes of the dormant season. No work was carried on during the winter months, as no significant differences had appeared in the midwinter blocks in the preliminary studies. The pruning was moderate, consisting generally of thinning out surplus shoots. Heading back was done only where a tree showed a tendency to make too much growth at the top. Large branches were removed only when it was necessary to remove diseased or injured parts.

During the progress of these studies, observations were made as to the healing of wounds, drying back at the tips of the shoots, and tree vigor. As an index of vigor, shoot growth was measured in the fall- and spring-pruned block. Representative trees in each block were selected and measurements were made in each tree of 10 shoots selected at random. In 1920 not more than 10 trees were included in any variety. In 1921 the numbers were increased where it was possible to select representative trees. Summarizations of the data for 1920 and 1921 growth appear in Tables II and III, respectively.

Examination of these tables shows that there was practically no difference in vigor of growth between the fall- and the spring-pruned trees. In some cases the slight advantage was in favor of spring pruning, but generally it was in favor of fall pruning. The differences can not be considered as significant, however, as the difference of 0.1 foot in favor of the general average of all fall-pruned trees in 1920 is equal to only 1.2 inches, and the difference of 0.14 foot in favor of fall pruning in 1921 is equal to only 1.7 inches. However, the data show that fall pruning has not been detrimental to the growth of several hardy varieties in different localities.

In addition to the measuring of shoot growth, observations which continued until the spring of 1923 were made on the healing of wounds and on drying back at the tips of shoots which were headed back. On all vigorous healthy trees the wounds were healing satisfactorily in both the fall- and spring-pruned blocks. Pruning wounds on weak

trees, whether made in the fall or the spring, did not heal rapidly. Apparently the rate of wound healing is more closely related to the vigor of the tree than to fall or spring pruning. No appreciable difference was noted between the fall- and spring-pruned trees in the matter of shoots drying back at the tips.

TABLE II

SUMMARY OF MEASUREMENTS OF SHOOT GROWTH OF 1920 AFTER PRUNING IN THE FALL OF 1919 AND SPRING OF 1920

Variety	Location	Age	Fall pruned			Spring pruned		
			No. of trees	No. of shoots	Average length of shoots	No. of trees	No. of shoots	Average length of shoots
		Years			Feet			Feet
Duchess (Oldenburg)	U. Farm	5	9	90	1.46	10	100	1.37
	Rockford	6	4	40	1.81	7	70	1.61
	Willmar	6	10	100	1.72	10	100	1.77
	Average	..	..	...	1.67	..	...	1.58
Wealthy	U. Farm	5	10	100	1.56	10	100	1.52
	Newport I	5	10	100	1.28	10	100	1.27
	Newport II*	5	10	100	1.85	10	100	1.79
	Rockford I	6	10	100	1.85	10	100	1.61
	Rockford II	8	10	100	1.22	10	100	1.07
	Rockford III†	6	10	100	2.03	10	100	1.84
	Willmar	6	10	100	1.70	10	100	1.56
	Average	..	..	...	1.64	..	...	1.52
Whitney (Crab)	Newport	5	10	100	1.47	10	100	1.41
	Willmar	6	10	100	1.78	10	100	1.83
	Average	..	..	...	1.63	..	...	1.62
Patten (Greening)	Rockford	6	8	80	1.86	8	80	1.39
	Willmar	6	10	100	1.70	10	100	1.68
	Average	..	..	...	1.77	..	...	1.55
Transcendent (Crab)	Willmar	6	10	100	1.83	10	100	1.79
Wolf River	Willmar	6	106	100	1.62	10	100	1.74
Grand average all varieties		..	..	...	1.67	..	...	1.57

* Top-worked on Virginia Crab stock.
† Top-worked on Hibernal stock.

In conclusion, it is evident that fall pruning is a safe practice in Minnesota if the trees are kept in normal vigor and pruned moderately. This possibility may be used to advantage by the apple grower. Pruning, a necessary orchard operation, can be done with safety in Minnesota in the fall when other work is not pressing, hence it can be done less hurriedly and better work should result. There is less demand on the grower's time in the fall than in the busier spring season. If pruning is done in the fall, there will be no danger of the work being omitted by reason of conflict with other urgent farm operations. Growers who do pruning for others may prune over a longer time than is available in the spring.

TABLE III

SUMMARY OF MEASUREMENTS OF SHOOT GROWTH OF 1921 AFTER PRUNING IN THE FALL OF 1920 AND SPRING OF 1921

Variety	Location	Age	Fall pruned			Spring pruned		
			No. of trees	No. of shoots	Average length of shoots	No. of trees	No. of shoots	Average length of shoots
		Years			Feet			Feet
Duchess (Oldenburg)	U. Farm	6	10	100	1.54	16	100	1.43
	Rockford	7	2	20	1.32	4	40	1.18
	Willmar	7	16	160	1.65	15	150	1.49
	Average	..	..	...	1.58	..	...	1.43
Wealthy	U. Farm	6	19	180	1.78	15	150	1.86
	Newport I	6	25	250	1.67	25	250	1.62
	Newport II*	6	24	240	2.01	18	180	1.99
	Rockford I	7	14	140	1.36	16	160	1.18
	Rockford II	9	16	160	1.09	16	160	0.82
	Rockford III†	7	20	200	1.81	20	200	1.56
	Willmar	7	20	200	1.68	20	200	1.51
	Average	..	..	...	1.67	..	...	1.52
Whitney (Crab)	Newport	6	25	250	1.84	13	130	1.76
	Willmar	7	15	150	1.72	10	100	1.60
	Average	..	..	...	1.79	..	...	1.69
Patten (Greening)	Rockford	7	5	50	1.10	7	70	1.07
	Willmar	7	20	200	1.62	20	200	1.53
	Average	..	..	...	1.51	..	...	1.41
Transcendent (Crab)	Willmar	7	17	170	1.62	19	190	1.54
Wolf River	Willmar	7	11	110	1.49	14	140	1.49
Grand average all varieties		..	..	...	1.65	..	...	1.51

* Top-worked on Virginia Crab stock.

† Top-worked on Hibernal stock.

II. RENOVATION

Many orchards in Minnesota have either not been pruned or have been pruned at irregular intervals. Close planting has been the rule and in the majority of orchards the trees are only 16 feet apart. While it is evident that complete renovation of these orchards must include a general thinning of the trees, removal of all dead or badly weakened trees, improvement in methods of soil management to increase tree vigor, and also improvement in spraying methods and machinery, some pruning renovation must be practiced on each remaining tree. In order to determine the practicability of renovation pruning for both young and old trees, studies have been carried on at University Farm and numerous observations have been made in other orchards.

Renovation was carried on in the orchard at University Farm, where the trees were badly crowded and were all high headed with thin tops, and from 8 to 10 years old. In order to correct these defects

the pruning was very severe. In view of the larger wounds made and the longer time required for healing, it would doubtless be better to have pruned less severely, but the trees responded with vigorous growth which in a few years led to the reformation of the tops, as shown in Figures 4 to 7, which illustrate one tree in its development after renovation. The history of the other trees in this orchard is very similar. The new growth was easily pruned to develop a spreading rounded head in three or four years. Most of the wounds made in the first pruning healed rapidly, but some developed "sap blisters" which fermented and killed the bark. Typical examples of this injury are shown in Figure 8. This injury is sometimes found after heavy pruning and adds to the undesirability of severe pruning.

Fig. 4. Typical Head of Neglected Young Tree Before Renovating
Plum seedlings were removed to provide more head room.

No fruiting records were kept for these trees. Very little fruit was produced during the renovation period, but the trees were considered to be in a fruiting condition at the close of the renovation work.

Renovation of older trees was attempted in 1914 in a limited way with some Patten (Greening) trees 16 years old which previously had had little or no pruning. These trees were growing in an old orchard at University Farm and were in a healthy condition but badly crowded.

In one group of trees no attempt was made to correct scaffold defects which would have left large wounds. The pruning consisted mainly in thinning out the smaller branches of the bearing head. The trees were also headed back somewhat at the tops. The pruning gen-

Fig. 5. Same Tree as in Fig. 4 After Very Severe Pruning

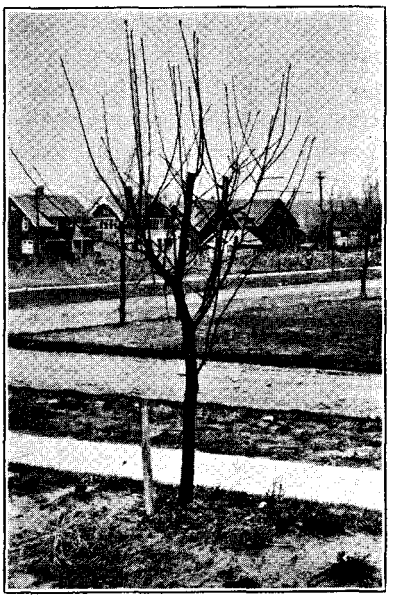

Fig. 6. Same Tree as in Fig. 4, Showing Vigorour Shoots from Which the New Head Was Formed

erally was moderately heavy. Another group of trees was pruned to correct scaffold defects and also very heavily pruned back to the extent of "dehorning" in an attempt to reduce the head height. The moderately renovated trees made vigorous growth but fruiting was not disturbed. The severely renovated trees made very vigorous growth, which was considerably injured by fire blight, and fruiting was reduced to approximately one third the production of the moderately renovated trees over a period of three years; also the large wounds in these trees were slow in healing. Figure 9 shows a typical moderately renovated tree and Figure 10 shows the growth after this pruning. Figure 11 shows a severely renovated tree and Figure 12 illustrates the type of growth following severe pruning. As it has been found that the average life expectancy of apple trees in Minnesota is about

30 years,[3] it is evidently much better to renovate the older trees moderately. In these 16-year-old trees there could be little gain in improving the scaffold at the expense of two-thirds of the crop for three of the prospective fourteen years of their existence. Large wounds which take a long time to heal make decay of the heart wood very likely, which in turn may lead to the breaking down of the tree before the normal life period is completed. The moderately pruned tree, even with undesirable features in the scaffold, should continue in normal production, and in general will not be exposed to wood decay as is the case in severe renovations. Serious weaknesses in the scaffold may be strengthened by bolting, or by the use of wire bracing. In this way large wounds may often be avoided. Basing conclusions on these points, moderate renovation in older trees appears to be the best method when renovation is necessary.

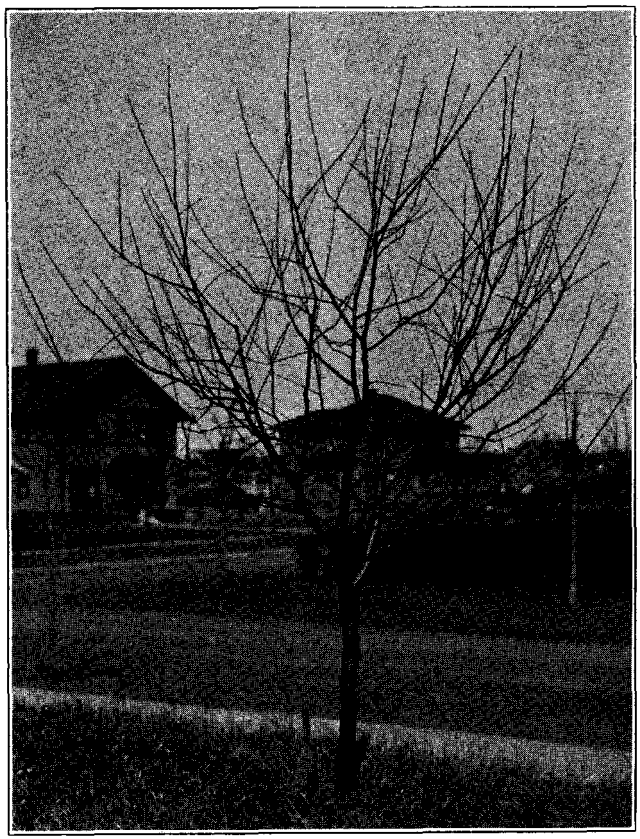

Fig. 7. Same Tree as in Fig. 4, Four Years Later

[3] Brierley, W. G. "Length of life of apple trees in Minnesota." *In* Proc. Am. Soc. Hort. Sci. pp. 211-13. 1921. Also in Minn. Horticulturist 50:247-8. 1922.

The effects of general renovation of older trees was noted in the orchard of W. G. Bach in Washington County.[4] This 18-year-old orchard of about one acre of mixed varieties was thinned out, somewhat heavily pruned, and thoroly sprayed as a demonstration of orchard renovation in 1921.[5] Previous to that time the orchard had borne very little fruit. The effects of this treatment were immediate and have continued with the maintenance of good management. Considering the lack of pruning for seventeen years, this orchard has shown very satisfactory wound healing. Yields and income have increased, and culls are practically eliminated, as shown in Table IV. This orchard produced very satisfactory yields in 1923 and 1924 and should continue to do so for many years in the future.

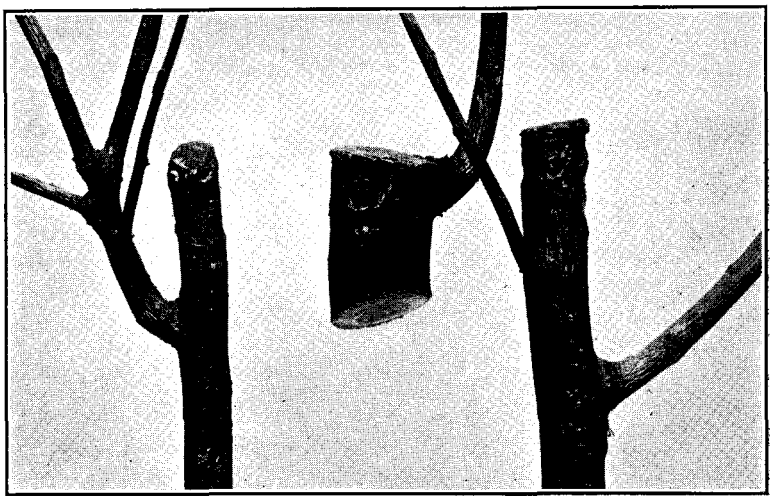

Fig. 8. Injury Caused by "Sap Blisters" Which Fermented and Killed the Bark Near the Wounds

The photograph was taken after specimens had dried.

It may be concluded from these rather limited experiments that renovation is practicable in neglected Minnesota orchards which are in fairly good health. Renovation pruning should not be more severe than is actually necessary to thin out the bearing head of the trees. Pruning should follow a thinning of the orchard when the trees are crowded and the branches interlocking. Thoro spraying and proper attention to the nutrition of the trees should accompany thinning and pruning.

[4] Brierley, W. G. "What pruning and spraying accomplished in the Bach orchard, Washington County." *In* Minn. Hort. 51:48-9. 1923.

[5] The owner followed the directions given by the author relative to thinning and pruning. The spraying was under the direction of Prof. A. G. Ruggles of the Division of Entomology and Economic Zoology.

TABLE IV

PERFORMANCE RECORD OF THE BACH ORCHARD BEFORE AND AFTER RENOVATION*

Year	Yield	Culls	Sold	Income
	Bushels	Bushels	Bushels	
1917	Not enough for home use	Nearly all	None	0
1918	300	200	100	?
1919	About enough for home use	Nearly all	None	0
1920	About enough for home use	Nearly all	None	0
1921	360	5	355	$810
1922	740	0	740	$908

* The orchard is of mixed varieties and about 1 acre in size. It was renovated in 1921.

Fig. 9. A 16-Year-Old Patten (Greening) Tree After Moderate Renovation Pruning

Fig. 10. Same Tree as in Fig. 9, Showing Growth Following Renovation Pruning

Fig. 11. A 16-Year-Old Patten (Greening) After Very Severe Renovation Pruning

Fig. 12. Same Tree as in Fig. 11, Showing Rank Growth Following Renovation Pruning

III. WOUND HEALING

The statement is sometimes made by apple growers in Minnesota that pruning is an unsafe practice because the wounds do not heal. To find out what was happening in regard to wound healing, studies were made in the fall of 1917 and the spring of 1918. Pruning wounds were examined in orchards at University Farm and in several private orchards in the vicinity of Excelsior. Some of these were well cared for and others were more or less neglected. Notes were taken as to whether the wounds were properly or poorly made, the size of the wounds, extent of healing, vigor of the trees, and whether the wounds were protected in any way. A total of 2256 wounds was examined. The size and condition of these wounds are shown in Table V.

An examination of this table shows that for the wounds examined failure to heal was not associated with size of wounds. Failure to

heal in most cases was due to poor pruning, as is shown by the loss of 3.4 per cent where stubs were left (see Figure 13 and picture on title page), and 2.1 per cent where bad shoulders were left. (See Figure 15 and picture on title page.) These two items account for 5.5 out of 6.3 per cent of wounds not healing. The remaining 0.8 per cent represents a total of 17 properly made wounds which did not heal. Ten of these did not heal because of the entrance of diseases such as fire blight or black rot canker. Two others probably were checked by disease but this could not be determined definitely. Three failed on account of the development of sap blisters which fermented and killed the bark (see Figure 13). The cause of failure for the remaining 2 wounds could not be determined.

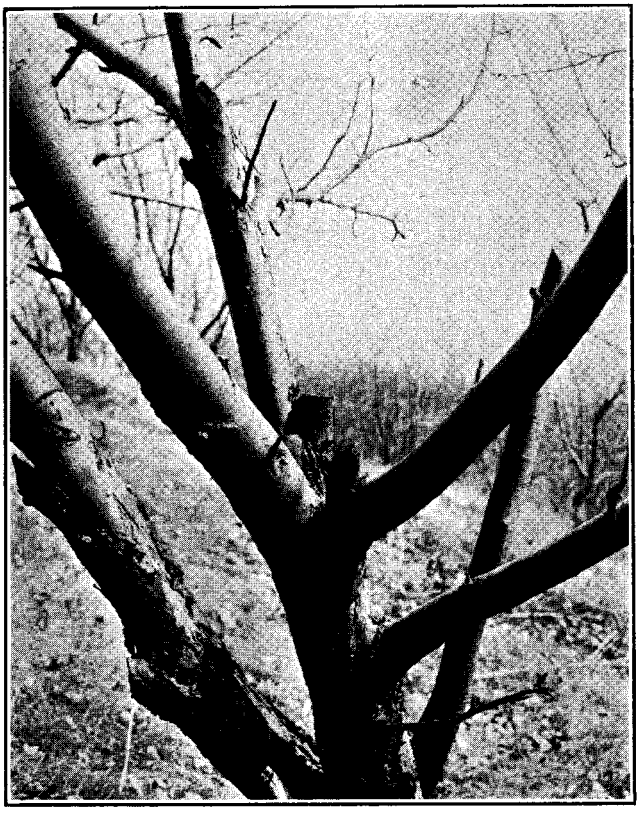

Fig. 13. Stubs Left by Poor Pruning
Nearly two thirds of the failures to heal were due to this defect in pruning.

Of the 28 wounds healing at the margins but with the centers decaying, 11 were half an inch or less in diameter and these would not materially affect the development of the trees on which they were found. The wood decay in the wounds of larger size frequently appeared to be the result of poor pruning. In some cases it was evident that a stub had been left farther out on the branch and the removal later was not in time to prevent wood decay. In several cases failure to heal was evidently due to the lack of vigor in the trees.

Fig. 14. Bad Shoulder Left by Poor Pruning (on Branch at Left)

One third of the failures to heal were due to this defect in pruning. The wound at the left is not healing at the top. Properly made wounds on the branch at the right are healing normally. The bad shoulder at the right of the knife is a newly made wound.

In the study of these wounds it was evident that the rate of healing was directly related to tree vigor. The more vigorous the tree the more rapid the healing of wounds. (See Figure 15.) No statistical evidence was prepared in regard to this, but as healing of wounds is a growth process, it is evidently as much an expression or result of vigor in the tree as is length of shoot growth. Good vigor in the tree, while of great value in the healing of pruning wounds, is also desirable

in its relation to fruit production, as a tree in good vigor is usually a better producer than one below normal in vigor.

TABLE V

SIZE AND CONDITION OF PRUNING WOUNDS

Wounds	Healing					Healing		Not healing				
Size	No.	Healing	Healed	Total	Per cent	But center decayed	Per cent	Stub	Bad shoulder	Properly made	Total	Per cent
Inches												
¼	170	115	41	156	91.8	4	2.3	7	3	..	10	5.9
½	203	130	55	185	91.1	7	3.5	8	3	..	11	5.4
¾	239	161	59	220	92.1	1	0.4	11	6	1	18	7.5
1	360	267	70	337	93.6	1	0.3	13	6	3	22	6.1
1¼	262	185	58	243	92.7	..	..	10	7	2	19	7.3
1½	248	179	48	227	91.5	6	2.4	4	10	1	15	6.1
1¾	197	145	38	183	92.9	1	0.5	6	3	4	13	6.6
2	194	143	35	178	91.7	3	1.6	9	2	2	13	6.7
2¼	93	80	9	89	95.7	..	..	2	1	1	4	4.3
2½	79	65	9	74	98.7	1	1.3	2	2	..	4	5.0
2¾	38	35	..	35	92.1	..	..	2	..	1	3	7.9
3	51	43	4	47	92.1	2	3.9	1	1	..	2	3.9
3¼	23	21	1	22	95.6	..	..	..	1	..	1	4.4
3½	34	27	1	28	82.3	2	5.9	..	3	1	4	11.8
3¾	10	..	10	10	100.0	..	..	..	..	..	..	..
4	55	48	4	52	94.5	..	..	1	1	1	3	5.5
Total	2256	1654	432	2086		28		76	49	17	142	
Per cent of total	100	73.3	19.2	92.5	...	1.2	..	3.4	2.1	0.8	6.3	..

Fig. 15. Pruning Wounds Healing Rapidly on a Vigorous Tree

It is evident that vigorous trees heal pruning wounds more rapidly than weak trees and that well made wounds heal more quickly than poorly made ones. Evidently the management of an apple orchard should be planned to include the best pruning methods and also to maintain vigor in the trees.

SUMMARY

1. General pruning practices are as necessary and as desirable in Minnesota as in other sections where apples are grown.

2. Dormant or winter pruning can be done at any convenient time from November to April. There is no evidence that injury to the tree is caused by pruning in late fall or winter.

3. The growth, wound healing, and general behavior of fall-pruned trees have been similar to those of spring-pruned trees.

4. Pruning in the fall may be a more economical use of time, as the operation is not crowded into the busy spring season.

5. Fall pruning may be done less hurriedly than spring pruning, and better work should result.

6. Healthy young trees which have been neglected can be renovated in a few seasons.

7. Neglected trees of bearing age can generally be renovated successfully, but the pruning should consist of the removal of smaller branches in the bearing head rather than of large scaffold branches, as large wounds require considerable time for healing and decay may result before healing is complete.

8. Poor pruning is the main cause of wounds failing to heal.

9. The rate of wound healing apparently is directly related to tree vigor. The more vigorous the tree the more rapid the healing.

10. Pruning, while necessary in itself, is inseparably related to other management practices, such as spraying and the upkeep of soil fertility. These other practices, which tend to keep the tree in vigor and health, contribute materially toward the successful healing of pruning wounds.