Before the early 1950's, most apple trees sold in the U.S. were propagated on apple seedling rootstock produced by planting seeds from an apple known for vigor and other desirable characteristics. Since then, increasing numbers of trees are produced on vegetatively propagated or "clonal" rootstocks—a practice originated in Europe. In addition, some nursery trees have both a clonal root system and a different special trunk section or "interstock," usually to accomplish a desired degree of dwarfing. To further complicate the choices, for the fruit-bearing top of the trees (the part grafted onto the rootstock or interstem), spur-type and non-spur apple varieties have been introduced. Spur-type strains of common varieties have leaves closer together, branch less, and produce more flower clusters than non-spur (standard) types. They generally grow more slowly and occupy less space in the orchard than non-spurs. Some spur types are intermediate in vigor and spurriness. Spur-type trees grow more slowly than non-spur types, but will eventually reach about 75 to 80 percent the size of non-spurs. The growth of spur types may be different on clonal rootstocks than on seedling. The fact that some non-spur type apple varieties are more vigorous than others must also be considered when choosing a rootstock. Newtown and Granny Smith are much more vigorous than Golden Delicious, for example. The choice of rootstock also depends on the proposed orchard design and the soil type. Combined, these variables greatly complicate the choice of rootstocks. This publication is intended to help growers choose among apple rootstocks currently available from U.S. nurseries.

Origin of Apple Rootstocks

The first series of vegetatively propagated rootstocks imported to the U.S. was the East Malling (M.) series, which includes M 7, M 26, M 9 and others. These stocks had been in European nurseries under the names Doucin and Paradise for a long time before they were collected, studied, and named by the experiment station at East Malling, England. M 7 was an unnamed Doucin stock; M 16 was called "Ketziner Ideal" later named "Doucin U3" by Spath in Berlin; M 9 was "Jaune de Metz," selected as a chance seedling in France about 1879. The Malling-Merton (M-M) series are selected hybrids between an aphis-resistant apple variety and certain Doucin rootstocks that were released by the East Malling research station. Since all of the old rootstocks had accumulated viruses, the East Malling and Long Ashton research stations developed techniques to remove viruses, which led to release of M 7a, which is partially virus-free, and finally to the E.M.L.A. series, which are free of all known viruses. These virus-free rootstocks tend to give trees that are 10 to 15 percent more vigorous than the old releases of the same clones. The virus content of the scions that nurseries graft onto these rootstocks is not known in every case. Only if the finished trees bear a label indicating that they are certified virus-tested can you be sure that they are as free of known viruses as is currently possible.

Washington nurseries soon will be marketing a series of virus-free rootstocks from stock treated at Prosser, Washington.

The viruses contained in the original M-series rootstocks did not prevent most apple varieties from being long-lived and productive when grafted to them. A few varieties did not grow well because of their virus content.

Collar Rot and Other Problems

Collar rot is caused by *Phytophthora cactorum*, a "water mold." It can kill trees whenever the collar (bark area just above the roots) of the tree trunk just below ground level is wet for a prolonged period, especially if the weather is warm. To prevent accumulation of water around the collar, which might lead to collar rot, hill the soil along the row center to a level of about 6 inches or more above the row middles before planting. Good weed control around the base of the tree will reduce the length of time that the tree is wet. If orchard conditions are sufficiently favorable to it, most root-
stocks will be infected by collar rot, but some stocks are more susceptible than others.

Apple trees planted on sites where apple trees grew previously frequently fail to grow well, even when they have received excellent care. The cause of this "replant problem" is complex and little understood.

Trunk bark cracking is a physiological phenomenon that has been noted in Golden Delicious. It was more severe on M 106 and M 7, with about half as much on M 26. It doesn't appear to have a serious effect on tree growth or yield.

Tomato ring spot, a virus spread by soil-borne nematodes, has killed some trees on MM 106 rootstocks in the eastern U.S. Trees on all stocks are susceptible to this disease.

General Characteristics of Rootstocks

All trees on clonal rootstocks must be planted with the graft union above ground; otherwise the variety will strike roots, the rootstock influence will be lost, and the tree usually will grow vigorously. Plant with the union about 3 to 4 inches above ground to allow for settling.

Seedling: Seedling or "standard" rootstocks produce more vigorous apple trees than do most of the currently used clonal rootstocks. Seedling-rooted trees have an advantage over some clonal stocks in not requiring artificial support, but they have the great disadvantage of being much slower to begin bearing than trees on clonal roots. This difference in the onset of productivity is true for spur types on seedling too, even though they tend to begin bearing at a younger age than non-spur types. For several years after beginning to bear, trees on seedling roots may be less productive than trees on most clonal stocks. The characteristics of seedling rootstocks, such as poor resistance to collar rot and other problems, are variable. Most seedlings are susceptible to woolly apple aphid, but aphids on roots seldom interfere with productivity in Pacific Northwest orchards.

MM 111: This stock gives semi-vigorous trees, only slightly smaller than seedling, and is moderately susceptible to collar rot. It is well anchored and does not need support. MM 111 is less resistant to woolly apple aphid than MM 26. Since MM 111 is the least tolerant of high arsenic levels, it would not be a good choice on an old orchard site where there is a large accumulation of arsenic. It should be satisfactory where arsenic is not high and fumigation is used to control the apple replant problem. Where used as a portion of the trunk, aerial root initials form "burr knots" on MM 111, but these are less troublesome than with M 26. It is advisable, therefore, to plant the graft union only about 3 inches above the soil surface. MM 111 is least tolerant of the apple replant problem. In the nursery it has been more cold hardy than seedlings.

MM 106: Where collar rot is not a problem, this has been a superior, semi-vigorous rootstock, producing trees larger than M 7 and slightly smaller than trees on seedling roots. It doesn't sucker and can stand without support. It is relatively sensitive to cold, heat, and drought. Trees on MM 106 rootstock are late to defoliate and therefore may suffer more injury in an early freeze. It is ranked as less tolerant to arsenic than seedling rootstocks. The main limitation of this stock is its susceptibility to collar rot.

M 7a: The "a" indicates that some viruses that were in the original M 7 rootstock material have been removed. Trees on M 7a are slightly smaller than those on MM 106, about 75 percent as large as those on seedling. M 7a-rooted trees on light soils tend to be stunted. Trees on M 7a tend to lean if planted on a windy site, and may need staking in the early years. The problem can be reduced by grafting high and planting deep. This practice helps on light, well-drained soil, where trees are most likely to lean. Trees planted with the top root 10 to 14 inches below the surface are not sickle of fine texture, however, tend to grow slowly due to root suffocation, and a substantial percentage of the trees may die in the first year or two. In some comparisons, trees on M 7a have been less productive the first 9 years than trees on MM 106, but much more productive than trees on seedling. Trees on M 7a, especially spur types, are highly productive for the space occupied. M 7a has the bad characteristic of suckers from the roots, especially with shallow planting. Injury from cultivation or pruning will increase sprouting. This is a nuisance, but tolerable. M 7a is susceptible to collar rot, but much less so than MM 106. M 7a is most tolerant of the apple replant problem. Used as an interplant for otherwise grown under unfavorable conditions, it is readily stunted and may produce small fruit. M 7 is as cold hardy as seedling rootstocks.

M 26: Since M 26 was introduced later than the other clones, we know less about its performance in the field. Trees on M 26 are slightly smaller than those on MM 7a grown under identical conditions. Spur types on M 26 are similar to or smaller than non-spur on M 9, but are not as brittle-rooted as M 9. Trees on M 26 begin to bear earlier than those on M 7a and produce more fruit for the space occupied. It is more cold hardy than any of the other clonal rootstocks. Trees on M 26 may need staking in the early years, and tend to bear so early that support is needed for the fruit. Trees on M 26 may bloom a day or two later than others, and mature their fruit slightly earlier.

The M 26 wood has fluted or flattened trunks as a varietal characteristic, not a disease. The trunk of M 26 has clusters of aerial root initials, which appear as "burr knots." Trees grafted high on M 26 vary in size. Plant M 26-rooted trees with the graft union only 3 inches above the soil line. Although M 26 is highly susceptible to woolly apple aphid, the insect seldom is a problem in orchards. In eastern states, M 26 has shown susceptibility to fire blight caused by a bacterium, Erwinia amylovora, but that has not been a problem in the Pacific Northwest with this rootstock. M 26 has aver-
age susceptibility to collar rot, and has little tolerance of heavy or excessively acid soils or for unusually wet or dry soils.

**M 9:** This rootstock produces the smallest, earliest bearing, and most productive trees of any stock presently marketed for use in commercial orchards. M 27 gives smaller trees, but they are too small for commercial use. Non-spur trees on M 9 rootstock are 20 to 30 percent as large as trees on seedling. Because M 9 roots are brittle and break easily, trees will need artificial support until the trunk diameter exceeds 10 inches. Trees on M 9 stop growing earlier in summer and initiate more flower buds than on any other stock. Spur-type trees on M 9 are far too small for use in commercial orchards. Because of grower resistance to use of adequate artificial support, M 9 is rarely used in commercial orchards in the Pacific Northwest. Consequently, its nursery availability is limited. It is resistant to collar rot. M 9 is not shallow rooted, as is often assumed, nor is it short-lived. It does sucker a little, but not seriously. M 9-rooted trees may be stunted on shallow soils or those of extremely coarse or fine texture. It is highly susceptible to woolly apple aphid. M 9 is about as cold hardy as other stocks.

**Other rootstocks:** Trees on MM 104 have been planted in some orchards in this region. With non-spurs, it gives vigorous trees that, with some varieties, are slow to begin bearing. It does not tolerate wet soils. MM 104 is inferior to many seedling stocks. Even so, it has been successful at a few locations.

Some excellent rootstocks other than those currently offered by most nurseries such as M 2, M 4, and M 13, do exist but are hard to find. Trees on M 1 are as vigorous as on seedling but much more productive. They are both self-supporting. M 1 induces early bearing; trees on M 2 are semi-vigorous, shorter, more tolerant of collar rot, and tend to be more productive than trees on seedling. M 3 is tolerant of clay soils. Trees on M 4 are semi-dwarf and outstandingly productive, but require artificial support on a windy site. According to some sources M 4 is not as cold hardy as other rootstocks.

**New rootstocks** are being developed but are not yet available from nurseries.

**Interstem trees**

One idea behind interstem trees is to obtain good anchorage by use of a vigorous rootstock, such as MM 111, plus heavy flowering and more dwarfing by including a section of M 9 wood in the trunk. The amount of dwarfing is influenced by the length of the interstem. The rootstock, however, exerts the dominant influence on tree size. The limited cold hardiness of M 9 used as a stem piece is the principal drawback to this approach. In addition, M 9-interstemmed trees have been broken off by high winds. Because of the need to graft or bud twice, interstem trees are appreciably more expensive than regular trees. If the lower portion of the interstem is below ground, snow cover may be high enough to protect it from freezing.

Another reason to use a special trunk and framework is to obtain a measure of protection from freezes. Apple varieties that have been used for cold-hardy frame stock include Hibernal, Antonovka, Red Astrachan, Beacon, Hawkeye, Ottawa 292, McIntosh, Haralson, and Red Wealthy. The easiest route to a hardy framework is to purchase a tree of McIntosh or other hardy variety and bud or graft 6 to 12 inches out on the scaffold limbs. It requires skilled labor and will delay the onset of fruiting. The hardy framework variety also influences the productivity of the scion variety. It may be a good way to get a tender variety such as Newtown or Gravenstein started.

**Designing Orchards with Clonal Stocks**

In recent decades, the most popular orchard design is the semi-dwarf or semi-vigorous "hedge-row," spaced 10 x 20 (218 trees/acre), or 12 x 18 (201 trees/acre). The trees are free-standing and trained to a central leader. This is the most popular design from the old standard seedling-rooted stock spaced sometimes as close as 20 x 10 (108 trees/acre), but more often 25 x 25 (70 trees/acre), or even 30 x 30 (48 trees/acre). The mistake in selection of tree vigor also influences the rootstock/scion combination as serious consequences for orchard management in these newer, higher-density plantings. Both the vigor implanted by the rootstock and that of the scion variety should be considered. Some common scion varieties in decreasing order of vigor are: Gravenstein, Newtown, Granny Smith, Delicious non-spur, Golden Delicious, Delicious spur type, Golden Delicious spur type. Gravenstein, Newtown, and Granny Smith need dwarf or semi-dwarf rootstocks such as M 9 or M 26 to adapt them to these higher-density "hedgerows." On many soils, though, spur types on M 26 or M 7a would be too small for the spacings mentioned. It would be better to use semi-vigorous MM 106 or MM 111 roots for spur types in this design concept. On the better soils, spur types on MM 106 are vigorous enough for 10 x 18 spacing, but not on soils less favorable to growth. In replant situations, it is generally advisable to use more vigorous trees on the assumption that some degree of the apple replant problem may be encountered. Preplant fumigation often will overcome the apple replant problem.

A situation difficult to manage occurs when two varieties, one very vigorous and the other of much lower vigor, are included in a planting on the same rootstock. If spacing is right for the variety of lower vigor, the more vigorous trees will crowd their neighbors. It will be necessary to over-prune to contain them. This can lead to reduced production and fruit of poor quality, with bitter pit. If, for example, you want to use Newtowns, or Granny Smith as pollinizers in an orchard of non-spur Delicious, they should be on a more dwarfing
rootstock than the Delicious. If spur-type Delicious is used, a still more dwarfing rootstock should be used for the Newtowns or Granny Smith. Since pollinator trees constitute only 10 to 20 percent of the orchard, it is of little consequence if they are somewhat overly dwarfed.

If you want to minimize the amount of fruit from the pollinator variety it is best to include them in the rows of the main variety rather than to have separate rows of pollinizers. About 10 percent pollinizers is generally considered a minimum. If every 10th row were a pollinator, there would be a heavy seeded fruit set and greater tendency to biennial bearing in rows adjacent to the pollinator row than several rows away. Results from chemical thinning would vary greatly with distance from the pollinator.

Another orchard design concept, common in Europe but only recently being adapted to a limited extent in the U.S., is the high-density hedge-row or "fruiting wall." Spacings of 4 x 12 (907 trees/acre) up to about 6 x 16 (453 trees/acre) would fit within this concept. Non-spurs on M 9, or M 26 on poorer soils, and spur types on M 26, M 7a, or MM 106 on poorer soils, are suitable for use with this design concept. Spur-type trees on M 7a or M 26 can become stunted under poor growing conditions. It is difficult to stimulate renewed tree vigor when this happens. Artificial support is utilized frequently, but not always, for trees in high-density fruiting walls. Trees are trained to a narrow central leader without limb spreading and the central leader is fastened to a wire trellis, in some cases, to individual posts. Earlier bearing and simplified tree training are advantages over the medium-density hedgerows, but much higher initial costs for trees and a support system are distinct disadvantages. A general lack of experience with this type of orchard in the Pacific Northwest is another important disadvantage. Earlier production results not only from increased numbers of trees per acre, but from allowing the trees to fruit and producing artificial support rather than removing the fruit as is done in the standing hedgerow. This presumes that conditions will be good enough for simultaneous fruiting and young tree growth. Naturally, when replanting an old orchard under these conditions often do not occur. To obtain satisfactory tree growth under difficult conditions, it may be necessary to remove all of the fruit for the first two or three seasons, or until the 4th or 5th summer after planting.

A older design concept that fits in well with some existing orchard operations is the relatively low-density free-standing, multiple-leadered orchard. The advantages of using vigorous, flower-promoting, clonal rootstocks are important, even with this concept. Trees on vigorous rootstocks such as MM 111 or M 1 will start producing earlier and produce more fruit, consistently, than most seedling-rooted trees. This is true even if a spur-type scion is used. Filler trees that will be removed after 10 to 12 years will hasten the onset of commercial production. Thinning trees to a triangle by removing alternate trees in alternate rows will allow more trees per acre, with the same distance between trees. Final spacings of 15 x 20 (181 trees/acre) to 22 x 22 (90 trees/acre) for spur-types on vigorous roots, or 25 x 25 (69 trees/acre) for non-spurs, would be manageable on average soil and would permit greater productivity than some wider spacing formerly used. This type of orchard would be more suitable for harvesting by shaker and catching frame than high-density orchards. Since most mechanical harvesters are at least 20 feet in spread, it is difficult to use them in closely spaced apple orchards.

**Table: Scion-Roostock Combinations that Give Trees of Approximately Equal Tree Size When Grown on Good Soil.**

<table>
<thead>
<tr>
<th>Scion Rootstock Combinations</th>
<th>Trees of Approximately Equal Tree Size When Grown on Good Soil</th>
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<tbody>
<tr>
<td>Non-spur Delicious/M 26</td>
<td>Spur-type Delicious/M 2</td>
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<tr>
<td>Non-spur Delicious/M 7a</td>
<td>Spur-type Delicious/M 7a</td>
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<tr>
<td>Non-spur Delicious/ seedling</td>
<td>Spur-type Delicious/ seedling</td>
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<tr>
<td>Non-spur Golden D./M 26</td>
<td>Spur-type Golden D./ M 26</td>
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<td>Non-spur Golden D./M 7a</td>
<td>Spur-type Golden D./ M 7a</td>
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<tr>
<td>Non-spur Golden D./M 111</td>
<td>Spur-type Golden D./ M 111</td>
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<tr>
<td>Granny Smith or Newtown/M 26</td>
<td>Non-spur Delicious/M 26</td>
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<tr>
<td>Granny Smith or Newtown/M 7a</td>
<td>Non-spur Delicious/M 7a</td>
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<tr>
<td>Granny Smith or Newtown/M 111</td>
<td>Non-spur Delicious/M 111</td>
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<td>Spur-type Golden D./ M 26</td>
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<tr>
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<td>Non-spur Golden D./ M 26</td>
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<tr>
<td>Spur-type Delicious/M 106</td>
<td>Non-spur Golden D./ M 7a</td>
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<tr>
<td>Spur-type Delicious/ seedling</td>
<td>Non-spur Golden D./ M 111</td>
</tr>
</tbody>
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Published and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914, by the Cooperative Extension Services of Oregon State University, Henry A. Wadsworth, director, Washington State University, J. O. Young, director; the University of Idaho, Fred E. Kohl, acting director; and the U.S. Department of Agriculture, cooperating. Extension's programs are available equally to all people.