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APPLE ORCHARD DESIGN AND PLANTING DENSITY

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Introduction

Fresh-market apple production is an important agricultural enterprise in some areas of New York State, although the number of apple producing farms has decreased substantially during the last 20 to 30 years.

The location close to such large markets as New York City and other urban areas, has certainly stimulated the development of substantial apple production in New York State. With modern transportation this favorable location has become less important. Highly efficient apple production will therefore be required in the future, when competition with apple producers throughout the country as well as from abroad can be expected.

Research is constantly making available new technological advances to apple producers which means that a traditional orchard may become obsolete in a relatively few years. To keep production up-to-date is a more serious problem in fruit production than for many other enterprises because decisions and planning for one year affect production for years ahead.

This study was conducted to examine the economical aspects of tree density per acre. Emphasis is naturally placed on use of dwarfing rootstocks and size-controlled trees. As it will take years to get satisfactory empirical data from New York apple producers, this is not meant to be a final answer to all the questions concerning size-controlled trees. This study has drawn heavily on experience in Holland and other European countries where densely planted orchards have been used to a greater extent for some years. The main purpose of this study has been to adjust this experience to New York growing conditions, and to pinpoint those factors which should be considered important in the development and comparison of different orchard designs.

Types of Orchards Studied

In order to have an exact frame for this discussion of tree density, the planting system and tree size for five orchards were defined. The number of trees per acre ranged from 41 to 1300. Forty-one trees per acre represents, more or less, the traditional apple production in New York State until recently (23, 24). Thirteen hundred trees per acre, on the other hand, is the most densely recommended planting system in Holland (5). Facts about each orchard follows:

Orchard A, 41 trees per acre.
Planting distance: 35 x 30 ft.
Tree height at maturity: 17 1/2 ft.
Crown spread: 25 ft.

* This study, done under the direction of Professor B. A. Dominick, Jr., is a condensation of an M.S. Thesis.

This represents an average for traditional apple production. For this planting distance vigorous rootstocks equal to the seedling rootstocks are assumed to be the best solution.

<u>Orchard B</u>, 87 trees per acre.
Planting distance: 25 x 20 ft.
Crown height at maturity: 13 1/2 ft.
Crown spread: 17 ft.

There has been a tendency in New York during the last few years to use clonal rootstocks at spacings approximately like this (37). In this study Orchard B is assumed to be trees on semi-standard rootstocks. For weak-growing varieties vigorous rootstocks should be used.

<u>Orchard C</u>, 370 trees per acre.
Planting distance: 15 x 8 ft.
Crown height at maturity: 7 ft.
Crown spread: formed as a 7 ft. wide hedge at the bottom, and 2 ft. wide at the top.

This is assumed to be trees on dwarf rootstocks (M IX and M 26) for most varieties. For weak-growing varieties this spacing may successfully be used with a dwarfing interstem only. It is assumed that it will be necessary to use one stake per tree for support.

<u>Orchard D</u>, 870 trees per acre.
Planting distance: 10 x 5 ft.
Crown height at maturity: 7 ft.
Crown spread: formed as a 5 ft. wide hedge at the bottom, and 2 ft. wide at the top.

In this case the alley way is reduced to only 5 feet which would create problems in the use of conventional machinery and equipment. Lighter equipment should be used, as it is in Holland, and can be implemented without increasing machinery cost. For a planting like this, M IX is the only actual rootstock of those in common use. It is assumed that a stake per tree is necessary from the year of planting.

<u>Orchard E</u>, 1300 trees per acre.
Planting distance: 10 x 3 1/3 ft.
Height and spread as for D.

<u>Age and Size of Apple Trees in New York</u>

The first survey of the New York apple industry was carried out in Wayne County more than 60 years ago, and the results were published in 1905 (9). It showed that the number of trees per acre, based on planting distances or net orchard area, was 42.1/

1/ Net orchard area is used for the area directly allocated to the fruit trees, based on planting distances. Necessary area for roads, hedges, farmstead, etc. is not taken into account.

New York Crop Reporting Service (24, 25) has obtained information on the fruit industry in each county in New York for many years including number of trees per acre (Table 1). Snyder, however, found that information of acreages obtained from farmers tended to be too high when compared to aerial photographs.(36). Even with some error included the New York State apple industry has not changed much with regard to planting distances (Table 1).

Table 1. Total Number of Trees and Acreage in Apple Production Eastern and Western New York, 1966

	Western N.Y.	Eastern N.Y.
Total number of trees	1,552,633	1,184,755
Acres in apples	43,704	30,672
Trees per acre	36	35

Source: New York Crop Reporting Service. New York Fruit Tree and Vineyard Survey 1966. A.M.A. Release No. 98 and 100.

Western New York has more trees than Eastern New York in all age groups, with the exception of the group 17 - 26 years (Figure 1). A substantial part of the apple trees was older than 26 years in 1966 (trees planted before 1940). The percentages were 37.5 for Western New York and 35.8 for Eastern New York.

There is an increase in the use of "dwarf and semi-dwarf trees" as it is reported by New York Crop Reporting Service (25). Size-controlled trees are also used to a larger extent in Western New York. Sixty-one percent of the trees planted during the period 1963-65 were reported to be dwarf to semi-dwarf, as compared to 39 percent for Eastern New York.2/ The proportions of size-controlled trees calculated on the basis of the total number of apple trees were 22.1 and 10.6 percent for Western and Eastern New York, respectively.

Effects of Rootstocks on Tree Size and Yield

Chemical growth regulators have been introduced into apple production during the last few years, but so far the use of dwarfing rootstocks has been the most successful method of obtaining size-controlled trees.

2/ Information on size-controlled trees is based on information from selected counties. For Western N.Y.: Wayne, Niagara, Monroe and Orleans. For Eastern N.Y.: Ulster, Colombia, Dutchess, Orange, Saratoga, Clinton and Essex. Figure 1 is also based on the proportions of size-controlled trees in these counties.

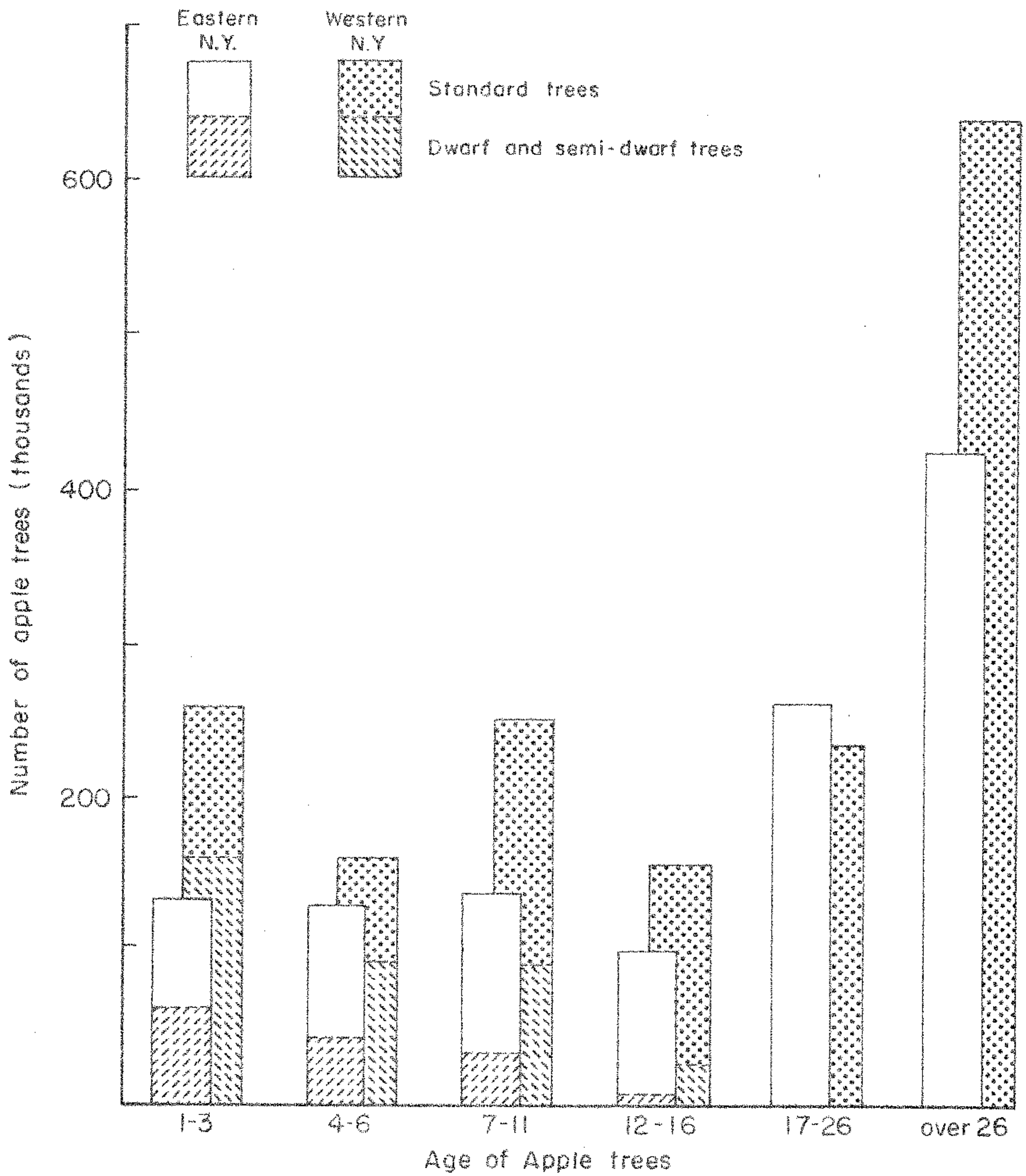

Figure I. NUMBER OF APPLE TREES IN DIFFERENT AGE GROUPS, AND PROPORTION OF DWARF AND SEMI-DWARF TREES. Eastern and Western New York, 1966

SOURCE: New York Crop Reporting Service, New York Fruit Tree and Vineyard Survey 1966. A.M.A. Release No. 98 and 100

Most of the selection and systematizing of clonal rootstocks have been carried out at the East Malling Research Station in England. Among the rootstocks in the two series released (M-series and MM-series), vigor is ranging from very dwarfing to about equal to the traditional seedling rootstocks. Although growth is influenced by several factors, it is now possible to get more or less tailor-made trees.

The most commonly used apple rootstocks can roughly be classified as follows (6, 27, 28, 29).

Dwarf:..........M IX, M 26

Semi-dwarf:.....M VII, MM 106

Semi-standard:..M II, M IV, MM III

Standard:.......Seedling, M XVI, M XXV, MM 104, MM 109

Crab C, Alnarp 2

Reduction of tree size can also be achieved by use of a dwarfing interstem only. This has been used to some extent by New York apple producers, in order to combine the good anchorage of a vigorous rootstock with the size-reducing effect of the dwarfing interstem (6).

Of the moderate-growing rootstocks, M VII has been until recently predominate in many countries. It was recommended in New York by Brase and Way (6) for smaller trees than M II could give. During the last five or ten years MM 106 has been recommended as a substitute for M VII because of its productivity (11, 28). In Holland, where apple production is more intensive than anywhere else, the most dwarfing rootstocks are used extensively. For the main variety, Golden Delicious, M IX is about the only rootstock used. For the less vigorous variety, James Grieve, a rootstock of the semi-dwarf type, is usually recommended (1, 5).

Yield is to some extent a function of the area covered with tree crown or more correctly, it is a function of the volume of tree crown. Therefore, it is not surprising to find that yield is correlated with tree size the first 10 or 15 years of a tree's life. At least it is not surprising in a rootstock trial where no pruning, or moderate pruning, is used. For the three rootstock trials reported by Preston (27, 28, 29) there is a close relationship between the growth (tree size) of Cox's Orange and the accumulated yield for the first 15 years. This may be less obvious for a shorter period of time, and, for some varieties, the more dwarfing rootstocks will start with highest yield, even when yield is calculated on a per tree basis.

The conclusion of the many rootstock trials seems to be that for many varieties, especially the more weak-growing where there is no problem with flower bud formation, it is common to find that yield is closely correlated with growth and crown volume. These varieties do not fit the "generalized yield curve" indicated by Cain (8).

For other varieties, usually classified as late-cropping varieties which often are associated with vigorous growth, it is possible to get an extra yield during the first years by using dwarfing rootstocks.

This extra yield in the first years does not mean much economically in an orchard with 50 - 100 apple trees per acre. One bushel extra per tree the fifth year after planting gives only 50 - 100 bushels per acre, which often is required as a minimum for picking a block of apples. On the other hand, if 500 trees were planted per acre, an extra yield of one bushel per tree would be very significant economically.

When dealing with rootstocks, it should also be mentioned that there is reason to believe that the genetic constitution of a rootstock affects yield, in addition to vigor. For instance, several rootstock trials during the last decade show that MM 106 gave heavier yield than other rootstocks with the same vigor (11, 21, 28).

When considering the rootstock effect on yield, three factors seem to be of importance:

1. Special effect of the rootstock.

2. The vigor of the rootstock.

3. The number of trees planted per acre.

Light Distribution and Production Within Tree Crown

A tree crown is not an homogeneous unit. Most of the fruit on a large tree is found near the periphery where light conditions are most favorable. Usually we find few apples located in the center of large trees. Those growing under poor light conditions usually have unsatisfactory quality.

Heinicke and Childers (12) found in the 1930's that a quarter to a third full sunlight was necessary for photosynthetic production in apple leaves.

Heinicke (13, 14) in recent studies used a uranyl oxalate actinometer to measure light at different locations within the crown. By this method he could obtain values for the accumulated light received at these locations for a longer period of time. Heinicke found, as one would expect, that received light decreased the deeper into the tree canopy the measurements were taken. As an average, for two trees he found that about one third of total leaf area received more than 60 percent of full sunlight on a sunny day. One third of the leaf area received between 30 and 60 percent of full sunlight, and the remaining one third of the leaf area received less than 30 percent of full sunlight (14). This last zone corresponds with what Heinicke and Childers (12) found to be unproductive leaves.

In studying different tree sizes, Heinicke (15) found that 92 percent of the leaf area of a dwarf tree (ten-year old tree on M IX) received more than 30 percent of full sunlight, as compared to only 77 percent on a standard tree (25-year old tree on seedling rootstock). The total leaf area per acre of orchard receiving light above this floor level was also larger for the dwarf trees, although the height was only eight feet for these trees as compared to 20 feet for the standard trees.

Heinicke (16), in a later study, found that Red Delicious apples exposed to more than 70 percent of full sunlight had the best color and that 50 percent of full sunlight was necessary for satisfactory fruit size.

If we take our present knowledge about light distribution within a tree canopy into consideration, it is possible to take a somewhat newer approach in calculating yield potential for different orchard designs.

Based on Heinicke's work, it is obvious that there is too little light deeper than five feet into the tree crown for any production at all -- less than 30 percent of full sunlight. Then in a zone out to somewhere between 50-70 percent of full sunlight, there is some photosynthetic activity on sunny days. However, the light in this zone is not enough to influence flower bud formation and production of apples of satisfactory size and quality. Yield potential will then be a function of a rather limited zone next to the periphery of the tree crown. This zone is set at two feet deep in this study for calculation of productive crown volume. Berlage and Yost (4) used tentatively a three feet thick shell to calculate "theoretical fruiting volume." More sunny days in the State of Washington's fruit growing areas may account for this difference of one foot. However, the high productivity of the slender spindle trees used in Holland, indicates that the productive crown volume is a rather thin shell of the crown. For comparison of conventional crown forms, it does not make much difference whether a one or a three feet thick shell is used.

The "partly productive crown volume" is assumed as not being effective in production of apples although some photosynthesis obviously takes place on sunny days (Figure 2). This is consistant with results obtained by Forshey and McKee.3/ They found a larger production of wood took place in large McIntosh trees and a lesser production of apples based on leaf area. Based on growth and light distribution in the tree crown, total crown volume and productive crown volume have been calculated (Table 2).

It is possible to reduce the unproductive part of the orchard by using smaller trees (Table 2). The productive part of total crown volume is less than one third for Orchard A at full tree size, as compared to 96.1 percent for Orchard D and E. Orchard D and E are equal at full tree size, because it is assumed that these hedges shall have the same form.

If it were possible to reduce the alley way, as indicated by Cain (7), the figures for Orchard D and E indicate that it is possible to increase productive crown volume. It seems logical, however, that one will run into diminishing return, because the neighboring row will have more and more influence on the light condition.

3/ Unpublished paper.

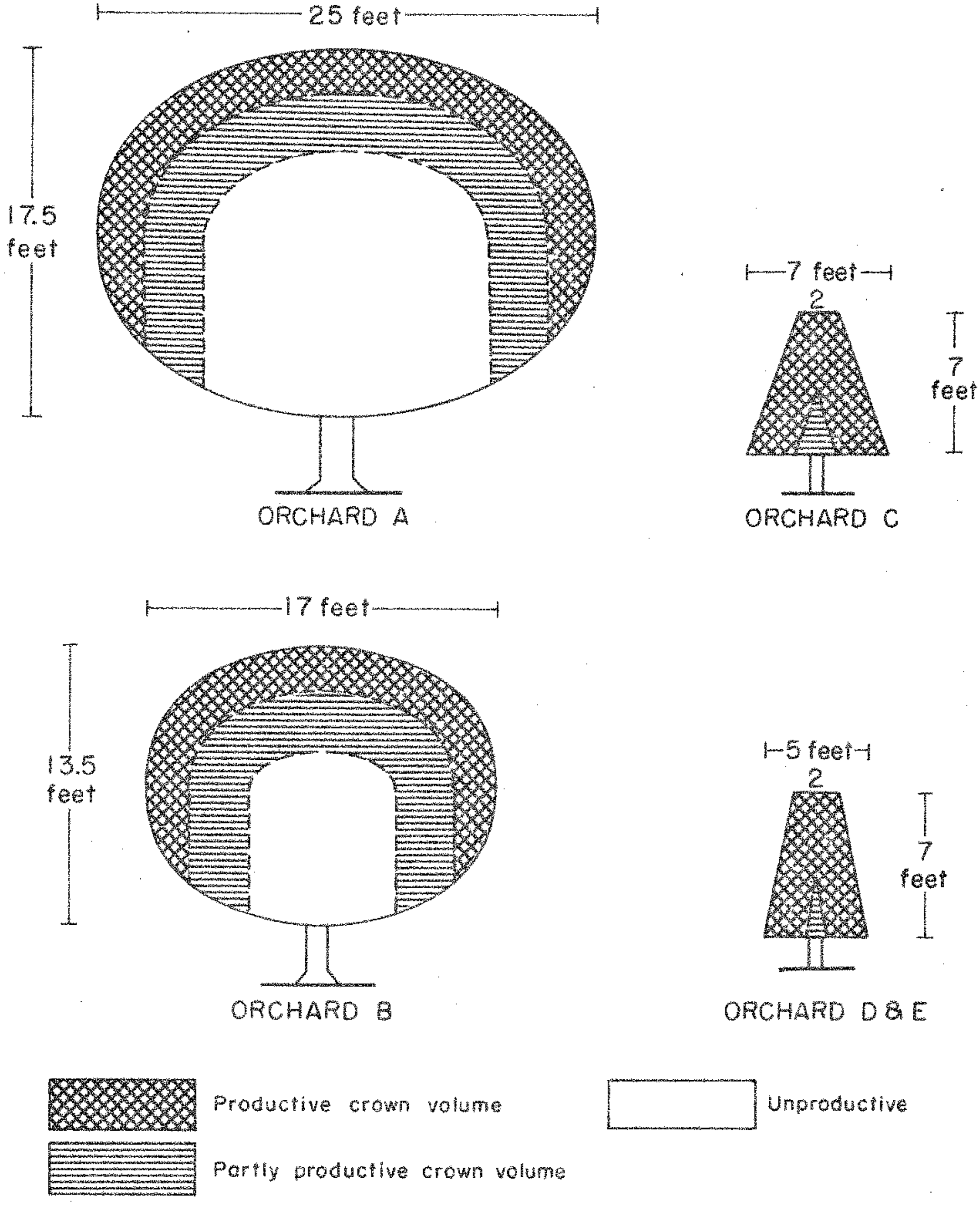

Figure 2. TREE FORM AND PRODUCTIVE PART OF TREE CROWN FOR DIFFERENT PLANTING SYSTEMS AT TREE MATURITY

Table 2. Total Crown Volume and Productive Crown Volume Per Acre at Maturity for Four Planting Systems*

Orchard	Total crown volume per acre	Productive crown volume per acre	Proportion of productive crown volume
	Cu. ft.	Cu. ft.	Percent
A (41 trees)	234,684	71,914	30.6
B (87 trees)	177,741	75,342	42.4
C (370 trees)	91,476	75,213	82.2
D (870 trees)	106,722	102,540	96.1
E (1300 trees)	106,722	102,540	96.1

* Increase in crown spread up to full tree size: 1 1/4 ft. for Orchard A, 1 1/8 ft. for Orchard B, and one foot for Orchard C, D, and E. Same increase in tree height is assumed up to ten feet, and from then on only half the increase in height as compared to crown spread.

Crown volume is calculated as a sphere until crown spread and height have reached ten feet and as an ellipsoid later. Though the tree form in a hedge row will be somewhat different, it is assumed that they have the same increase in crown volume as if they had grown as individual trees.

It is, of course, of importance to increase productive crown volume per acre from 75,000 cubic feet to over 100,000 cubic feet as it seems possible to do. That does not mean that Orchards A, B and C are equal with respect to yielding capacity. There is an important difference because of the number of years required for Orchard A to reach maturity. When previous assumptions for tree growth and the limitation of productive crown volume based on light distribution are combined at different ages, yield potential for the whole orchard's life can be calculated. The great advantage of using a large number of trees per acre is the substantial increase in productive crown volume it is possible to obtain during the first 10-15 years (Figure 3).

A good approximation of yield potential for different orchard designs is possible when available yield records are compared to the curves of productive crown volume for different tree densities. It may be of special interest to recognize that observations from Holland indicate that it is possible to reach a "full crop" of 1,000 bushels per acre 6 years after planting Golden Delicious.

In designing orchards for the future, it is of importance to compare yield potential at full tree size, but it seems to be of even greater importance to determine whether full yielding capacity can be obtained in six to seven years or in twenty years.

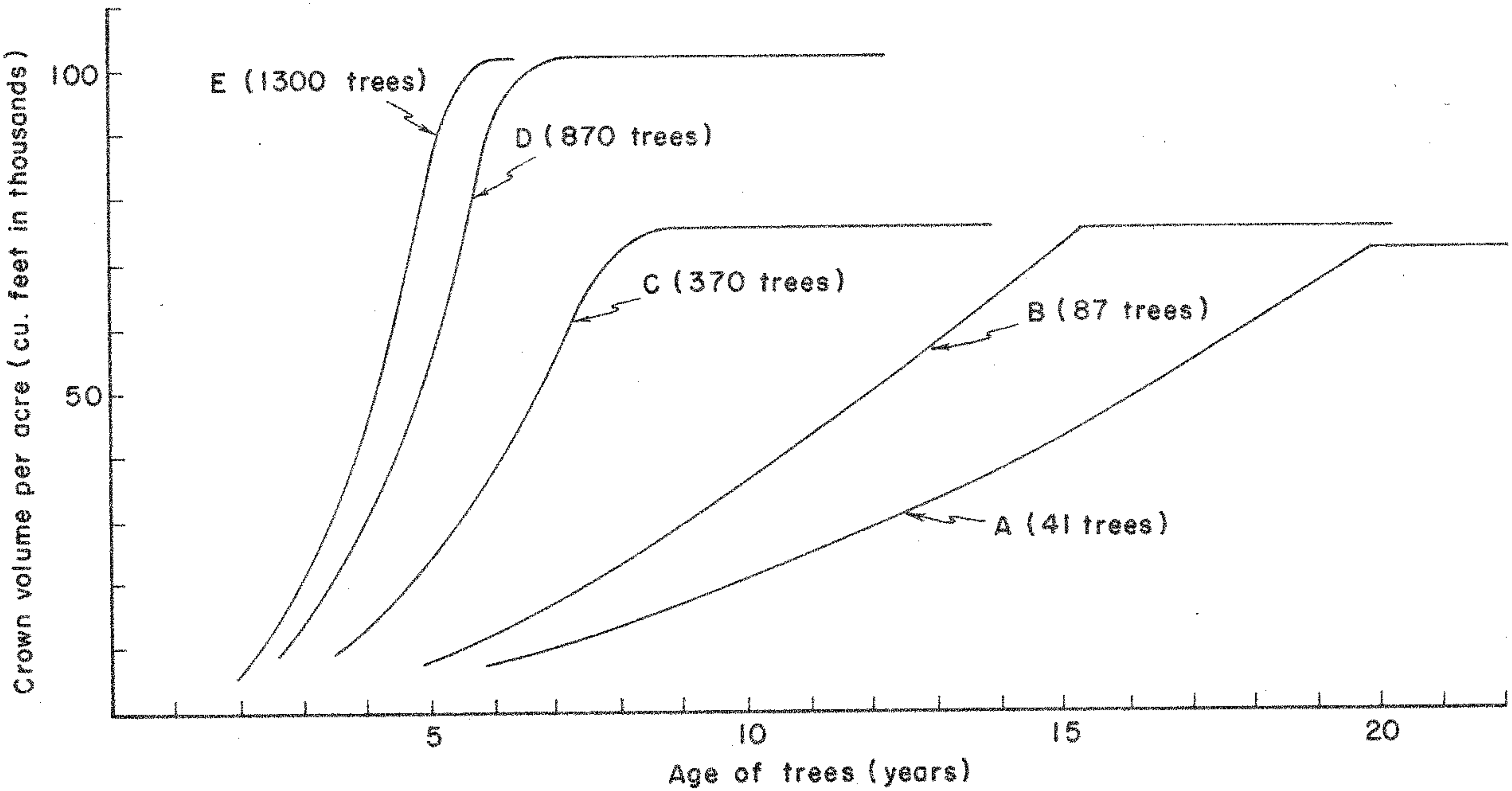

Figure 3. INCREASE IN PRODUCTIVE CROWN VOLUME PER ACRE OVER TIME FOR ORCHARDS WITH DIFFERENT NUMBERS OF TREES PER ACRE

Cost Items Affected By Orchard Design

Harvesting Costs for Fresh-Market Apples

Apple picking is a critical operation in apple production, not only because it accounts for a large proportion of the labor cost, but it has also become more and more a bottleneck for many orchardists, because a relatively large labor force is required over a rather short period of time. When specialization into apple production takes place in an area, as in some parts of Washington and New York State, lack of available labor makes it difficult to tackle these peak needs (3). Also, fruit growers are faced with increasing wages and a larger proportion of untrained pickers.

A few studies, dealing with production costs in apple production in New York State during the last 30 - 40 years, show that harvesting costs have increased in relative importance (Table 3).

Table 3. Trends in Harvesting Costs and Total Production Costs for Apples

Selected Studies in New York 1931 - 1966

Source	Year of study	Growing cost	Harvesting cost	Production cost
		Cents per bushel		
Williamson (41)	1931	54	16	70
Scoville (35a)	1934	n.a.	20	n.a.
Scoville (35b)	1947	59	32	91
Fan (10a)	1956	75	38	113
Fan (10a)	1957	117	40	157
Stanton and Dominick (39)	1962	72	45	117
Snyder (37)*	1964-66	78	37	115

* Study of size-controlled trees.

Much research has been done in many countries toward developing machinery for mechanical harvesting of apples, as well as for other fruits. So far, the shake-and-catch system has not been successful for fresh-market apples. Rollins (32) compared hand picking and mechanical harvesting for several varieties. For Golden Delicious he registered a loss, per bushel, of $1.47 and $2.44 for low and high trees respectively for mechanically harvested apples. This loss was due to reduced quality and reduced prices for the mechanically harvested fruit.

It is obvious that management skill and the quality of the labor force affects the picking cost, but several characteristics of the fruit tree itself will also be of great importance. The most important factors are:

1. Tree height

2. Fruit size and Variety

3. Yield per acre (especially important for large trees)

4. Tree width

Of these, tree height is the most obvious one, because a larger part of the time will be spent moving and climbing ladders. Davine (10) found that one third of "total orchard time" was work with ladders for 24 foot high trees. At least for untrained people, the picking operation itself will also be slower some feet above the ground, because there will be a tendency to use only one hand, which greatly reduces the picking rate (35). Schuricht (34) found that four bushels were picked per hour for standard trees as compared to eight bushels when the picker could stand on the ground and pick from high-yielding slender trees. Average fruit weight in both cases was 120 grams.

In Michigan, Ricks (30) found smaller differences in comparison picking productivity from high and low trees. For trees over 19 feet, 9.1 bushels were picked per hour, as compared to 11.5 bushels for trees eight feet or less. However, the number of observations of small trees was limited, and trees per acre or yield per acre is not reported in this case.

From the facts above, it is obvious that differences in picking costs are important in comparing planting systems with different tree heights. The picking rates used in this study are used to explain differences in tree height and also differences in fruit size. As an apple tree becomes older, there will also be a tendency to smaller apples.

Apple picking is frequently paid on a piece work basis. The rates paid, however, will reflect tree heights and other factors which are shown to influence labor productivity (Table 4).

Total harvesting cost for traditional apple production (Orchard A) is calculated at 57 cents per bushel at full tree size. If this is compared to the Hudson Valley study in 1962 (39) and if 40 percent increase in farm labor wages is taken into account, (26) we get approximately the same harvesting cost.

It may be argued that it is possible to use some sort of mechanization to reduce picking cost per bushel even with relatively large trees (2). However, this will to some extent be counter-balanced by increased cost of machinery and "other labor," because a labor force will be needed to operate the equipment. A substitution of machinery for labor may still be profitable if it is the only way to get the picking done. In other cases investment in labor-saving equipment may reduce part of the untrained picking staff resulting in increased efficiency. The relatively high cost of picking is used for all types of orchards in this study (Table 4). A higher proportion of other labor and other costs may be the optimal solution for the larger trees, but the important thing, in this connection, is the validity of the total harvesting cost.

Table 4. Harvesting Cost for Planting Systems for Mature Trees

Type of cost	Orchard A 41 trees	Orchard B 87 trees	Orchard C 370 trees	Orchard D 870 trees
		Cents per bushel		
Picking	35	30	20	18
Other labor	10	10	10	10
Containers, etc.	12	12	12	12
Total	57	52	42	40

Cost of Spraying

According to Stanton and Dominick in the Hudson Valley study of 1962 (39), spray and dust material accounted for 22 cents per bushel or 31 percent of the growing costs until harvesting. It is therefore of importance in comparing different planting systems to determine the effect of orchard design on spraying.

Much effort has been expended to find the most effective method of combating pests and diseases which are a constant threat to the orchard and to solve the technical problems involved in effective distribution of these insecticides and pesticides. In this connection, emphasis has usually been placed on labor-saving equipment because time is often a critical factor in controlling serious pests. Less attention has been given to the economic aspects of spraying, beyond the fact that serious damage can be caused by pests and insects in an apple orchard.

Effective pest-control usually depends upon effective distribution of the spraying materials. For most pesticides and insecticides it is of importance to have every shoot and leaf covered with the spraying material. In light of this, it seems logical to assume that the leaf area and the volume of tree crown are important factors. Attention should be drawn to previous calculations, where an acre of full grown standard trees (Orchard A) had a crown volume of 235,000 cubic feet, as compared to 91,000 cubic feet for the dense planting at 15 x 8 feet of Orchard C. This means that it is necessary to distribute the spraying material to a crown volume two and half times larger in the first case. In addition, more power is required for effective distribution the further away from the sprayer and the deeper into the canopy it is necessary to blow the pesticide.

Further, it seems logical that less spray materials would be wasted where there is an orchard design with continuous rows rather than single trees which have more room between the trees in the rows.

Hilkenbaumer in West Germany (18) has calculated the use of spray material to represent a cost of $60 per acre for standard trees and $36 for spindle trees when 12 applications per year were used.

In the study of size-controlled trees in New York, Snyder (37) found that the cost of spray material varied from $42 - $60 per acre for the three years, 1964-66. However, this case was a study of size-controlled trees in orchards where the observed plots usually represented a small part of the total area in the orchard. Under such circumstances it may be a question of whether spraying practices and equipment were adjusted to obtain the most effective spraying on these plots.

Based on previous studies of the New York apple industry and of crown volume and tree height, the cost of spray and dust is assumed to increase with tree height up to $90 for Orchard A and $80 for Orchard B. Because of less crown volume and fewer problems with penetration into the tree canopy, this cost is set at $45 and $65 for Orchards C and D, respectively. The cost of labor for spraying, on the other hand, is set higher for dense plantings, because of increase in mileage of rows per acre.

<u>Pruning</u>

The labor requirement for pruning Orchards A and B is assumed to increase with tree size up to 40 and 35 hours per acre. However, there will be an interrelationship between pruning, fruit quality, and spraying. If pruning is neglected it will naturally affect tree height and harvesting cost. Because this study is dealing with apples for fresh market, it is assumed that a relatively high degree of pruning is necessary to keep a satisfactory quality of older trees.

For size-controlled trees pruning requirements have not been established. There have been examples of hardly any pruning at all for several years. Roosje (33) gives 25 - 40 hours per acre as a standard in Holland, but most of the very dense orchards are still less than ten years of age. In this study an increase in pruning up to 55 hours per acre for Orchard D, with 870 trees per acre, is assumed. As pointed out by Berlage and Yost (4), "tree walls" will probably be a requirement for effective mechanization of apple production in the future. As development of equipment takes place, it may therefore be expected that more mechanical pruning will be introduced in uniform orchards like Orchards C and D. From a budgeting point of view, this may result in a lower labor requirement per acre, but a somewhat higher cost of machinery and equipment.

Other Costs

One of the obvious differences when comparing different tree densities is tree cost. In this study Orchards C and D are charged with a cost of one stake per apple tree planted. In addition it is assumed some replanting of trees during the first years after planting is necessary.

The different cost items are pulled together (Appendix 1-4) and an effort is made to show the variation in costs throughout the trees' life. Where size of the enterprise will affect costs, the figures given represent a medium sized apple enterprise of 25 to 50 acres.

Economic Analyses of Different Planting Systems

Establishment and Production Costs

Calculations on the establishment cost and average cost for periods of 2 and 5 years throughout the different orchards' life are based on a medium yield level of 750 bushels per acre at maturity for A, B and C, and 1000 bushels per acre for D (Appendix Tables 1-4). Labor wages are set at $2.00 per hour. The price of a fruit tree is set at $1.25, and Orchards C and D are charged with a cost of $1.00 for a stake per tree.

These figures for labor requirement and expenses are based on literature referred to in previous sections, and on information obtained at the Department of Pomology at Cornell University and at the Agricultural Experimental Station, Geneva, New York. Many of the cost items are independent of planting systems or are only slightly influenced by orchard design. A few such costs are orchard rental, fertilizer, cost of machinery, supervision, and cost of containers. These costs are, to a large extent, based on previous studies of the New York orchard industry (36, 37, 38, 39).

Total expenses, total estimated yield for the different orchards' life, and stipulated life-time for the different planting systems are calculated (Table 5). For Orchards C and D, especially, some uncertainty is associated with the figures given. Bos (5) had 90 percent of all establishment costs depreciated within the 15th year. In some cases an orchard may become obsolete early because of loss of trees, or because of poor compatibility between rootstock and scion, while a 50-year-old orchard may be high-yielding under other circumstances. For fresh-market apples the reduction in fruit size and quality on older trees have to be taken into account. These factors do not affect production cost per bushel as much as they affect selling prices and profits.

Establishment cost is usually referred to as accumulated cost in the pre-bearing period (5, 39). There may frequently be difficulty in deciding what year is the first bearing year in practice. In a U.S.D.A. bulletin (40) bearing age is defined as the age at which 20 percent or more of full production is reached. In this study, the first year of bearing is the year when the calculated yielding potential is 50 bushels per acre.

Table 5. Accumulated Yield and Expenses Per Acre Over Stipulated Orchard Life: Medium yield level used for comparison of four different planting systems

Orchard	Stipulated life-time	Total expenses*	Total yield
	Years	Dollars	Bushels
A (41 trees)	35	17,520	16,200
B (87 trees)	30	15,211	14,850
C (370 trees)	20	10,525	10,815
D (870 trees)	17	13,078	12,780

* Without interest cost.

Establishment costs for the different planting systems are given with an increase of eight percent calculated so that the total establishment cost represents the value of the trees in the orchard in the last non-bearing year (Table 6). Calculated establishment costs range from $791 per acre for 41 trees per acre to $3901 with 870 trees per acre. 1300 trees per acre is not considered in this section because it is similar, but inferior to Orchard D. Compared to D, an establishment cost of $1100 - $1200 higher than for D can be expected, but an extra yield of only 650 bushels per acre during the first years can be expected.

Table 6. Establishment Costs Per Acre with Different Planting Systems at an Interest Rate of Eight Percent

Orchard	Years of non-cropping	Expenses	Interest	Total establishment cost*
			Dollars	
A (41 trees)	5	665	126	791
B (87 trees)	4	741	110	815
C (370 trees)	3	1603	208	1811
D (870 trees)	2	2892	199	3091

* Represents the value of the orchards in the last year of non-cropping

For calculation of production cost, it is necessary to take into account the differences in distribution of income (yield) and expenses using the following procedure:

1. Total expenses throughout the orchards' life are divided by total yield.

2. An eight percent discount table is used to calculate the present value of future expenses and of future yield. Production cost is found by dividing the present value of all expenses throughout the tree's life by the corresponding reduced amount of yield.

3. The interest cost per bushel of apples is calculated as the difference between 2 and 1 above.

By using this method it is possible to charge each bushel of apples with the same establishment cost and the same interest cost.

Production cost per bushel of apples is given for different yield levels showing that Orchard A (41 trees per acre) is inferior to B and C at all yield levels considered (Table 7). Production cost is a little lower for B than for C if maximum yield is set as low as 500 bushels per acre of net orchard. From 750 bushels to a top yield of 1500 bushels, Orchard C with 370 trees per acre gives the lowest production costs. The differences are not large, however, and it appears that differences in prices and fruit quality will be of greater importance in choosing the most profitable planting system.

The picking cost is set to be the same per bushel for all yield levels which may not be quite realistic. At least at a very low yield level, there will be a tendency toward higher picking cost, especially with the traditional tree size. The effect of crop will be less as yield increases beyond a fairly good crop.

Interest is higher for Orchard A than for Orchard B because A requires more years to produce a substantial yield and also because average yield per year is lower for the orchard with the larger planting distances (Table 7).

Factors Affecting Production Cost and Profitability

Yield: If top yield is doubled from 500 to 1000 bushels per acre, production cost declines by 53 percent for Orchard B. High yield is even more important for intensive apple production with a large investment in trees per acre. Decrease in production cost is 66 percent for Orchard D when yield is doubled from 750 to 1500 bushels per acre of net orchard area. The effect of 100 bushels increase in yield per acre will be less at the higher yield level.

Table 7. Production Cost Per Bushel for Four Planting Systems at Four Yield Levels Including Eight Percent Interest

Orchard	Top yield:*	500 bushels			750 bushels			1000 bushels			1500 bushels		
	Type of cost:**	1	2	3	1	2	3	1	2	3	1	2	3
		Dollars per bushel											
A (41 trees)		1.34	0.30	1.64	1.08	0.20	1.28	0.95	0.14	1.09	0.82	0.09	0.91
B (87 trees)		1.28	0.27	1.55	1.02	0.18	1.20	0.90	0.12	1.02	0.77	0.08	0.85
C (370 trees)		1.25	0.32	1.58	0.97	0.22	1.19	0.84	0.16	1.00	0.70	0.11	0.81
D (870 trees)		1.34	0.40	1.74	1.02	0.27	1.29	0.87	0.20	1.07	0.71	0.14	0.85

* Top yield 33 percent higher for D.

** 1 Total expenses throughout the trees' life divided by total production
2 Interest on establishment costs
3 Total production cost

Inflation: In the post-war period prices on goods and services have increased. If the same trend of inflation can be expected in the future, it certainly will affect decision-making in apple production where long-term investments are necessary. Assuming approximately four percent increase in costs and prices, today's value of future costs and income have been calculated for an acre of apples (Appendix Tables 1-4). Because of differences in the stipulated life-time for the different orchards, present value of future income and expenses are used in order to make a comparison with a stable price situation possible (Table 8).

A four percent discount table is used for calculation of production price to describe a situation with four percent inflation[4] and a nominal interest of eight percent (Table 8). The production price gives lower values where inflation is assumed because each bushel of apples will be charged with less real interest when price is expressed in value of money in the year of planting. Also, a situation with inflation slightly favors the most densely planted orchards. Production price for D is calculated to be 7.5 percent higher than for B in a stable price situation, but only 4.6 percent higher in a four percent inflationary situation.

Comparison of the different types of costs is expressed in percentages of total production cost (Table 8). The most remarkable change in the case of inflation is the reduced percentages for establishment costs. This reduction has been eight to ten percent, but it is slightly higher for the orchard with a large number of trees per acre.

If a higher price increase for labor cost was assumed than for other costs and prices, the picture would change, giving an even more favorable position to size-controlled trees.

Apple Prices: In a short-run situation, the production method giving the lowest cost is not necessarily the optimal solution from a profit-maximizing point of view. If an apple producer can produce at a cost lower than the price obtained, he should also take this excess profit into account. Cost accounting for apple production in New York State shows that there has been a positive profit in 10 out of 12 years during the period 1954-65 (20). This difference between cost and price has been as high as 66 cents per bushel in 1954 and down to 12 cents in 1958. Average profit has been 19 cents per bushel for the growers included in this study. When different varieties are considered, this profit becomes even more important.

The total amount of profit obtained per acre of apples is a product of yield and the difference between production cost and price. Orchard A gives the lowest average yield per acre when total yield is divided by assumed orchard life-time because it takes several years to reach bearing age, and because there is another period of increasing but relatively low yield (Table 9). Average yield increases with the number of trees per acre and is naturally highest for Orchard D.

4/ By using a four percent discount table in a situation with 8% interest, actual rate of inflation (r) can be found from the equation: $1.0\ (1.04) - 1 = (1 + r)\ (1.08) - 1$, which gives $r = 3.85\%$.

Table 8. Proportion of Various Cost Items in Both a Stable Monetary Situation And a Four Percent Inflationary Situation. Medium Yield Level

Type of cost	Planting system:	A (41 trees)		B (87 trees)		C (370 trees)		D (870 trees)	
	Situation:	Stable	Infl.	Stable	Infl.	Stable	Infl.	Stable	Infl.
				Percent of total growing cost					
Establishment cost* included interest		18.5	9.9	18.8	11.0	30.9	22.7	38.5	30.2
Growing cost:									
Labor (preharvest)		13.4	14.8	13.7	15.0	14.2	15.9	14.2	16.1
Spray and dust		10.0	11.0	9.5	10.4	5.0	5.6	5.0	5.7
Real estate		7.3	8.1	7.3	8.0	6.6	7.4	4.5	5.1
Other growing costs		7.3	8.0	8.3	9.1	8.0	9.0	6.9	7.8
Harvesting costs:									
Picking		26.3	29.1	24.2	26.5	16.8	18.8	13.9	15.8
Other harvesting labor		7.8	8.7	8.3	9.1	8.4	9.4	7.7	8.8
Miscellaneous		9.4	10.4	10.0	11.0	10.1	11.2	9.3	10.5
Total		100.0	100.0	100.1	100.1	100.0	100.0	100.0	100.0
Production cost in dollars per bushel**		1.28	1.16	1.20	1.09	1.19	1.07	1.29	1.14

* Including all cost in the pre-bearing period plus interest of establishment costs.

** Value of money in the year of planting also used in the case of four percent inflation.

Table 9. Average Yearly Yields Per Acre Based on Assumed Life Span

Orchard*	Top Yield per Acre			
	500	750	1000	1500
		Bushels per acre		
A (41 trees)	309	463	617	926
B (87 trees)	330	495	660	990
C (370 trees)	361	541	721	1082
D (870 trees)	501	752	1002	1504

* Top yield 33 percent higher for Orchard D.

If a maximum yield of 750 bushels per acre is assumed with the profit per acre calculated at different price levels, Orchard C with 370 trees per acre gives the highest profit at a price level of $1.25 and $1.50 (Table 10). At a price above $1.55 Orchard D, with 870 trees per acre, gives the highest profit. In other words, high prices favor intensive apple production because of the higher yield it is possible to obtain.

From this calculation (Table 10) it can also be concluded that a higher number of trees will give maximum profit under good management and under good growing conditions. These factors tend to increase yield and decrease production cost, and, hence, a larger difference between production cost and price can be expected.

Table 10. Annual Profit Per Acre for Four Planting Systems At Four Price Levels*: Medium Yield Level

	Apple price			
Orchard	1.25	1.50	1.75	2.00
		Dollars per acre		
A (41 trees)	- 13	102	218	333
B (87 trees)	25	149	272	396
C (370 trees)	32	168	303	438
D (870 trees)	- 30	158	346	534

* Apple price received at the farm minus post-harvest costs as storage, packing and selling

Adjustment to a Given Market Situation: Apple prices fluctuate from year to year. This phenomenon is also common between prices of different varieties (36). This considerable variation may sometimes reflect differences in production cost, where a variety's productivity is of importance as pointed out earlier. However, the variation among varieties may also be due to inability of the apple industry to keep pace with changes in the market. In traditional apple growing, with a life-time of 40 to 60 years for an orchard, it is not surprising that the market situation may change during the orchard's life.

From time to time new and popular varieties are added to the selection of varieties and also the consumers' preferences of existing varieties may change. In traditional apple growing it takes many years to adjust to changes in demand. The apple producer's problem has always been to plan for the future market situation. It is desirable, of course, to have large quantities of varieties where the price obtained is well above production cost. Over a longer period of time the apple industry will be more or less able to adjust to a new situation, but favorable prices for some varieties often last for a shorter period of time.

The new planting systems with a larger number of trees per acre and a relatively high yield in the first years after planting should give the orchardist a better opportunity to adjust to new market situations and take advantage of favorable prices.

If an apple grower in a planning situation expects a price for a scarce variety to be $2.40 for the first five years, then decline over a period of ten years to $1.40 and from then on maintain a stable price of $1.40, profit can be calculated for an acre of apples for the different planting systems over a period of about 35 years (Table 11). This means that the whole life-time for Orchard A and the life-times of two orchards of type D are included. For Orchard C only 30 years are included because the following five years of the next planting would not produce any yield.

It may also be of interest for an apple grower to consider whether to keep an orchard of a low-price variety or to replace it with a more popular variety, with the prospect of relatively high prices for a period of 15 years (Table 11). Expected price is $1.40 for the existing variety of 20 year old trees of type A. Production cost is assumed to be equal for both varieties. Profit for the next 15 years can then be calculated to be:

A (41 trees) for remaining 15 years: profit $1284

D (870 trees) for the first 15 years: profit $6588

Again, the planting of 870 trees per acre is superior to traditional planting, because of the possibility to utilize a given market situation. This is true even though the dense planting in this case is compared to the most productive period of the traditional planting's life.

Table 11. Total Profit Per Acre Over 35 Years For Four Planting Systems and Declining Prices*

Orchard	Number of years included**	Total profit in dollars per acre
A (41 trees)	35	2671
B (87 trees)	30	4396
C (370 trees)	20 + 15	7015
D (870 trees)	17 + 17	8208

* Apple price minus post-harvest costs set to $2.40 per bushel for the first five years, then a linear decline to $1.40 through the 15th year, and a stable price during the rest of the period.

** Differences are due to unequal life-time for four orchards.

Labor Wages: In a situation with rapidly increasing wages, it may be of interest to examine the effect of wages on production cost. The cost per bushel of apples originating from the different types of labor indicates small differences in labor requirements for the different planting systems in the pre-harvest season (Table 12). More labor is naturally required for establishment of the densely planted orchards, which include all labor in the non-bearing phases of the four types of orchards. The real differences are to be found in picking costs as stated before. Picking alone represents 26.6 percent of total production cost for Orchard A, 24.2 percent for B, 16.8 percent for C, and 15.3 percent for Orchard D.

Table 12. Labor Cost per Bushel and Type of Labor: Medium Yield Level at a Labor Cost of $2.00 Per Hour

Type of labor	Orchard A 41 trees	Orchard B 87 trees	Orchard C 370 trees	Orchard D 870 trees
	Cents per bushel			
Establishment*	1.2	1.4	3.5	4.3
Preharvest season	17.1	16.4	17.0	18.4
Picking	33.6	29.0	20.1	18.0
Other harvest l.	10.0	10.0	10.0	10.0
Total labor cost	61.9	56.8	50.6	50.7

* Includes all labor in the pre-bearing period, but not interest associated with these establishment costs.

Varying labor costs per hour of $1.50, $2.00 and $2.50 are considered (Table 13). A 50 cent reduction in labor wages represents a reduction in production cost of 16.8 cents per bushel for Orchard A and 14.0 cents for C. These were the extremes, and the variation from traditional to small trees may be less than expected, when compared to the variation in type of labor cost (Table 12). However, in a situation with stable prices and eight percent interest on investment, the higher labor cost in the establishment period for Orchards C and D will count relatively more than differences in picking cost towards the end of the tree's productive life. This difference would probably have been larger in a situation with increasing labor wages over time.

Table 13. Production Cost Per Bushel At Varying Wage Rates
Medium Yield Level

Orchard	Average cost per hour of labor		
	$1.50	$2.00	$2.50
		Dollars per bushel	
A (41 trees)	1.11	1.28	1.44
B (97 trees)	1.05	1.20	1.35
C (370 trees)	1.05	1.19	1.33
D (870 trees)	1.15	1.29	1.44

Nevertheless, higher labor wages and the reduction of the labor-peak during the harvesting season will favor use of size-controlled trees, when picking has to be done by hand. This has not resulted in lower production costs or higher profit in these calculations because it has been assumed that the labor force was available at a fixed price. A reduction of the picking job to 60 percent of that found in traditional apple growing means a reduction of picking crew to well below half. This should be a realistic assumption based on the variation usually found in pickers' productivity (30). An expected increase in average productivity should occur when the number of untrained pickers can be reduced.

Price of Trees and Stakes: Because expenses for trees and stakes becomes important when the number of trees per acre reaches 500 - 1000, the effect of price variation will be examined. The price per tree so far has been set at $1.25, and the price per stake at $1.00. A price level 50 percent higher and 50 percent lower is used for calculation of the production price (Table 14).

A 50 percent reduction in price of trees and stakes reduces production cost per bushel by only 1.0 cent for Orchard A, but the corresponding reduction is 18.0 cents for Orchard D with 870 trees per acre. At this price level the most densely planted orchard is competitive with the other planting systems. Production cost for D is only two cents above C, which again has the lowest production cost at a medium yield level. This reduction in cost is partly due to the reduced cost of trees and stakes directly, and partly to the reduced interest which is a substantial cost for Orchard D (Table 7).

Table 14. Production Cost Per Bushel With Varying Prices Of Trees and Stakes*: Medium Yield Level

Orchard	Price of trees and pillars		
	Trees $0.63 Stakes 0.50	Trees $1.25 Stakes 1.00	Trees $1.88 Stakes 1.50
A (41 trees)	1.27	1.28	1.29
B (87 trees)	1.18	1.20	1.22
C (370 trees)	1.09	1.19	1.30
D (870 trees)	1.11	1.29	1.48

* Stakes used only for Orchard C and D.

It should be mentioned that the lowest price level is still above the price used for trees and stakes in Holland (5). This may also explain why Dutch apple producers are not considering less than 500 - 600 trees per acre.

For a price level 50 percent above the original price, Orchard B gives the lowest production cost, and an orchard of type D becomes highly unfavorable.

There is discussion among apple growers and research workers concerning whether or not it is necessary to support each tree on a dwarfing rootstock with a stake. With at least 370 trees per acre (Orchard C) it may be possible for a weak-growing variety to use a dwarfing interstem without stakes. At a medium yield level this would mean a reduction in production cost of 8.1 cents per bushel. For Orchard D the cost of stakes means a cost of 14.0 cents per bushel at a medium yield level. However, with the presently used rootstocks and growing practices it is doubtful that anything but M IX can be used as a rootstock for 870 trees and more per acre. This implies also that a stake is necessary to secure satisfactory establishment of the trees in the orchard.

Fruit Quality and Prices: Most varieties of apples produce larger fruits on young trees. Because of better light condition, apples on small trees will also achieve a better color (17). According to the experience in Holland, the positive effect on fruit quality is one of the great advantages of trees on M IX, besides the dwarfing effect itself (5).

The same is also reported for M IX and M 26 from England (31). In a study of Cox's Orange, Jackson (19) compared large trees (7 - 8 meters crown spread) with small trees (3.5 - 4.0 meters crown spread) and found substantial differences in fruit size as well as color. The differences were found to favor small trees.

It is difficult to transcend these differences in qualities from one country to another and to get monetary expression for them. There will often be differences in varieties as well as grading, and it is also common to find discrepancy in consumer preference from one locality to another. It is obvious, however, that the value of a crop depends upon quality as well as quantity.

The apple price obtained during a shorter period of time at the Hudson Valley Sales is given for different qualities of two varieties which indicates clearly that there may be a substantial price gain from improved quality (Table 15).

Table 15. Effect of Fruit Quality on Apple Price
Hudson Valley Sales, New York, 1969

Grade	McIntosh*	Red Delicious**
	Dollars per carton - film bags 12 - 3 lb.	
U.S. Fancy	3.79	5.23
U.S. No. 1.	3.28	n.a.
U.S. Utility	1.95	2.41

* Average for March 10th to May 19th, 1969

** Average for March 10th to April 28th, 1969

Source: State of New York Department of Agriculture and Markets, Market News Service, Weekly Reports.

Fruit size has an effect on apple prices (Table 16). For Red Delicious there has been a gain of $0.56 per bushel by increasing fruit size from the 2 1/4" group to the 2 3/4" group. For Golden Delicious the gain has been $1.13 from the lower to the higher size group. The higher size group is from 2 1/2" and up in this case. These price differences should be related to previous calculations of profit per acre when the apple price is above production cost.

Table 16. Effect of Apple Size on Price: N.Y. Orchard Run, Hudson Valley Sales, New York 1968 - 1969

Fruit Size	Red Delicious*	Golden Delicious**
	Dollars per bushel	
Over 2 3/4"	6.06	n.a.
Over 2 1/2"	n.a.	4.56
Over 2 1/4"	5.50	3.43

* Average for April 1969

** Average for November 18th to December 16th, 1968

Source: State of New York Department of Agriculture and Markets, Market News Service, Weekly Reports.

Summary

This study was undertaken to examine the economical aspects of different orchard designs. Orchards with the following tree number per acre have been considered:

Orchard A:	41 trees
Orchard B:	87 trees
Orchard C:	370 trees
Orchard D:	870 trees
Orchard E:	1300 trees

Because yield records were not available in New York State for the most densely planted orchards considered, increase in yield up to full cropping was based on tree growth and distribution of light within the tree crown. The calculated "productive crown volume" was also, to some extent, used to compare the yielding capacity of the different orchards. It was found that productive crown volume at full tree size was approximately the same for Orchards A, B, and C. It is important to recognize, however, that it takes only nine years for Orchard C to reach full production, while it takes 20 years for Orchard A.

It was also calculated that productive crown volume per acre at full tree size can be increased from about 75,000 cubic feet to 102,500 cubic feet by decreasing the alley to five feet as assumed for Orchards D and E. This indicates a top yield of about 1,000 bushels per acre for Orchards D and E under circumstances where the other orchards would yield 750 bushels per acre.

Harvesting costs were based on hand picking and as long as this is necessary lower picking costs for the small trees will highly favor the new orchard design. Average picking cost for the whole trees' life was calculated to 33.6 cents per bushel for the traditional orchard (A), as compared to 29, 20 and 18 cents for Orchards B, C, and D, respectively.

Spraying cost was also estimated to be lower for the smaller trees because of less crown volume to spray per acre and because less spraying material would be wasted in orchards formed as hedges rather than individual trees.

The highest tree population will, on the other hand, have a substantially higher establishment cost because of the relatively high cost of apple trees in the United States. It was also assumed that it will be necessary to have a stake per tree for Orchards C, D, and E. The value of an acre of orchard (land not included) was calculated to be $791 in the last non-cropping year for 41 trees per acre. The corresponding value was $3,092 for 870 trees per acre.

For the most densely planted orchards, it is assumed that the dwarfing rootstock M IX should be used. This rootstock has also been tried in New York State, but has a reputation of being less resistant to frost damage than some of the other rootstocks. However, the greatest hardiness problem in New York State is usually caused by sudden drop in temperature early in the winter. Under these circumstances the rootstock's effect on the growth and maturity of the scion may be more important than the frost resistance of the rootstock itself.

Nevertheless, the larger proportion of young apple trees in an orchard with a rotation of about 20 years, will probably make the densely planted orchard a more risky business where winter damage is a problem since a higher establishment cost is involved per acre, and young apple trees are usually more susceptible to damage during the wintertime.

Production cost was calculated with an interest of eight percent on establishment costs. At a low yield level (top yield 500 bushels per acre of net orchard area) Orchard B had the lowest production cost. At a higher yield level Orchard C, with 370 trees per acre, was found to give the lowest production cost. Orchard A was found to be inferior to B under all conditions examined. Orchard E with 1300 trees was not thoroughly analyzed, but it will usually be inferior to Orchard D. The calculated differences in production costs were rather small, especially between Orchards B and C.

If recommendation should be based on the economic analysis in this preliminary study, several factors should be taken into consideration. Calculation of production costs indicates that less than 87 trees per acre should not be planted under any circumstances. At a medium to high yield level, 370 trees per acre has a slightly lower production cost. When differences in fruit quality are taken into account, Orchard C with 370 trees per acre will probably be close to the minimum number of apple trees that should be planted under any conditions.

When apple prices are expected to be well above production cost, the number of apple trees should be increased towards Orchard D with 870 trees per acre. This situation may occur when a scarce variety is planted, or when growing conditions and management are above average. This will also tend to increase yield and hence a positive difference between apple price and production cost can be anticipated.

Because a high interest rate of eight percent was used in the economic calculation, the establishment costs will be of great importance. By reducing the cost of trees and stakes by 50 percent, production cost was found to decline by one cent per bushel for Orchard A, but by as much as 18 cents for Orchard D. If Orchard C could be planted with the same result without stakes, it would mean a reduction in production cost by 8.1 cents per bushel at a medium yield level. This cost accounted for 13.8 cents per bushel for Orchard D.

Appendix

Table 1. Orchard A (41 Trees Per Acre). Yield, Annual Labor Requirement And Cost Per Acre Throughout the Orchard's Life of 35 Years*

Age of trees:	Year of Planting	2 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35
					Hours per acre			
1. Growing cost per acre								
A. LABOR (hrs.)								
Planting etc.	10	2	-	-	-	-	-	-
Pruning, removal	2	5	10	20	25	30	35	40
Spraying	2	2	4	5	5	5	5	5
Supervision	5	5	5	5	5	5	5	5
All other	5	5	8	10	10	10	10	10
Total hrs. of labor	24	19	27	40	45	50	55	60
					Dollars per acre			
B. EXPENSES								
Trees and pillars	51	6	-	-	-	-	-	-
Labor (from above)	48	38	54	80	90	100	110	120
Spray and dust	5	10	30	50	70	80	90	90
Machinery	10	5	10	20	30	40	40	40
Lime, fertilizer	5	5	10	10	10	10	10	10
Interest on real estate (land etc.)	50	50	50	50	50	50	50	50
Other expenses	8	8	10	10	10	10	10	10
Growing cost per acre	177	122	164	220	260	290	310	320
II. Harvesting cost per A.								
Picking	-	-	40	100	200	263	252	235
Other labor	-	-	14	34	62	75	72	67
Containers	-	-	12	28	50	60	58	54
Miscellaneous	-	-	6	14	25	29	29	27
Total harvesting cost	-	-	72	176	337	428	411	383
Total Cost (I + II)	177	122	236	396	597	718	721	703
Average yield in bushels per acre	-	-	140	340	620	750	720	670

* Averages given for columns where more than one year is included.

Table 2. Orchard B (87 Trees Per Acre). Yield, Annual Labor Requirement And Cost Per Acre Throughout the Orchard's Life of 30 Years*

Age of trees:	Year of Planting	2 - 4	5 - 10	11 - 15	16 - 20	21 - 25	26 - 30
				Hours per acre			
I. Growing cost per acre							
A. LABOR (hrs.)							
Planting etc.	18	4	-	-	-	-	-
Pruning, removal	3	5	15	25	30	30	35
Spraying	3	3	5	6	6	6	6
Supervision	5	5	5	5	5	5	5
All other	8	5	8	10	10	10	10
Total hrs. of labor	37	22	33	46	51	51	56
				Dollars per acre			
B. EXPENSES							
Trees and pillars	109	15	-	-	-	-	-
Labor (from above)	74	44	66	92	102	102	112
Spray and dust	10	20	40	60	70	80	80
Machinery	15	10	25	40	40	40	40
Lime, fertilizer	10	8	10	10	10	10	10
Interest on real estate (land etc.)	50	50	50	50	50	50	50
Other expenses	8	8	10	10	10	10	10
Growing cost per acre	276	155	201	262	282	292	302
II. Harvesting cost per A.							
Picking	-	-	50	154	225	219	204
Other labor	-	-	20	57	75	73	69
Container	-	-	16	46	60	58	54
Miscellaneous	-	-	8	23	30	29	27
Total harvesting cost	-	-	94	280	390	379	353
Total cost (I + II)	276	155	295	542	672	671	655
Average yield in bushels per acre	-	-	200	570	750	730	680

* Averages given for columns where more than one year is included.

Table 3. Orchard C (370 Trees Per Acre). Yield, Annual Labor Requirement And Cost Per Acre Throughout the Orchard's Life of 20 Years*

Age of trees:	Year of Planting	2 - 3	4 - 5	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	18 - 20
						Hours per acre				
I. Growing cost per acre										
A. LABOR (hrs.)										
Planting etc.	72	8	4	-	-	-	-	-	-	-
Pruning, removal	10	15	20	20	20	25	30	30	35	40
Spraying	5	6	8	10	10	10	10	10	10	10
Supervision	5	5	5	5	5	5	5	5	5	5
All other	10	10	10	10	10	10	10	10	10	10
Total hrs. of labor	102	44	47	45	50	50	55	55	60	65
						Dollars per acre				
B. EXPENSES										
Trees and pillars	833	50	25	-	-	-	-	-	-	-
Labor (from above)	204	88	94	90	100	100	110	110	120	130
Spray and dust	10	15	25	30	35	40	40	40	45	45
Machinery	20	10	30	35	40	40	40	40	40	40
Lime, fertilizer	10	10	10	10	10	10	10	10	10	10
Interest on real estate (land, etc.)	50	50	50	50	50	50	50	50	50	50
Other expenses	10	10	10	10	10	10	10	10	10	10
Growing cost per acre	1137	233	244	225	245	250	260	260	275	285
II. Harvesting cost per A.										
Picking	-	-	40	94	146	150	150	149	145	141
Other labor	-	-	18	47	73	75	75	75	73	70
Containers	-	-	14	38	58	60	60	60	58	56
Miscellaneous	-	-	7	19	29	30	30	30	29	28
Total Harvesting cost	-	-	79	198	306	315	315	314	305	295
Total cost (I + II)	1137	233	323	423	551	565	575	574	580	580
Average yield in bushels per acre	-	-	180	470	730	750	750	745	725	705

* Averages given for columns where more than one year is included.

Table 4. Orchard D (870 Trees Per Acre). Yield, Annual Labor Requirement And Cost Per Acre Throughout the Orchard's Life of 17 Years*

Age of trees:	Year of Planting	2	3	4 - 5	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17
						Hours per acre				
I. Growing cost per acre										
A. LABOR (hrs.)										
Planting etc.	150	17	17	8	-	-	-	-	-	-
Pruning, removal	20	30	30	30	30	40	45	50	55	55
Spraying	10	10	10	15	15	15	15	15	15	15
Supervision	7	7	7	7	7	7	7	7	7	7
All other	12	12	12	12	12	12	12	12	12	12
Total hrs. of labor	199	76	76	72	64	74	79	84	89	89
						Dollars per acre				
B. EXPENSES										
Trees and pillars	1958	120	120	50	-	-	-	-	-	-
Labor (from above)	398	152	152	144	128	148	158	168	178	178
Spray and dust	25	40	40	50	50	50	60	60	60	65
Machinery	30	25	25	40	40	40	40	40	40	40
Lime, fertilizer	10	10	10	10	10	10	10	10	10	10
Interest of real estate (land, etc.)	50	50	50	50	50	50	50	50	50	50
Other expenses	12	12	12	12	12	12	12	12	12	12
Growing cost per acre	2483	409	409	356	290	310	330	340	350	355
II. Harvesting cost per A.										
Picking	-	-	24	80	169	180	180	180	176	175
Other labor	-	-	12	44	94	100	100	100	98	97
Container	-	-	10	35	75	80	80	80	78	78
Miscellaneous	-	-	5	17	38	40	40	40	39	39
Total harvesting cost	-	-	51	176	376	400	400	400	391	389
Total cost (I + II)	2438	409	460	532	666	710	730	740	741	744
Average yield in bushels per acre	-	-	120	440	940	1000	1000	1000	980	970

* Averages given for columns where more than one year is included.

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