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SUMMARY

1. A study of the performance records of more than 2,500 thinned and unthinned branches of eight standard varieties of apples in Michigan during 1932-1935 established these facts:

(a) The natural tendency of weak branches—those with thin wood—is to produce small apples, and the tendency of strong branches is to produce large apples.

(b) Slender wood cannot be made, even by severe thinning, to produce good fruit of merchantable size, and those branches should be removed by pruning.

(c) On the intermediate and more stocky wood the spacing of the fruits left at thinning should be inversely proportional to diameter and apparent vigor of wood—that is, the stouter the wood, the more apples which can be left.

(d) The different classes of bearing wood tend to be localized in different areas of the tree.

2. "Graduated-space" thinning, which leaves the fruit spaced according to the diameter of the branch, compared with "uniform space" thinning, which leaves the fruit more or less uniformly spaced regardless of diameter of branch:

(a) Effects a slight decrease in total yield (about 10 per cent) as compared with no thinning, while "uniform space" thinning effects a considerable decrease (about 17 per cent).

(b) Effects a marked reduction in the yield of small fruits (about 84 per cent) as compared with no thinning, while "uniform space" thinning effects a smaller reduction (about 56 per cent).

(c) Effects a marked increase (about 99 per cent) in the yield of medium sized and large fruits, as compared with no thinning, while "uniform space" thinning effects a much smaller increase (about 56 per cent).

(d) Costs less per tree and per bushel of harvested fruit than "uniform space" thinning.

(e) Effects a substantial increase in monetary returns over and above thinning costs, as compared with no thinning, while "uniform space" thinning effects only a slight increase.

3. Thinning should be commenced as soon as the June drop is over and should, if possible, be completed within three or four weeks. For best results "graduated-space" thinning should be used in conjunction with the "thin wood" method of pruning.

The "Graduated Space" Method of Thinning Apples

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Lack of adequate size is responsible for more low grade apples than any other single factor with which the Michigan apple grower has to contend. Grading records show that approximately one bushel in every seven fails to qualify for the higher grades because of deficiencies in size. As this undersized fruit sells for only a fraction of the price obtained for the larger specimens, it is clear that size deficiencies result in material financial loss.

It has been shown frequently that size of fruit can be increased by removal of fruits in such manner that those remaining stand at some arbitrary, uniform distance apart. Unfortunately the increase in size of the smaller fruits is not usually sufficient to warrant placing them in higher grades, and "uniform space"-thinned trees, therefore, often bear a considerable amount of undersized fruit. Because of this and the fact that gains in size, resulting from the use of the "uniform space" method, are usually attended by considerable reduction in yield, monetary returns from the resulting crop usually are not materially increased. When the cost of doing the work is taken into account, returns are, in fact, sometimes actually diminished.

There exists an obvious need for a thinning method that will substantially reduce the amount of undersized fruit and at the same time improve the grade of the larger specimens without so materially reducing yield that the profit of the operation becomes a matter of doubt. The details of such a method have been developed and are here described as the "graduated space" method of thinning.

REVIEW OF LITERATURE

Review of early horticultural writing indicates that thinning of fruits was a recognized practice 2,000 years ago. Theophrastus (12)—(370-285 B. C.), pupil of Plato and Aristotle, in discussing trees which overbear has this to say:

> "These trees produce such great quantities of fruits that the strength of the tree is not sufficient to ripen them. Therefore, the farmers are accustomed, when there are too many fruits on the tree, to break off a part of them."

In referring to the practice, Theophrastus says that farmers are "accustomed" to thin. One might almost conclude that the operation was more commonly employed in ancient times than at present, when only a small percentage of Michigan growers systematically thin their fruit. Present-day readers are often surprised to learn that Theophrastus apparently had a knowledge not only of practices but of some of the more obscure principles

involved. For example, the fact that he recognized the existence of a relationship between leaf number and area and fruit size is indicated by the following:

"A fourth unnatural phenomenon in plants is: a too unlike relationship of leaves to fruits, i. e., when the quantity of fruits is too great for the leaves."

Around 1650 LeGendre (9), or whoever wrote under his name, stated in the chapter of his book devoted to "On the way to have beautiful fruit":

". . . One can not have them (fruits) very large unless he take care to thin them when they are set and to remove them from trees which have too many; for it is certain that the sap which spreads into too great quantity of fruits cannot make them enlarge or nourish them with all the abundance which is necessary for their perfection. This is the reason that one should leave fruit on trees only in proportion to their vigor . . .

"When there is too much fruit on the trees, one should pluck it at the beginning of June, and take care to leave but little on the weak branches, since these do not have enough sap to nourish it well and for the same reason it should be retained on the good branches only in proportion to their vigor and to leave but one or two pears to each cluster, particularly on Bon Chretien pears, which thus become incomparably more beautiful . . . "

La Quintinie (11), another 17th century authority, thought the subject of thinning so important that he devoted a section of his book, "The Complete Gardener", to the practice. The preface, in which he outlines the subjects to be discussed, contains this passage:

"In the fifth part, I will direct how to thin them of their fruit, by plucking off as many as occasion shall require, when they grow too thick; for we are not to leave so many fruits upon a tree as it had blossoms, but have reason rather to be suspicious of those that blossom too much, the excess of their good will, if I may say so, being reckoned a great fault; because it most certainly disables them from bringing their products to perfection."

It is interesting to note that La Quintinie recognized the fact, since enlarged upon by modern investigators, that the potentially superior fruits can be recognized early in the season and that they should not be removed in thinning. He makes this clear by the following:

". . . It is fit to tarry, until the fruits be pretty large and well form'd in order to take away such as are superabundant, and particularly to prefer the most beautiful and most sizable . . ."

The fact that the early 18th century writer, Langley (8), whose "Pomona" was considered one of the best works of the times, considered thinning an important practice is brought out by the fact that Part 4 of his book deals with:

"Rules for the thinning of their young-set fruits, so as to leave no more than nature can strongly support, and ripen in the greatest perfection."

The late 18th century authority, Thomas Hitt (7), in his book, "A Treatise of Fruit Trees", stated:

"When there is too great a quantity of fruit suffered to remain upon any part of the tree, it is not so good as if there were only a proper quantity, left on; and sometimes a tree becomes weak by bearing too plentifully."

These references to thinning, chosen from a great number found in early horticultural writings, make it clear that cultivated fruits have been thinned since before the dawn of the Christian era. The records also indicate that

many of the early writers were familiar not only with the fundamental idea (that by removing a portion of the crop, the remainder may be improved), but also with many of the refinements discussed in the writings of modern investigators.

Beach (2) was the first modern horticulturist to report at length on the subject of apple thinning. He published a preliminary report of his work in 1896, and during the next several years presented papers before a number of horticultural groups. A final report appeared in bulletin form in 1903. Beach not only wrote at some length but with authority, most of his conclusions being based upon experimental evidence. The trials were started at the New York (Geneva) station in 1896 and continued for several years. Three commercial varieties of apples were included in the trials and three methods of thinning were investigated. Observations were made on the effect of thinning upon the color, size, market value of the fruit, and upon the amount and regularity of fruit production. Beach summarized his results as follows:

"Color. When the trees were well-filled with fruit, thinning generally improved color.

"Size. Whenever the trees bore well, thinning had the effect of increasing the size of fruit.

"Market value. . . . The thinned fruit, as a rule, was better adapted than the unthinned for making fancy grades, for marketing in boxes, etc. Where such ways of marketing can be advantageously used, the thinned fruit should bring an increase in price corresponding to its superiority in real value. But where it must be put upon the ordinary market in barrels, there is less chance for the thinned fruit to sell at sufficient advance over the unthinned to pay for thinning, especially if the thinned fruit cannot be furnished in large quantities.

"Amount and regularity of fruit production. In these experiments the practice of thinning the fruit did not appear to cause any material change in either the amount or the regularity of fruit production.

"Methods of thinning. No exact rule for thinning apples should be laid down. The requirements vary with the different individual trees and with the same tree in different seasons . . . In thinning apples all wormy and otherwise inferior specimens should first be removed and no more than one fruit from each cluster should be allowed to remain.

"Does it pay to thin apples? The reply of Mr. Wilson, a practical fruit grower in whose orchard these tests were made, is in effect that where there is a general crop of apples, the set full, the chance for small apples great and widespread, it would pay to thin enough to insure good sized fruit; otherwise not, except to protect the tree.

"Methods of removing the fruit. No way of jarring or raking off the fruit is advised in thinning apples, since by these methods all grades are removed indiscriminately. Hand work is best. It permits selection of superior, and rejection of inferior, specimens.

"Time to thin. The experiments in thinning apples and other fruits lead to the opinion that early thinning gives best results. Begin with apples within three or four weeks after the fruit sets even if the June drop is not yet completed.

"Cost of thinned as compared with unthinned apples. The cost of thinning mature trees which are well loaded should not exceed fifty cents per tree and probably would average less than that."

Although Beach's reports were more specific than those of his predecessors, it is interesting to note that his recommendations are not essentially different from those made by the earlier writers. Although later investigators have accumulated more evidence, most of the subsequent work seems merely to have substantiated the findings of Beach and added but little to the general

fund of available information on the subject of thinning. There are, however, a few whose work seems worthy of special notice.

Whitehouse (13), who studied size variations in apples during the growing season, found that:

"The rank of an individual apple among its fellows at the time of thinning is a fairly accurate index to its probable rank at maturity."

Although earlier writers had said essentially the same thing, the experimental evidence recorded by Whitehouse definitely establishes what may have formerly been opinion or conjecture. As this fact has a direct bearing on the practice of thinning, the significance of the finding is apparent.

Auchter's report (1), based upon a five-year study, appeared in 1917. In addition to verifying in a general way the findings of Beach and others he makes another point which seems worthy of special mention. Under the heading of, "Method and Distance to Thin", he says:

"In thinning, it should be the aim to remove all injured or insect-eaten fruit and the small green and knotty apples on the *lower inside limbs which seldom ever become marketable.*" (Italics are the authors.)

Although LeGendre (1650) recommended that little fruit be left on the weak branches, this point seems either to have been missed or regarded as of little significance by most of Auchter's contemporaries.

Although it had long been known that fruit size is influenced by the size and number of leaves, studies by Haller and Magness (6) on the "Relation of leaf area to the growth and composition of apples" threw considerable light on the quantitative nature of this relationship and led to other work along this line. The results of the original and subsequent studies suggested improvements in thinning methods and this work undoubtedly represents an important contribution to the available information on thinning.

Still more recently Fisher (4) has reported on the influence of long continued thinning on tree size and yield. He states:

"During a period of 12 years, there has been little difference in the total yield of fruit produced by heavily, medium, and lightly thinned trees. The fact that heavily thinned trees have, in most cases, yielded just as much fruit as medium and lightly thinned trees, is due partly to increased size of fruit, and partly to increased size of tree, for the heavily thinned trees have grown larger than those receiving medium and light thinning."

In addition to those studies, which have dealt primarily with apple thinning, considerable work has been done on the thinning of other fruit crops. The results of these investigations indicate that other fruits respond to thinning in much the same way as does the apple. In most instances size and color are improved and total yield diminished. In those cases in which large fruits command a premium sufficiently more than to offset reductions in yield and the cost of the work, thinning returns a profit. Drobish's work (3) with olives is typical. He found that thinning materially reduces yield but that, inasmuch as olives of large size command a considerable premium, thinning which results in increased yield of large sizes is profitable.

When the premiums for large sizes are not sufficient to more than compensate for reductions in yield, the practice is not usually recommended. The results of Parker's orange thinning experiments (10) are typical. He concluded that:

"The price ranges that have been studied hypothetically have been such that the differential in favor of large-sized fruit has not been sufficient to offset the

effect of the decreased total volume of crop in the year of thinning, and a financial loss would usually be anticipated in the first year as a result of thinning.

"In the light of these findings it seems unlikely that thinning of orange fruits will become a general practice."

This review leads to the conclusions:

1. Thinning, i. e., removing a portion of the fruit for the purpose of improving that which remains, has been practiced for more than two thousand years.
2. The way in which the subject is handled indicates that many of the early writers deemed it an important operation.
3. The experimental evidence compiled by the first modern investigator, Beach, confirmed many of the general statements made by earlier writers and, in addition, made available specific information on many phases of thinning.
4. The results obtained by subsequent workers have, for the most part, substantiated Beach's findings.
5. In a limited number of cases experimental work has thrown light on certain of the more obscure phases of thinning.
6. The methods now used are essentially the same as those advocated by the early writers. The results usually obtained are seldom, if ever, entirely satisfactory. An obvious need exists for a more effective procedure.

CHARACTERISTICS OF BRANCH PERFORMANCE UPON WHICH "GRADUATED SPACE" THINNING IS BASED

It has long been known generally that all the branches of a bearing apple tree are not equally productive. Early in the course of the branch performance studies which were made in connection with the investigation of the "thin wood" method of pruning (14), it became apparent that these studies would throw considerable light on thinning practices. The results of the pruning work, therefore, were made the basis of a series of thinning trials which led to the development of the "graduated space" method of thinning with which this paper deals.

Branch Performance Studies

The first step in the branch performance studies was the classification of different types of wood. The preliminary work led to the classification of all fruit-bearing branches on the basis of the diameter of the four-year-old wood.

"Thin" branches, whose four-year-old wood was 2/8-inch or less in diameter.

"Intermediate" branches, whose four-year-old wood was from 2/8- to 3/8-inch in diameter.

"Thick" branches, whose four-year-old wood was more than 3/8-inch in diameter.

More than 2,000 branches were studied—an equal number of each class being selected at random from representative trees in each of several orchards. Eight standard varieties of apples were included in the investigation, and the records, begun in 1932, were supplemented by others made in 1933 and 1934. The class, age, length, average annual growth, number of spurs, leaves

per spur, total number of leaves, and the number of leaves per apple were recorded for each branch studied. In addition, a harvest record was made consisting of a size and color classification of each apple borne by the selected branches, together with the total number and the aggregate weight of the fruits borne by each branch. The probable errors of the mean values indicate that the samples studied were truly representative. The marked similarity of the data obtained from different varieties, different orchards, and in different years indicates that the same general principles hold true regardless of season, orchard or variety. A typical set of records for Wealthy branches of one size class, obtained in orchard No. 18, is presented in Table A of the supplement. Table B of the supplement presents the mean values for Wealthy shoot records obtained in six different orchards. Comparable data for the seven other varieties studied are summarized in Table C of the supplement. The detailed presentation in these tables is summarized in Table 1.

Table 1. Performance record of average wealthy branches*.

Branch Characteristics		Branch Performance		
Diameter of 4-year wood (Inches)	Average Annual Growth (Inches)	Apples per Branch (No.)	Total Weight Fruit per Branch (Ounces)	Predominant Color Grade
less than 2/8"	5.3	3.4	10.6	U. S. Commercial
2/8" to 3/8"	9.9	5.8	22.6	U. S. Number 1
more than 3/8"	15.4	10.6	46.7	U. S. Fancy

*Based on a study of 208 branches of each class (see table B of the appendix).

The significant facts relating to thinning, brought out by the branch performance studies, are:

Branches of large diameter and long terminal growth commonly produce a comparatively large number of apples of large size and good color. Branches of small diameter and short terminal growth commonly produce a relatively small number of apples of smaller size and inferior color. The size, color and number of fruits produced by branches of intermediate diameter and moderate terminal growth lie between the two extremes. A photograph of typical "thick", "intermediate", and "thin" branches, each with its load of fruit (Fig. 1), visualizes the average relative productivity of the three types of wood.

The differences in the amount and grade of fruit produced by branches of the different classes, for the varieties included in this study, are so great that it would probably be safe to say that, on the basis of fruit sales, the value of the average branch of large diameter is at least 10 times that of a branch of the same age of small diameter. Branches showing even greater variations than those of the "average" branches shown in Fig. 1 are, of course, found in almost every bearing tree.

In using the commonly employed "uniform space" method of thinning most Michigan growers thin all branches (approximately) to some arbitrary distance without regard to their productive capacities. Because "thin" or

weak branches are incapable of producing fancy apples, even after being thinned, the "uniform space" method improves but little the undergrade apples commonly produced by these branches. Because "thick" productive branches are capable of bearing a heavy load of high grade fruit, "uniform space" thinning, which often removes an undue amount of this fruit, results in an unnecessary reduction in the yield of the fancy fruit which these branches are capable of producing.

In brief, the branch performance studies suggest that **each branch be thinned on the basis of its capacity to produce fruit of adequate size.**

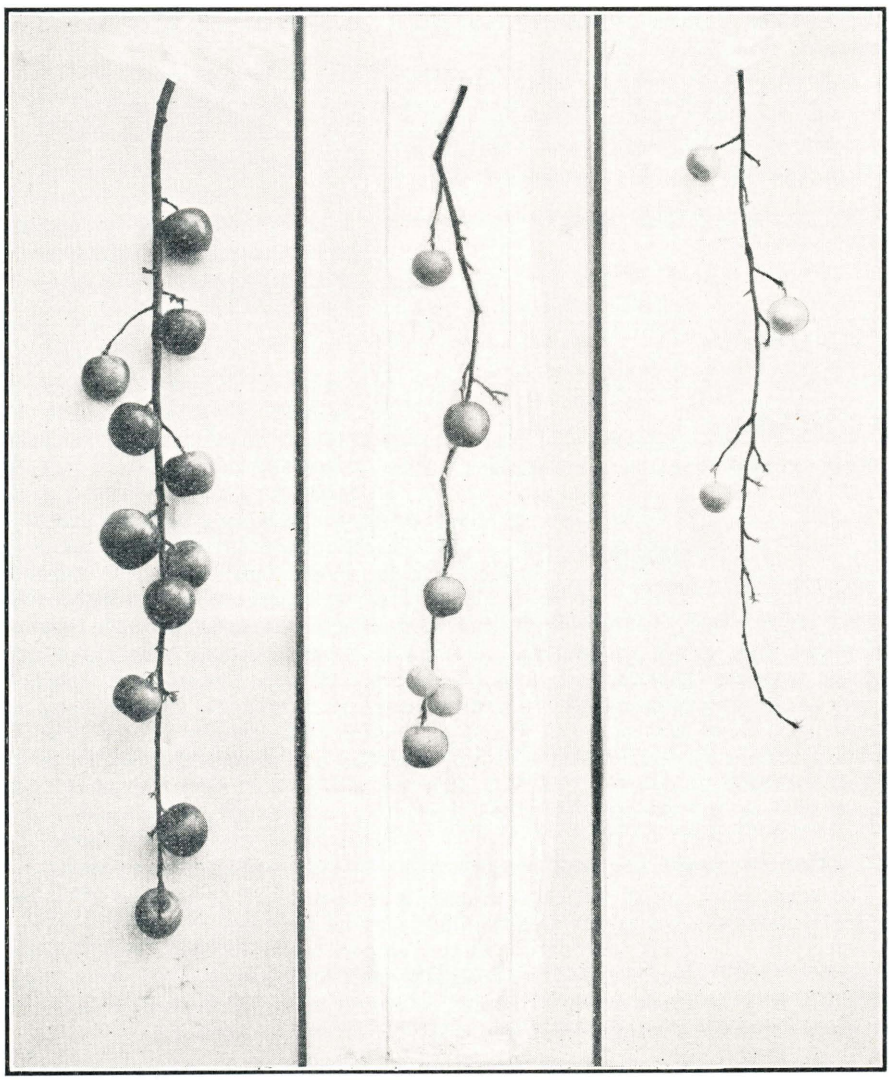

Fig. 1. Typical "thick", "intermediate", and "thin" branches, each with its load of fruit. Note the variation in productive capacity.

Branch Capacity Studies

Before this principle could be applied, it was necessary to determine the capacity of different classes of wood to produce fruit of satisfactory size. To accomplish this end, some branch studies were undertaken. Comparable branches of each class, located in vigorous productive trees, were subjected to thinning treatments of different degrees of severity. Only typical trees which had not received severe or unusual pruning were studied. The sizes of all apples produced under each treatment were recorded at harvest time and averages calculated. The treatment which resulted in the greatest number of fruits of satisfactory size and color was obviously the best. The method used and the results obtained can perhaps be best explained by a typical example. (See Table 2.)

Table 2. Results of branch capacity studies made of wealthy branches*.

Diameter of 4-year wood (Inches)	Average Distance Between Fruits			
	4″ to 7″	7″ to 10″	10″ to 13″	13″ or more
	Average diameter of apples produced, in inches			
less than 2/8″	.....	2-2/8	2-2/8	2-3/8
2/8″ to 3/8″	2-3/8	2-3/8	2-4/8	2-5/8
3/8″ and more	2-3/8	2-4/8+	2-6/8−	3

*Based on a study of 32 branches of each class.

It will be observed that none of the thinning treatments employed enabled the "thin" weak wood to produce apples with an average diameter of 2½ inches or more. As fruit of smaller size is seldom profitable, the studies indicate that, in Wealthy at least, all the fruit should be removed from the "thin" weak wood. On wood of intermediate character, to produce apples averaging 2½ inches or more in diameter, it was necessary to make the average spacing between 10 and 13 inches. It was found that "thick" productive branches would produce the maximum number of 2½-inch apples when the spacing was between 7 and 10 inches. The results of the branch capacity studies made of seven standard varieties are summarized in Table D of the appendix.

Recommendations which may be made on the basis of these trials are:

1. How to space the fruit on weak, relatively unproductive wood.

The weak wood of all varieties is usually incapable of producing 2½-inch apples, regardless of thinning treatment, and all of the fruit should, therefore, be removed. A better alternative is to remove wood of this character at pruning time. Inasmuch as 2⅜- or even 2¼-inch Jonathans often sell well, an exception may be made in this variety. When fruit is left on small wood in Jonathan trees the average spacing should be 10 inches or more.

2. How to space the fruit on wood of intermediate vigor and productivity.

On Jonathan and Baldwin the spacing should be 7 to 10 inches.

On Wealthy, Duchess, and McIntosh the spacing should be 10 to 13 inches.

On Transparent and Grimes the average spacing should be 13 inches or more. If, as is often the case, 2¼-inch Grimes are readily salable the spacing for this variety may be reduced to 7 to 10 inches.

3. How to space the fruit on "thick", vigorous, productive wood.

On Baldwin, Jonathan, McIntosh, and Grimes the average spacing should be 4 to 7 inches.

On Duchess and Wealthy the average spacing should be 7 to 10 inches.

On Transparent the average spacing should be 10 to 13 inches.

The Character of Wood Found in Different Parts of the Tree

During the course of the branch capacity studies, it became apparent that there is a tendency for the different classes of bearing wood to be localized in certain areas of the tree. With the thought that the results of a study of this tendency might be used advantageously in working out a more satisfactory procedure in thinning, the character of the bearing wood in different sections of representative trees was studied.

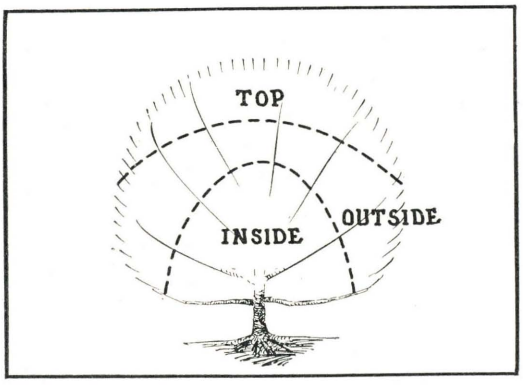

Fig. 2. Certain trees were divided, for purposes of study, into "inside", "outside", and "top." The character of the wood as well as the amount and grade of fruit produced by the various sections differs greatly.

Each tree was, for purposes of study, arbitrarily divided into inside, outside, and top. Figure 2 shows diagrammatically a sectional view of such a tree and indicates what in this case is meant by the terms "inside", "outside", and "top". The bearing wood in each section of the tree selected for study was gone over at harvest time and its character recorded. Variations due, no doubt, to differences in the ages of the trees, orchard practices, and character of soil were of course observed. On the whole, however, the results revealed a striking similarity between all the trees included in this study. Although there was, of course, no sharp line of demarcation, it was found that:

1. The bearing wood of the top is predominantly thick, vigorous and productive.
2. The bearing wood of the outside is predominantly of medium diameter, vigor and productivity.
3. The bearing wood of the lower and inner part of the tree is predominantly thin, weak and relatively unproductive.

The fact that the bearing wood in any particular part of the tree is similar means, essentially, that the same spacing could be applied to large sections of the tree. It was later found that this fact greatly facilitated the actual practice of the method.

DETERMINING THE VALUE OF THE "GRADUATED SPACE" METHOD OF THINNING

The experimental blocks were located in eight representative orchards, and records were obtained on the following varieties: Steele Red, McIntosh, Duchess, Jonathan, Baldwin, Wealthy, Grimes, Winter Banana, and Yellow Transparent. In selecting trees for the actual thinning trials, only reasonably heavy producers of standard varieties were chosen. Trees which had been recently subjected to severe or unusual pruning or thinning were eliminated. The experimental blocks included 51 trees in 1934 and 66 in 1935. They varied in age between 16 and 41 years. After locating a reasonably uniform block of trees which met these conditions, final selections were made, just after the June drop, on the basis of uniformity of fruit set. The trunk circumference, height, and average spread of all trees under consideration were recorded, and the different thinning treatments were applied to adjacent trees of comparable size. The experimental blocks included trees thinned by the "Graduated Space" method, the "Uniform Space" method, and unthinned checks. At harvest time one-half the apples, selected at random, were sorted into six size grades and the number of bushels of each grade recorded. A record was also made of the color grade of each specimen as sorted.

RESULTS OBTAINED BY THE "GRADUATED SPACE" METHOD OF THINNING

The size, color, and yield data for the 117 trees included in the final thinning trials are presented in Table E of the Supplement. The similarity of the data obtained regardless of season, orchard, or variety indicates that, other things being equal, "Graduated Space" thinning may be expected to give comparable results in other Michigan orchards. The nature and significance of these results becomes apparent when the yields of fruit produced by trees receiving different treatments are compared. To make comparisons easy, "total yields" of respective size grades (from Table E, Appendix) are here presented (Table 3).

These data bring out several facts which warrant special consideration.

Both "uniform space" and "graduated space" thinning reduced total yield.

Table 3. A comparison of the yield and grade of fruit produced by trees which had received no thinning, "uniform space" thinning and "graduated space" thinning.

Treatment	No. of Trees	Bushels of respective size grades						Total (bu.)
		Less than 2″	2″ to 2¼″	2¼″ to 2½″	2½″ to 2¾″	2¾″ to 3″	3″ or more	
Unthinned	39	46.25	146.00	257.50	178.00	54.75	4.00	686.50
"Uniform Space" thinning	39	20.25	64.75	126.75	205.75	135.50	27.50	570.50
"Graduated Space" thinning	39	4.25	26.75	115.00	290.25	159.00	22.75	618.00

Most of the experimental evidence available indicates that it is impossible to remove a part of the crop without reducing the amount which would otherwise have been produced. Although it may be assumed that all methods reduce yield to some extent, some systems result in greater reductions than others. In the trials here reported "uniform space" thinning, for example, reduced average yield 17 per cent. When the "graduated space" method was employed, the reduction was slightly less than 10 per cent.

"Graduated Space" thinning is a more effective means of reducing the yield of small apples than is "Uniform Space" thinning.

Both thinning methods employed reduced the yield of small apples. The "Uniform Space" method reduced the quantity by 56 per cent. The elimination of undersized fruit is, of course, one of the objects of thinning, and the results obtained by this method were reasonably satisfactory. The "Graduated Space" method, however, reduced by 84 per cent the small (less than 2¼ inches in diameter) apples which would otherwise have been produced. Figure 3 gives a graphical conception of the superiority of the "graduated space" method.

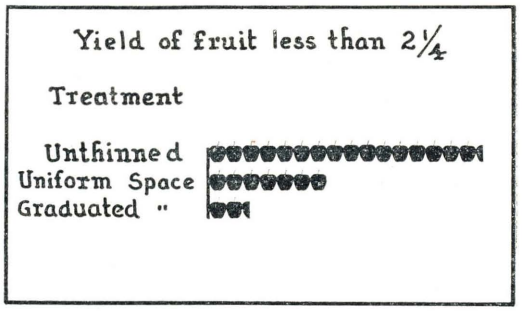

Fig. 3. "Graduated-space" thinning proved a much more effective means of reducing the yield of small apples than did "uniform space" thinning.

"Graduated space" thinning materially increases the yield of large apples.

Although the elimination of undergrade apples is important, increasing the yield of adequately sized fruit is of even greater importance. Ordinary "uniform space" thinning is a moderately effective means of accomplishing this result. In these experiments this method increased the quantity of medium to large apples (those 2½ or more inches in diameter) by 56 per cent. "Graduated Space" thinning, however, proved a much more effective means of accomplishing the same end. It should be borne in mind that fruit of this size is relatively easy to sell and that it almost invariably commands top prices. More fruit of large size is almost sure to mean greater returns and increased profits. The magnitude of the increase in capacity to produce fruit of large size is shown graphically in Fig. 4.

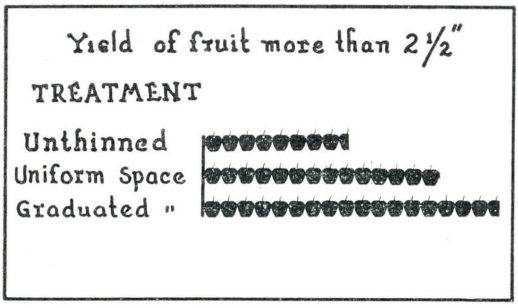

Fig. 4. "Graduated-space" thinning proved a much more effective means of increasing the yield of large apples than did "uniform space" thinning.

"Graduated space" thinning improves color grade.

The removal, from the lower and inner part of the tree, of most or all of that fruit which would inevitably be more or less deficient in color automatically raises the color grade of that which remains. On the average "graduated space" thinning increased the production of apples of fancy color by about 31 per cent, as compared with the 10 per cent increase effected by "uniform space" thinning. This difference is brought out in Fig. 5.

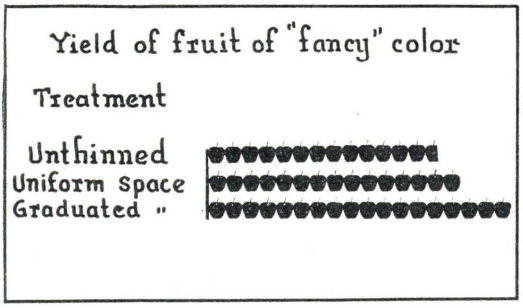

Fig. 5. "Graduated-space" thinning proved a much more effective means of improving the color grade than did "uniform space" thinning.

"Graduated space" thinning increases the uniformity of the crop.

In a study of consumer demand, Gaston (5) found that all classes of apple buyers preferred and were willing to pay a premium for uniformity of size, color, and maturity. Uniformity facilitates not only marketing but also sorting and packing. "Graduated-space" thinning eliminates much of that fruit which would otherwise develop into specimens lacking in size, color, and maturity. The resulting increase in the uniformity of that portion of the crop which is allowed to mature makes selling easier and returns greater.

"Graduated space" thinning increases monetary returns.

In the final analysis, the yardstick by which most producers measure the value of a given practice is its influence on monetary returns. Is it profitable? In the trials here reported, total returns from "uniform space" thinning amounted to only 56 cents per tree more than those from unthinned trees, little more than enough to pay the cost of doing the work. On the other hand the increase obtained by the use of the "graduated-space" method amounted to $1.95 per tree, a sum adequate to pay the cost of thinning and leave a profit of approximately $1.50 per tree.

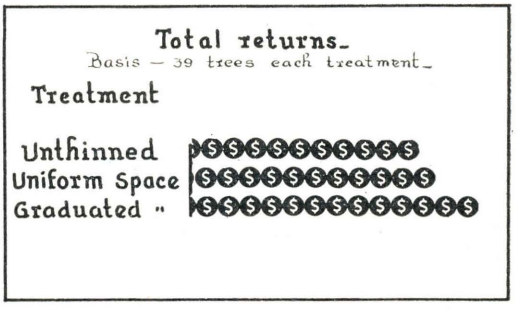

Fig. 6. "Graduated-space" thinning increased average monetary returns by 24 per cent. From this standpoint, this method proved more than three times as effective as "uniform space" thinning.

From the standpoint of increasing returns the "graduated space" method is more than three times as effective as the one in common use. Returns from all trees included in the studies are presented in Table 4. Figure 6 shows graphically the difference in total returns from the trees in the experimental blocks.

Table 4. A comparison of the monetary returns from trees receiving no thinning, "uniform space" thinning, and "graduated space" thinning.

Treatment	No. of Trees	Returns derived from respective size grades						Total Returns
		Less than 2″	2″ to 2¼″	2¼″ to 2½″	2½″ to 2¾″	2¾″ to 3″	3″ or more	
Unthinned	39	$3.70	$32.12	$126.17	$113.92	$44.35	$3.84	$324.10
"Uniform Space" thinning	39	1.62	14.24	62.11	131.68	109.75	26.40	345.80
"Graduated Space" thinning	39	.34	6.88	56.35	185.76	129.20	21.84	400.37

NOTE:—The returns were calculated on actual sales. The price data were supplied by the cooperative exchange through which much of the fruit from the experimental blocks passed.

"GRADUATED SPACE" THINNING IS RELATIVELY INEXPENSIVE

The "Graduated Space" method of thinning is relatively inexpensive. A record was kept of the man-hours required both to thin and to harvest the trees in the experimental blocks. The cost of labor was fixed at 25 cents per hour, and on this basis the cost of thinning and harvesting operations per bushel of harvested fruit was calculated as follows:

Thinning

Average cost per bu. of harvested fruit { "Uniform Space" thinning 3.6 cents; "Graduated Space" thinning 2.8 cents }

Harvesting

Average cost per bu. of harvested fruit { Unthinned 4.2 cents; "Uniform Space" thinned 3.8 cents; "Graduated Space" thinned 3.2 cents }

The average cost of "graduated-space" thinning per bushel of harvested fruit was 2.8 cents. The fact that this figure was materially lower than for "uniform space" thinning can be accounted for by the fact that in "graduated-space" thinning comparatively more of the work can be done from the ground and the lower steps of the ladder and somewhat less in that part of the tree which requires considerable climbing and high ladder work. Differences in harvesting costs between thinned and unthinned trees are due to the fact that the former bear a smaller percentage of undersized and a greater percentage of large apples. Because the relative amount of fruit borne in the lower and interior part of the tree is materially reduced by "graduated-space" thinning, the picker, when harvesting "graduated-space"-thinned trees, can do most of the work from the outside.

WHEN TO START THINNING

Because fruit increases in size daily throughout the growing season, the results of thinning depend to a considerable extent upon the time at which the work is done. For this reason some time-of-thinning trials were included

in the investigation. The first of these experiments were undertaken to determine the relative merits of thinning done just before the June drop and comparable work done just after the drop.

Two of the four comparable Transparent trees selected for study were thinned by the "graduated-space" method just preceding the June drop. An equal number of Duchess trees were thinned at this time. When the drop was over, the two remaining trees of each variety were likewise thinned by the "graduated-space" method. Both varieties responded in the same way, and the four trees under each treatment are here treated as one unit.

The cost, per bushel of harvested fruit, of the early thinning was 5.7 cents, while that of the work done later was 3.1 cents. Total returns from the sale of fruit borne by the four trees thinned before the June drop were $31.08, while those from the four remaining trees were $35.44. The difference in favor of the later thinning was in this case $1.09 per tree.

The early thinning not only cost almost twice as much as that done later but it proved a less effective means of improving size and grade. The relatively high cost of the early thinning was because in thinning at that time many apples were removed by hand that would otherwise have fallen during the June drop. It is also true that in this stage of development the fruits are smaller and more difficult to see. Another disadvantage of pre-drop thinning is that differences in size and shape due to position on the spur, which ultimately become obvious, at that time are difficult or impossible to detect.

The results of thinning done immediately after the June drop were next compared with those obtained when the work was done somewhat later in the season. The regular thinning trials conducted in 1935 included five Jonathan trees thinned June 25. Three additional trees were thinned July 10, and three others July 25. The results of these trials are summarized in Table 5.

Table 5. A comparison of the costs of thinning at different times and of the net returns per tree.

Treatment	Thinning Cost per Bushel of Harvested Fruit	Average Yield	Average Returns per Tree	Returns less Cost of Thinning
	(Cents)	(Bu.)		
Unthinned trees (5)	.....	16.25	$13.10	$13.10
"Graduated-space" thinned—June 25 (5)	2.6	14.75	15.30	14.92
"Graduated-space" thinned—July 10 (3)	2.6	14.25	15.10	14.73
"Graduated-space" thinned—July 25 (3)	2.4	13.25	14.20	13.88

During the course of the experiment some definitely biennial-bearing trees were thinned in the blossom stage. The results of these experiments led the authors to conclude that very early thinning may cause a biennial bearer to fruit in the "off-years." Other investigators have obtained similar results. Such results indicate that a practical means of breaking the biennial bearing habit may be developed. However, as the work here reported had to do primarily with the immediate effects of thinning, this significant phase of the investigation was not followed further.

Thinning almost invariably reduces yield, regardless of the particular time at which the work is done. The time-of-thinning trials indicate that, as might be expected, delaying the operation increases the extent to which the yield is reduced. This disadvantage was largely offset by the superiority of the fruit borne by late-thinned trees over that produced by the early-thinned trees. This is probably due to the fact that as the season advances it is easier to distinguish and to eliminate potentially undergrade specimens.

It will be observed that the total returns from trees thinned two weeks later were only slightly less than those from trees thinned immediately after the June drop. The experimental evidence indicates that good results may be expected from thinning done as late as four weeks after the drop; and the writers observed cases in which reasonably satisfactory results were obtained up to within six weeks of the time the fruit was harvested. The time-of-thinning trials and results obtained by growers who tried various methods on a commercial scale led the writers to conclude that:

1. The commercial fruit grower should commence his thinning operations as soon as the June drop is over.
2. He should thin the early varieties first.
3. He should, if possible, employ enough help to enable him to complete the work within three or four weeks.

Although the number of trees included in these trials was small, the results corroborated those obtained by other investigators, and further trials were deemed unnecessary.

HOW TO KNOW WHICH APPLES TO REMOVE

Usually considerable variation exists in both the size and grade of fruit borne by the unthinned tree. For this reason, the most satisfactory results are obtained by removing only that fruit which, if allowed to remain, would develop into specimens deficient in grade or size. Fruits which give evidence of having been damaged by insects or disease should be removed whenever encountered. All badly frost-marked apples, those which show mechanical injury, and specimens of irregular shape should also be eliminated. As the percentage of apples falling into these classes is not likely to be great, additional thinning is usually necessary. This should be done on the basis of potential fruit size.

Experimentation showed that it is possible, even at thinning time, to predict with reasonable accuracy whether a particular apple is likely later to attain satisfactory size. The diameters of some 300 apples were measured soon after the June drop and again at intervals throughout the growing season. It was found that with few exceptions the fruits whose diameters were below average at the time of the first measurements developed into specimens of inferior size. Most of those fruits of more than average size on July 1 were of superior size at harvest time. Whitehouse (13) reported similar results in more extensive trials conducted at the Oregon station in 1916. This, of course, means that those apples which, at thinning time, are of less than average size, should be removed. If the worker will bear these simple principles in mind and in thinning remove that fruit which is likely, if left, to be of low grade or poor size, satisfactory results are almost inevitable.

HOW TO REMOVE THE FRUIT

During the course of the investigation several methods of removing the fruit were tried. When scissors or light shears were used to clip the stems, progress was so slow that the cost of the operation was practically double that of removing the fruit with the fingers. A direct pull exerted on the apple in an effort to separate the stem from the cluster base often meant pulling off the entire cluster or even the fruit spur itself, which is of course undesirable. It was found that the most satisfactory method is that in which the apples are separated from the stems, which are left attached to the fruit spurs. This may be accomplished by grasping the stems firmly between thumb and forefinger and pulling the fruit off the stem with the second and third fingers. This may be difficult in the case of short-stemmed varieties, in which case the desired results can usually be attained by rotating the fruits as they are pulled. Rapid work depends upon the use of both hands. A little practice will enable most workers to thin two branches simultaneously.

Different varieties may necessitate slight variations in procedure, but a few preliminary trials will usually enable the thinner to discover a method by means of which good results may be obtained, regardless of variety or stage of growth. Apples removed from the upper part of the tree should either be dropped through openings or tossed out away from the tree so that they will not strike and bruise fruits located on branches further down. Protecting the thumb and forefinger with adhesive tape will usually prevent the development of sore spots, during the first two or three days when the hands are still tender.

HOW TO SPACE THE FRUIT

Spaces between the fruits borne by an unthinned branch vary considerably. The removal of some of the apples does not eliminate such variations. Spacing on thinned branches cannot then be regular or equal. However, in actual thinning the worker should compensate for an interval of more than average length between fruits by leaving a proportionately shorter interval between the next ones encountered. There is, of course, a limit to the application of this principle. On the productive wood under observation in the branch capacity studies fruit size did not appear to be affected materially when spacings were increased beyond 18 inches. Inasmuch as such wide spacings do not commonly occur on branches which need thinning, satisfactory results are obtained when the fruit is thinned in such a way that the **average** interval between apples equals or is at least approximately equal to the most desirable spacing.

HOW TO USE THE "GRADUATED SPACE" METHOD

Reduced to its simplest terms, **"graduated space" thinning consists in spacing the fruit in such a way that each branch will produce its maximum load of high grade fruit.** Although the same end may be accomplished in any one of several different ways, the authors usually divide the work of thinning a given tree by the branch method into three steps.

THE FIRST STEP: The worker walks into the lower and inner part of the tree and makes a preliminary inspection. If, as is usually the case, he finds that practically all the bearing wood is of the weak, unproductive type, all of the fruit is usually removed from these branches. It is usually possible to do most of the thinning from the ground, or by stepping on to

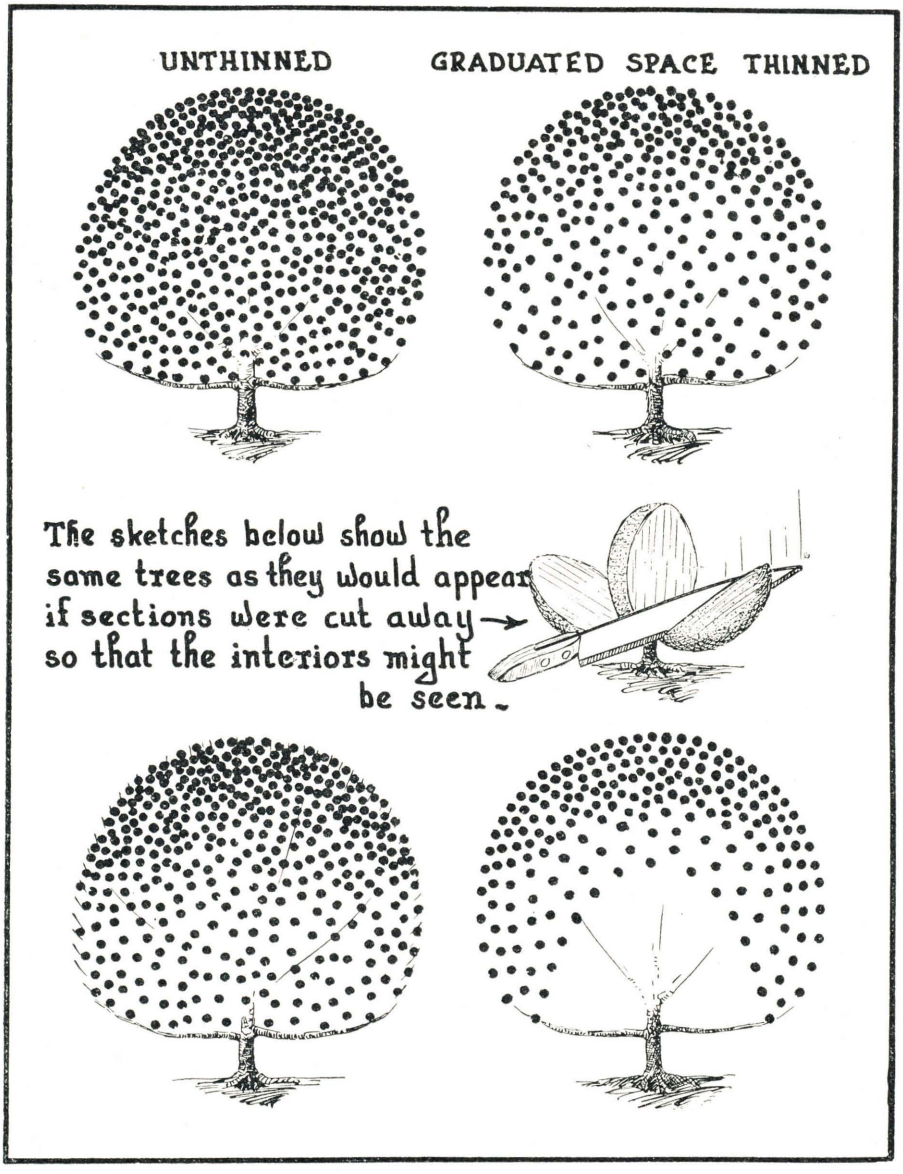

Fig. 7. The two upper drawings represent a tree before and after "graduated-space" thinning, as it would appear from a distance. The lower figures represent the same tree as it would appear in cross section.

the lower branches of the tree, and the work can be done rapidly. When all of the fruit has been removed from the weak wood, or, as in some cases, has been adequately spaced, the worker is ready to begin on the wood of intermediate type.

THE SECOND STEP: In this stage it is usually necessary for the worker to climb further into the tree (a stepladder may be required) where wood of intermediate character is encountered. When the intermediate wood in the "inside center" has been finished, the writers usually proceed to thin the "outside bottom" where more wood of intermediate character is usually found. Most of this can be reached from the ground or from a short step-ladder.

THE THIRD STEP: Although a large percentage of the fruit still remains, it is growing on branches which can support comparatively heavy loads. When the fruits on thick productive branches remaining in the top have been properly spaced, the job is finished. The authors prefer to work from stepladders, but it may be necessary in the case of large trees to use a straight ladder. Sketches (See Fig. 7) showing the tree before and after thinning will help the reader to see how the tree is treated and what the completed job looks like.

There is, of course, no sharp line of demarcation between the lower inside, upper inside, outside—bottom, and top; and branches of somewhat different capacity are found in the same producing area. A glance at the character of the branch, however, will indicate the approximate spacing which should be used.

HOW TO OBTAIN GOOD RESULTS WITH INEXPERIENCED HELP

When unskilled help is employed, some growers require the men to carry specimens of the three types of wood cut to lengths which will serve as guides in proper spacing. The inexperienced man is handed a "thin" branch cut to 12 or 14 inches and told that all the fruit should be removed from wood of this character. He may receive a typical intermediate branch 10 inches in length and be told that the average spacing on wood of this character should correspond to the length of the branch. The example of thick wood which he receives may be five inches in length, this distance being equal to the average spacing which should be employed in thinning wood of this character. The carrying of such "measuring sticks" in a pocket where they can be referred to as occasion demands gives even inexperienced help confidence and enables them to do good work almost from the first. The length of the sticks used depends on circumstances and new ones can be cut at the discretion of the foreman or owner, should conditions, such as a change in variety, warrant.

"GRADUATED-SPACE" THINNING SHOULD FOLLOW "THIN WOOD" PRUNING

"Thin wood" pruning consists in removing from the tree the thin, weak branches of low productive capacity. Pruning of this type is an effective means of eliminating a considerable portion of the fruit which would otherwise develop into specimens deficient in size and color. Undergrade fruit eliminated in this way does not have to be dealt with at thinning time, and the labor required to perform this operation is, therefore, materially reduced. "Thin wood" pruning not only eliminates a large percentage of the small apples but increases the capacity of the tree to produce larger ones. This fact also tends to reduce the amount of thinning which would otherwise be advisable. The two operations are based upon the same fundamental principles. Each one contributes materially to the final results, and most growers will find it distinctly to their advantage to use them in conjunction.

DISCUSSION

Commercial fruit growers are in the business to make money, and they judge an orchard practice on the basis of whether it yields a profit. The fact that only a small percentage of mid-western and eastern growers practice regular and systematic thinning of apples indicates that they are not convinced that the operation is profitable. A good reason for this attitude has been that unless there is a considerable differential in price between sizes there will not be much difference in receipts for the products of unthinned and "uniform space" thinned trees.

Investigators as well as growers have recognized the fact that the "uniform space" method is not entirely satisfactory, and efforts have been made to discover a better system. Although most of the fundamental principles upon which the "graduated-space" method is based have been known for some time, they have not been made the basis of a definite and practical system of thinning. The "graduated-space" method herein described is based upon established facts of so simple and logical a nature that the principles can be grasped quickly even by the inexperienced help, which it is often necessary to employ in thinning. The system not only is practical but, from the standpoint of increasing monetary returns, it is more than three times as effective as the one now used.

Although the results obtained in the preliminary studies proved entirely satisfactory as a basis for the thinning trials later conducted, it should be remembered that the distances here suggested represent averages and that in actual practice conditions may make it advisable to vary somewhat from these averages. It is recognized that the productive capacity of a given branch is influenced by such factors as the age and bearing habit of the tree, pruning, and cultural practices. The best results can be obtained only if such factors are used as guides to proper spacing.

Generally, conditions or practices such as a fertile soil, an abundant water supply, cultivation, and the use of fertilizers tend to increase the productive capacity of the tree and decrease the necessary spacing. On the other hand, poor soil, poor foliage, inadequate moisture, and insufficient cultivation usually mean that the spacing should be increased. Past performance is also

an excellent guide to proper spacing. With these aids to guide him it is usually possible for the grower to decide how the fruit should be spaced. With such aids as the location in the tree and the "measuring sticks" already described, even inexperienced help can be quickly taught to do good work.

The fact that the growers in whose orchards the authors worked had little difficulty in learning and applying the method in actual practice indicates that the system is fundamentally sound and practical commercially as well as experimentally. The results obtained by these men in most cases have been gratifying. They indicate that it probably would be safe to say that there are few other single orchard operations in which the investment of a few cents per bushel of harvested fruit will do as much toward making the growing of apples more profitable.

In the trials here reported the "Graduated Space" method of thinning proved effective. It should, however, be borne in mind that this study considers only the immediate effects of thinning and does not take into account the secondary or cumulative effects which may be important, and might modify the conclusions drawn from this work.

ACKNOWLEDGMENTS

The writers express their appreciation to the fruit growers in whose orchards experimental thinning was conducted. Without the cooperation of these growers the work would have been impossible. These men not only allowed their trees to be used for experimental purposes, but in many cases helped with the record taking and other labor involved. The following growers made material contributions to the success of the work: Harry T. Bigelow, R. A. Buyce, Geo. Herman, Bert Hills, Harry Hogue, C. C. Kniebs, John Miller, Herbert Nafziger, Merit Overton, J. A. Richards, L. A. Royal, Scott Bros., Clyde Smith, Steimle Bros., Abe Teichman, Tice and Sprague, and Harry Wakeman.

The writers are also indebted to V. R. Gardner, R. E. Marshall, and F. C. Bradford of the Section of Horticulture, for many helpful suggestions and criticisms during the progress of the work and in the final preparation of this paper. The writers are especially grateful to Prof. Bradford, who, in addition to the services already mentioned, made some of the translations used in the Review of Literature and assisted in locating other early references to thinning.

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APPENDIX

Table A. Performance of wealthy branches 2/8 inch to 3/8 inch in diameter, 1933.

Branch No.	Number of Apples in Respective Size Groups						No. of Apples per Branch	Total Weight in Ounces	Number of Apples in Respective Color Grades			Age	No. of Spurs	Av. No. of Leaves per Spur	Total No. of Leaves	Leaves per Apple	Length in Inches	Av. Annual Growth in Inches
	Less than 2″	2″ to 2¼″	2¼″ to 2½″	2½″ to 2¾″	2¾″ to 3″	More than 3″			U. S. Fancy	U. S. No. 1	U. S. Com'l.							
1	.....	2	2	.....	.....	.....	4	11	.....	3	1	10	23	1	23	5.8	117	11.7
2	.....	1	1	3	.....	.....	5	18	.....	5	.....	9	18	2	36	7.2	72	8.0
3	.....	3	.....	1	.....	.....	4	11	.....	1	3	8	18	2	36	9.0	70	8.7
4	.....	.....	.....	4	1	.....	5	21	1	2	2	6	16	4	64	12.8	46	7.7
5	.....	1	3	2	.....	.....	6	20	.....	4	2	4	18	3	54	9.0	35	8.7
6	.....	1	1	2	.....	.....	4	14	1	.....	3	7	16	3	48	12.0	45	6.4
7	.....	1	3	2	.....	.....	6	20	.....	2	4	7	23	2	46	7.7	79	11.3
8	.....	.....	.....	3	2	.....	5	22	2	3	.....	4	21	4	84	16.8	53	13.2
9	.....	.....	4	.....	.....	.....	4	12	1	3	.....	8	11	2	22	5.5	43	5.4
10	.....	1	1	5	.....	.....	7	26	1	5	1	6	21	3	63	9.0	53	8.8
11	.....	1	2	2	.....	.....	5	17	1	2	2	7	20	2	40	8.0	71	10.1
12	.....	1	.....	4	.....	.....	5	19	.....	2	3	6	13	3	39	7.8	66	11.0
13	.....	.....	.....	3	1	.....	4	17	2	2	.....	7	17	3	51	12.8	45	6.4
14	.....	.....	.....	.....	3	.....	3	15	.....	2	1	6	20	3	60	20.0	42	7.0
15	.....	.....	1	3	1	.....	5	20	2	1	2	5	21	3	63	12.6	75	15.0
16	.....	.....	.....	.....	2	.....	2	10	.....	1	1	8	21	3	63	31.5	63	7.9
17	.....	.....	.....	4	.....	.....	4	16	.....	3	1	4	14	4	56	14.0	60	15.0
18	.....	.....	.....	3	2	.....	5	22	1	1	3	5	20	3	60	12.0	70	14.0
19	.....	1	1	3	1	.....	6	23	4	2	.....	5	27	3	81	13.5	70	14.0
20	.....	.....	.....	4	1	.....	5	21	.....	2	3	6	28	3	84	16.8	63	10.5
21	.....	1	.....	2	.....	.....	3	10	2	1	.....	6	22	3	66	22.0	46	7.7
22	.....	.....	.....	.....	3	.....	3	15	1	2	.....	6	10	4	40	13.3	38	6.3
23	.....	.....	.....	3	2	.....	5	22	.....	1	4	6	23	4	92	18.4	61	10.2
24	.....	.....	.....	2	1	.....	3	13	.....	3	.....	4	14	4	56	18.6	38	9.5
25	.....	.....	1	2	.....	.....	3	11	1	2	.....	5	14	3	42	14.0	50	10.0
26	.....	.....	.....	1	.....	1	2	10	1	.....	1	5	13	3	39	19.5	76	15.2
27	.....	.....	1	1	1	.....	3	12	2	1	.....	6	12	3	36	12.0	37	6.2
28	.....	.....	.....	1	4	.....	5	24	1	1	3	4	20	5	100	20.0	46	11.5
29	.....	.....	.....	.....	3	.....	3	15	1	1	1	8	16	3	48	16.0	46	5.7
30	.....	.....	.....	3	1	1	5	24	.....	2	3	8	18	3	54	10.8	42	5.2
31	.....	.....	.....	.....	3	.....	3	15	.....	3	.....	9	17	3	51	17.0	48	5.3
32	.....	.....	1	3	.....	.....	4	15	.....	.....	4	10	12	2	24	6.0	61	6.1
33	.....	.....	.....	1	3	.....	4	19	2	1	1	8	10	3	30	7.5	26	3.2
34	.....	.....	.....	2	2	.....	4	18	1	3	.....	6	24	2	48	12.0	72	12.0
35	.....	.....	.....	1	2	.....	3	14	.....	2	1	9	15	3	45	15.0	53	5.9
36	.....	.....	.....	3	1	.....	4	17	1	1	2	7	31	3	63	15.8	87	12.4
Mean	.39	.61	2.03	1.11	.06		4.19	16.92	.81	1.94	1.44	6.53	18.25	2.97	52.97	13.38	57.36	9.25
Per cent	9.0	15.0	48.0	27.0	1.0		.....	.....	19.0	46.0	35.0	.....	.....	.....	.....	.....	.....	.....
Probable Error							.131	.509	.....	.....	.....	.193	.569	.099	2.11	.61	2.01	.36

Table B. Performance records of wealthy branches in six orchards.

Orchard Number	Year	No. of Branches	Diameter	Percentage Distribution of Apples in Size Groups						No. of Apples per Branch	Total Weight in Ounces	Per Cent of Apples in Respective Color Grades			Age	No. of Spurs	Av. No. of Leaves per Spur	Total No. of Leaves	Leaves per Apple	Length in Inches	Av. Annual Growth in Inches
				Less than 2"	2" to 2¼"	2¼" to 2½"	2½" to 2¾"	2¾" to 3"	More than 3"			U. S. Fancy	U. S. No. 1	U. S. Com'l.							
7....	1932	33	Less than 2/8"	14	18	28	31	9	.....	3.3	10.5	17	35	48	3.9	9.0	2.6	23.4	7.1	22.4	5.7
16....	1932	18		9	14	43	30	4	.....	3.1	9.5	18	37	45	5.2	9.7	7.3	22.3	7.2	27.5	5.3
27....	1932	35		11	21	35	17	12	4	3.9	13.1	19	41	40	2.9	7.2	3.1	22.3	5.7	18.9	6.5
18....	1933	36		2	15	44	30	9	.....	2.7	9.3	15	33	52	7.0	10.6	2.0	21.2	7.8	41.0	5.9
31....	1933	36		9	19	40	28	4	.....	3.4	10.0	17	32	51	10.9	11.0	2.0	22.0	6.5	37.7	3.5
20....	1934	50		7	16	41	31	5	.....	3.2	10.5	20	40	40	5.1	10.3	2.5	25.8	8.1	26.6	5.2
Total or average.....208				8	17	39	28	7	1	3.4	10.6	18	37	45	5.9	9.7	2.4	23.1	7.1	29.4	5.3
7....	1932	33	Between 2/8" and 3/8"	6	11	31	40	10	2	7.6	27.3	20	49	31	3.4	15.4	3.3	50.8	6.7	31.7	9.3
16....	1932	18		3	11	26	52	8	.....	6.3	22.8	22	50	28	4.7	17.0	3.4	57.8	9.2	41.3	8.8
27....	1932	35		6	23	33	23	10	5	7.3	24.4	26	52	22	2.9	13.7	4.1	56.2	7.7	29.1	10.0
18....	1933	36		.....	9	15	48	27	1	4.2	16.9	19	46	35	6.5	18.2	3.0	54.6	13.0	61.0	9.4
31....	1933	36		.....	5	17	38	35	5	4.2	19.7	14	31	55	7.6	22.7	3.0	68.1	16.2	63.4	8.3
20....	1934	50		.....	4	17	38	32	9	5.7	24.5	21	47	32	2.9	12.6	5.5	69.3	12.2	35.3	12.2
Total or average.....208				2	10	22	39	23	4	5.8	22.6	20	46	34	4.6	16.3	3.9	60.4	11.1	43.5	9.9
7....	1932	33	More than 3/8"	3	14	30	37	13	3	14.8	53.7	54	31	15	4.0	32.7	4.2	137.3	9.3	71.8	17.9
16....	1932	18		3	17	31	35	13	1	10.5	37.1	48	33	19	5.2	29.1	4.5	130.9	12.5	77.8	15.0
27....	1932	35		8	13	37	24	11	7	11.0	39.0	55	32	13	3.4	23.5	5.2	122.2	11.1	56.0	16.5
18....	1933	36		.....	.....	6	36	45	13	8.2	39.4	59	29	12	4.8	30.5	4.3	131.0	16.0	75.0	15.6
31....	1933	36		.....	.....	3	18	50	29	7.0	42.5	48	36	16	5.1	34.5	4.9	169.0	24.1	70.6	13.8
20....	1934	50		.....	1	5	24	47	23	11.7	59.1	45	37	18	5.1	33.1	5.1	168.8	14.4	72.3	14.2
Total or average.....208				2	6	16	28	33	15	10.6	46.7	51	33	16	4.6	30.9	4.8	146.2	14.8	70.1	15.4

Table C. Branch performance records of seven standard varieties.

Number of Branches Studied	Diameter	Per Cent of Apples in Respective Size Groups						No. of Apples per Branch	Total Weight in Ounces	Per Cent of Apples in Respective Color Grades			Age	No. of Spurs	Av. No. of Leaves per Spur	Total No. of Leaves	Leaves per Apple	Length in Inches	Av. Annual Growth in Inches
		Less than 2″	2″ to 2¼″	2¼″ to 2½″	2½″ to 2¾″	2¾″ to 3″	More than 3″			U. S. Fancy	U. S. No. 1	U. S. Com'l.							
Jonathan																			
104	2/8″−	22	33	33	10	2	.....	4.1	12.6	21	38	41	5.3	9.5	2.2	21.5	5.2	31.9	6.3
104	2-3/8″	6	34	40	17	3	.....	7.9	26.8	61	19	20	4.5	22.6	3.4	80.1	10.3	59.8	14.3
104	3/8″+	2	27	37	26	7	1	12.1	41.7	76	19	5	5.0	38.9	4.9	194.8	16.0	103.7	22.4
McIntosh																			
64	2/8″−	8	21	44	25	2	.....	3.4	10.5	1	10	89	5.3	11.9	2.5	30.1	9.2	38.9	7.5
64	2-3/8″	.....	5	38	40	15	2	5.9	22.1	9	16	75	4.2	20.7	4.3	88.4	16.0	54.2	12.8
64	3/8″+	.....	1	16	48	29	6	10.3	44.1	41	35	24	3.9	34.2	5.5	190.4	18.6	82.1	21.4
Duchess																			
57	2/8″−	22	30	29	18	1	.....	3.2	8.6	.....	11	89	8.2	7.2	2.6	19.2	6.0	30.3	3.7
57	2-3/8″	7	10	26	45	12	.....	6.1	21.8	5	36	59	7.3	15.7	4.2	65.2	10.8	49.3	6.8
57	3/8″+	2	3	14	45	36	.....	9.3	41.9	23	44	33	4.8	29.7	6.1	18.1	20.2	65.0	13.6
Baldwin																			
51	2/8″−	33	35	23	8	1	.....	3.9	8.9	7	20	73	10.5	12.0	2.2	25.7	6.7	31.6	3.0
51	2-3/8″	5	17	38	35	4	1	6.5	21.4	18	22	60	7.2	24.6	3.1	75.5	11.7	49.7	6.9
51	3/8″+	2	6	29	49	12	2	12.0	46.1	61	29	10	4.9	31.6	4.2	133.0	11.1	55.7	11.9
Northern Spy																			
21	2/8″−	8	47	35	9	1	.....	4.7	12.8	8	24	68	8.2	9.5	2.3	2.9	4.7	40.4	4.9
21	2-3/8″	6	19	32	31	11	1	7.9	26.9	5	20	75	6.6	22.0	3.4	74.8	9.5	67.0	10.2
21	3/8″+	.....	1	12	40	37	10	11.8	53.8	42	31	27	5.3	37.8	5.5	185.0	15.7	92.0	17.4
Grimes																			
115	2/8″−	29	43	23	5	.....	.....	3.7	8.5	.....	.....	.....	8.3	14.7	2.2	32.0	8.5	37.7	4.6
115	2-3/8″	9	34	46	11	.....	.....	6.1	17.0	.....	.....	.....	7.7	28.1	2.9	80.1	13.5	58.2	7.6
115	3/8″+	1	18	52	27	2	.....	11.8	35.9	.....	.....	.....	5.8	43.9	4.7	219.6	17.2	63.8	11.2
Transparent																			
70	2/8″−	61	27	12	.....	.....	.....	3.0	4.3	.....	.....	.....	8.0	8.0	2.9	22.5	8.3	33.6	4.2
70	2-3/8″	39	32	26	3	.....	.....	6.0	12.5	.....	.....	.....	7.5	16.2	3.7	58.6	10.8	55.7	7.6
70	3/8″+	14	34	44	8	.....	.....	10.8	28.6	.....	.....	.....	5.6	25.7	5.3	135.7	13.3	68.7	12.5

Table D. Results of branch capacity studies made of seven standard varieties.

Variety and Number of Branches Studied	Branch Diameter (Inches)	Average Distance Between Fruits (Inches)				
		Less than 4	4 to 7	7 to 10	10 to 13	13 or more
		Approximate Diameter of the Average Apple				
Jonathan	Less than 2/8	1-7/8	2-2/8	2-2/8	2-3/8	2-3/8
48 each class	2/8 to 3/8	2-1/8	2-2/8	2-3/8	2-4/8	2-5/8
	3/8 and more	2-2/8	2-3/8	2-4/8	2-4/8	2-5/8
Grimes	Less than 2/8	.....	2	2-1/8	2-1/8	2-1/8
38 each class	2/8 to 3/8	.....	2-2/8 −	2-2/8	2-2/8	2-3/8
	3/8 and more	2-2/8	2-3/8	2-4/8	2-4/8	2-4/8
McIntosh	Less than 2/8	.....	2-2/8	2-2/8	2-2/8	2-2/8
36 each class	2/8 to 3/8	.....	2-3/8	2-3/8	2-4/8	2-4/8
	3/8 and more	2-4/8 −	2-5/8 −	2-5/8	2-5/8	2-5/8
Wealthy	Less than 2/8	.....	.....	2-2/8	2-2/8 −	2-3/8
32 each class	2/8 to 3/8	.....	2-3/8	2-3/8 +	2-4/8	2-5/8
	3/8 and more	.....	2-3/8 −	2-4/8 +	2-6/8 −	3
Duchess	Less than 2/8	.....	2-1/8	2-2/8 −	2-2/8	2-3/8
34 each class	2/8 to 3/8	2-1/8	2-3/8	2-3/8 +	2-4/8	2-5/8
	3/8 and more	2-3/8 −	2-3/8 −	2-4/8	2-6/8	2-7/8
Baldwin	Less than 2/8	.....	2-2/8	2-3/8	2-3/8 −	2-3/8
18 each class	2/8 to 3/8	2-2/8	2-3/8 −	2-4/8	2-4/8	2-4/8
	3/8 and more	2-3/8 −	2-4/8 −	2-5/8	2-5/8	2-6/8
Transparent	Less than 2/8	.....	1-7/8	1-7/8	1-7/8	2
42 each class	2/8 to 3/8	.....	1-7/8	2-1/8	2-1/8	2-3/8
	3/8 and more	2-1/8	2-2/8	2-2/8	2-3/8	2-4/8

Table E. A comparison of the yield and grade of fruit produced by trees having received "uniform space" thinning, "graduated space" thinning and no thinning.

Variety	No. of Trees	Treatment	Bushels of Respective Size Grades						Total Bu.	Color Grades Expressed in Per Cent		
			Less than 2"	2" to 2¼"	2¼" to 2½"	2½" to 2¾"	2¾" to 3"	3" or more		U. S. Fancy	U. S. No. 1	U. S. Com'l.
Steele....	2	Unth...	1.00	4.50	23.50	18.00	1.00	.....	48.00	83	9	8
1934	2	Unif. .	.50	3.50	10.00	17.50	9.50	1.00	42.00	82	11	7
	2	Grad...	.....	.....	1.00	17.50	23.00	1.00	42.50	96	3	1
McIntosh.	3	Unth...	1.50	15.00	45.75	21.75	1.50	.....	85.50	75	11	14
1934	3	Unif. .	.50	3.00	5.50	34.50	26.25	2.25	72.00	88	7	5
	3	Grad...	.....	.....	1.50	56.25	23.25	1.50	82.50	93	5	2
McIntosh.	3	Unth...	.25	.75	11.50	25.50	14.00	.75	52.75	68	17	15
1935	3	Unif. .	.25	.25	3.00	19.50	17.00	3.25	43.25	72	15	13
	3	Grad...	.....	.....	1.50	31.50	12.00	1.00	46.00	82	15	3
Duchess...	5	Unth...	1.25	13.75	31.25	12.50	2.50	.....	61.25	19	42	39
1934	5	Unif. .	.....	.....	10.00	25.00	17.50	2.50	55.00	30	45	25
	5	Grad...	.....	.....	3.75	27.50	25.00	2.50	58.75	39	46	15
Jonathan..	3	Unth...	9.50	25.00	13.50	1.00	.....	.....	48.75	68	16	16
1934	3	Unif. .	4.50	12.25	10.25	10.25	4.00	.....	41.25	72	15	13
	3	Grad...	.....	1.00	19.00	23.00	1.50	.....	44.50	84	12	4
Jonathan..	5	Unth...	.....	2.50	16.25	28.75	10.00	1.25	58.75	74	19	7
1935	5	Unif. .	.....	1.75	12.00	24.00	9.00	2.00	48.75	79	16	5
	5	Grad...	.....	.....	9.25	26.75	13.75	1.75	51.50	89	8	3
Baldwin...	3	Unth...	3.50	5.25	11.00	10.00	4.00	.....	33.75	68	18	14
1935	3	Unif. .	1.50	2.75	5.00	11.00	6.25	.50	27.00	77	13	10
	3	Grad...	.25	.50	2.50	13.25	10.25	3.50	30.25	90	9	1
Wealthy..	5	Unth...	2.25	17.00	39.75	30.25	11.00	1.00	101.25	5	21	74
1935	5	Unf. .	.75	6.50	15.75	23.00	27.50	5.25	78.75	14	34	52
	5	Grad...	.....	.75	9.25	43.50	27.50	2.50	83.50	34	36	30
Grimes...	3	Unth...	2.75	10.00	20.25	6.25	.....	.....	39.25	.....	.....	.....
1935	3	Unif...	.25	3.00	10.00	17.00	4.00	.....	34.25	.....	.....	.....
	3	Grad...	.....	1.00	17.00	17.00	1.00	.....	36.00	.....	.....	.....
Winter	2	Unth...	1.50	6.00	13.75	19.00	10.75	1.00	52.00	.....	.....	.....
Banana	2	Unf. .	.75	2.00	5.50	11.00	14.25	10.75	44.25	.....	.....	.....
1934	2	Grad...	.....	.....	3.00	14.75	21.25	9.00	48.00	.....	.....	.....
Trans-	2	Unth...	9.00	10.50	14.00	2.50	.....	.....	36.00	.....	.....	.....
parent	2	Unif. .	5.00	5.50	17.00	6.50	.25	.....	34.25	.....	.....	.....
1934	2	Grad...	.....	4.00	19.50	10.50	.50	.....	34.50	.....	.....	.....
Trans-	3	Unth...	14.00	35.75	17.00	2.50	.....	.....	69.25	.....	.....	.....
parent	3	Unif...	6.25	24.25	22.75	6.50	.....	.....	59.75	.....	.....	.....
1935	3	Grad...	4.00	19.50	27.75	8.75	.....	.....	60.00	.....	.....	.....
Total all	39	Unth...	46.25	146.00	257.50	178.00	54.75	4.00	686.50	.....	.....	.....
Varieties	39	Unif...	20.25	64.75	126.75	205.75	135.50	27.50	570.50	.....	.....	.....
	39	Grad...	4.25	26.75	115.00	290.25	159.00	22.75	618.00	.....	.....	.....