BETTER ROOTSTOCKS FOR CITRUS GROWN IN HAWAII

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CITRUS FRUITS have been grown in Hawaii ever since 1792, when seeds of the so-called "Hawaiian orange" were introduced from Cape Town, South Africa, by Captain Vancouver. This same type of orange has been known on Hawaii as the Kona orange, on Oahu as the Waialua orange, and on Kauai as the Waimea orange. Since the original introduction, thousands of citrus trees have been grown in home fruit gardens, and numerous, small semi-commercial plantings of tangerines, limes, and oranges have also been made. Acreages have remained small, however, and at present there are only about 60 acres of commercial citrus plantings in the state, divided about equally between tangerines and oranges.

In the past, little attention was paid to selecting suitable rootstocks for citrus, and a large proportion of trees grown are either seedlings or air-layered trees. The remainder are grown on rootstocks chosen by circumstance or from convenience rather than on the basis of desirable or useful qualities.

Rootstocks are important in that they influence productivity and vigor of the tree, as well as quality of fruit produced. In new or replacement home plantings, as well as in contemplated trial orchards, it is only common sense and good judgment to use the best rootstock available. Because of difficulties commonly met in marketing island-grown citrus fruit, any means of improving quality and marketability would be very desirable and worthwhile.

The use of resistant rootstocks is usually advisable and often necessary, as a protective measure against gummosis or gumming disease, which is a serious problem, especially on heavy soils and under conditions of high rainfall and humidity. Gummosis is caused by soil-borne fungi attacking the tree
near ground level (see Figure 3). Because of this, gummosis-resistant rootstocks should be used whenever possible and should always be grafted at least a foot or more above ground level to provide maximum protection.

Resistance to "tristeza" is also considered important because this disease is known to be present in Hawaii, having been introduced in citrus nursery stock imported from the Mainland, where this disease is common. Tristeza, often referred to as, and probably synonymous with, "quick decline," is caused by a virus infection which results in the blocking or interference of conducting tissue at the graft union of susceptible top-rootstock combinations. Slow decline, dieback, and a general, unhealthy condition are usual symptoms of an infected tree. When the bark is removed, pitting or pitted furrows can usually be found in the wood of trees suffering from tristeza (see Figure 2). Rootstocks resistant to tristeza are the only effective protection known against this disease.

According to evidence accumulated to date, rootstocks suggested in Table 1 appear to be the most satisfactory for use in Hawaii. More than a dozen other rootstocks are presently on trial in experimental plantings, but it is too early to determine their adaptation and eventual use under the wide variety of growing conditions and soils found in the state.

In general, rough lemon and pummelo seedlings are not satisfactory as rootstocks for tangerines and oranges, and other rootstocks listed in Table 1 are suggested as more suitable. Orange and tangerine trees grown on rough lemon roots tend to be susceptible to gummosis, especially on heavy soils or in high-rainfall areas. In general, they produce fruit lower in sugar content and coarser in texture than those grown on other rootstocks suggested. Pummelo seedlings are frequently not compatible with other citrus, except grapefruit, and therefore cannot be considered safe to use as rootstocks for tangerines and oranges.

Up to now, competition from high-quality, well-colored, imported oranges has placed locally grown oranges at a dis-
advantage on island markets. This trend can be expected to continue unless the quality of island-grown oranges is markedly improved. Experience in Hawaii does not support the idea that even with superior rootstocks, improved fertilizer practices, and a good spray program, high-quality oranges can be produced in spite of climatic limitations. In Hawaii, as in other areas with mild tropical climates, it is seldom possible to produce top-quality, well-colored oranges with the most desirable ratio of acidity to sweetness. This is because the island climate is generally not conducive to the development of quality oranges competitive with California-grown fruit. However, in any attempt to improve and standardize quality of citrus fruit produced in Hawaii, the use of well-adapted, disease-resistant rootstocks is one of the factors which should be given due consideration. Table 1 lists rootstocks desirable for citrus fruits most commonly grown in Hawaii.

Table 1. Suggested rootstocks for citrus fruits in Hawaii

<table>
<thead>
<tr>
<th>Type of Citrus Fruit Propagated</th>
<th>Suitable Seedling Rootstocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangerines (Citrus reticulata)</td>
<td>Cleopatra mandarin and Troyer citrange</td>
</tr>
<tr>
<td>Orange (Citrus sinensis)</td>
<td>Cleopatra mandarin, Troyer citrange and Hawaiian orange</td>
</tr>
<tr>
<td>Limes (Citrus aurantifolia)</td>
<td>Ungrafted lime seedlings are preferred; Hawaiian orange and rough lemon are acceptable rootstocks for seedless varieties</td>
</tr>
<tr>
<td>Grapefruit (Citrus paradisi)</td>
<td>Troyer citrange and Cleopatra mandarin</td>
</tr>
<tr>
<td>Pummelos (Citrus grandis)</td>
<td>Pummelo and grapefruit</td>
</tr>
</tbody>
</table>
THE FOLLOWING is information on specific properties of particular rootstocks, including discussion of objectionable features and limitations of certain rootstocks which have been used in the past.

*Cleopatra Mandarin*

Cleopatra mandarin, a small-fruited, sour type of tangerine, is an excellent all-around rootstock, especially for tangerines and sweet oranges. It is resistant to both tristeza virus and gummosis and appears widely adapted. Trees grafted on it generally grow well and produce good-quality fruit on a variety of soils. It is considered a good, safe, disease-resistant rootstock to use if in doubt, and in general, it has given dependable results. Although Cleopatra has sometimes been criticized by Mainland nurserymen because of relatively slow growth in the nursery, it grows fast enough in Hawaii so that seedlings large enough for grafting or budding can readily be produced within one year’s time.
**Troyer Citrange**

Troyer citrange, a hybrid of trifoliate orange, is much better adapted to tropical growing conditions than the trifoliate orange so widely used as a rootstock for producing high-quality tangerines in many subtropical citrus-growing areas. Troyer also has the capacity of growing well under tropical conditions on heavy soils and high-rainfall conditions, where trifoliate orange characteristically makes slow, unsatisfactory growth. However, Troyer is like its trifoliate parent in that better-than-average-quality tangerines and oranges can be produced when it is used as a rootstock. Troyer is considered to be a vigorous, dependable rootstock for tangerines, oranges, and grapefruit. It is resistant to both tristeza and gummosis.

**Hawaiian Orange**

Seedy types of Hawaiian orange introduced into Hawaii by Captain Vancouver and later from Montserrat, British West Indies, by H. L. Greenwell of Kona have been found to be satisfactory rootstocks for oranges and limes. The quality of oranges produced on this stock is relatively good, depending upon location, and trees grafted on it are resistant to tristeza virus. It may possibly have some degree of resistance to gummosis but is probably less resistant than either Troyer or Cleopatra.

Hawaiian orange is a vigorous, hardy rootstock deserving wider use. It should be thoroughly tested on various soil types in comparison with Troyer and Cleopatra to determine the most suitable rootstock for specific areas. However, since the Hawaiian orange's resistance to gummosis has not been confirmed, Troyer and Cleopatra probably are safer rootstocks to use on heavy or poorly drained soils and in high-rainfall areas.

Figure 1. A 3-year-old Kona tangerine grafted on Troyer citrange.
Sour Orange

Sour orange is not recommended for general use as a rootstock because trees grafted on it are susceptible to the tristeza virus complex. Many citrus trees imported from Mainland nurseries in the past carry this virus, which is readily spread by aphids from infected to healthy trees. Sour orange as a rootstock produces vigorous trees which give satisfactory fruit quality. However, it does not appear to be a wise rootstock choice because of the danger of tristeza virus in the presence of insect vectors, which spread this disease from old, infected trees to young, healthy citrus trees.
**Rough Lemon**

Although it has been the most widely used rootstock in Hawaii in the past, rough lemon has very serious faults as a rootstock. It is relatively susceptible to gummosis, a serious disease in most citrus-growing areas of the state, and it produces lower-quality fruit than most other rootstocks, especially with oranges. Oranges grown on this rootstock in Hawaii tend to be puffy and relatively low in both acidity and sugar content. About the only desirable characteristic of rough lemon as a rootstock is that it is vigorous and produces a grafted tree of saleable size rather quickly in the nursery. However, since quality of oranges in Hawaii is generally not outstanding, fruits produced on trees grafted on rough lemon rootstocks are not likely to meet quality standards required for successful marketing. Acid citrus, such as limes, which do not require development of high sugar content, may however be grafted on rough lemon. This rootstock is best adapted to light sandy soils, but citrus trees are seldom planted on sandy soils in Hawaii. Rough lemon is not recommended as a rootstock at the present time, except for limes.

*Figure 3. Advanced stage of gummosis on sweet orange.*
Seedling Citrus Trees

In the past, many individual trees, as well as a few, small, semi-commercial orchard plantings of tangerines and oranges, have been grown from seed, particularly in the Puna, Kona, and Pahoa districts. It is possible to do this because many, though not all, varieties of citrus come relatively true from seed. This is explained by the fact that citrus seeds, unlike the seeds of most tree fruits, have the property of developing several vegetative or non-hybrid embryos per seed. Such seeds, known as “polyembryonic” or “nucellar” seeds, produce relatively uniform seedlings which are largely true to type or variety. Nucellar seedlings tend to be more vigorous and thorny than grafted trees of the same variety, and have the disadvantage of taking several years longer to come into bearing. However, if off-type and weaker-growing seedlings are eliminated in the nursery, most of the remaining seedlings are dependably true to variety.

A notable exception is found in pummelos, also called “shaddocks” or “jabon,” which have recently been reintroduced from Tahiti as “pumpelmous,” a French common name for pummelo. Regardless of the name used, pummelos have monoembryonic seeds with sexual embryos, and seedlings grown from these seeds are highly variable. There are hundreds of seedling pummelo, jabon, or pumpelmous trees planted throughout Hawaii, which vary widely in type, quality, and flavor of fruit produced. The fruit of these seedlings is seldom as good as that of the variety which furnished the seed. Seedling pummelo trees rarely produce satisfactory fruit and are useful mainly as ornamental trees, although a few selected trees with better fruit have been selected and propagated.

Limes, on the other hand, are highly polyembryonic and come true from seed so reliably that they can easily be grown true to variety as seedlings, provided the small proportion of weak and off-type seedlings are eliminated in the nursery. The so-called Chinese, Mexican, or Key limes, as well as Rangpur-type limes, come true from seed and seedling trees usually
come into bearing within 3 to 4 years. Air-layered or grafted lime trees present no real advantage over seedlings except in the case of certain seedless varieties, such as Tahitian or Persian, which must be grafted. Lime seedlings also have an additional advantage in being initially free from virus diseases.

Air-Layered Citrus Trees

Orange, tangerine, and lime trees are frequently air-layered to provide planting stock of desired varieties or selected individual trees. Air-layered tangerine trees may perform satisfactorily and are probably more suitable for orchard planting than air-layered oranges or limes, which are somewhat slower growing than seedlings or well-grown grafted stock.

A major disadvantage of air-layered citrus plants compared with grafted stock is that grafting permits the use of tristeza- and gummosis-resistant rootstocks in cases where own-rooted trees of the scion variety are susceptible to these diseases.

In general, propagating citrus trees by air-layering is slow, laborious, and inefficient compared with budding or grafting on vigorous seedling rootstocks with well-developed root systems. Air-layering has no readily apparent advantage over easier, faster, and cheaper methods of grafting or budding on seedling rootstocks.

General Considerations

Although choice of rootstocks is considered important in citrus, it is well to bear in mind that no rootstock can be expected to make up for deficiencies in temperature requirements necessary to insure satisfactory fruit quality. In areas where temperatures seldom fall below 55°F. or rise above 85°F., color and sugar content of oranges and tangerines are characteristically less satisfactory than in areas where wider temperature fluctuations exist. This is especially true of oranges in home garden plantings and small semi-commercial orchards found in the state, where orange trees seldom pro-
duce fruit with satisfactory color, acidity, and sugar content. Tangerines, on the other hand, are more adaptable to the mild island climate of Hawaii and fruit of satisfactory quality and acceptable appearance can often be produced in selected locations on all of the major islands. Temperature and other climatic factors should be kept in mind when choosing sites for planting citrus, as well as in deciding whether or not commercial plantings could actually be expected to be economically feasible.
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