Horticultural Considerations and Summation

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Introduction

Contemporary citrus rootstock research is heavily oriented to virus and virus-like disease problems and, to a somewhat lesser extent, to resistance to nematodes and *Phytophthora* spp. Lectures presented in this course have reflected the concern of both researchers and growers with pest control through the use of appropriate rootstocks.

The current state of science in relation to systemic disorders is obviously in its infancy. The complexity of these problems has become evident as research has advanced. We continue to identify most of these disorders by symptom expression rather than on the basis of definite chemical bodies that constitute virus or other particles. We speak rather vaguely of severe and mild strains of viruses, and we still occasionally find a disease once thought to be a virus is not.

Even so, much has been learned about virus and virus-like diseases and we are becoming surer of how to deal with them. There is a beginning of research related to cross-protection or immunization. We are learning not only to "live with" systemic disease problems but to harness them by infecting trees with selected viruses to control tree size.

The problem of nematodes has also become more complex with the discovery that nematodes can change slightly and cause damage to plants hitherto undamaged by them. As in the case of viruses, we are also learning to accept and control them. Use of Milam rootstock as a biological buffer to prevent the spread of *Radopholus similis*, the spreading-decline nematode, is an excellent example of an imaginative control measure.

Even that old citrus nemesis, *Phytophthora* spp. has become more complex than was once thought, as new strains are found. The proper method for evaluating rootstocks for resistance is still being debated but we are becoming sufficiently knowledgeable to accept the fact many rootstocks which are much less resistant to *Phytophthora* spp. than sour orange and trifoliate orange are sufficiently resistant to serve as rootstocks on the well-drained sands of central Florida. Some of these same rootstocks would not be satisfactory under soil conditions favoring this disease.

Florida growers should consider the fact they are almost alone in not taking full advantage of the rootstock's resistance to foot-rot caused by *Phytophthora* spp. Lecturers have repeatedly emphasized budding "high" to avoid foot-rot problems. Florida nurseries still produce and growers plant virtually all of its trees with bud unions at or near the ground line - a costly mistake!

Rootstocks, also affect yield, fruit size and quality, resistance to cold and drought, and tree size. These factors as well as resistance to pests must be considered in selecting rootstocks.

Yield

Yield of fruit, whether measured in units of weight, boxes of fruit, or pounds of soluble solids, is the most important factor in profitable fruit production. Yield is also the most difficult tree response to measure because of the tremendous variation in yield from tree to tree and from year to year. This variation may be several fold even though environmental conditions are similar and plant material is genetically the same.

Moreover, a given rootstock experiment, even when well designed and evaluated over a period of many years, describes only a limited set of conditions. Thus, a review of all available research and observations of tree performance under grove conditions are needed to develop valid conclusions. Nevertheless, there are some generalizations that can be made.

Citrus trees on rough lemon, 'Palestine' sweet lime and rangpur lime rather consistently outyield trees on other commonly used rootstocks over a wide range of soils; however, their advantage is particularly noticeable on coarse, sandy soils where moisture retention is low. The advantage of these stocks is also less when yield is calculated on the basis of pounds of solids per unit of land.

Trees on cleopatra mandarin and sweet orange often yield poorly but this response is not consistent, varying with tree age, soil, virus status and scion variety. Sweet orange on cleopatra mandarin generally yields poorly the first 15 years of age. Yields of 'Valencia' sweet orange on cleopatra are particularly low. 'Hamlin' and 'Pineapple' sweet oranges and grapefruit yield reasonably well on cleopatra mandarin but not as well as on rootstocks such as rough lemon. 'Temple' yields well on cleopatra, as do properly pollinated 'Orlando' and 'Minneola' tangelos and 'Robinson' tangerines. Parthenocarpically produced (seedless) tangelos yield more poorly on cleopatra than on the lemon and sweet lime rootstocks unless girdled or sprayed with gibberellic acid. Trees on cleopatra yield better on rich soils and when clay is close to the surface of sandy soils.

Trees on sweet orange are very droughty. Yields of all cultivars on sweet orange rootstock are good to excellent on heavier soils that are retentive of moisture but very poor on coarse sands unless careful attention is given to irrigation.

Trees on sour orange generally yield moderately well, but 'Valencia' on sour orange on coarse sand yields little if any better than trees on cleopatra.

Trifoliate orange yields rather poorly on coarse sands because trees are stunted and fruit is small. The low yield on trifoliate orange differs from that on cleopatra in that large trees of cleopatra produce few fruit while trees on trifoliate tend to be dwarfed and fruit size is small. The interaction of variety with trifoliate rootstock on deep sands is inadequately known.

Trees on trifoliate orange produce standard-size trees with good yields and large fruit on rich soils that are retentive of moisture.

Trees on 'Carrizo' citrange, a stock rapidly rising in popularity in Florida and of considerable significance in California, yield well on the basis of research results and observations of commercial plantings to date but their performance on deep sands over a long period of years is unknown.

There are other trifoliate orange hybrids with promise. 'Swingle' citrumelo has yielded extremely well in Texas trials but it has been inadequately tested on coarse sands in Florida.

Internal Fruit Quality

Influence of rootstock on internal fruit quality (juice quality) is rather constant. Rootstocks can be separated into about 2 or 3 groups on the basis of the soluble solids (an estimate of sugar) and acid content of the juice.

Lemon and lime rootstocks generally result in the lowest soluble solids and acid contents by a wide margin, with rough lemon characteristically producing the poorest quality. Trees on rangpur lime have somewhat better quality than trees on rough lemon but still rank well below those producing high quality fruit.

Trees on sour orange have long been noted for producing fruit of high internal quality; however, cleopatra mandarin, sweet orange, trifoliate orange, 'Carrizo' citrange and similar stocks produce fruit of quality equal to that produced on sour orange.

Some cultivars produce fruit of excellent quality for the fresh fruit market even on stocks such as rough lemon. 'Valencia' and 'Pineapple' sweet oranges and 'Temple' are notable examples. Grapefruit produces reasonable quality fruit on rough lemon and sweet lime stocks, which are widely used for grapefruit on coarse sands; however, stocks such as sour orange result in superior quality.

Mandarins (tangerines) and tangelos, with the exception of satsumas, are generally of sufficiently high quality to tolerate the reduction in solids resulting from the use of lemon rootstock. In fact, the low acidity of the fruit often results in early legal maturity and shipment. 'Temple' in Florida, for example, matures fruit of excellent quality on rough lemon that is mature in December, while trees on cleopatra do not reach maturity until January or February.

On the other hand, the flesh of many mandarins tends to become dry or "ricy" early, and rough lemon contributes to this problem. Fruit from young 'Temple' trees on rough lemon may actually become too dry to ship before legal maturity is reached.

Total soluble solids of the juice and juice content are, of course, important when selling fruit for processing on the basis of pounds of soluble solids. The high levels of total soluble solids in combinations of sweet orange on sour orange rootstock results in more pounds of solids per box of fruit but the greater number of boxes of fruit per tree or per unit area of sweet orange on rough lemon rootstock results in much larger yields of soluble solids per unit area when rough lemon is the rootstock. 'Hamlin' sweet orange on rough lemon, for example, produces the poorest quality of fruit and the lowest pounds of solids per box but this combination produces the largest amount of total soluble solids per unit area when compared to that produced by other rootstocks traditionally used in Florida. This may not be true for some of the newer stocks such as rangpur lime and 'Carrizo' citrange, for which there are insufficient data from commercial plantings.

The date fruit reaches legal maturity, which is largely determined by the content of total soluble solids, acidity, total soluble solids/acid ratio and juice content, varies according to which rootstock is used. Fruit of high quality, such as 'Valencia' and 'Pineapple' oranges, and 'Temple' generally reach legal maturity earliest on rootstocks such as rough lemon, which reduces both the total soluble solids and acid contents. Legal maturity of these cultivars is limited by the high acid content, which is reduced relatively more than is the total soluble solids content. On the other hand, low quality cultivars, such as 'Hamlin' sweet orange and 'Orlando' tangelo often reach legal maturity first on rootstocks such as sour orange. Fruit from low-quality cultivars are limited by failure to meet the minimum level of total soluble solids required, not because of excessive acidity. Juice content is rarely a limiting factor in legal maturity of varieties except pink and red grapefruit on any rootstock.

Obviously, factors other than rootstocks influence quality and maturity but rootstocks exert a major influence in this respect.

Fruit Size

Rootstocks play a large role in determining fruit size, which in turn is important in determining price on the fresh fruit market. Some cultivars can tolerate a reduction in fruit size but others cannot.

Trees on rough lemon, 'Palestine' sweet lime, rangpur lime and *Citrus macrophylla* are noted for large fruit sizes. 'Dancy' tangerines are produced almost exclusively on rough lemon in Florida to take advantage of the large fruit sizes produced on this rootstock. Sweet lime is used in some areas of the world partly because of large fruit sizes produced in it and this rootstock warrants serious consideration for grapefruit in Florida. 'Orlando' tangelos are being budded on 'Palestine' sweet lime to some extent in Florida both to increase parthenocarpic yields and fruit size.

Cleopatra mandarin, on the other hand, is notorious for small fruit sizes resulting from its use. 'Dancy' tangerine on cleopatra would be a poor combination. 'Hamlin' orange trees on cleopatra were frequently topworked to other cultivars that performed better on cleopatra, before the development of frozen orange concentrate. Grapefruit, particularly 'Redblush' on cleopatra suffers a substantial reduction in fruit suitable for fresh fruit due to the small sizes produced. On the other hand, 'Temple' fruits and sizes well on cleopatra. 'Minneola' and 'Orlando' tangelos also size well on cleopatra. 'Robinson' and 'Murcott' size fairly well on cleopatra but not as well as would be liked.

Fruit sizes from trees on rootstocks such as sour orange, sweet orange, trifoliate orange and 'Carrizo' citrange lie between the large sizes produced on rough lemon and the small sizes on cleopatra. 'Carrizo' approaches rough lemon in the size of fruit produced by trees budded on it and sour orange lies closer to cleopatra. Trifoliate orange produces very small fruit on coarse, droughty sands but large fruit sizes on rich soils. Using trifoliate as a rootstock for 'Dancy' would be highly questionable even on rich soils but nucellar red grapefruit and exocortis-free old-line grapefruit have produced fruit of satisfactory sizes even on sandy soils.

External Fruit Quality

The influence of rootstock on such factors as rind color, texture and thickness is less well known, and less pronounced and consistent than the difference in internal quality. For example, the total soluble solids content of citrus fruit grown on sour orange will be higher than that produced on rough lemon almost regardless of the conditions under which they are produced while peel color is so closely related to temperature and exposure to sunlight that climate may mask any small differences due to rootstock.

Generally speaking, fruit produced on stocks such as rough lemon and sweet lime, which impart great vigor of growth, have thick, coarse-textured rinds and less intense orange color. Rootstocks, which tend to produce fruit of high internal quality, such as sour orange, cleopatra mandarin and trifoliate orange, and induce less growth vigor than the lemon and lime rootstocks, have thinner, smoother rinds and slightly better peel color. Cleopatra mandarin is particularly noted for producing fruit with smooth, thin rinds. Such fruit is beautiful but it increases the tendency of sweet oranges, and some tangerine cultivars to split. Splitting and creasing are important problems, in Florida at least, and a significant cause of low yields in some groves. There are few if any cases where a thinner rind would not improve grapefruit. Thick rinds are quite desirable in kumquats where the edible peel is the primary part used. Thinner rinds are particularly desirable in hot, desert regions where the fruit rinds tend to be thicker than in humid regions.

Resistance to Drouth

Influence of rootstock on the ability of the tree to withstand drought has not been as intensively or as widely evaluated as other rootstock influences. Rough lemon and 'Palestine' sweet lime are accepted as best adapted to coarse drouthy sands while sweet orange has been considered very unsatisfactory.

Trees on sweet orange wilt during dry periods in advance of the occurrence of wilt of trees on other rootstocks and moisture stress is reflected by lower yields.

Trees on trifoliate orange also show early wilting of leaves on coarse sands when the trees are relatively young but still bear heavy crops, the moisture stress being reflected in small fruit sizes.

Causes of differences in resistance to drouth are incompletely known. Differences in depth and density of rooting must play an important role in drouth resistance. Field studies of the depth of rooting of various rootstock generally bear out the greater depth of rooting of 'Palestine' sweet lime and rough lemon as compared to cleopatra mandarin, sweet orange, sour orange, trifoliate orange, and various citranges; however, the correlation of rooting patterns with drouth resistance is not perfect.

Hardiness to Cold

Research, and observations of commercial plantings following freezes have shown conclusively cold hardiness of trees is influenced by rootstocks. The differences are not great but they are very meaningful. The difference of 2 or 3 degrees F of cold hardiness often means the difference in damage or no damage and even death or survival.

There is little information as to how rootstocks influences cold hardiness in the cultivar budded on it but their influence on the dormancy of the tree is at least part of the reason. Many cultural practices and climatic conditions as well as rootstock influence dormancy. Thus, the response of trees to freezing temperatures varies to some extent with each freeze. One can only generalize on the basis of all of the research results available and the history of tree performance on various rootstocks following freezes over a span of many years.

Trees on sour orange, cleopatra mandarin and trifoliate orange attain their maximum cold hardiness. Trees on trifoliate orange, however, are more variable in this respect. There is evidence, although not as complete as would be liked, that trees on trifoliate orange tend to go into dormancy later in the winter then do those on sour orange and cleopatra mandarin and are thereby not as tolerant of cold as are those of sour orange and cleopatra mandarin during early winter.

Trees on rough lemon and 'Palestine' sweet lime are the most sensitive to cold, while those on sweet orange and 'Carrizo' citrange are intermediate. Trees on sweet orange, however, approach the cold hardiness of those on sour orange. The generalization has been made that there is a relationship between the cold hardiness of the rootstock and its hardiness to cold, with the most cold hardy rootstocks importing the most cold hardiness to the top. This generalization is not sufficiently consistent to be useful.

Tree Size

There is a definite influence of rootstock on tree growth and the cumulative effect over the span of several years may result in an appreciable difference in tree size. Trees on rough lemon and 'Palestine' sweet lime are larger than those on other stocks on the deep sandy soils of central Florida. Trees on cleopatra mandarin, sour orange, sweet orange, and 'Carrizo' citrange are intermediate in size while those on trifoliate orange and 'Rusk' citrange are much smaller.

Soil type greatly influences, however, the performance of some rootstocks in this respect. As examples, citrus trees without exocortis on trifoliate orange grow as large or larger than trees on sour orange if the soil is fertile and retentive of moisture. Trees on cleopatra mandarin grow much better when clay is closer to the surface than does rough lemon, which is better when clay is closer to the surface than does rough lemon, which is better adapted to deep, sandy soils. Thus, one must define the soil conditions in describing the performance of a rootstock in relation to tree size.

The influence of a rootstock on tree size is also greatly influenced by the virus content of the tree. Many of the results of past rootstock experiments are clouded by the fact the budwood contained certain viruses. There are several strains of each virus and these strains vary in the severity of the symptoms they cause.

The entire body of information involving rootstock must be understood in order to interpret and draw valid conclusions from the tree responses observed.

There has been much interest in developing dwarf citrus trees that are comparable to dwarf apple trees. Even though the vigor of growth of various cultivars is related to rootstock, there is no way as yet to satisfactorily produce dwarf citrus. The use of certain strains of exocortis virus to dwarf trees on trifoliate orange is perhaps the most promising means. There has been considerable research to demonstrate the feasibility of this procedure and plants are intentionally innoculated with exocortis in Australia and with xyloporosis in Israel to dwarf trees. As yet, however, completely satisfactory production of dwarf citrus trees will not be possible for some time to come.

Selecting Rootstocks

The rootstock selected for a commercial planting is obviously of utmost importance because it has such a large influence on the performance of the tree. Moreover, selection of a rootstock is a final decision that cannot be changed without great difficulty There are rare situations in which the rootstock is replaced by planting seedlings around the base of the tree and then inarching them into the trunk. Trees are sometimes scion-rooted by girdling the trunk just above the bud union and mounding over the girdled area with soil. Roots develop from the trunk and form a new root system. Replacing the rootstock both by inarching and scion rooting are unusual cases designed to overcome decline problems.

There is a tendency in selecting a rootstock to oversimplify its response to various environmental conditions. For example, there is the tendency to categorize rootstocks as either susceptible or resistant to diseases such as foot rot and either hardy or sensitive to cold, disregarding the broad spectrum of responses that exist.

There is also a tendency to place too much emphasis on results obtained from laboratory or greenhouse testing. Such techniques are valuable in screening large numbers of selections in rootstock improvement programs but they are not a satisfactory substitute for field trials and widespread observations of tree performance in commercial plantings.

The most reasonable way to approach the selection of rootstocks is to first determine the environment in which the rootstock is to be used. One should determine the depth of the soil to restrictive layers such as a water table or an impermeable clay layer. Fertility of a soil and its capacity for retaining moisture, the need to protect against diseases and other pests are all important. The purpose for which the fruit is to be used may bear on the rootstock selection. For example, fruit size and quality may be of considerably more importance to those who produce for the fresh or gift fruit market than those who are producing for processing.

There is often 1 limiting factor that must be taken into account above all others and thereby limits the choices available. For example, any rootstock selected for use in the northern fringes of the Florida citrus area must impart maximum cold hardiness to the tree because of the occurrence of damaging freezes precludes the use of such rootstocks as rough lemon. There are areas in which a disease, such as tristeza, is so severe that those rootstocks not having the highest level of resistance to the disease must be discarded. Brazil is an example of such an area.

Some cultivars produce fruit of such small size that the use of rootstocks such as cleopatra mandarin which would further accentuate the size problem cannot be tolerated.

After the elimination of obvious poor choices, there is often not much from which to choose. Even so, the grower is then faced with the problem of potential threats. For example, the threat of tristeza has been looming over the Florida industry for over 2 decades and yet damage from this disease has been modest. Sour orange rootstock, an unthinkable selection in a tristeza area, has been planted in large numbers despite this threat. Because of the threat of young-tree decline on rough lemon, there has been a further surge in the use of sour orange and it is the leading rootstock being planted today. Whether history will continue to bear out the wisdom of those who continued to use sour orange, only time will tell. The financial condition and the personal philosophy regarding risks of the grower are involved at this point.

There are some who would hedge against the possibility of certain threats by using a series of rootstocks, assuming that not all will prove to be unsatisfactory. On the other hand, such a procedure almost guarantees that 1 or more of the rootstocks will prove to be undesirable or, at least, much less satisfactory than the others. Here again, one's personal philosophy on risks and economics is the deciding factor. Many prefer to make the most intelligent selection possible and chance being wrong.

There are some who appear attracted to new rootstocks, even though these rootstocks have been tested superficially. In such a case, one should weigh the possible advantages against the known performance of an established rootstock. Using a rootstock simply because it is new has no merit but those willing to take risks for great advantages have often made fortunes.

In summation, one should not overemphasize small advantages or take into account general advantages of a rootstock that have little relevance to a given situation. After one eliminates all of the obviously poor choices for a carefully studied situation, there are generally only a few choices left. Choosing rootstocks on the basis of their unknown potential or on the basis of a potential threat to a standard rootstock involves the personal economic condition and philosophy of the individual.