these conditions; we usually get a 95% take, or better, in our double-buds.

MODERATOR MELOTT: Are there any questions for Kent?

MR. DAVID A. LAWYER: Is Flemish Beauty pear satisfactory as a stock between Bartlett and quince?

MR. KENT BROOKS: We don't use it. We have used Hardy, but we prefer the Old Home on account of it's vigor. We think it does a better job of making a good compatible union.

MODERATOR MELOTT: The next speaker needs no introduction to this group. He's been around in horticultural circles for years and most of you know him much better than I. Dr. H. B. Tukey from Michigan State is going to talk to us on propagation of clonal apple rootstocks. May I present Dr. Tukey!

THE HISTORICAL BACKGROUND, THE DEVELOPMENT, AND THE PROPAGATION OF CLONAL APPLE ROOTSTOCKS IN AMERICA

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I have chosen to speak in general terms. You are fortunate in having horticultural experts in your midst, as well as able nurserymen and orchardists, who can give you detailed information on specific points for this region far better than I can do. But, perhaps looking in from the outside, I can point out the general features of clonal apple rootstocks and where they seem to me to fit.

Let us, then, consider three topics:

1. Why are we interested in clonal apple rootstocks?
2. What clonal apple rootstocks command our major interest and what do we know about these rootstocks?
3. How do we propagate clonal apple rootstocks?

Why Are We Interested In Clonal Apple Roostocks?

The tremendous interest in dwarfing rootstocks comes about because (a) we are historically due for the next step in the refinement of growing fruit, which is to adopt predictable clonal rootstocks to combine with our predictable scion varieties; and (b) we sense the solution to many of the modern problems of the fruit industry by the use of specific rootstocks, such as the East Malling and the Malling-Merton apple rootstocks.

The Historical Background

Centuries ago — in fact, only decades ago in some regions — fruit trees were propagated from seed. No two trees were alike. But we no longer raise our fruit orchards from seed. We have standardized on certain clonal scion varieties as the foundation of our industry, which are budded and grafted for uniformity of product. But the rootstocks upon which our scion varieties are propagated are seedling in nature and similarly present considerable variation.

The next step in development is, of course, to standardize the rootstock as well as the scion variety. Whether we use dwarfing rootstocks or not is beside the point — the important consideration is that we are ripe for uniform, reliable, clonal rootstocks upon which to bud and graft our selected, desired scion varieties. There are some in this room who will recall this sequence of events in the walnut industry. First, orchards consisted of seedling walnuts. Then came selected varieties, or clones, of walnut. We can observe the same sequence in the avocado industry. The next step will be clonal rootstocks.

In fact, propagation on special rootstocks has entered areas other than fruit production. Grafted tomato plants, cucumbers, melons, and other crops are becoming more and more common in vegetable production — watermelon on certain gourds, sugar melons on pumpkin, cucumber on gourds, and so on. It is all a part of the effort to control our situation. Tomatoes are grafted at the rate of 100 plants per hour, with 100 percent survival.

Man's Objective Is To Control His Environment.

Man must have seemed a very puny creature when he appeared among the great forces of nature. But he possessed the ability to adjust — either to adapt to his environment, or to change his environment. Little by little, he learned through the centuries to control fire, to provide shelter for himself, to clothe himself, to domesticate both plants and animals, and to provide a more reliable food supply.

The story of the development of power — water, coal, petroleum, electricity, atomic energy — together with refinements of agriculture, including plant breeding, insect and disease control, fertilizers and nutrition, cold storage, and transportation are the great stories of modern man. It is so commonplace that we fail to recognize the amazing achievements.

And, every time you look at this progress, you will find that it is an attempt to replace uncertainty with certainty, to provide warmth, to provide shelter against both cold and heat, to provide a constant food supply — cold storage, canning and freezing, and rapid transportation to bring food from all parts of the world. It is all, as I have said, a part of man's desire to adapt to his environment or control his environment.

Similarly, in fruit growing we have moved along these same lines and in the same direction. The trend is now towards specialization, refinement, automation, and the abundant use of cheap energy. We speak of biological engineering or horticultural engineering. Crops will be grown where they can be grown best, by men who can grow them best, and are transported widely. To be sure, there will always be a limited place for choice produce grown near to market for special purposes, but this will become the exception, and not the rule. Stoop labor is a thing of the past. Mechanical operations will rule — even the harvest. There are those who predict that the dairy cow will be as uncommon on farms within the next fifty years as the draft horse has become. This is the sort of overall thinking we must indulge in. It is into this kind of a world that fruit growing and dwarfing rootstocks must fit.

The Need To Solve Some Immediate Problems In The Fruit Industry.

Our sudden awareness of clonal rootstocks, especially dwarfing rootstocks, is due also to the fact that they suggest the solution to some of the pressing modern problems of the fruit industry. We demand still further control of our destiny in the fruit industry. We refuse to be subject to the whims of biennial bearing, drouth, pests, market gluts, labor shortages, and all the rest. We seek a regular, predictable, uniform supply of fruit of quality which can be economically grown, brought into early bearing, rotated to suit our needs, economically and easily sprayed, harvested, handled, and tailored to a consumer and a market demand which we intelligently command. In short, we demand compact trees and controlled production, and clonal rootstocks seem to suggest helpful possibilities.

Many of the solutions which we should like to attain, of course, may be realized in other ways than by the use of clonal rootstocks. Thus we can bring trees into early fruiting by the selection of early-fruiting varieties such as Gallia, Cortland, and the spur-type trees. Or, we can aid by low-heading, good cultural practices, little pruning, bending, root pruning, scoring and the like. Much of this we know. Or we can combine these factors with the rootstock opportunity. Much of this lies with the choice and the capacity of the individual.

But it is to the rootstock that many are turning for the greatest help in solving these immediate problems.

What Clonal Apple Rootstocks Command Our Major Interest And What Do We Know About These Rootstocks?

What do we know about the Malling and Malling-Merton rootstocks? Where did they come from? How should we use them? At the risk of repetition, let me trace briefly the story of dwarfing rootstocks.

In the first place many of them are very old. Some people think of them as something quite new, but they really are not. In fact, Alexander the Great, three centuries before Christ, sent back dwarfing apple rootstocks to Greece from his conquests of Asia. The name "Paradise" which has been given to one group of dwarfing rootstocks is suggestive of Persia and the Garden of Eden.

These dwarfing rootstocks down through the centuries increased in form and variety, and were broadly divided into the (a) "Paradise" rootstocks which were characteristically hairyrooted, and usually severely dwarfing, and (b) "Doucin" rootstocks which were characteristically straight-rooted and usually semi-dwarfing.

Further, centers of the nursery industry, or of fruit production, tended to pick up or select certain rootstocks which were preferred locally, and known by local names of descriptive terms, such as "French Paradise," "English Paradise," "Hollyleaf," "Jaune de Metz," "Holstein Doucin," "Ketziner's Ideal," and so on. As transportation and communication increased, notably prior to the nineteenth century, these rootstocks became spread around and mixed. Much dissatisfaction arose because of the misnaming, lack of uniformity, and unpredictability of performance, just as scion varieties of fruits were widely mixed, and confused a half century ago.

From time to time, horticulturists attempted to clear up and standardize these rootstocks, but with not very great success. But about 1912, or 1913, another attempt was made at the East Malling Research Station, Kent, in England. The leader was Wellington, who was Director of the Station, and who brought together clonal apple rootstocks from many sources in England and from the Continent. The First World War then intervened, Wellington answered the call of his country, and the work was left in the hands of his assistant, Ronald Hatton.

Through careful study, Hatton, later Director Hatton, and, still later, Sir Ronald Hatton — still living — rogued out and standardized sixteen lines of apple rootstocks from among the many rootstocks he had secured. These he numbered with Roman numerals and introduced to the world as "true-to-name." They were called the East Malling apple rootstocks, as "East Malling I," "East Malling II," and so on, later abbreviated to "EM I," "EM II," and so on. The sixteen individual rootstocks can be found fully described and pictured in the literature, and will not be detailed here.

Some of the rootstocks were found to be very dwarfing. Some were less dwarfing, some were not dwarfing at all. In short, here were sixteen standardized scion varieties, representing considerable range in dwarfing and in general performance in both nursery and orchard.

At about this same time, fruit growers of Australia, and New Zealand were being plagued with woolly aphis on the roots of apple trees. The East Malling rootstocks were not immune; in fact, many of them were quite susceptable to attack. The Northern Spy apple was relatively resistant but it made poor rootstock material for other reasons.

To meet this situation an attempt was made in England, as a British Commonwealth service, to breed apple rootstocks which were resistant to woolly aphis. Crosses were made between the East Malling rootstocks and the Northern Spy apple. The work was done jointly by the East Malling Research Station and the John Innes Research Station at Merton, England. From this came eleven numbered apple rootstocks, fairly resistant to woolly aphis ,and which have been called "Malling-Merton" from their origin. These were numbered in Arabic, beginning with 101 through 111, and designated "Malling-Merton 101," Malling-Merton 102," and so on, abbreviated to "MM 101," "MM 102," and so on. In trials these were found, like their predecessors (the EM rootstocks) to represent various degrees of dwarfing and specific characteristics of nursery and orchard performance.

The list of standardized East Malling materials has subsequently been raised to twenty-six, and there are additional interesting clonal materials from other sources as A2 from Alnarp, Sweden, and Robusta 5 from Canada. As time goes on, we may expect additional rootstock materials from other parts of the world. It is thoroughly likely that there will be clonal rootstock materials developed here in the Pacific Northwest. I would urge you to make the effort. You could quickly assume a commanding lead.

And, so we do know considerable about these clonal apple rootstocks, although we have a great deal more to learn. But we have enough information about them to operate upon — perhaps not with final perfection, but at least with a fair degree of security. There will always be improvements. If one waits until all the answers are in, he will not live to attempt much in life. There is always the calculated risk in everything one undertakes.

Not only do we know that some of these rootstocks are very old, but we know that they have been widely used in Europe for a considerable time with a reasonably good record of performance.We know that in some areas of Europe essentially all fruit trees are grown on clonal rootstocks. We know also that some of these rootstocks are undesirable so that some have been discarded for the time being. Thus we confine our efforts to EM I, II, IV, VII, IX, XIII, XVI, XXV, and 26, and to MM 104, 106, 109, and 111. To this may be added A2 and Robusta 5.

Our first concern, perhaps, is in the degree of dwarfing or size control that each rootstock offers. This we understand in general terms, and we may divide them into the following five classes:

Class A—Very dwarf—EM IX
Class B—Dwarf—EM 26
Class C—Semi-dwarf or medium dwarf—EM VII, MM 106
Class D—Medium vigor—EM IV, MM 111
Class E—Vigorous—EM I, II, XIII, MM 104, A2
Class F—Very vigorous—EM XVI, XXV, MM 109

For simplicity, the general size relationship is EM IX, EM 26, EM VII, MM 106, EM IV, MM 111, EM II, EM I, EM XIII, MM 104, A2, EM XVI, MM 109, EM XXV.

But, it is not alone the degree of dwarfing which attracts us. Each rootstock is different from the others in many specific characters, just as the Delicious apple is different from the

Rome, the Jonathan, or the Winesap. This is a very great asset to our industry. It means that we have the opportunity to choose rootstocks for qualities beyond dwarfing.

Thus, the Malling-Merton rootstocks are resistant to woolly aphis, as already mentioned. EM I seems susceptible to collar rot, although I have never been satisfied that collar rot was not secondary, following winter injury at the crown. The matter of maturity at the crown is something we have not fully recognized. There is a disposition at the moment to set the union of dwarfed trees several inches above the ground so as to avoid scion rooting. I am suspicious that in some season we may see severe damage from an early fall freeze. One must choose between the chances of scion rooting and this kind of injury. Certainly, I have seen, vigorous trees destroyed by cold injury at an immature union. I have seen, for example, double-worked trees destroyed by complete killing at the unions just above and below the intermediate stem-piece. Every other part of tree — scion, rootstock, and intermediate stem-piece — was uninjured.

To continue. some rootstocks, as EM I. will accept cool, moist, relatively heavy soil, are susceptible to drouth, and are good for weak-growing varieties. EM II is better on light soils. EM XIII and XVI will also tolerate wet, heavy soils. EM 26, which is intermediate in size between EM IX and VII, is better anchored than EM IX; EM VII seems to have a wide adaptation; MM 104 is slightly larger than EM II, prefers light, well-drained soil, and is resistant to collar rot; MM 106 is not unlike EM VII but has better anchorage, suckers less, and is adapted to heavy soils; MM 109 is as large or larger than EM XVI but is suited to dry soils; MM 111 is about the size of EM II and will stand drouthy conditions.

Some rootstocks bring trees into bearing considerably earlier than others, as EM IX, whereas others are later, as EM XIII. Although the most dwarfing rootstocks are associated with early fruiting, and the most vigorous rootstocks with late fruiting, this is not a reliable rule. The EM IV, which produces a semi-dwarf tree will induce fruiting earlier than other trees the same sze on EM II.

The top-root ratio varies with the rootstocks. EM IV induces a vigorous early-fruiting top which inclines towards leaning and blowing over without support. Allowing for this, EM IV is an excellent rootstock and one that might do well in the Pacific Northwest. Some rootstocks require support, as EM IX, whereas other do not, as EM XVI.

Further, the scion variety has a direct relation to the success of a rootstock. Generally speaking, the more vigorous scion varieties are best on the more dwarfing rootstocks, and vice-versa. Thus, when Gallia is placed on EM IX, it is so weak and so early-fruiting that it virtually gets down on it's knees. On the other hand, Northern Spy, which is a vigorous, notoriously late bearer is excellent on EM IX. Each stock-scion combination must be evaluated as a different individual. We cannot speak about the rootstock without knowing the scion variety.

Still further, the performance of each scion variety varies with the length of the growing season and the general climate and cultural conditions provided. Combinations with EM IX (very dwarf), for example, may be insufficiently vigorous for northern regions, as British Columbia, but will be well adapted to the states of Washington and Oregon. Conversely, EM II may be too vigorous for Washington and Oregon and yet just right for British Columbia.

When I was in Angers, France, a few years ago, I was impressed by the La Page system of growing trees on trellises, in which the trees are set as yearling slips at a 45-degree angle. Branches are developed outward and upward at a 90-degree angle with the main stem. Enough shoot growth is made in one season ,using the EM IX rootstock, to fill the trellis with fruiting wood. But when I tried this at East Lansing, Michigan, with our short season, it took three years to attain the same growth.

Some rootstocks, as the EM IX, induce blossoming a week to 10 days early in spring, with accompanying earlier fall harvest.This may be an advantage or a liability, depending on circumstances. Low-growing trees may lose an entire fruit crop from spring frost, while taller trees may safely carry fruit in their tops. Wind damage may be severe in more widely spaced trees, but almost absent in a close planting of dwarfed trees.

The efficiency of the scion variety is altered by the rootstock on which it is growing. Dr. Al Roberts at Oregon State University has shown you the concept of tree-unit efficiency. Some stock-scion combinations produce more wood in proportion to fruit than do others, while some produce more fruit in proportion to wood. Golden Delicious and Rome have generally high tree-unit efficiency, but Golden Delicious has proved especially efficient on EM I and EM VI at Corvallis. Not one rootstock can be used universally — each has its favorite consorting variety for efficiency of production and performance. Trees on seedling roots are generally less efficient.

As a general rule, trees on the dwarfing rootstocks cannot be left to shift for themselves. They represent a refinement in horticulture, and they succeeded best in the hands of men who have the knack of growing good trees.

These, then are some of the problems we face. And the answers will come largely from the cut-and-try method which is often so disappointing, but also often so surprisingly satisfying. We are in an era of grower experimentation, and progress will depend upon meetings like this of the Plant Propagators' Society and meetings like those of the Northwest Dwarf Tree Association, where experiences of practical men are dove-tailed with the results of the scientist.

At all events, I am sure that the final results will show a degree of specificity that many of us may have failed to recognize. I feel sure that our answers will not be in broad, easy, generalities, but in the more narrow, more difficult, specifics of detail involving various combnations of rootstock, scion, and environment

How Do We Propagate Clonal Apple Rootstocks?

Now, how do we propagate the clonal apple rootstocks of our selection and for which we have demand? Each clone, just like each scion variety of fruit, has certain special characteristics which can be taken advantage of or which must be catered to. However, all of the common methods of propagation find a place, as propagation by hardwood cuttings, root cuttings, softwood cuttings, leaf-bud cuttings, mound layering, trench layering, nurse-root grafting, and double-working.

We should remember that the clonal rootstocks which we are discussing are characterized by their ability to regenerate roots. In fact, this ease of rooting carries over into the orchard, so that the stand of trees in a new orchard planting is proportionally much higher than with seedling roots. This is another good feature of clonal rootstocks. And so, we are beginning with material that is especially suited to propagation. The Malling-Merton rootstocks behave especially well in the nursery and are well liked by nurserymen.

Propagation By Hardwood Cuttings.

Hardwood cuttings are made from mature, dormant shoots. Of the three forms of cuttings (hardwood, root, and softwood), hardwood cuttings are the most readily procured and most easily handled. The land area occupied is less than for layering, and the attention required is less than for layering or for either softwood or root cuttings. Unfortunately, convenience and economy are offset by the fact that only a few of the desired rootstocks will produce roots readily from hardwood cuttings. However, these that will propagate by this method produce excellent rooted material very economically.

Next to the inherent nature of the plant material itself, the most important factors are friable soil, adequate moisture, and equable climate, and a relatively long growing season. In the United States, these conditions are generally better provided in the South and in the Pacific Northwest than in the North and Northeast.

Dormant, moderately vigorous shoots of the current season's growth (one-year-old wood) supply the material for hardwood cuttings. It is best to establish a row of a plantation especially for a supply of wood. In regions where winter cold is not severe, another source of material is the tops of budded, lining-out stock. The best tops are those which have made a vigorous growth in the nursery row and which have sent out vigorous lateral shoots. These laterals may be torn from the main stem and used as cuttings, and the main stem discarded. The tops should be cut at least 6 inches above the bud, and should be collected as late in the season as possible, yet before severe freezing weather has set in.

Perhaps the best source of wood is from stoolbeds which have been established for layering. When the bed has been harvested for rooted shoots in the fall of the year there will always be some shoots which are either sparsely rooted or not rooted at all. The bases of these shoots have probably been covered somewhat with soil so that the formation of root primordia has been induced. Cuttings of this type will root almost 100 percent. In fact, it is in this way that the hardwood cutting method is most useful for some of the Malling apple rootstocks; namely, as a supplement to layering.

Wood should be collected as late in the fall as possible, but before a severe freeze has occurred. Quince cuttings made from wood collected in November rooted 82.94 percent in one season, compared with only 2.74 percent for quince wood collected in March of the following year.

Cuttings should be stored for several weeks at temperatures of 60 to 70 degrees F., where they will form callus tissue over the base, and then be transferred to cool temperatures (32-35 degrees F.) to hold for spring planting. Many cuttings will initiate roots by spring. In fact, if the storage period is thought of as a period of root formation and if favorable conditions are provided, a good percentage of well-started cuttings will be secured by planting time. Even the apple, EM II, which does not root readily from hardwood cuttings, has given 100 percent rooting of basal cuttings when packed in damp sawdust at 38 to 40 degrees F. for three months.

In the spring, as early as possible, the cuttings are planted 2 or 3 inches apart in rows 18 inches apart, and placed so that the top will be about 2 inches above the soil level. Time of planting is important In mild sections, as in England or on the Pacific Coast of America, fall planting or mid-winter planting is ideal, the planting being done shortly after the cuttings are made.

If planting is done by hand, a good practice is to make a trench with one vertical side, against which the cuttings are placed. A little sharp sand or peat moss may then be thrown against the base of the cuttings and the soil drawn up over them. Excellent results have been secured by the use of peat moss in this way on soil which might otherwise have been too heavy for hardwood cuttings.

Propagation By Root Cuttings.

Propagation by root cuttings consists in planting small pieces of dormant roots upright in the soil; they then develop adventitious shoots from the upper end and roots from the lower end. This method is particularly useful where there is a shortage of plant material. Handling is not unlike that for hardwood cuttings, and the percentage of usable rooted shoots is high.

Roots should be selected which are about the size of a lead pencil — $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter — and cut into pieces 3 inches in length. Sections as short as 1 inch may be used, and even material slightly under $\frac{1}{4}$ inch diameter is useful.

The cuttings are bundled and buried until planting time in damp sand or peat moss in a nursery cellar or some similar location at a temperture of 36 to 38 degrees F., where they will not freeze. In the spring they are planted as early as possible, as with the hardwood cuttings, planting the root pieces firmly 2 to 3 inches apart in rows 18 inches apart. The procedure is essentially the same as with hardwood cuttings excepting that the root pieces are smaller and more delicate, and require a more intensive operation. Small beds or cold frames are good. Supplemental irrigation is useful. A 2 inch top dressing of peat moss, sand, sawdust, or light soil which does not bake and crust-over is almost a requirement so as to permit easy emergence of shoots, especially on heavy soils.

As an emergency measure, root cuttings have been made the last of February in the greenhouse, kept cool (60 degrees F.) for a week or 10 days, and then pushed at 70 degrees F. Nearly 100 percent rooting has been secured in this manner with root cuttings of apple EM I, II, IV, V, and IX. Other types could probably be rooted similarly.

The rooted plants were transplanted to the field in mid-May, and were large enough to be budded in August.

Propagation By Softwood Cuttings.

Softwood cuttings are made from immature or growing shoots with leaves attached. They are more difficult to handle than either hardwood cuttings or root cuttings. The introduction of intermittent mist propagation has greatly increased the usefulness of the method. Plants that are difficult to propagate by other means will usually respond to this method.

Wood is selected from vigorously growing plants, as from lining-out stock or stoolbeds. The wood must be just mature enough and stiff enough so it offers resistance to the thumb at the tip when the shoot is held in the fist and the tip bent by pressure from the thumb. This condition is usually reached in late June and early July.

All of the Malling rootstocks can be propagated in this way, although the same types which propagate most easily by mound-layering and from hardwood cuttings, also propagate most easily from softwood cuttings. Since nutrients are leached from the leaves by misting, small amount of nutrients can be supplied in the mist. Olives are propagated commercially very successfully under glass in California and in Italy by this method, and the apple rootstock A2 has been propagated similarly in Sweden. If plants are propagated in March in the greenhouse from potted mother plants brought inside in January and forced, the rooted plants may be transplanted to the field and budded the same season.

Propagation By Layering.

Layering consists of establishing a plantation of the desired rootstocks, and inducing new shoots to develop and root each season while still attached to the mother plant. The rooted shoots are cut from the mother plant each fall, and a new crop induced to arise each successive year.

There are two principal variations of layering used for the commercial production of clonal apple rootstocks, namely (a) mound layering, or stooling and (b) trench layering, or etiolation.

In *mound layering,* the mother plant is maintained as a closely cropped crown from which new shoots arise each year, as with gooseberry and currant bushes. The operation consists in cutting back a well-established and permanent "mother plant," or stool, during the dormant season to about soil level, so that in spring a number of shoots arise from the crown of the mother plant. By mounding with soil, these shoots are induced to form roots along 2 to 4 inches of their growth at the base. They are removed at the completion of the growing season and the entire process is repeated the next year. This method is especially well suited to the less vigorous clonal apple rootstocks, such as EM IX, and to those having a large number of growing points, as EM III, IV, V, VI, and VIII. It has also been used successfully for EM I, II, VII, X, XII, XIII, XVI, and MM 101, 104, 106, 109, and 111. There is no reason to believe that others of these types will not behave similarly.

A level site, in a sheltered location, well-drained, should be selected for the stoolblock. A friable loam soil of good fertility, which will not dry out, is important. The incorporation of peat moss into the stoolblock will improve the physical condition of the soil and assist in the mounding operation.

Well-rooted, No. 1 grade, lining-out stock is best for planting. The plants may be set upright 12 inches apart in rows 7 to 8 feet apart. It is a good plan to set the original plants in a shallow trench 2 inches below the ground level so as to help keep the crown low in the soil.

During the first growing season, the block should be cultivated and cared for so as to encourage vigorous growth and ensure a well-established mother plantation from which, in subsequent years, a good yield of rooted shoots may be cut.

Early the next spring, before growth has begun, the soil should be pulled away from the plants and the tops cut back to about an inch above the crown. Cutting at this height helps, again, to maintain the plants low in the soil so the mounding operation is more easily accomplished.

From the exposed crowns new shoots develop. When they have reached a height of 4 to 6 inches, soil is mounded up to and between them to half their height. When the shoots have reached 8 inches, more soil is again added, and the process repeated during the season once or twice more until the shoots are covered to a depth of 8 to 10 inches, or more.

Stoolblocks may be maintained in a profitable condition for a number of years. Thirty or forty years is not uncommon. They do require, however, the liberal use of fertilizer and of materials which will keep the soil friable and in good physical condition.

Diseases and insects are troublesome but controllable. Leafhoppers and aphids can get out of hand if not sprayed. Woolly aphid has been found on EM I, IV, VII, and I but less on EM II, XII, XIII. and XVI. This pest can be controlled with chlordane and aldrin. Crown gall has been troublesome at times on EM VII and IX, but has been controlled commercially by persistant rogueing of infested plants.

In the fall of the year the mounds are pulled down and the rooted shoots cut or torn from the mother plants. Some apple clones mature earlier than others. Harvesting should not be done until the leaves show a yellowish cast. Much rooting occurs late in the fall. EM I matures early followed by EM IV, VII, and XIII. EM XVI and, especially, EM XII, matures late, and may even, of necessity, in cold regions be left unharvested until the following spring.

Yield of rooted shoots varies per plant with the material. EM I, IV, VII, IX, and XIII apple rootstocks will produce more shoots than EM II and XII. MM 104, 106, 109, and 111 have rooted exceptionally well; namely, 16, 10, 20, and 19 shoots per plant respectively, averaging 85 to 100 percent rooting. Records in New York State show yields of 68,230 rooted shoots per acre for 20-year-old stoolblocks of EM IX; 45,070 of EM VII; 21,750 of EM II; 48,460 of EM I; and 47,500 of EM XIII.

Propagation by mound-layering is most successful in areas of equable climate, with neither extremes of winter cold nor summer heat and drought, and with either a minimum of two or three inches of rainfall during the summer months or with standby irrigation available.

In addition, the growing season must be sufficiently long to permit the shoots to root, as well as to provide an open period of weather adapted to harvesting the rooted shoots and carrying on the operations necessary to put the stoolblock into a good condition for winter. It is a common and disappointing experience to examine a stoolblock in late September or early October, and find very few roots formed on the shoots arising from the mother plant. It is then just as common, but a more satisfying experience, to examine the stoolblock two to four weeks later and find excellent rooting.

The place in America most similar to the above-mentioned climatic conditions is along the Pacific Coast, west of the Cascade Mountains, in northwestern United States and southwestern Canada — in Oregon, Washington, and British Columbia.

It would seem that these are the areas in which large commercial enterprises must eventually be developed to meet the demand for clonal dwarfing rootstocks.

Propagation by *trench layering* differs from propagation by mounding in that instead of the new shoots arising from the crown of the mother plant, they come from arms of the mother plant which have been laid in the row in a horizontal position. In addition, the plants are covered with an inch or so of light friable soil before bud break in early spring so as to prevent — for a time — light from reaching the young shoots. The method is especially useful for materials which do not root readily from cuttings, mounds, root cuttings, or hardwood cuttings.

It is noticeable that trench-layering is usually abandoned by nurserymen when sufficient planting stock is available to permit close planting and propagation by mounding. Extra labor is required for pinning the plants down. Perhaps more decisive, horizontal shoots or arms which develop from the mother plant become large, extensive, and lie close to the surface of the ground. They are thus poorly protected against winter cold and they are often caught by cultivating tools and ripped out, making great gaps in the block and causing considerable damage to the plantation.

Propagation By The Nurse-Root Method.

Another method of increasing rootstocks, especially those which are difficult to raise by hardwood cuttings, is by the use of nurse-roots. This method consists in grafting a dormant scion of the desired rootstock onto a short piece of some available root. The grafted combination is set deep to induce scion rooting, and the piece of root serves to sustain the scion until that is accomplished.

The grafts are handled as any other grafts, or like hardwood cuttings. At the end of the growing season, the grafts are dug, the seedling root is cut off, and the rooted scions are graded and stored for spring planting as lining-out stock. An improvement in the method is to tie a thin copper wire, such as used for nursery labels, tightly around the graft at the union. As the grafts grows, the wire tends to girdle the root-piece and promote scion rooting. Forty-one to seventy-six percent rooting of Malling apple rootstocks has been secured by this method. In about half the cases, the wire had cut off the nurse-root. With the others it was necessary to snip off the nurse-root.

The Trees In The Nursery.

The handling and performance of trees propagated as clonal rootstocks is essentially the same as for similar operations with seedling rootstocks. One difference is, however, in the height of budding. In the propagation of standard trees, the bud is placed about two inches above the collar of the rootstock. For clonal apple trees, the trend has been to place the buds an inch or two higher (three to four inches above the collar) so as to reduce the chances of scion rooting when the trees ar planted in the orchard. In fact, the bud may be placed six or seven inches above the collar or about four to five inches higher than usual for standard trees.

Some nurserymen regularly bud dwarfed apple trees as high as eight inches, so as to provide a stem-piece of rootstock which is twelve or more inches in length. This permits deep planting in the orchard and has been shown to give better anchorage for the first few years for trees that are inclined to lean. New roots arise from the stem-piece to provide better bracing. High budding can be used to advantage also with varieties of apple which are susceptible to collar rot. The Coxe's Orange Pippin apple is, for example, subject to this disease, whereas the following rootstocks are resistant, namely EM IX, VII, II, and XXV, and MM 104, 106, and 111. Coxe has been successfully budded on these rootstocks at a height of 12 inches above the ground line. The trees have been satisfactory in the nursery, and have performed well in the orchard.

Double-Working.

Double-working, as the name implies, involves more than a single union between two consorting parts. It has been used to produce a dwarfed tree by placing an intermediate stem-piece of dwarfing material between a rootstock and the scion, as with the so-called Clark Dwarf. It may be accomplished by making a double-graft during the dormant season, by combining budding and grafting, or by budding during two seasons.

In the case of double-grafting, a 3 to 3½-inch piece-root from a straight-root seedling is grafted with a 6-inch stem-piece of the material desired for the intermediate, as EM IX, VII, Clark Dwarf, A2, K41, and so on. Onto this, the scion variety is grafted, and the entire combination is handled as a hardwood cutting or as a bench graft.

If the procedure is by grafting and budding, a dormant graft is made in winter, composed of a 5-inch piece of dwarfing interstock, as Clark Dwarf or EM IX, whip-grafted onto either a seedling or a clonal rootstock. The graft is lined-out in the spring and budded with the desired scion variety.

If the method is to be by budding alone, the desired rootstock, material is lined-out in the nursery. This may be a seedling rootstock, as a French Crab or Delicious seedling, or it may be a clonal rootstock, as EM XVI. Budding is done as for standard trees, the bud of the dwarfing intermediate being placed about 2 inches above the ground line.

The next season, the top of the rootstock is cut off just above the bud, forcing the development of a shoot from the dwarfing intermediate material. This, in turn, is budded during the summer with the chosen scion variety at a height on the intermediate which will provide a 2 to 3 inch length of stem-piece in the finished tree.

The third season, the top of the intermediate is cut off so as to force the scion variety to develop as a strong budling. The tree is thus composed of a scion variety and a rootstock, between which is interposed, just above the crown, a 2 to 4-inch section of dwarfing stock.

Another double-working technique is double-shield budding. It consists of placing one bud-shield upon another so that they unite with the rootstock as well as each other, and so form a three-tier tree in one budding operation. The intermediate tier may be a dwarfing rootstock so that a dwarfed tree is formed by the introduction of the stem-piece of this material.

This operation is essentially the same as for shield budding. However, the T-shaped incision must be sufficiently large to accommodate the two buds, one upon the other. A small budless shield is cut from the plant material which is to supply the intermediate. It is prepared in such a way that a portion of the bark of the shield is removed from the top side, thus exposing the cambium on both the inner and the outer sides of the shield. The shield is slipped well down into the bottom of the T-shaped incision. Then a bud-shield of the chosen scion variety is cut from the budstick and inserted in the T-shaped incision in such a manner that it rests not upon the stock but upon the outer exposed cut section of the budless shield. With a good season and good technique, a double-worked tree will be formed which is approximately the same height as a single-budded tree — all in one season.

A modification of this technique was proposed by F. Nicolin of Germany, about 1953. The method has assumed the name, "Nicolieren," after its originator. A budless shield is taken from a stem of the interstock material as described in the paragraph above. However, care is taken to take a thin strip of bark from the outer face of the shield. This exposes an oval ring of cambium on the outer face of the shield. The budless shield is then slipped into the T-shaped incision. Then the shield-bud of the chosen scion variety is similarly slipped into the incision but on top of the prepared budless sheild. Here again, the budless shield unites with the stock as well as with the scion bud. The next year. a tree forms from the double-budding combination which consists of the rootstock, a short intermediate stem-piece, and the scion variety.

Summary and Conclusions.

1. The apple industry of America has reached the age in development where the refinement is desired which clonal rootstocks offer.

2. The clonal apple rootstocks which are available provide a range of control of orchard performance demanded by modern orcharding, including the need for early cropping. high acre-yields, economical spraying, pruning, harvesting and general management, and adaptation to specific local conditions.

3. The use of clonal rootstocks increases rather than de-

creases the competitive problems of orcharding just as the refinement of any operation demands a perfection of fit which a more gross operation does not require.

4. The clonal apple rootstocks under special consideration at this time are: EM I, II, IV, VII, IX, XIII, XVI, XXV, and 26; MM 104, 106, 109 and 111; and perhaps A2 and Robusta 5. Each has it's special characteristics, it's advantages and disadvantages, quite aside from various degrees of size control and fruiting yields.

5. Generalizations are dangerous. Each stock-scion combination must be considered as a special entity, and each must be considered also in relation to the soil, climate, management procedures, and general environment in which it is to be placed.

6. Clonal apple rootstocks may be propagated in a variety of ways, depending upon the facilities available, the environment, the nature of the particular rootstock, and the special needs for which the rootstock is being propagated. Double-working, involving the use of a dwarfing intermediate stem-piece is another method of developing size-controlled fruit trees, employing clonal material.

7. Clonal rootstocks are with us to stay, from which the industry will not turn back, but will move steadily towards even greater refinement and exactness in predictability and controlled orchard performance.

8. The Pacific Northwest is well suited to the propagation of both clonal fruit tree sootstocks and fruit trees on clonal roots, and is in a position, with proper leadership, certification, cooperation, and organization to play a most important role, if not to dominate, the production of clonal apple rootstocks in America.

MODERATOR MELOTT: Are there any questions for Dr. Tukey?

MR. ARNESON: I would like to ask what Dr. Tukey thinks of the future for Malling-Merton 109?

DR. TUKEY: Well, 109 is a large tree. It propagates well. It has a place. I wouldn't predict anymore than that at the moment. Our thinking is in terms of smaller trees, so I would not be too sure about MM 109. In some places ,yes I am sure; but we are looking for things smaller than 109.

MR. ARNESON: How about E.M. 25 and E.M. XVI?

DR. TUKEY: Well, XVI also makes a big tree. That is one of those old Spaeth rootstocks from Germany — very, very old; it is called E.M. XVI now. It is marvelous over on the Continent where they want a bigger tree that is well rooted. It is a good cropper. They like it pretty well in some areas. I think that it has a place; they talk of it as a standard full-grown tree, but I agree with you that XVI would get to be a pretty big tree, so I wouldn't think there would be too much demand for this as a dwarfing stock.

MODERATOR MELOTT: Dr. Mel Westwood of Oregon State University is going to talk on hardwood pear cutting propagation. I give you Dr. Westwood!

DR. MEL WESTWOOD: Before getting into my prepared talk, I would like to give a little background on the Old Home pear. In 1915 before Professor R. C. Riemer made his extensive exploration trips to China, Japan, and Korea to search for blight-resistant pear rootstock materials from those areas, where many species grow wild, he went to the eastern and mid-western United States in search of blight-resistant pears which could be used for frame stocks in the West to protect the main body of pear against that devastating disease. He found an amateur gardener at Farmingdale, Illinois, who had in his backyard a number of pear trees, among which were the Old Home pear and the Farmingdale pear. At that time, in 1915, Professor Riemer collected cuttings from this small planting of Mr. Benjamin Buckman and brought these cuttings of Old Home to Oregon where he grafted them to a seedling rootstock at the Medford Experiment Station. He tested this for blight and he had selected it because it had shown no blight in an area where most of this gentleman's trees were dying from fire blight. He found that it was a French type, very highly resistant to fire blight. It was a very vigorous grower as a trunk stock. It made very wide angle crotches, a very desirably-shaped tree on which one could topwork or scaffold-work the variety, such as Bartlett, and have a very productive tree in which the body stock was protected against fire blight. In 1921, with some reluctance, Mr. Buckman sent Professor Reimer the Farmingdale variety, and as far as we know some time shortly after that Mr. Buckman died and his heirs rooted out his little collection of trees. As far as we know, and someone may want to correct me on this, there was no other budwood of those two varieties taken by any research person, and ultimately then many people went to Professor Reimer at the Oregon Agricultural Experiment Station to get their supply of Old Home or Farmingdale budwood from which to make their blight-resistant body stocks. Subsequent to the time when both of these types were obtained, Professor Reimer made crosses of Old Home by Farmingdale and collected the seeds and found that from 90 to 97% of the seedlings of these crosses were also highly resistant to fire blight and, in general, compatible as seedlings with the major pear varieties that we were growing. So then there came along in the late forties in British Columbia, in the fifties in Washington, in the late fifties and early sixties in Oregon and now in California, a devastating new disease called pear decline. In a search for something which would give us a resistance or tolerance to the disease which was learned to be a rootstock-induced disorder, it was learned that Old Home trees, that is trees with Old Home trunks which had been planted many years ago for blight resistance, had in many cases rooted-off above the union so that the trees were double-rooted.

They had roots of Old Home and they had roots of the original seedling; where trees were well-rooted above the union there appeared to be a tolerance to this disorder, pear decline. The trees were healthy, where those — in many cases — on susceptible rootstocks, where no rooting of the Old Home had occurred, the trees were dying. That leads us then to the topic of how to get production of rooted cuttings or vegetative propagation of a rootstock which is highly resistant to pear decline and which also has other desirable characteristics.

PROPAGATION OF HARDWOOD PEAR CUTTINGS

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and
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Old Home pear (*Pyrus communis*) has been used for about 40 years as a blight-resistant trunkstock and as a compatible interstock for quince. If the graft-union is placed below ground, the Old Home stem will root above the union. Such trees, with a predominance of Old Home scion roots, are resistant to pear decline disease, a disorder which causes tissue injury at the union when the rootstock is a susceptible type. Seedlings of domestic and imported French pear (*P. communis*) and those of *P. calleryana* are more or less resistant to decline. However, 10 to 20 percent of the seedlings will be susceptible and are thus unsatisfactory. Trees propagated on self-rooted Old Home or self-rooted varieties do not develop decline and are thus superior in that respect.

In 1958, Dr. H. T. Hartmann and Prof. C. J. Hansen at the University of California, Davis, reported that cuttings of Old Home rooted quite well if taken in November, the bases soaked 24 hours in 200 ppm indolebutyric acid (IBA), callused in moist peat for 4 weeks at 65° F., then planted immediately in the nursery. But, if after callusing, the cuttings were stored for 10 weeks at 40° F. before planting, only about 1/3 as many survived. Further work by Hartmann and co-workers indicated that late October was the best time to collect Old Home cuttings for rooting, and that 100 ppm IBA soak was better than 200 ppm.

Extensive tests have been made in Oregon during the past 4 seasons to determine the best methods for rooting hardwood pear cuttings under Oregon conditions.

In addition to work done with Old Home, one of us (Lyle Brooks has, for 8 years, rooted hardwood cuttings of Old Home x Farmingdale seedlings on a commercial basis. Such cuttings are much easier to root than Old Home, but in general, the same treatments can be used for both types. We have rooted Bartlett, Anjou, Bosc, and Seckel pear by the same methods, but generally only about 15 to 30 percent of them rooted At this time we do