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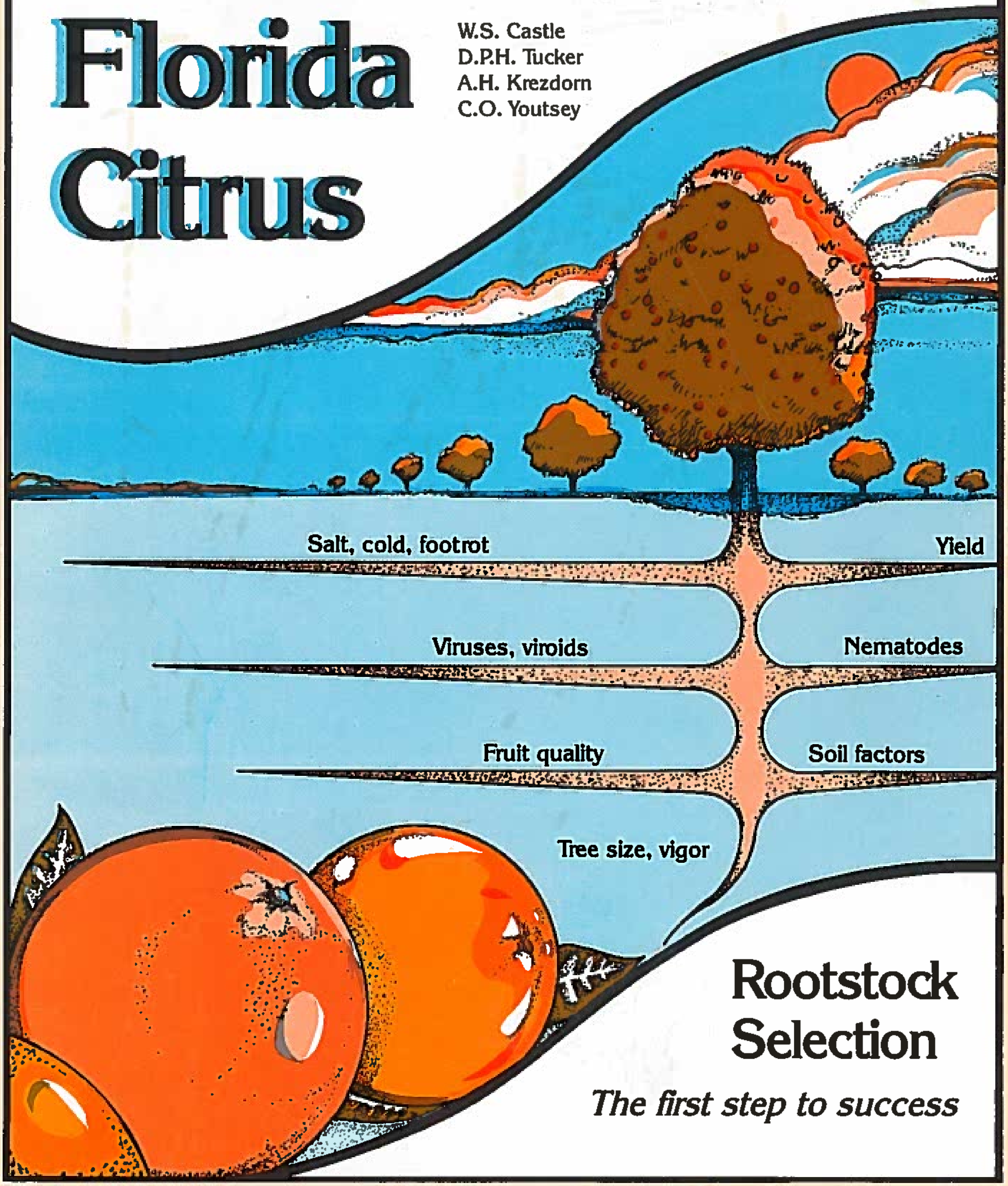

Rootstock Selection

The first step to success

INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES / UNIVERSITY OF FLORIDA, GAINESVILLE / JOHN T. WOESTE, DEAN FOR EXTENSION

Rootstocks for Florida Citrus

Rootstock Selection: The First Step to Success

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Preface

One of the earliest Florida publications about citrus rootstocks was published in 1955. The author, Jasper Joiner, stated that rootstocks "can mean the difference between success and failure in a grove operation" (University of Florida Extension Circular 132). Sour orange, rough lemon, sweet orange, Cleopatra mandarin, grapefruit, trifoliate orange, Rusk citrange and Rangpur were described in four pages. Fred Lawrence and Don Bridges expanded the discussion in a 1974 IFAS extension circular (No. 394) to include Carrizo citrange plus several rootstocks which had been recently released because of tolerance to the burrowing nematode. More importantly, however, blight was introduced as a limiting factor to rootstock selection.

The basic premises and purposes of these earlier circulars remain unchanged in our publication. It is still true, and perhaps even more so today, that rootstock selection is a significant economic factor in citriculture and that sound decisions are informed ones.

Interest in rootstocks has broadened and intensified greatly since the 1974 circular was published. As a result, we felt a change in scope was necessary and have written a considerably expanded and more comprehensive publication. Each section treats a specific aspect of citrus rootstocks beginning with introductory material relating the purpose of rootstocks and their history in Florida. We included some discussion of propagation primarily to insure that readers become familiar with the Bureau of Citrus Budwood Registration and with the definition and horticultural significance of a clone. Clonal propagation is an essential and central concept in citriculture.

The last sections are detailed discussions of rootstock characteristics, strengths, weaknesses and suggested uses as well as selection strategies. Two new rootstocks of recent commercial interest, Swingle citrumelo and Volkamer lemon have been added to the list of those previously described. Also, readers interested in new rootstocks will find a section describing ones suitable for small scale trial.

This publication will be informative and useful to readers ranging from citrus professionals to students, and to others associated with the citrus industry. A glossary has been included which contains terms that are possibly new or unfamiliar especially to readers without a background in plant science or citriculture.

Readers should recognize that the study of citrus rootstocks is not an exact science. The information contained herein was developed from experiment data, commercial experience and our collective observations. We have attempted to combine the information from these sources in as factual a manner as possible and to indicate when the information is otherwise.

In writing this publication, we called upon colleagues in research and extension as well as citrus growers, managers and nurserymen, to review the manuscript. We appreciate their effort and contributions. Also, we wish to acknowledge the assistance of Eileen Castle who helped with the cover concept and David Miller, the IFAS artist who converted the concept into a bold and attractive final design. We especially want to thank Eileen Hoobin for her competence and patience in the typing of many manuscript drafts and Sally Knox, our expert production editor in the IFAS editorial department.

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Introduction

Citrus rootstocks affect more than 20 horticultural and pathological characteristics of the tree and fruit. As a result, rootstock use is considered essential in citriculture because of the strong influence rootstocks have on where and how successfully citrus can be grown.

Rootstock effects on scion vigor, yield, fruit size, juice quality and pest tolerance are generally of greatest interest because of the direct relationship these factors have on grove profit. Tree growth and yield, however, interact strongly with climate, soil, tree spacing and other factors, often producing contradictory reports on rootstock performance. Tree size and vigor are particularly important because of the trend toward increasing plant density. In the past, growers generally sought large, vigorous, highly productive trees that were widely spaced. Such trees are still acceptable but it is now generally recognized that closer spaced trees have a much greater yield potential per unit of land area, especially in the early years. Furthermore, smaller, less vigorous but yield-efficient trees are more suitable for dense planting.

Rootstocks have had a substantial role in the development of the Florida citrus industry. Prior to about 1970, the industry was well-served by two rootstocks — rough lemon and sour orange — for most scion cultivars. Cleopatra mandarin was the common rootstock for mandarin cultivars. The risks in growing citrus at that time were occasional freezes, phytophthora foot rot, nematode damage in some parts of Florida and a small loss of trees on sour orange rootstock to citrus tristeza virus.

During the 1970s and 1980s, rootstocks became a more critical issue than in previous years largely because of blight and the increased incidence of tristeza and frequency of freezes. These three factors have contributed greatly to reducing the expected life of a grove. Therefore, foremost in growers minds are strategies to prevent or reduce the impact of one or more of these factors. Rootstocks relate directly to these factors and will continue to be a key element in establishing and maintaining a profitable citrus grove.

Purpose of Rootstocks

Citrus trees are commonly propagated on rootstocks rather than as seedlings or as cuttings because rootstocks provide certain advantages that are beneficial to a citrus tree regardless of its use as a commercial, ornamental or dooryard plant.

Rootstocks serve three general purposes:

- **Reduction of juvenility.** Trees grown from seed are slow to bear, often very upright and vigorous in growth habit, and thorny. These juvenile characteristics are avoided because even though a rootstock seedling is used during propagation, it is budded with scion material from a fruiting (mature) tree. Thus, budded trees fruit earlier, and more regularly and uniformly than seedling trees.
- **Environmental adaptation.** Citrus rootstocks differ in their tolerance to various soil factors, pests, diseases and environmental stresses. This variation between rootstocks is directly related to expanding or limiting the areas where citrus can be grown.
- **Horticultural performance.** Citrus rootstock interactions with the scion and environment affect tree water relations, mineral nutrition, growth, productivity and several aspects of fruit quality.

History of Seedling and Budded Trees

The citrus industry in Florida grew out of 16th Century Spanish introductions of plants and seeds of sour orange, sweet orange, lemon, lime and citron. Many wild groves of trees became established from these seeds and seedling plants. Citrus was spread further by Indians and by pioneers who settled the hammocks, rivers and lakes of north Florida and the eastern seaboard. There was limited commercial cultivation of these wild plantings but it was not until better transportation was available for market expansion that interest developed in improved horticultural practices. Captain Dummit, of Merrit Island around 1830, was among the first to attempt to raise citrus for the commercial fresh fruit market. Following his lead, others began to topwork scions onto their wild groves of sour orange seedlings in an attempt to increase production, modify tree habit and reduce losses from foot rot to which seedling sweet orange trees were susceptible. As the industry developed, sour orange remained the favorite rootstock for trees in the northern areas of Lake and Marion counties where they survived major freezes. Also, trees on sour orange were widely known to be tolerant of foot rot and yield fruit of excellent quality. For these reasons, sour orange was a favored rootstock for both interior and coastal areas where it performed well in hammock soils.

The success of sour orange as a rootstock enhanced the popularity of budding which soon became the accepted propagation method in citrus nurseries. Seedling trees were eventually eliminated. Budding allowed growers to readily propagate and thereby increase their superior, better producing trees while also encouraging interest in additional rootstocks. As a result, the industry grew and increased in diversity because many new rootstock and scion cultivars were introduced and their adaptability evaluated much more quickly than could be achieved with seedling trees.

Production of Citrus Nursery Trees

Seed and Budwood Sources

The citrus nursery tree, the foundation of any citrus industry, is composed of a scion and a rootstock. The performance of the nursery tree in the grove is closely related to the quality of each part, i.e., the rootstock and scion cultivar have proven attributes, and are true-to-type and free of pests and diseases. In order to preserve these characteristics, propagation material should be obtained only from seed and budwood sources that have been established for this purpose from tested material. It is essential to avoid collecting seeds and buds from trees of unknown or uncertain origin and untested characteristics.

It is the primary purpose of the Division of Plant Industry (DPI), Bureau of Citrus Budwood Registration, to provide citrus nurserymen with propagation materials of known identity and performance. The Bureau maintains a repository, the Foundation Grove, which serves as Florida's principal source of budwood enabling nurserymen to plant and grow their own validated or registered sources of rootstock seed and/or scion budwood.

Many nurserymen have their own seed or budwood planting or purchase these items from other reputable sources; however, the industry continues to use other traditional sources that may not be as reliable. Wild seedlings of sour orange, sweet orange and lemon growing in warm, hammock-like sites are still being used as seed sources as well as fruit on rootsprouts arising from freeze or disease damaged trees. Likewise, scion buds are sometimes taken from "superior" trees that have never been objectively evaluated. Serious problems can result from either of these situations. <u>Nursery trees grown from registered materials are a worthwhile investment</u>.

Details concerning the DPI validation and registration program are available at the Citrus Budwood Bureau office in Winter Haven. Supplementary information regarding rootstocks for seed source trees is presented in Appendix A.

The Clone

Variation is a fundamental part of the biological world and understanding its significance to citriculture is essential. The basic concept is that some of the variation expressed in plants can be in the form of a unique trait of practical value which is identified and subsequently maintained through propagation. Even though these differences among plants arise from naturally occurring variation, the plants are separated and classified in cultivation according to their useful characteristics. Such a group of cultivated plants with a special trait that is reproduced during propagation is called a **cultivated variety** or **cultivar**. This term is preferred over the less precise term — **variety**.

Cultivars are reproduced either sexually or asexually. One that is reproduced asexually is known as a **clone** which is defined as **a group of genetically uniform plants derived by asexual (vegetative) propagation from a single plant. Clonal propagation**, or **cloning**, is a horticulturally significant practice because it allows the advantages of a single, superior plant to be exploited. Also, because they are genetically uniform, those plants comprising a clone are uniform under grove conditions for such factors as tree growth, size, yield and so on.

The terms **cultivar, clone** and another one, **budline**, are often mistakenly used synonymously. Confusing these terms can easily be avoided by remembering that a clone is simply an asexually reproduced cultivar. Orlando tangelo is an example of a cultivar because it has certain features which clearly distinguish it from other kinds of citrus. This cultivar is asexually propagated by budding, therefore, Orlando trees comprise a clone according to the previous definition.

Valencia sweet orange is different from the tangelo in that there are actually many clonally propagated cultivars of Valencia. This situation exists because a number of Valencia variants that are distinguishable from the parent cultivar have been selected for various traits such as yield, time of fruit maturity and juice color. Each variant is sufficiently different to warrant being considered as a new cultivar.

In Florida, a promising variant is usually entered into the citrus budwood program where it is coded (see glossary terms, **Validation** and **Registration**) and then evaluated. If shown to be commercially valuable because of its different characteristic(s), the variant is released as a new cultivar and is clonally propagated. An example is the Rohde Red Valencia which is a named cultivar.

A budline is a specific source of propagation material within a cultivar, for example, the Hughes nucellar valencias. Each budline, such as V-S-SPB-1-14-19 or V-S-SPB-1-10-23, originated from a single nucellar seedling and has since been clonally propagated.

Both scion and rootstock cultivars must be clonally propagated in order to preserve their unique characteristics such as the burrowing nematode resistance of Ridge Pineapple sweet orange. Rootstock cloning occurs at two times. First when establishing seed source trees which should be done by budding; and second, when seedlings are raised for use as a rootstock in the nursery. Many rootstock cultivars are clonally reproduced because the seedlings are of nucellar origin, but the seedling population is not a pure clone. Some seedlings of sexual origin may be included among them if not removed by roguing.

A clear understanding of a cultivar, clone and budline has broad application, particularly among nurserymen and those who purchase nursery trees. Without this knowledge, nurserymen may jeopardize cultivar or budline advantages and buyers may risk receiving nondescript trees that are not the best cultivars or budlines available unless the specific, desired one is requested.

Production Systems

Nursery trees are produced by two systems in Florida. The oldest and conventional method is the field nursery which typically involves about two years and three steps to grow a finished tree. An outdoor seedbed is sown in the spring and the seedlings transplanted the following fall or spring. These seedlings are budded, and the scion grown for another year.

The newer method, which became more prominent beginning in 1978, is an indoor, containerized procedure. Seedlings raised under cover in a reuseable container are transferred in about 90 days to another container filled with a soilless medium composed of peat and other materials. They are budded within several months and the scion grown for 9 to 12 months. Trees can be produced by this method in 12 to 18 months but their trunk caliper is smaller than that of field-grown trees.

The second method is purported to have certain advantages. Trees raised in this manner are easily protected from cold weather, have a shorter production cycle, should be free from soil-borne disease, primarily foot rot, and are easily transplanted and established in the field. While container-produced trees have become an important part of the citrus nursery industry, these potential advantages and disadvantages to both nurserymen and growers are still being examined. The number of trees produced by this method has increased rapidly and some nurserymen have combined these methods in order to utilize the best features of each one. These operations involve the use of a greenhouse to grow seedlings followed by transplanting to the field for budding and finishing.

Changes have occurred in the techniques and procedures used to grow nursery trees by either method. Among these is budding height. Nurserymen in Florida have traditionally budded trees very low as compared to other citrus-growing areas around the world, usually within two inches of the soil line. In the 1970s, because of persistent problems with phytophthora foot rot above the bud union on young grove trees, many nurserymen began budding at least four inches above the soil.

Nursery Tree Movement

The DPI, Bureau of Plant Inspection, conducts an annual inventory during January through June to determine the number of plants in Florida citrus nurseries. In addition, the Bureau of Citrus Budwood Registration annually compiles and publishes data reported by nurserymen propagating registered citrus nursery trees. This information shows rootstock and scion trends.

Scion-Rootstock Compatibility

During propagation, usually two genetically different plant materials are combined to form the citrus tree. The relationship between scion and stock, which is commonly termed affinity or compatibility, is of fundamental importance to successful long-term commercial performance.

When the union between scion and stock takes place readily and the tree continues to grow and develop without difficulty, it is said to be a compatible union; however, not all citrus species are compatible with each other or with species of other genera. In general, plants that can be sexually hybridized can be successfully worked together in propagation. The degree of compatibility is related in some measure to the closeness of the genetic relationship between each component.

Experience in Florida has demonstrated that the commonly grown orange, grapefruit and mandarin cultivars are compatible with most citrus rootstocks. The trees can be long-lived and productive with smooth bud unions. These same cultivars can also be grown on some species of genera closely related to *Citrus*. For example, oranges propagated on trifoliate orange, which belongs to a different genus (*Poncirus*), and some of its hybrids such as Swingle citrumelo, have produced very satisfactory trees though the stock normally overgrows the scion, suggesting that the combination is not a fully compatible one. Occasionally, Murcott trees on Carrizo citrange rootstock have declined and died in less than ten years with a bud union disorder (Fig. 1). This decline, which is different from the Murcott collapse associated with excessive fruiting, may be caused by the citrange stunt virus.

Occasional compatibility problems have also occurred with certain mandarin hybrids and some of the ornamental citrus cultivars including calamondins, kumquats and limequats on trifoliate and its hybrids. Other combinations, e.g., Orlando tangelo on trifoliate orange and citrange rootstocks, seem to be unaffected.

A word of caution. When considering planting trees of scion/stock combinations for which there is little or no information regarding their compatibility, the following precautions should be observed. Many compatibility problems do not appear until the trees are several years old, therefore, it would be unwise to plant large acreages until experience suggests otherwise. Also, **some incompatibilities can be virus induced; therefore, always plant registered trees.**

Rootstock Relationships to Viruses, Viroids, Soil-Borne Organisms, Blight and Environmental and Soil Factors

Viruses and Viroids

There are more than 27 virus or virus-like agents described for citrus. A number of these agents cause tree decline or reduce production regardless of the

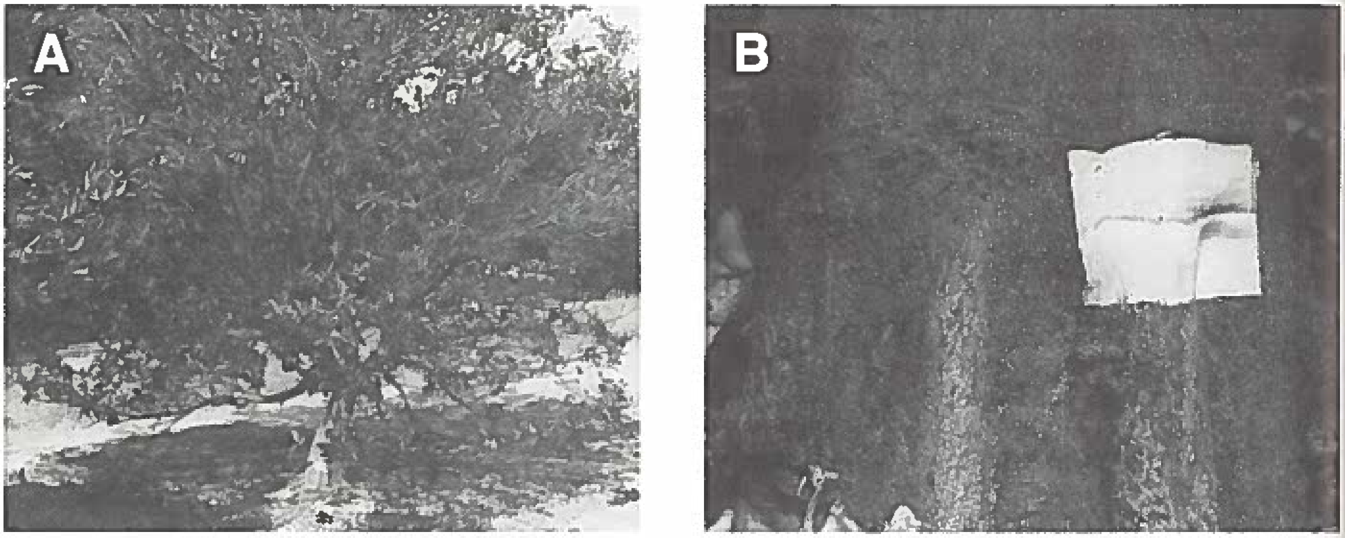

Figure 1. (A) Declining 8-year-old Murcott tree on Carrizo citrange and (B) associated bud union crease.

scion and rootstock combination while others cause damage only to certain specific scion-stock combinations. Viral agents have affected the production of citrus the world over. Citrus tristeza virus (CTV) introduced into Brazil and Argentina in the 1930s, for example, caused the virtual destruction of the industry because of the extensive use of sour orange rootstock. Many cultivars of citrus may be symptomless carriers of these agents and grow vigorously with no obvious indication of disease throughout the life of the tree. Costly failures have resulted from topworking virus-infected, but symptomless, older trees with a new scion cultivar that was highly susceptible to one or more viruses present in the older tree. Some virus or virus-like organisms, such as CTV, are vectored by insects, some are transmitted only through infected budwood, and some are transmitted mechanically via budding and pruning tools. Seed transmission can occur but is rare.

Many serious losses have resulted from budding susceptible rootstock cultivars with virus-infected budwood taken from symptomless and apparently healthy trees. Many scion cultivars propagated on various species of *Citrus* and their near relatives commonly used for rootstocks, are susceptible to certain viral agents and cannot be grown satisfactorily when infected with them.

Testing of selected citrus trees has been done in Florida since 1953 by the Bureau of Citrus Budwood Registration. Through registration of bud source trees, adequate supplies of virus-tested, horticulturally sound budwood are available to the Florida industry of all commercial cultivars in current production.

Among the diseases in Florida that are caused by a virus or virus-like organism, the most important is CTV, a disease capable of causing serious losses in both new and old plantings. Citrus tristeza virus affects virtually all scion cultivars on sour orange rootstock except lemon. Psorosis, citrus exocortis virus (CEV) and xyloporosis, for all practical purposes, have been eliminated from commercial planting stock through the use of tested propagation material and should no longer pose a threat for the grower planting new acreage. When rejuvenating old plantings, these agents if present, may be a problem for certain scions.

A summary of virus and viroid effects on scion cultivars is given in Table 1. See Appendix E for a summary of rootstock susceptibilities. A comprehensive description of field virus symptoms for diagnostic purposes can be found in the *IFAS Florida Citrus Integrated Pest and Crop Management Handbook*.

Citrus Tristeza Virus (CTV)

This disease was first recognized in Florida about 1950 and in the years since has been spread by aphids and infected nursery stock into every citrus growing area of the state. Florida growers have long used sour orange as a rootstock with only minor losses in most growing areas because most trees appeared to be infected with "mild strains" of CTV that did not cause tree decline.

While some tree decline due to CTV has been evident in mature groves in certain areas of the state for the last 20 years, notable increases in affected trees occurred in several regions of Florida during the 1980s. At the same time, large numbers of young trees were reported to be affected by apparently severe strains of CTV that primarily stunted the trees. In some plantings, as high as 40 to 60%, and in others, 100% of the trees were affected. Nursery trees on sour orange rootstock infected with these CTV strains show an obvious lack of vigor when compared to other trees of the same age infected with "mild" CTV strains or that are virus free. No cultural practice will restore these trees to a vigorous condition. They should be destroyed.

In many countries, strong strains of CTV are present which cause severe pitting of the stems and

Table 1. Commercial scions and the viruses or viroids affecting their performance.[z]

Scion	Susceptibility
Dancy tangerine Grapefruit Minneola tangelo[x] Murcott tangor Satsuma mandarin Sweet orange Temple tangor	Tolerant to all viruses commonly found in Florida except psorosis[y] and ringspot virus.
Clementine mandarin Fallglo mandarin[x] Lee tangerine Nova tangelo Orlando tangelo Osceola tangerine Page orange Robinson tangerine Sunburst tangerine[x]	Affected by psorosis and may show severe to mild decline caused by xyloporosis on any rootstock.
Key lime Tahiti lime (Persian)	Affected by psorosis and tristeza on any rootstock.
Bearss lemon	Affected by psorosis. Tolerant to tristeza even on sour orange or *C. macrophylla* rootstocks.

[z] The information presented concerns the direct effects of viral agents on different scions. Readers should not confuse this information with rootstock related viral effects. In this Table, susceptible scions will be affected regardless of the rootstock. Tolerant scions, if infected, become latent carriers of the viral agent and if budded on an intolerant rootstock, tree damage will result.

[y] The term "psorosis" includes related viral agents, such as blind-pocket and concave gum.

[x] Tentative rating.

trunks of sweet oranges and grapefruit. The severity of the problem is enhanced by the presence of the brown citrus aphid, *Toxoptera citricidus*, the most efficient insect vector of CTV. This aphid is not found in Florida. Frequently, older trees infected with CTV for one or two years will have a conspicuous overgrowth of the scion at the bud union (Fig. 4).

A number of research trials are being conducted in several countries to observe the reaction and performance of trees intentionally infected with mild strains of CTV in order to "protect" the tree from later invasion by a stronger strain of the virus that would normally cause severe damage. This approach is known as "cross protection." Preliminary observations in these countries suggest that orange and grapefruit cultivars can be protected from stem pitting strains even under conditions of heavy pressure from field infection. Mixed results have been observed in Florida trials using mild strain inoculations with sweet oranges on sour orange rootstock. In the meantime, growers are encouraged to use rootstocks other than sour orange and *C. macrophylla* for new plantings because these stocks are highly susceptible to CTV. Palestine sweet lime should also be avoided as there has been some field loss among trees on this stock as well.

Citrus Exocortis Viroid (CEV)

The viral nature of this disease was only demonstrated as recently as 1950 by Australian workers who called the disease "scaly butt" due to the bark scaling symptoms found on infected trees budded on *Poncirus trifoliata* rootstocks. In 1952, the disease was called "Rangpur lime disease" because it appeared in trees budded on Rangpur rootstock in certain plantings in the United States. In succeeding years it was soon proven that these disorders were caused by the same virus-like agent now classified as a viroid.

Citrus exocortis viroid can be easily spread from diseased trees to healthy ones by using infected budwood, by topworking infected trees, or on pruning and propagation tools if precautions are not taken to sanitize the equipment while moving from tree to tree. Spread of this disease by insects has not been observed.

It is important that CEV-free budwood is used when propagations are made on rootstocks such as Troyer and Carrizo citrange, trifoliate orange, Rangpur and certain citrumelos. These stocks are susceptible to CEV and will not make vigorous, healthy trees if infected. The significance of CEV-free budwood to the industry is obvious. The existence of CEV-free budwood was a major factor enabling Carrizo citrange rootstock to be used as a replacement for rough lemon when the latter was no longer propagated because of blight susceptibility.

Citrus exocortis viroid, unlike most of the other viral agents, may have a beneficial use. The existence of mild strains that only reduce tree vigor without other adverse effects has encouraged research workers in several countries and in Florida to experiment with these mild strains of CEV to control tree size.

Citrus Psorosis Virus Group

Reports of investigators from both California and Florida describing the bark scaling in older citrus plantings that is typical of psorosis, indicate this disease has been recognized since the 1890s. For convenient discussion, this general heading includes disease agents that may have similar or common symptoms. Psorosis (scaly bark), blind pocket, concave gum, and citrus ringspot (CRV) are thought to be part of a disease complex as yet not fully characterized. Crinkly leaf and infectious variegation were thought at one time to be closely related to the psorosis group, but they have now been determined to be separate disease agents.

Unlike CEV and CTV, the psorosis group is capable of causing decline, and reducing yield and tree vigor in all citrus cultivars regardless of the rootstock. These diseases are the basic ones for which budwood registration and cultivar improvement programs were originally designed to eliminate. Rootstock selection cannot be used to protect against the psorosis complex of diseases. Psorosis has been shown to be seed transmitted to a small extent from infected trees of Carrizo and Troyer citrange and trifoliate orange. For this reason, seed source trees tested free of psorosis are important in the elimination of this disease. Furthermore, it is important not to use fruit from rootsprouts as a seed source.

Xyloporosis Viroid

In general, sweet orange and grapefruit cultivars as scions, are tolerant to this disease, expressing few or no symptoms. Many selections of mandarin, tangelo, and tangor scions are quite susceptible and are severely affected by this viroid regardless of the rootstock (Table 1). Certain mandarin types are notably less affected than others. The disease is only known to be budwood transmitted. Infected trees on the susceptible rootstocks, Palestine sweet lime, *Citrus macrophylla*, and Rangpur, will show a severe reaction.

Previous problems with this disease have now been virtually eliminated. Tolerant rootstocks are used and the budwood available at the DPI Foundation Grove is xyloporosis-free. The only remaining risk would be in topworking old virus-infected trees with a susceptible scion such as Orlando tangelo.

Nematodes

Three plant parasitic nematodes have been a sociated with significant damage to Florida citrus. T citrus nematode, *Tylenchulus semipenetrans*, t burrowing nematode, *Radolpholus similis*, and t coffee lesion nematode *Pratylenchus coffeae* cause sl decline, spreading decline and citrus slump, resp tively. These disorders occur when the proper co bination of rootstock, plant parasitic nematode a environmental conditions is present.

The resistant plant is the most energy efficient a environmentally safe means of minimizing yield loss due to plant pathogenic nematodes. Considerab research effort has been invested in the developme of nematode resistant[a] or tolerant[a] citrus rootstock Most rootstocks are susceptible[a] to the burrowing a citrus nematode. The exceptions are Carrizo citran which is tolerant to burrowing nematodes, while Mila lemon and Ridge Pineapple sweet orange are resista to some biotypes of this nematode. Swingle citrume and certain trifoliate oranges are resistant to Flori populations of the citrus nematode. Planting certifi trees on these rootstock cultivars in conjunction wi preplant nematode sampling followed by fumigati of infested areas will allow trees to obtain a bett start and offer the grower a reduced risk of developi resistance-breaking nematode populations.

Foot Rot and Root Rot

Foot rot is a disease of the bark on the lower trun or crown roots of citrus caused by the invasion ne or at ground level of the soil-borne fungal organis *Phytophthora parasitica*. The distinctly differe damage caused by attacks on fibrous roots by the sam fungus, is called root rot. Similar trunk and ro damage is also caused by another species, *Phytophtho citrophthora*. Rootstocks differ in their tolerance t these two species; however, the following discussio concerns only the former as field studies have indicate that it is the more common species in Florida.

The common and widespread occurrence of *Phy tophthora* fungi pathogenic to citrus continues to hav a significant influence on the world rootstock situatio While much can be done to prevent serious infectio by the adoption of improved cultural practices and th use of suitable preventive measures includin fungicides, the ultimate solution to a severe diseas problem is the use of resistant rootstocks. Unfor tunately, some of the *Citrus* species that are highl resistant to foot and root rot are unsatisfactory fro other standpoints. Thus, in practice, many susceptibl rootstocks have to be planted because of their superi ority in other more essential aspects.

When planting trees, foot-rot tolerant rootstock should be selected and used in combination with othe precautionary measures that are based on the nee

[a] These terms apply to many interactions of rootstocks with pest and diseases. The differences in the meaning of these term are important to understand. They are defined in the glossary

for avoiding contact of susceptible bark with the soil, and for creating more ventilation to hasten the drying out of bark after irrigation or rainfall. Therefore, trees should not be planted too deeply, injury to bark should be avoided to preclude entrance of the fungal organisms, weed growth should not be allowed to become established under the canopy and around the tree trunk, and soil should not be banked against the trunk (for cold protection) without pretreatment with approved fungicides. Removing the soil bank without injury to the tree after the threat of cold weather is very important. Trees with trunk wraps should be checked periodically.

Budding height is a frequently overlooked preventive procedure. Many scion cultivars are more susceptible than the rootstock on which they are budded. When budding height is increased, the susceptible scion is effectively moved further away from the source of *Phytophthora*, the soil, and the potential for foot rot is reduced.

The only commercial rootstocks resistant to foot rot are trifoliate orange, *C. macrophylla* and some citrumelos, including Swingle. Sour orange, Cleopatra mandarin and Carrizo citrange are tolerant while rough lemon, Milam, Volkamer lemon, Rangpur and Palestine sweet lime are susceptible. Sweet orange is generally considered as the most susceptible when used as either a scion or rootstock.

The above grouping of rootstocks is based on extensive experience gained from controlled testing and field observations. Nevertheless, it is a generalization and there are exceptions and inconsistencies. The ranking of a particular rootstock may not correspond to individual commercial experience. Certainly there are many groves of trees on rough lemon with few or no foot rot losses and some groves of trees on more tolerant stocks with many problems. Factors that can influence this apparent inconsistency are tree age, cultural practices and the level of *Phytophthora* spp. inoculum present. There is also variation within rootstock sources. The rootstock seed sources maintained at the DPI Foundation Farm were propagated from the best selections in USDA *Phytophthora parasitica* screening tests.

Our understanding of foot rot and its apparently erratic appearance is incomplete but the judicious selection of rootstocks, cultural practices and fungicides will do much to minimize the impact.

Phytophthora spp. also infect and cause fibrous root rot of citrus (Fig. 2). Although it is well-known that the disease can occur in nurseries and weaken and kill seedlings, the magnitude of fibrous root loss in grove trees has only recently been documented. Losses have been assumed to be minimal except on perhaps the most susceptible rootstocks such as sweet orange.

With the advent of new fungicides which control *Phytophthora parasitica*, the extent of fibrous root loss and its consequences on tree vigor and production can now be evaluated. Greenhouse evaluations have provided the following ranking of rootstock root rot resistance: trifoliate orange = Swingle citrumelo> sour orange> Carrizo citrange = Cleopatra mandarin> rough lemon and similar rootstocks> Pineapple sweet orange.

Mycorrhizal Relationships

Citrus roots can be colonized by several soil organisms including mycorrhizal fungi with which they form symbiotic associations. These fungi produce hyphal networks extending into the soil which benefit the plant primarily by aiding in the absorption of water and nutrients, especially immobile nutrients such as phosphorus (P) and copper (Cu).

Citrus rootstocks differ in their dependency on mycorrhizae for optimum growth based on comparisons of the ability of mycorrhizal and non-mycorrhizal plants to take up P from P-deficient soils. Observations of stunting of citrus in fumigated nurseries and pot studies using sterilized soil where mycorrhizal fungi are killed, suggest that there are substantial differences among the commercial rootstocks.

From studies using seedlings grown in low P sandy soils, the order of rootstock dependency is: sour orange = Cleopatra mandarin> Swingle citrumelo> Carrizo citrange> trifoliate orange; however, it has not been demonstrated in Florida that additions of mycorrhizal fungi to plants are beneficial or even essential for maximum growth in the nursery or grove. Furthermore, mycorrhizae will not substitute for a lack of available P in a commercial citrus grove.

Blight

Citrus blight, a root-graft transmissible disorder of unknown cause, has rendered millions of trees unproductive in Florida and elsewhere in the world. Observations from rootstock trials and commercial plantings have provided the only useful measure of rootstock susceptibility to the disorder. Other methods of evaluating blight susceptibility are being explored but a final ranking of scion and rootstock cultivars is far from complete. The rootstock blight rankings that

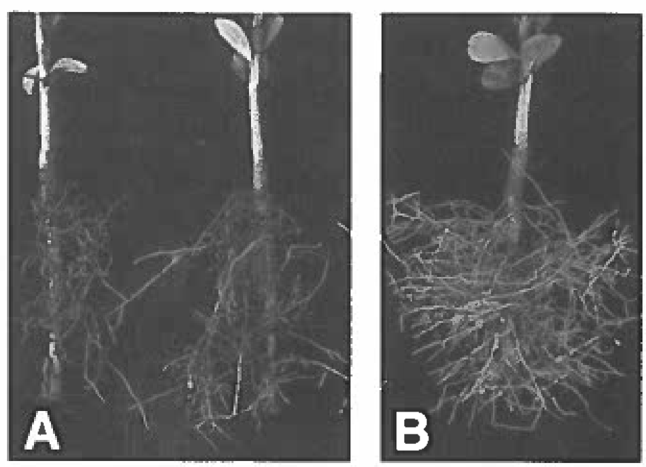

Figure 2. (A) Citrus roots damaged by *Phytophthora parasitica* and (B) uninfected roots.

follow are based primarily on observations among established, solid plantings and are useful for selecting rootstocks for new groves. Less confidence can be placed in these rankings if they are used to choose rootstocks for replanting in blight affected groves. It is likely that many of the differences between rootstocks will be less pronounced because some observations suggest that replant trees decline again and sooner than the original trees even on tolerant rootstocks.

In general, those rootstocks which induce maximum vigor and yield, e.g., rough lemon, Rangpur, Palestine sweet lime, Volkamer lemon, *Citrus macrophylla*, and Milam, can be considered the most susceptible. Limited observations also indicate that trifoliate orange should be included in this group.

Trees on Carrizo citrange are also quite susceptible, but the incidence of blight among trees on this rootstock is variable. Sour orange, sweet orange and Cleopatra mandarin are apparently the least susceptible with sweet orange being the most reliably so at present. High rates of decline from blight have been reported in some plantings of 15- to 20-year-old trees on Cleopatra.

Swingle citrumelo is a new rootstock in Florida and most plantings are presently too young for a reliable blight susceptibility ranking. Among the oldest plantings, blight has affected trees on Swingle but the incidence has been comparatively low.

In the absence of other options, rootstock selection is the only choice available to growers to minimize tree loss from blight.

Cold Tolerance

During the winter months in Florida, citrus trees do not normally flush and they appear to be relatively inactive. At this time, citrus trees are described as dormant and they are undergoing various physiological changes resulting in a condition called cold hardiness or tolerance. The degree of cold tolerance acquired by a tree is influenced by environmental conditions, mainly cool temperatures. Maximum cold tolerance would ordinarily be developed in the northern part of the industry because of lower average winter temperatures, as compared with trees growing in the southern areas and along the coasts.

A plant's cold tolerance is also influenced by the scion and rootstock. There are inherent differences in cold tolerance among scion cultivars regardless of the rootstock. Mandarins as a group are the most tolerant followed by sweet oranges and grapefruit. Lemons and limes are very susceptible to cold. Observations following freezes in Florida, Texas and California have clearly shown that scion influence is greater as compared to that of the rootstock during freezes that have been preceded by favorable cold-hardening conditions. However, when sharing a common scion, it is also clear that rootstocks have a measurable effect on the cold tolerance of citrus trees.

Most rootstocks can be placed into one of three general groups according to their relative effect on cold tolerance. Trees on rough lemon, Rangpur, Volkamer lemon, Milam, Palestine sweet lime and *C. macrophylla* are the least cold tolerant but because of their vigor, they can recover rapidly if not severely damaged or subjected to several freezes in one winter or in succeeding years. Sweet orange and Carrizo citrange induce intermediate cold tolerance while trees on sour orange, Cleopatra mandarin, trifoliate orange and Swingle citrumelo are the most cold tolerant.

The relative performance of any rootstock in relation to cold tolerance is highly dependent on environmental conditioning. The best example is trifoliate orange which as a seedling is very cold hardy. Trees budded on this stock only show their superior cold hardiness in cool climates. In warmer areas like Florida, trees on trifoliate orange are frequently less cold tolerant early in the winter than trees on other rootstocks such as Cleopatra mandarin and sour orange that are very cold tolerant in both cool and mild climates.

Drought Tolerance

Drought tolerance has decreased in importance in rootstock selection particularly in recent years because of the widespread use of irrigation which can mask rootstock differences. However, increasing regulation may affect the future supply and use of water for agriculture in Florida. It is one factor among several that may cause rootstock drought tolerance to be reexamined.

The commonly used rootstocks are not equally tolerant to drought. Differences among rootstocks may be attributed to variations in fibrous root distribution and quantity, the horizontal and vertical extent of root system development as well as in water uptake and transport efficiency. Water uptake is not always directly proportional to root quantity. Beneficial root system characteristics are best illustrated by rough lemon, a rootstock long recognized for superior adaptability to the deep sandy soils of the central Ridge. Trees on rough lemon have a wide-spreading root system extending as much as 50 feet laterally and more than 25 feet deep in these soils. Abundant and deep fibrous roots provide an adaptive advantage for rough lemon-rooted trees despite their large canopies and thus, large leaf evaporative surface areas. When the advantage of depth is removed, as it is for trees planted in the bedded flatwoods soils, small differences among rootstocks in root physiology, distribution and concentration are still meaningful. Rough lemon is a drought tolerant rootstock on both bedded and deep soils.

In contrast to rough lemon, trees on shallow-rooted stocks (Fig. 4) are often the first to wilt during prolonged periods of soil water deficit. Trees on other rootstocks such as sweet orange are also relatively drought susceptible even though they are moderately deep-rooted. The fibrous roots of sweet orange rootstock are poorly distributed and inefficient in deep follow are based primarily on observations among established, solid plantings and are useful for selecting rootstocks for new groves. Less confidence can be placed in these rankings if they are used to choose rootstocks for replanting in blight affected groves. It is likely that many of the differences between rootstocks will be less pronounced because some observations suggest that replant trees decline again and sooner than the original trees even on tolerant rootstocks.

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Tolerance to Flooding

Water management, which encompasses rainfall, irrigation and drainage, is one of the most challenging problems of citrus production in the poorly drained flatwoods soils of Florida. Both surface and profile drainage systems are necessary for satisfactory water control, while adequate irrigation is important because of the limited rooting volume available to trees on the flatwoods soil types.

A thorough understanding of rootstock tolerance to flooding is lacking. Such tolerance is often associated with resistance to the fungus *Phytophthora parasitica*. It has been assumed that flooded citrus roots die from oxygen deficiency and the resulting anaerobic conditions. This assumption is not always correct. Studies have shown that root survival under flooded conditions is influenced by such factors as rootstock, soil type and pH. The presence of hydrogen sulfide (H_2S) and other toxic metabolites manufactured in the root zone under anaerobic conditions can result in more rapid root destruction than oxygen deficiency per se. The pH of the soil solution influences the rate of root death when sulfides are present — the lower the pH the more rapid the root destruction.

Limited observations of seedlings under controlled conditions, and of commercial trees, indicate that rough lemon, Volkamer lemon, Milam and Swingle citrumelo are the most tolerant to flooding. Cleopatra mandarin, Carrizo citrange and *Citrus macrophylla* exhibit the least tolerance while sour orange, trifoliate orange and Palestine sweet lime are intermediate. Any variation from this ranking among field trees can probably be accounted for by differences in the soil and drainage characteristics of the sites.

Another factor affecting relative flood tolerance may be rootstock ability to replace dead roots with new ones. Rough lemon is generally considered to be more tolerant to flooded conditions than sour orange. Trees on rough lemon have the ability, as probably do those on most of the other lemon-like rootstocks, to rapidly initiate new roots after flooding.

Sites without adequate drainage should not be considered for planting citrus based on our limited knowledge of flooding tolerance. Trees on all rootstocks are eventually damaged to some degree under flooded conditions. Therefore, to insure the economic viability of a planting on poorly-drained sites, a sound management program should include proper engineering and land preparation prior to planting.

Soil Factors

Soil physical and chemical characteristics are two factors to consider during the rootstock selection process. In Florida, citrus trees are grown in two general regions, the flatwoods and the central Ridge, where the soils differ in depth especially to the natural water table, soil texture, water-holding and cation exchange capacities and pH as well as other characteristics that affect tree performance.

In the central Ridge citrus areas, the soils are mainly deep, well-drained, very sandy and comparatively uniform over multi-acre planting sites. They are infertile but this deficiency is corrected with fertilization. It is the soil physical characteristics that determine which rootstocks are best suited for such conditions. As a result, when Ridge sites were first planted, rough lemon became the decidedly superior rootstock. Trees on this rootstock and others which can develop extensive, deep root systems are well-adapted to the Ridge soils and their low water-holding capacity. Trifoliate orange was not considered suitable for Ridge sites because trees on this rootstock were small, shallow-rooted and drought intolerant; however, as irrigation has become commonplace, it is clear that soil physical factors are less critical in rootstock decisions. The problems associated with low water-holding capacity are reduced but the necessity for good drainage remains.

Unlike the Ridge citrus areas, flatwoods soils are highly variable, often within sites of only one acre or less. Also, both soil physical and chemical factors may affect rootstock peformance at a particular site. Therefore, it cannot be expected that a single rootstock will be entirely satisfactory throughout a given location.

The better flatwoods soils normally used for citrus are not limiting for most rootstocks if the site is properly prepared. The relative performance among trees on the commercial rootstocks will differ little for yield and juice quality between flatwoods and Ridge locations. Soil factors and rootstock selection become more important when the poorest flatwoods soils are planted.

Some flatwoods soils have comparatively low fertility levels and water-holding capacities. Only rootstocks such as rough lemon and Volkamer lemon are suitable for these soils. Extremely impoverished sandy soils are difficult to manage economically and should be avoided.

Flatwoods soils vary greatly in pH. Where the soil pH is alkaline because of large amounts of calcium present in the soil, growing citrus can be difficult and uneconomical. As the soil pH rises well above 7.0, to 8.0 or 8.2, decreases in nutrient availability adversely affect trees on most rootstocks; however, there are some noncommercial rootstocks that merit small scale trial in Florida because of their tolerance to alkaline conditions (Table 2).

Trifoliate orange, Carrizo citrange and certain other trifoliate orange hybrids are the worst affected rootstocks. They suffer severe calcium-induced iron chlorosis as pH values approach 8.0. Growers also frequently observe incipient manganese and zinc deficiencies among trees on Carrizo at pH values between 6.0 and 7.0. These deficiencies often soon disappear or are easily corrected with micronutrient sprays.

Swingle citrumelo is also a trifoliate orange hybrid. A preliminary study in commercial groves showed that in places where calcareous rock or thick marl layers appeared to dominate the surface 12 inches of the soil profile, trees on Swingle yielded poorly. In other sites, where the pH of the surface six inches was 8.0 and sea shells or small amounts of marl were present, Swingle trees seemed normal in size and production. Additional study is needed, however, before any firm recommendations can be made regarding Swingle and other citrumelos and their use in calcareous sites.

Salinity Tolerance

Citrus is generally classified as a salt sensitive plant because relatively low levels of salinity can reduce tree performance. This aspect of water quality has not been of major concern in Florida largely because high annual rainfall usually washes out any salt build-up that occurs in the soil. Salt effects can be cumulative and occur in proportion to the salinity level present. Yield and/or tree effects may not be noticed until a certain threshold is exceeded. Visible leaf symptoms often appear after other plant processes have already been affected.

Salt problems in Florida result from the sodium chloride (NaCl) and other salts primarily present in the irrigation waters used in flatwoods areas near the east and west coasts. Salinity tolerance has historically been a low priority factor in choosing a rootstock for these areas and conditions. The principal difficulty with saline water has been leaf damage and loss resulting from the use of overhead irrigation systems. This problem was eliminated by the adoption of under-tree irrigation methods; but the low application rates for some of these new systems may cause salt accumulation in the soil when saline irrigation water is used. Salinity remains an issue and is becoming more serious as the citrus industry continues to plant heavily in areas where the primary water supplies are highly saline.

The rootstock determines salt tolerance in a citrus tree. This tolerance is related to several salt effects including the rootstock's ability to prevent the accumulation of Na^+ or Cl^- ions in leaf tissue. Cleopatra mandarin and Rangpur have been consistently ranked as relatively NaCl tolerant. Rough lemon, Swingle citrumelo and Carrizo citrange are NaCl sensitive while Milam and trifoliate orange are very sensitive.

Rootstocks and the Citrus Root System

Knowledge of the rate and extent of root system growth, and root function, distribution and ecology is essential to citriculture. Roots are the water and nutrient gathering portion of the tree and it is the root system that is directly affected by various cultural practices, in particular, fertilization and irrigation. The importance of the root system is not commonly recognized. Much of production management is actually root system management.

The citrus root system consists of two kinds of roots — woody, and fibrous or feeder roots. Woody roots are the large lateral roots, the taproot(s) and other long, slender roots which together form the root system framework. Citrus trees usually have 8 to 12 large scaffold roots evenly distributed around the crown of the tree (Fig. 3). They descend 6 to 18 inches and then extend laterally to as far as 50 feet from the trunk. Scattered among these roots is a network of long, slender roots to which are attached bunches of fibrous roots forming a very dense root mat (Fig. 3).

The developmental pattern described above is evident in field-grown nursery trees and to a lesser extent in container-grown trees. The root system of young trees can expand rapidly. In a recent study, the total fibrous root length of a field-grown nursery tree increased nearly 10,000 feet in 13 months after transplanting to a large root observation chamber.

The soils of the central Ridge favor the maximum expression of differential rootstock effects on root distribution and density because these soils are deep sands. Root growth is not impeded by poor drainage or other detrimental soil characteristics. The taproot(s) can grow to depths of 30 feet or more and additional lateral roots can then develop along the taproot.

The root systems of trees on the common rootstocks grown in Ridge soils, tend to be either widespreading and deep or relatively shallow with most of their fibrous roots occurring near the surface under the canopy. Rough lemon represents the first type. Trees on this and other stocks have fibrous roots as deep as 30 feet with a significant portion at depths greater than three feet. These deeper roots, although distributed throughout a much larger soil volume than the 30 to 50% of fibrous roots occurring in the surface 12 inches, are functionally important. Deep roots can explain the well-known adaptation of rough lemon to the central Ridge and the superior drought tolerance of trees on this rootstock. Trifoliate orange exemplifies the second type with most other rootstocks having intermediate characteristics.

Oftentimes the root system of Florida citrus trees grown in the deep, central Florida soils appears to be shallow. This erroneous conclusion can be credited to the way trees are removed from a grove. When trees are lifted from the soil, most of the deeper roots are broken off and left in the soil, leaving the impression that the only roots are those associated with the surface mat of woody and fibrous roots. Repeated studies, however, have consistently demonstrated the vertical distribution shown in Fig. 4.

Growing trees on flatwoods soils does not alter the basic developmental pattern of the root system except substantially less vertical growth occurs. Virtually all of the fibrous and other roots occur within two feet

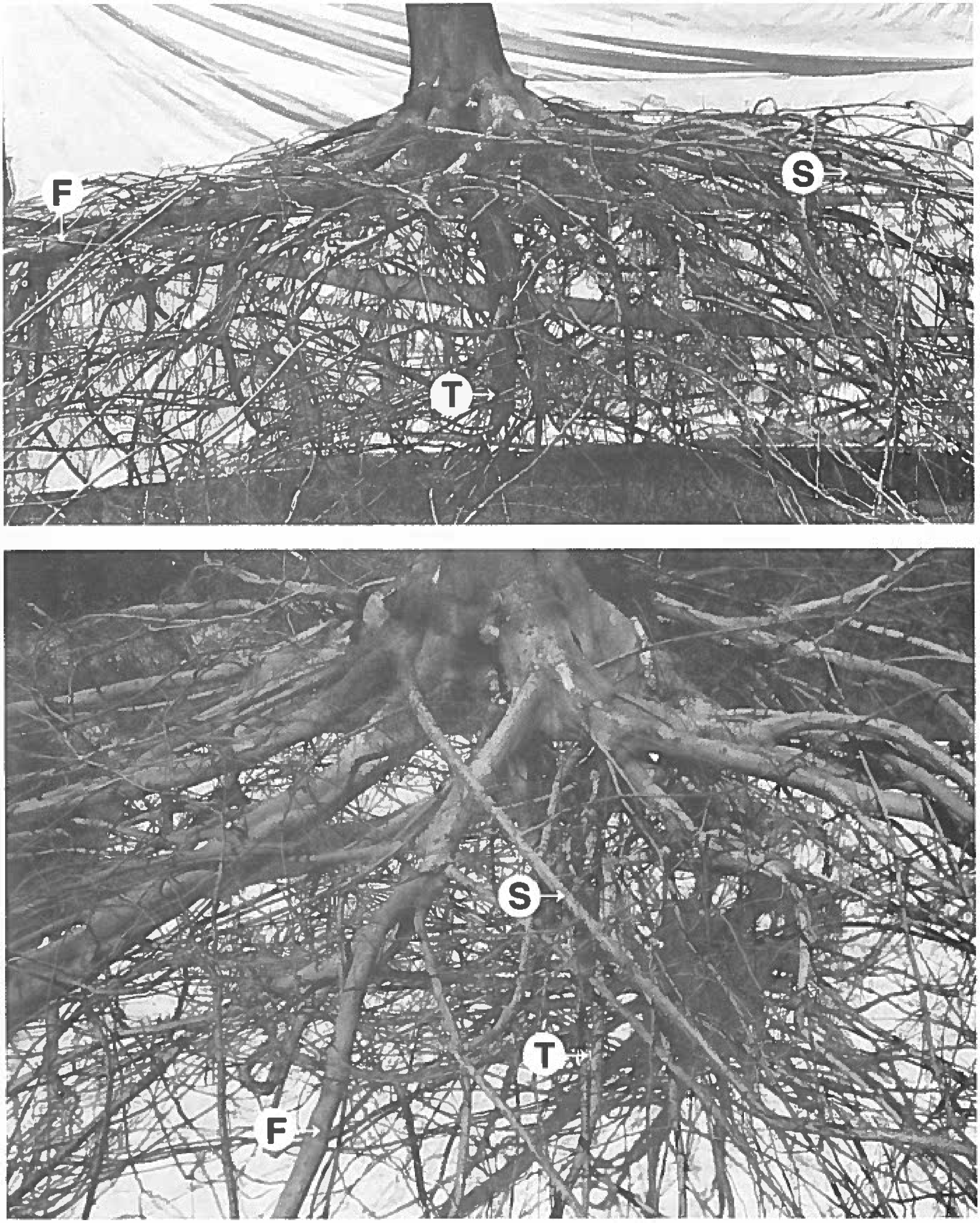

Figure 3. Two views of the root system of a 12-year-old Valencia orange tree on rough lemon rootstock excavated from Astatula fine sand soil. Most of the fibrous (feeder) roots have been removed to illustrate framework (F) and slender (S) lateral roots and the taproot (T).

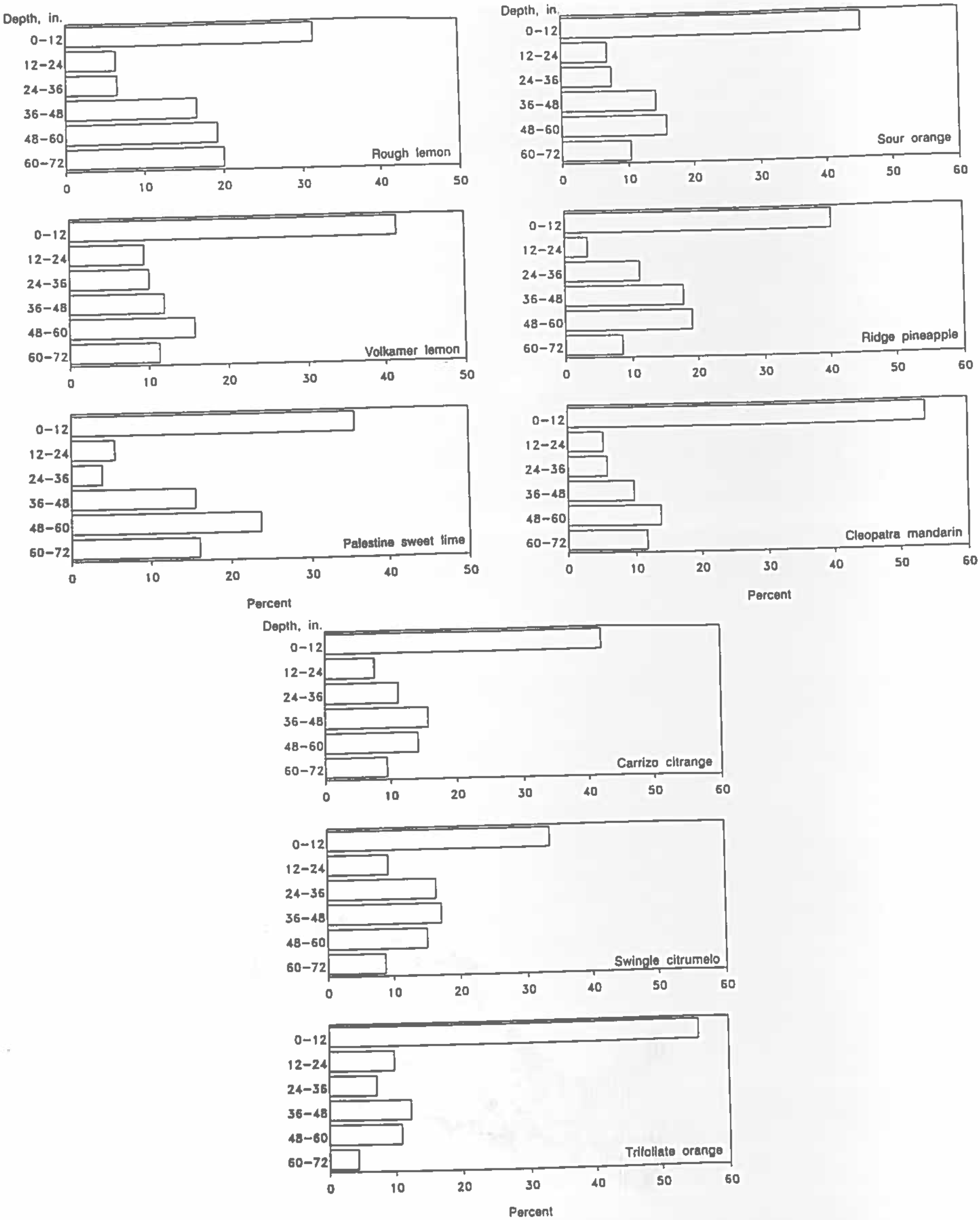

Figure 4. Vertical distribution of citrus fibrous (feeder) roots collected at the dripline of 10-year-old Valencia orange trees on several rootstocks growing in Astatula fine sand.

of the surface. A typical distribution would be 75% in the top six inches, an additional 15 to 20% in the next six inches, i.e., 90 to 95% in the surface 12 inches, and the remainder located in the second 12 inches of the profile. Trees grown under these conditions are considerably more vulnerable to drought and other factors because the root system is limited to a relatively small soil volume.

Rootstock Characteristics

Rough lemon

Florida rough lemon has been obtained from a wide range of sources and several variants have been found. Red rough lemon, a deep orange colored variant does not differ from the standard rough lemon in its performance as a rootstock. Estes rough lemon is a natural selection which, during a testing program, was found to grow among high populations of burrowing nematodes with only a modest reduction in tree vigor. It is no longer thought to have this tolerance.

Trees on rough lemon rank at or near the top in vigor of growth and size of tree produced when compared with trees on other stocks. Yields produced are among the highest for any stock and fruit sizes are large; however, the peel is relatively thick and juice quality is among the poorest. Fruit from trees on rough lemon do not hold on the tree as long as on certain other stocks, the flesh tending to dry out and become ricey. Rough lemon induces maximum tree sensitivity to cold; however, young trees damaged by cold recover more rapidly than trees on less vigorous rootstocks that are damaged as severely. Rough lemon should not be used as a rootstock in chronically cold sites.

Trees on rough lemon are tolerant of tristeza, exocortis and xyloporosis. Most old trees on this stock contain one or more of these viruses without apparent effect. It is susceptible to both burrowing and citrus nematodes and is affected by phytophthora foot rot but is not as susceptible as sweet orange. High susceptibility to blight is its major weakness and the reason why planting of trees on rough lemon was essentially discontinued in the late 1970s.

Rough lemon can be used on a wide range of soils but it is particularly well-adapted to deep, coarse sands on which many other rootstocks do poorly. It is not sufficiently tolerant of foot rot to be used on wet, poorly-drained soils, even though it is more tolerant of flooding than most rootstocks. It tolerates calcareous soils with pH's above 7.5 but is sensitive to saline soil conditions.

Trees on rough lemon have been widely planted in central Florida on the deep sands simply because of superior yields but they have not been popular in the Indian River citrus area where fruit are grown for the fresh market. Trees on sour orange produce fruit of considerably better quality than those on rough lemon. Rough lemon has been widely used for the small-fruited Dancy tangerine to increase fruit size, and occasionally for high quality mandarin hybrids to obtain early harvest; however, it is not, in general, a good stock for mandarins because fruit tend to dry out early, reducing the already naturally short harvest season of most mandarin cultivars. Also, the alternate bearing tendency of cultivars like Murcott is enhanced by the use of rough lemon.

Rough lemon is an excellent stock for round oranges, particularly when they are grown for processing, because the production of soluble solids/acre is unsurpassed by trees on most other rootstocks. Also, some cultivars have an inherently high juice quality such as Valencia. Budding them on rough lemon rather than sour orange does not greatly reduce their quality and such cultivars will yield best on rough lemon. Rough lemon is a poor choice for navel oranges because of the large, coarse, low quality fruit produced. Grapefruit quality is markedly reduced on rough lemon so stocks producing higher quality, such as sour orange, Carrizo citrange and Swingle citrumelo are commonly used where soils permit.

Milam; Milam lemon

Milam lemon was discovered in a Polk County grove of sweet orange trees on rough lemon rootstock. Nearly all trees in the grove had succumbed to burrowing nematode except one tree which was subsequently transplanted to the Citrus Research and Education Center, Lake Alfred and named Clone X. Under this name the rootstock was tested for its susceptibility to the burrowing nematode. It was eventually released as a burrowing nematode resistant rootstock renamed Milam after the owner in whose grove the original tree was found. Milam may be a rough lemon hybrid rather than a variant. Milam and rough lemon are distinctly different in several traits (see Rootstock Identification).

Trees on Milam behave similarly to those on rough lemon regarding tree growth, productivity, fruit characteristics and cold tolerance. Milam is susceptible to foot rot and occasionally growers have experienced high losses of young trees from this disease; however, sometimes the infection begins in the sweet orange or grapefruit scion. Higher than normal budding seems appropriate when using Milam or any of the more foot rot-susceptible rootstocks.

Milam is tolerant to tristeza, exocortis and xyloporosis. Stem pitting has been found in some trees; however, the pitting does not appear to be widespread or to affect the commercial performance of trees on this stock. Limited observations concerning blight indicate that Milam is susceptible and probably should be classified with rough lemon in this regard.

Milam has been used primarily as a rootstock for plantings on the deep sands of central Florida where burrowing nematodes are present. It has been planted sparingly in other areas but has the same range in soil adaptability as rough lemon. Growers occasionally report difficulties in establishing trees on Milam, particularly as bare-root resets. They apparently start off less vigorously than those on other rootstocks and seem to require additional care in the first year or two after planting. Additional fertilizer appears to be helpful in order for trees to grow at the rates experienced with those on other rootstocks.

Milam has been a satisfactory rootstock for oranges particularly for processing fruit, but should not be used for mandarin, navel and grapefruit cultivars if better choices are available. The primary usefulness of this stock has been for planting in burrowing nematode areas. Milam has been recommended for use as a biological barrier but that concept was eventually proven unsatisfactory. It was found that the lateral roots of trees on vigorous stocks such as rough lemon, growing in nematode-infested soil, were long enough to pass through a biological barrier and introduce the nematode. Moreover, burrowing nematode biotypes have developed that reproduce on Milam and reduce tree performance on this rootstock.

Rangpur; Rangpur lime

The Rangpur, often called Rangpur lime, fruit is an acid mandarin type. Calling it a lime is misleading because the fruit has little resemblance to the Key lime or Tahiti lime. There are several variants even though it is a highly nucellar cultivar. Otaheite is an acidless form, often used as a potted ornamental. Kusaie is a yellow-fruited form otherwise indistinguishable from Rangpur.

Rangpur is similar in many respects to rough lemon. It induces high vigor, large trees, minimum cold tolerance, high yields, large fruit sizes and juice quality only slightly better than that produced on rough lemon. Trees sprout badly and have no tolerance of either citrus nematodes or burrowing nematodes. Like rough lemon, it is highly tolerant to tristeza but unlike rough lemon, it is damaged by both exocortis and xyloporosis. It is susceptible to phytophthora foot rot but is one of the best rootstocks for salt tolerance.

There have been only a few small commercial plantings on Rangpur largely because this rootstock has no demonstrated substantial advantages over rough lemon in Florida. This contrasts with the extensive use of Rangpur in Brazil's huge citrus industry where its susceptibility to foot rot has not been limiting. Furthermore, trees on Rangpur in Brazil produce better quality fruit than those on rough lemon. Rangpur can be grouped with rough lemon regarding blight susceptibility. Trees with blight have been diagnosed in Brazil where the disorder is a serious problem among commercial trees.

Palestine sweet lime (often called sweet lemon in Florida)

The Palestine or Indian sweet lime is an insipid fruit, which is somewhat similar in size and form to the Tahiti lime, and has an acid counterpart in India. There are several variants in India where the fruit is widely used as a fresh fruit but they are unimportant as rootstocks. The Colombian sweet lime is merely sweet lime from Colombia and identical with Palestine.

Sweet lime is at least the equal of rough lemon and possibly superior to it in the vigor of growth, tree size, depth of rooting and yields induced. Fruit sizes are unusually large and juice quality only slightly higher or similar to that produced on rough lemon. Trees on sweet lime appear to be about as sensitive to cold as those on rough lemon, even though sweet lime itself is considerably more cold hardy. Sweet lime is not tolerant to either burrowing or citrus nematodes and is similar to rough lemon in its susceptibility to foot rot. Sweet lime is less sensitive to tristeza virus than sour orange but insufficiently tolerant for use where severe tristeza strains are present. It is susceptible to both exocortis and xyloporosis. The use of xyloporosis-infected budwood in research and commercial trials with sweet lime in Florida gave it an undeservedly bad reputation. Trees on sweet lime are affected by blight, based primarily on observations from rootstock experiments.

Research in Florida has indicated sweet lime is well-adapted to deep Florida sands. Sweet lime has been used commercially as a rootstock in Israel, Palestine and India where its use has now declined. It will probably never be a major rootstock for sweet oranges and grapefruit in Florida because of other equal or superior stocks. However, it is worthy of trial for self-incompatible mandarin hybrids such as Orlando tangelo that can set large crops of parthenocarpic fruit, and to induce maximum size in small-fruited mandarin cultivars. In warm areas, sweet lime would be satisfactory for Valencia.

Volkamer lemon

Volkamer lemon is a new rootstock in the Florida citrus industry and has been evaluated primarily as a replacement for rough lemon. Data from Florida rootstock trials and small commercial plantings indicate that trees on Volkamer lemon are generally similar in behavior but superior to those on rough lemon. Trees on Volkamer lemon are very vigorous and productive for their size as young trees. Fruit quality is relatively poor, but has consistently been slightly better than that for trees on rough lemon, Rangpur and *Citrus macrophylla*.

Trees on Volkamer lemon appear to be less affected by cold and foot rot than those on rough lemon. It is not susceptible to tristeza, exocortis or xyloporosis but is damaged by both burrowing and citrus nematodes. Trees on this stock have been affected by blight and appear to be as susceptible as those on rough lemon. Volkamer lemon is adaptable to a wide range of soils and would be suitable for use under most conditions. The vigor and productivity of young trees on this stock make it particularly useful for warm sites with orange cultivars where the fruit is destined for processing; also, for situations in which maximum productivity is desired in short periods of time.

Citrus macrophylla; Alemow

Alemow, the so-called common name for this rootstock, is rarely used in Florida. *Citrus macrophylla* or simply "macrophylla", is another lemon-like rootstock that may be a hybrid of citron. It has been used widely in California and Arizona as a rootstock for lemons. It is relatively new to Florida where it has been also used for lemons and limes and to a smaller extent for other scion cultivars.

Commercial interest in macrophylla is based largely on its precocious productivity. Trees on this stock grow vigorously for one or two years, with growth thereafter being considerably less vigorous because of heavy fruiting. Fruit size is large, but the fruit on young trees generally have a low juice and soluble solids content and tend to dry out early. Trees on macrophylla in rootstock trials have consistently produced fruit with the lowest juice quality.

Trees on macrophylla are very susceptible to cold damage in addition to tristeza, xyloporosis and blight. It is resistant to foot rot and is salt and boron tolerant. Magnesium deficiency has been a persistent problem on calcareous soils.

Despite its precociousness and heavy bearing, macrophylla is not a commonly used stock. Poor juice quality, tristeza, cold and blight susceptibility are factors that limit its attractiveness for most scion cultivars, although it performed well as an experimental stock for Tahiti lime and is now being used commercially.

Cleopatra mandarin

Cleopatra mandarin is a small-fruited mandarin that has been in Florida since 1875. Like sour orange and rough lemon, its performance as a rootstock has been established over many years. There are no recognized variants of Cleopatra. The vigor of growth of trees on Cleopatra is good, producing a standard to large tree. Fruit quality produced on Cleopatra is equal to that produced on sour orange but fruit sizes are consistently smaller. Yields vary greatly with the scion cultivar.

Cleopatra induces maximum cold hardiness in the scion and trees on this stock are unaffected by tristeza, exocortis or xyloporosis. Cleopatra is tolerant of foot rot but apparently it is very susceptible to root rot. This may explain the occasional serious losses of trees on Cleopatra from *Phytophthora parasitica*, particularly in wet, flatwoods sites with a high level of organic matter in the soil. In poorly drained sites, Cleopatra mandarin is best suited for the sandier, better drained locations.

Cleopatra has the highest salinity tolerance among the commercial rootstocks. It is susceptible to both citrus and burrowing nematodes. Blight affects trees on Cleopatra, but this rootstock ranks with sour and sweet orange as the most tolerant. Trees appear to decline only when they reach about 15 to 20 years of age, after which the rate of loss has been variable. The general tolerance of this rootstock, combined with the tree age when affected by blight, suggest that Cleopatra should be considered for use in resetting blight-affected groves.

The yield performance of Cleopatra as a rootstock for round orange cultivars has long been discussed in Florida. Cleopatra is considered a "lazy" rootstock, i.e., trees on Cleopatra grow well but fruit relatively poorly until they are perhaps 10 to 15 years of age or older. Similar reports of yield problems with Cleopatra have been received from many citrus areas outside Florida.

Sweet oranges on Cleopatra are "lazy" bearers but the differences between trees on this and other rootstocks are closely related to the cultivar. Hamlin and Pineapple, for example, are relatively productive cultivars and bear well on Cleopatra. They can be expected to lag behind for perhaps three or four bearing years before they produce as well as trees on Carrizo citrange or rough lemon; however, rootstock differences in cumulative yield are likely to be small. Valencia is naturally lower-yielding than either Hamlin or Pineapple regardless of the rootstock, and rootstock differences appear to be greater. Cleopatra has been less acceptable historically as a rootstock for Valencia than for other sweet oranges.

The poor reputation of Valencia on Cleopatra probably started with the low yields experienced when virus-infected, old line budwood was in general use. With the advent of the budwood registration program, nucellar budlines and improved old lines became available. These new bud sources increased Valencia yield industry-wide but the bearing habit of Valencia was unchanged. Also, the reputation of Cleopatra has certainly not been enhanced by its frequent comparison to rough lemon, the long-standing industry standard for high yield.

Data from field trials clearly show that trees of nucellar Valencia budlines on Cleopatra grow vigorously but do not bear well when compared to those on rootstocks such as rough lemon and Volkamer lemon. Yield per tree may be similar after about six bearing years but the cumulative yield will be substantially less for trees on Cleopatra even 12 years after planting. In some instances, the trees on Cleopatra have approached or surpassed the productivity of those on rootstocks like Swingle citrumelo, sour orange and sweet orange. There is evidence that Valencia on Cleopatra yields may improve on those Ridge soils with a clay layer close to the surface, or, in the most fertile and better drained flatwoods soils. The bud source may also affect performance on Cleopatra. Records from the DPI Foundation Grove suggest that nucellar budlines yield slightly better than virus-free, old line Valencia selections.

Grapefruit and nucellar navel orange yields on Cleopatra are also low during the early fruiting years. The smaller fruit sizes produced are even more limiting in many cases, particularly with grapefruit, but Cleopatra is often selected as the rootstock for a portion of the grapefruit trees in a grove. Fruit quality is excellent and the fruit store well on the tree.

Many years of commercial experience have demonstrated that Cleopatra is an excellent rootstock for all mandarin cultivars that are sufficiently large-fruited to tolerate the reduction in fruit size due to use of this stock.

Cleopatra mandarin has had limited use as a rootstock; however, considering the importance of cold, tristeza and blight tolerance, Cleopatra is one of the best rootstock choices among current commercial stocks for many cultivars. Its attributes may outweigh the yield and fruit size disadvantages and thus enhance the future value of this rootstock.

Sour orange

Sour orange is a distinctive, readily recognized species of citrus with numerous variants, most of which have no value as rootstocks. Bittersweet, an acidless form, is favored in some areas of Florida but it has no established advantage over standard sour orange. Such names as Texas and Brazilian sour orange have no more relevance than Florida sour orange. They merely identify the standard sour orange from that particular region. Australian sour orange is a misnomer for Smooth flat Seville and has few characteristics of sour orange, either as to shape and form or as to performance as a rootstock (Table 2).

Trees budded on sour orange are somewhat slower growing than those on rough lemon but it produces a tree of moderate vegetative vigor and size. Fruit yields vary considerably with soil type. The best yields are attained on hammock and finer textured soils where they may at times, approach those attained on rough lemon; however, more often, yields are less than for trees on either rough lemon or Carrizo citrange. Nevertheless, good commercial yields are attained on fertile soils. Sour orange yields much less on coarse, infertile sands, particularly when budded with Valencia orange, and therefore should not be used on such soils. Yield is so closely associated with soil type that reference is frequently made to sour orange and rough lemon soils.

Fruit sizes on sour orange are adequate but not as large as from trees on rough lemon. It is important to note, however, that fruit from trees on sour orange are less coarse than those on rootstocks that induce high vigor, they store well on the tree, and the peel is thinner and smoother. The juice and flesh quality induced by sour orange is the standard of excellence.

Sour orange induces maximum cold hardiness. It is tolerant of phytophthora foot rot, but less so to fibrous root damage by this fungus. It tolerates exocortis and xyloporosis viroid but it is extremely sensitive to citrus tristeza virus (CTV). It has no resistance to damaging nematodes. One of its most important attributes is low loss of trees from blight as compared to losses on rough lemon and other rootstocks. Sour orange does well on calcareous soils and is more tolerant of saline soils than rough lemon, but not as tolerant as Cleopatra mandarin.

Sour orange was once the most important rootstock in almost every citrus growing region of the world and it still ranks as one of the world's great and most widely used rootstocks. Its popularity has been due to adequate yields, superb fruit quality, and tolerance to foot rot and cold. Few trees of sweet orange, grapefruit or mandarin have survived on sour orange, however, in regions such as Brazil and South Africa where extremely virulent and damaging forms of CTV exist. It is these highly virulent forms of the virus and aphid vector populations that have doomed sour orange as a rootstock and caused an intensive search for replacements. Laws have been passed in some countries prohibiting the use of sour orange as a rootstock.

The many attributes of sour orange, including tolerance to blight, resulted in the widespread use of sour orange in Florida despite its susceptibility to CTV. It has been an excellent rootstock for grapefruit, especially in the Indian River district, and for navel oranges where the high quality of fruit produced on it is more important than for the round or sweet oranges. Among the latter, sour orange would not ordinarily be a recommended choice for Valencia because of this variety's naturally high soluble solids content and low bearing capacity compared with other round orange cultivars. Sour orange is sometimes used for Hamlin trees to complement ones on rough lemon. Hamlin fruit will mature earlier on sour orange because of their higher soluble solids.

Sour orange has been considered essentially the only rootstock choice in north Florida because of cold tolerance and is the principal rootstock of the east coast area where high quality grapefruit are grown. The popularity of sour orange has been declining because of CTV. The sour orange variant, Bittersweet, is equally susceptible. The continued use of sour orange is risky despite its many attributes and cannot be recommended except for a few special situations (see Rootstock Selection).

Sweet orange

Sweet orange seedlings were popular in Florida at one time. The trees were very productive mostly because of their large size but they exhibited the juvenile characteristics typical of seedling trees. A few such groves remain largely as relics of the days before budding and rootstocks became commonplace.

Many sweet orange cultivars have been used or tested as rootstocks but usually only those cultivars that produce seedy fruit. The discovery in Florida of Ridge Pineapple, which is resistant to the burrowing nematode and quite seedy, has led to some use of this cultivar as a rootstock. Sanguine Grosse Ronde and Algerian navel orange are burrowing nematode resistant. None of these cultivars, however, is citrus nematode tolerant nor have they been adequately evaluated as rootstocks. The little information available indicates that all of these selections would behave much the same as any sweet orange rootstock.

Trees on sweet orange have good vigor and achieve standard to large size. Yields on sweet orange are satisfactory if trees are supplied with adequate water, but they suffer from drought on unirrigated sandy soils. Under such conditions yields are lower. Fruit sizes and quality are good, quite similar to those produced on sour orange. Cold tolerance of scion cultivars budded on sweet orange is intermediate between sour and rough lemon. It is tolerant of tristeza, exocortis and xyloporosis.

There are relatively few plantings on sweet orange from which to determine its blight status but most of these as well as sweet orange trees on their own roots appear to be largely unaffected by blight. The factor which has precluded its common use in Florida is its high susceptibility to phytophthora root rot and foot rot. The availability of new fungicides reduces the importance of this shortcoming but does not eliminate it.

Sweet orange is compatible with all the major sweet orange, grapefruit and mandarin cultivars. There has been increased interest in sweet orange cultivars as rootstocks, largely because blight and tristeza tolerance merit serious consideration when compared to foot rot or root rot susceptibility in rootstock decisions.

Trifoliate orange

Trifoliate orange is a rootstock of world-wide significance that has been used commercially in Florida for many years on a limited basis. Many selections of *Poncirus trifoliata* have been made and named. They have been classified on the basis of differences in flower size and growth habit. Large-flowered types grow upright with little branching, while the small-flowered ones are less vigorous and have a bushy growth pattern. Research has shown that trees on the large-flowered types usually are slightly more vigorous and bear less fruit per unit of canopy volume than those on the small-flowered selections.

Tree size on a given selection of trifoliate orange can vary. This stock was generally considered as dwarfing until the effects of exocortis viroid and environmental conditions were better understood. Trifoliate orange can produce standard sized trees on clay and loamy soils and in Florida in the bedded flatwoods soils where the root zone is shallower. In the deeper Ridge soils, trees on trifoliate do not grow rapidly or achieve a large size. They are quite satisfactory, though, for close planting with irrigation.

Trees on trifoliate orange bear well for their size, although on sandy soils, the yield per tree will be less than for trees on other stocks better adapted to such soils. Fruit quality is excellent, generally with a high soluble solids and acid content and a smooth, thin peel. Fruit size can be undesirably small for fresh market use with some scions because of heavy fruit-set even on well-drained, infertile soils. Fruit hold well on the tree and juice color is excellent.

Trees on trifoliate are best suited for use in cool climates where maximum cold hardiness is developed. The trifoliate orange itself is very cold tolerant. It sheds its leaves and becomes dormant when exposed to constant cool weather. This has led to the common misconception that trees on this rootstock are more cold tolerant than those on other stocks. In Florida, where the winter is relatively short and is often interrupted by brief periods of warm temperatures, trifoliate does not provide consistent protection from cold. Furthermore, trees on trifoliate apparently become dormant more slowly even in the colder areas of the state; thus, they may actually be more susceptible to cold damage than trees on sour orange or Cleopatra mandarin.

Trifoliate orange is very valuable in breeding programs as a source of resistance to the citrus nematode, some species of *Phytophthora*, and to tristeza, but this rootstock is notably susceptible to exocortis. Trees on this rootstock can be very stunted when infected with exocortis and many such trees have been removed from Florida groves. All selections of trifoliate orange are not resistant to the citrus nematode and all are susceptible to the burrowing nematode. More recently, blight has become a serious concern affecting the continued or expanded use of trifoliate orange. The incidence of this disorder has been high among east coast groves in particular, but less in Ridge groves.

Trifoliate orange grows well on fertile, clay to loamy type soils. It does not develop a very deep or wide-ranging root system. It is poorly adapted to saline or calcareous conditions, but its resistance to foot rot makes it useful for wet conditions.

Trifoliate orange is a highly recommended rootstock in some areas of the world, most notably Japan, where many acres of Satsuma are grown on this rootstock. In Florida, the reputation of trifoliate orange was marred by the planting of trees propagated from budwood sources containing severe isolates of exocortis and by planting trees in unirrigated groves. It is important to use exocortis-free budwood on trifoliate orange. Irrigation can contribute to acceptable tree growth and productivity on Florida sandy soils. Whether irrigation will help to reduce problems of fruit size has not been fully determined.

Trifoliate orange is a generally satisfactory rootstock for most sweet orange cultivars, especially those in the navel group. Grapefruit cultivars are also satisfactory except that fruit size of red grapefruit may be unacceptable; also, some growers have found low juice content to limit legal maturity early in the season. Commercial experience in Florida has indicated that some risk is involved with using trifoliate orange as a rootstock for some mandarin and mandarin hybrid scions. These combinations occasionally decline from a bud union incompatibility.

Carrizo citrange

Hybrids of sweet orange and trifoliate orange are known as citranges. There are many named citranges such as Carrizo. They are hybrids largely produced in Florida in the early 1900s in an effort to create more cold tolerant sweet orange cultivars; eventually, however, citranges proved to be more useful as rootstocks.

Carrizo and Troyer are hybrids of Washington navel orange and *P. trifoliata*. These two citranges are visually indistinguishable and are of considerable interest throughout the world as rootstocks because of their tolerance to tristeza virus and foot rot. Troyer is widely used in California while Carrizo has been a leading rootstock in Florida.

Commercial use of Carrizo in Florida began in the 1960s. After more than 20 years of experience, it is clear that Carrizo is a general purpose rootstock. Trees on this rootstock are vigorous and achieve a large size comparable with trees on rough lemon or Cleopatra mandarin. Excellent growth occurs in all soils except those with high levels of available calcium. Carrizo, like its parent, trifoliate orange, usually performs poorly in highly calcareous situations. Trees may survive, but they do not grow or fruit well. Carrizo is also not very tolerant of saline conditions and should be avoided when either soil condition exists (see discussion under Soil Factors).

Trees on Carrizo often display symptoms of either zinc, iron or manganese deficiency or some combination of these nutrients in the spring flush. Sometimes the symptoms are persistent. Nutritional sprays usually seem to adequately correct this problem.

The history of Carrizo in Florida is based partly on expectations for cold tolerance of trees on this rootstock. Seedlings of Carrizo are cold hardy and it was anticipated that budded trees would perform similarly. Considerable field experience now indicates that trees on Carrizo are generally not as cold tolerant as those on sour orange, Cleopatra or Swingle citrumelo even in years with favorable environmental conditioning.

Carrizo inherited susceptibility to exocortis viroid from trifoliate orange. Severe isolates will cause infected trees to decline and be unproductive on Carrizo. Milder isolates are less injurious and are being studied as possible dwarfing agents. Xyloporosis and tristeza are not harmful to trees on this rootstock. Carrizo has been ranked as tolerant to phytophthora foot rot in screening tests. Commercially, growers experience only occasional problems. Carrizo is tolerant to citrus nematodes but this varies with the nematode biotype. Carrizo has been useful as a rootstock for planting in burrowing nematode sites; however, not all sources of Carrizo tolerate this nematode. Growers and nurserymen should be certain that their trees are being propagated from nematode tolerant Carrizo seed sources.

Blight affects trees on Carrizo. During the 1960s and later, Carrizo gradually replaced rough lemon because of severe losses from blight occurring among trees on the latter rootstock. Trees on Carrizo were heavily planted and some of these groves are now experiencing considerable tree loss from blight. The incidence of blight, nevertheless, is highly variable.

A substantial advantage of Carrizo is the excellent performance of young trees on this rootstock. They are vigorous and produce excellent crops of high quality fruit in their early years. Fruit size is usually medium to large and juice quality is similar to that of fruit from trees on sour orange. These traits are also representative of older trees on Carrizo.

Carrizo is an excellent rootstock for sweet orange and grapefruit cultivars and certain mandarin hybrids such as Orlando and Minneola tangelo. It has also been a popular choice for many other mandarin and mandarin hybrid cultivars but there has occasionally been some tree decline accompanied by a bud union crease (Fig. 1) among some of these cultivars on Carrizo.

Rusk citrange

Rusk is another citrange produced in Florida during the era of W. T. Swingle and H. J. Webber. It was eventually included in many of the large-scale U. S. Department of Agriculture rootstock trials. Rusk achieved only limited commercial importance, primarily in Lake County.

Ruby is the sweet orange parent of Rusk which distinguishes this stock from Carrizo and Troyer. Moreover, trees on Rusk are smaller in size and apparently more tolerant of exocortis viroid than those on most other citranges. The issue of tree size has been confusing because of conflicting observations. Rusk has a limited root system and is drought intolerant. These characteristics may account for some descriptions of Rusk as a dwarfing rootstock. In field trials with irrigation, trees on Rusk propagated with exocortis- and xyloporosis-free budwood have grown into moderate-sized trees after 12 years, showing that Rusk is not a dwarfing rootstock.

Rusk is similar to other citranges in that budded trees yield well, especially for their size, and produce high quality fruit. Trees on Rusk are tolerant to foot rot, cold, and tristeza. Blight susceptibility is unknown. This rootstock has performed well after ten years in field trials with Valencia and Hamlin. It appears suitable for sweet orange and grapefruit cultivars but is largely untested for most mandarins except Orlando tangelo. In small experiments, trees of Nova, Robinson, Page, and Fallglo compared favorably in yield after about ten years with trees on Cleopatra mandarin and the fruit had excellent juice quality and size.

Swingle citrumelo

There are many named and unnamed citrumelos (see Table 2) but Swingle has been the most widely and thoroughly tested. It is a hybrid of Duncan grapefruit and trifoliate orange produced in 1907 in Eustis, Florida. This rootstock is another product of the efforts by W. T. Swingle to breed cold-hardy scion cultivars. Swingle citrumelo attracted little attention until the 1940s when it began to be tested in Florida, Texas and California under its code name, CPB 4475. Because of its excellent performance, the hybrid was named in honor of Dr. Swingle and officially released by the USDA in 1974. Since then, Swingle citrumelo has risen faster to commercial status than virtually any other rootstock in the Florida citrus industry.

Trees on Swingle growing in Ridge or flatwoods soils vary in vigor according to the scion. Valencia trees are the least vigorous among the common sweet orange and grapefruit cultivars; however, the growth of trees in their first five years regardless of scion, is similar to that of trees on sour orange. Grapefruit cultivars grow vigorously on Swingle and produce large trees. Sweet orange trees, particularly Valencia, would be between trees on trifoliate orange and sour orange in size after ten years when growing in Ridge soils. On flatwoods soils, they are more vigorous.

The Swingle tree itself is very cold tolerant. Limited observations with field trees less than ten years old, indicate that trees on Swingle would rank as similar to trees on sour orange and Cleopatra mandarin and superior to ones on Carrizo citrange or rough lemon for cold tolerance.

Swingle citrumelo is a suitable rootstock for most soils except heavy clay or highly calcareous conditions. Soils with a clay content greater than 25 to 30% may restrict root growth. Soils with a high calcium content also limit tree performance (see discussion under Soil Factors) and Swingle is apparently sensitive to high soil copper levels. Trees on Swingle are moderately salt and drought tolerant and greenhouse tests with small potted plants have indicated good tolerance to flooding but this has not been confirmed under field conditions. Swingle citrumelo is resistant to the citrus nematode but not the burrowing nematode.

Growers usually experience little or no loss within the first few years after planting trees on Swingle, attesting to the foot rot resistance of this rootstock. Swingle citrumelo is tolerant to tristeza virus and the exocortis and xyloporosis viroids. Certain old line budwood sources have caused severe stunting of trees on Swingle with a diagnostic crease at the bud union. An unknown virus, possibly citrange stunt, may be the cause.

Blight has affected trees on Swingle although among the few older commercial plantings, the incidence has been low. Recent experiences with bacterial leaf spot in Florida citrus nurseries showed that Swingle seedlings are as susceptible as grapefruit seedlings to the Florida isolates of *Xanthomonas campestris*.

All of the Florida commercial scion cultivars have been propagated on Swingle citrumelo but very little information is available regarding their performance except for sweet orange and grapefruit cultivars. In general, grapefruit cultivars on Swingle are most similar to trees on sour orange. Swingle is a superior rootstock for grapefruit, producing high yields of large, excellent quality fruit with a high juice content. Early and midseason oranges on Swingle seem to yield as well as those on Carrizo citrange. Swingle appears to be an excellent rootstock for navel oranges. Valencia trees in field trials have consistently yielded less than trees on Carrizo. Less is known about Swingle as a choice for mandarins. Until further information is availabie, Swingle should be considered a trial rootstock to be used in combination with other rootstocks for mandarin cultivars.

Grapefruit

Grapefruit cultivars have had considerably greater success as scions than as rootstocks. Orchards of grapefruit seedlings were common in Florida many years ago. These trees were very large and were known to produce 50 boxes of fruit or more per tree when mature. As budded trees replaced seedlings, grapefruit was one of several common rootstocks in Florida because it was well-known and seeds were plentiful.

Grapefruit performed poorly as a rootstock in the past. There are a few remaining groves with trees on this rootstock, but typically the trees are large, shallow-rooted, drought intolerant and yield less than ones on rough lemon. Irrigation does not seem to overcome low yields. Trees on grapefruit produce small, low quality fruit and are susceptible to foot rot and cold. They are affected by tristeza but considerably less so than trees on sour orange. Blight has occurred among trees on grapefruit rootstock but there are too few trees planted for a reliable susceptibility rating. Possible blight tolerance has encouraged some small commercial trials with Duncan grapefruit rootstock.

Own-rooted citrus

The term "own-rooted" refers to seedling citrus trees, rooted stem cuttings, and to air layers or marcotts.

Seedling trees were considerably more prevalent throughout the world and in Florida many years ago than they are today. They have several well-known disadvantages, the principal one being a long juvenile period. This is the main reason why orange and grapefruit seedlings were replaced by budded trees. Nevertheless, the importance of seedlings must not be overlooked. Several commercial cultivars such as Hamlin and Pineapple sweet orange, were discovered in seedling groves. Others like the Hughes nucellar Valencia budlines also resulted from selection within a population of seedlings.

Seedling trees have not been planted in recent years in Florida except for two cultivars, Dancy tangerine and Orlando tangelo, that have performed grapefruit and trifoliate orange produced in 1907 in Eustis, Florida. This rootstock is another product of the efforts by W. T. Swingle to breed cold-hardy scion cultivars. Swingle citrumelo attracted little attention until the 1940s when it began to be tested in Florida, Texas and California under its code name, CPB 4475. Because of its excellent performance, the hybrid was named in honor of Dr. Swingle and officially released by the USDA in 1974. Since then, Swingle citrumelo has risen faster to commercial status than virtually any other rootstock in the Florida citrus industry.

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Seedling trees have not been planted in recent years in Florida except for two cultivars, Dancy tangerine and Orlando tangelo, that have performed well as seedlings. They come into bearing only one or two years later than budded trees of these cultivars and have not shown any of the other seedling disadvantages. Furthermore, they reproduce true-to-type from seed. Monoembryonic cultivars such as Temple are certain to produce groves of variable trees.

Seedlings do have the advantages of being virus-free and easy to propagate but it is unlikely they will return to their former popularity. Currently, there is only minor interest in seedlings, primarily with Ridge Pineapple sweet orange.

Citrus scion and rootstock cultivars have been propagated as cuttings. When taken from mature wood they do not exhibit the juvenility or vigor of seedlings. Many plants for the Tahiti lime industry in Dade County are still propagated by air-layering (marcottage). These plants generally fruit earlier but are not as long-lived as budded trees. Orlando tangelo has been grown from cuttings. They have performed as well as budded trees and would be preferred over seedlings. The history of rootstock propagation by cuttings in Florida is one where this method was used out of necessity. When Milam rootstock was released, seeds were scarce and the rootstock was commonly reproduced by cuttings. This was an easy task because Milam is a lemon type which roots readily. Trees propagated on Milam cuttings or seedlings do not differ substantially in root distribution or performance.

Some nurserymen have produced scion cuttings in response to grower interest after severe freezes. Cuttings frozen to the ground, as with seedlings, could recover without concern over rootstock sprouts. The use of cuttings never became popular, although during the mid 1980s interest in cuttings was briefly renewed when nursery trees were not available because of quarantines imposed upon the commercial nursery industry.

Data on the horticultural performance of scion cuttings are not available; however, some cuttings have been planted in commercial sites. In one field trial, the yield and quality of fruit from Valencia cuttings were improved by using rootstocks such as Carrizo citrange.

There is little justification in today's citrus industry for using seedlings of the standard sweet orange and grapefruit cultivars. The future of cuttings is at best speculative. Additional experience may demonstrate that some cultivars may be economically propagated and used successfully, for example, in closely spaced plantings.

Rootstock Selection

There are many rootstocks and each has a wide range of influence on the performance of scion cultivars budded on them. There are also scion effects on various rootstock characteristics but these effects are not as well-known or understood as those of the rootstock.

The broad and apparently complex nature of scion-rootstock interactions would seem to make choosing a rootstock a difficult process; however, certain limiting factors usually reduce the number of choices immediately because no single rootstock is perfect, nor is a given rootstock the best one for all situations. Sometimes certain factors expand the range of rootstock choices. An excellent example is the general availability of budwood sources free of exocortis and xyloporosis viroids.

When a rootstock is selected, the decision is often a highly individualized one and inevitably based on compromise and some relative assessment and ranking of the risks involved. The decision is also individualized because circumstances are never identical from grove to grove or business to business. Nevertheless, there are some considerations that may be common to many situations. For example:

- Solid planting or resetting?
- Short-or long-term objective?
- What are the principal performance criteria and their relative worth? e.g. Yield, fruit quality, cold, tristeza and blight tolerance.
- Should only one rootstock be selected or is it better to protect(?) yourself by selecting several? Will several rootstocks permit meeting multiple objectives?

Furthermore, any rootstock decision is strongly conditioned by experience and observations.

Blight, tristeza and cold tolerance have become the major limiting factors. Rough lemon is no longer used because of blight. Other rootstocks with characteristics similar to those of rough lemon, such as Rangpur, Volkamer lemon, macrophylla, Milam and Palestine sweet lime, are also infrequently used because of a high blight risk.

These rootstocks are classic examples of the decisions and compromises associated with rootstock selection. Their unpopularity is the direct result of blight susceptibility which many view as the primary limiting factor among rootstocks. However, the importance of this deficiency must be assessed against their high early yield. Trees on these rootstocks are highly productive and generate excellent net income per acre for this reason. In fact, these trees are normally so productive that yield per acre, even when 10 to 20% of the trees have declined from blight, may still be greater than for trees on sour orange or Cleopatra mandarin that are relatively unaffected. Recent field trial evidence which included adjustments in soluble solids production for actual blight losses, illustrated the superior performance that can be expected from trees on the vigorous rootstocks. Such a situation where high yielding trees are declining from blight emphasizes the value of a good replanting program, but at the same time raises questions about rootstock choices and recurrence of blight among replants. Observations suggest that replants decline sooner than the original trees but data are limited and not consistent.

If rough lemon or other similar rootstocks are selected, trees should be planted in the warmest sites. Also, if grove removal for replanting is anticipated within about ten years, these stocks are ideal for resetting because of their strong performance as young trees, especially Volkamer lemon.

Carrizo citrange has attained widespread use because of high yields and fruit quality as well as tolerance to citrus tristeza virus (CTV), foot rot and the burrowing nematode. It is blight susceptible; however, the attributes of Carrizo appear to compensate for its disadvantages clearly illustrating the justifiable value placed on yield and juice quality.

No rootstock is immune to tree loss from blight but trees on sour orange, Cleopatra mandarin and sweet orange are the least affected. There are different compromises and risks associated with these rootstocks.

Sour orange, which produces moderate yields of excellent quality fruit, has one glaring weakness, high sensitivity to CTV. The incidence of virulent strains of this virus in budwood source trees and in commercial plantings in recent years has made the use of this very popular stock unduly risky. Sour orange use might be justified for replanting in mature groves on sour orange where little or no loss has occurred from CTV. In propagating such trees, buds should be taken from apparently unaffected trees in the mature grove. If CTV has caused losses, resetting should be with CTV-tolerant rootstocks.

In the northern areas of the citrus industry and in any relatively cold sites, cold tolerance becomes a principal limiting factor. Sour orange might be an appropriate choice after careful evaluation of local CTV conditions and the use of CTV-free budwood; however, Cleopatra mandarin and Swingle citrumelo are other suitable choices that make sour orange a questionable risk.

Cleopatra mandarin has been used in Florida for many years where it has been and remains an excellent rootstock for most mandarin and mandarin hybrid cultivars. Cleopatra has blight, cold and CTV tolerance yet this stock has been used sparingly for sweet orange and grapefruit cultivars because of relatively low yields, particularly with Valencia. Moreover, fruit size can be undesirably small but this is not a problem for processing fruit except for possible increases in harvesting costs.

Clearly, Cleopatra is another excellent example of the value placed on yield. It has many fine traits but together they apparently do not surpass the importance of productivity. Cleopatra, however, is being increasingly used for Hamlin, Parson Brown and Pineapple oranges which yield relatively better than Valencia on this stock. There is also increased interest in Cleopatra for Valencia because in those groves where blight loss is heavy, Cleopatra may be the best choice for replants. Trees on Cleopatra may be slow to reach their full bearing potential but cumulative yield in conjunction with tree survival (blight tolerance) must be balanced against young tree behavior.

Swingle citrumelo, a relatively new commercial rootstock, is the major hope of Florida's orange and grapefruit growers. It tolerates all major rootstock/scion related viruses, including CTV. It is highly resistant to phytophthora foot and root rot and fruit quality of trees on Swingle ranks with the best. Commercial use has not been sufficient to obtain an accurate evaluation of tolerance to blight but indications so far are favorable.

Vigor of growth and yields of grapefruit on Swingle are excellent and very good for most oranges. Valencia on Swingle yields well for its size but is slow growing, thus, one should use relatively close spacings.

Sweet orange is a rootstock in which its selection is dependent on the risk given to a single characteristic — susceptibility to foot rot. Sweet orange is also drought intolerant, but this deficiency is largely overcome with good irrigation practices. Furthermore, foot and root rot are diseases that can be managed to some extent with applications of chemicals and other procedures, thereby reducing the risk for this problem. There are sufficient reasons to select sweet orange, especially for replanting among trees on a sweet orange rootstock where little or no loss had been experienced from foot rot or when resetting in a blight-affected grove. Trees on sweet orange are among the most blight tolerant.

There are other examples of single factor rootstock decisions. The burrowing nematode limits the choices to Milam lemon, Carrizo citrange and Ridge Pineapple orange. There are nematode biotypes that have lessened the value of these stocks and each stock has certain other limitations. Therefore, selecting a rootstock based on this factor alone is becoming less justified. Trees on non-tolerant stocks have been used in infested sites and produced reasonable yields providing they receive adequate water and nutrients.

Calcareous sites present difficult rootstock decisions. Such conditions generally exist in the poorly drained areas of Florida where extensive site preparations are required before a grove can be planted. Most rootstocks do not perform well in highly alkaline soils (pH 8.0 or greater).

A calcareous situation is not a true risk, but rather one requiring the management of soil pH and micronutrients to minimize problems. Calcareous sites dictate certain rootstock choices. Rangpur, Cleopatra and sour orange are the best suited rootstocks. Trifoliate orange and citranges should be avoided. Preliminary observations indicate that Swingle citrumelo may be used on certain sites.

In some circumstances, more than one rootstock may be reasonable, as when it is desired to hasten legal maturity of a given cultivar or to hold fruit late. Lemon and lime type rootstocks induce lower total soluble solids (Brix) and acid, but, the acid is lowered proportionately more. This raises the Brix/acid ratio and shortens the time to legal maturity of cultivars such as Valencia and Temple for which ratio is the limiting factor. There are other cultivars such as

Hamlin orange and Orlando tangelo, for which minimum soluble solids usually determines attainment of legal maturity. Rootstocks inducing high Brix, like sour orange, Carrizo and Swingle, result in relatively early maturity for such cultivars. Hamlin fruit from trees on Cleopatra have a relatively high Brix, comparable to that of fruit from trees on sour orange, however, the fruit from Cleopatra also have a higher acid content which lowers the ratio and lengthens the time to legal maturity as compared to fruit from trees on sour orange.

Multiple rootstocks are sometimes considered in the selection process as a means of overall risk reduction. If two or more rootstocks are used, the trees are commonly planted in solid blocks rather than as alternating trees within the row. The latter planting pattern is generally less desirable from a management standpoint.

A logical use of multiple rootstocks is for planting problem sites. Patches of coarse sand, chronically wet or cold sites, or calcareous spots can be found within a grove of generally better soils in flatwoods areas and elsewhere. Volkamer lemon, for example, is well-suited to coarse sandy (so-called "sugar" sand) locations. Thus, there is some merit in using this rootstock because trees on it grow and fruit better in such soils than ones on sour orange, Carrizo or Cleopatra.

In conclusion, it is appropriate to recognize that rootstock decision-making has changed. Previously, selecting a rootstock was relatively simple. In general, rough lemon was used in central Florida, sour orange in the flatwoods and Cleopatra mandarin for mandarins and mandarin hybrids. These stocks were commonly used because of superior yield, fruit quality and cold tolerance. These criteria are still dominant but there are new rootstocks to choose from, new levels of old risks (e.g., tristeza, cold) and new limiting factors (e.g., blight). Therefore, growers should realize that **a sound rootstock decision today results from circumspect consideration of risks and the best information available. Simply opting for traditional choices has been replaced by more deliberate decision making.**

A summary of the general steps in rootstock selection is presented in Appendix C.

Rootstock Research

The loss of a commercial rootstock can occur rather quickly, while the development of a new rootstock is inherently a much longer process. Furthermore, it is unlikely that any new rootstock will have only desirable attributes. The Florida citrus industry is constantly changing, and rootstock research is frequently directed to improving those rootstock traits of the highest priority. A new rootstock that is intolerant of citrus tristeza virus or blight but is otherwise above average, would probably be of limited commercial value.

New rootstocks are the result of selection and breeding procedures. Classical breeding involves flowers, pollination and hybridization. New techniques such as fusing cells, and tissue culture to regenerate whole plants, are faster and may circumvent some of the obstacles encountered in the classical approach. The goal in both approaches is to produce new rootstocks that have a pest and disease resistant root system compatible with a scion producing an abundance of high quality fruit. Such rootstocks should also possess certain other characteristics including:

- Adaptability to the soil and climatic conditions of the geographical area of intended use, with wide geographical adaptation preferable to narrow.
- Seediness, a high degree of nucellar embryony and ease of propagation by grafting or budding with economically acceptable scion cultivars.
- Correct degree of vigor to induce fruit set and maturation on a given scion cultivar in a given environment.
- Practical immunity or high levels of resistance to the pathological and entomological organisms of economic importance in the areas of intended use.
- Freedom from destructive viruses and decline disorders.

Such rootstocks do not presently exist nor are they likely to be found through natural selection. To produce such rootstocks through breeding programs, if possible, will probably require considerable time. Therefore, it is quite apparent that rootstock development and testing is inevitably a continuous activity. It should be equally apparent that on-site evaluation has many potential benefits for the local grower.

When new rootstock material becomes available it must be propagated and evaluated. Development typically begins by fruiting the new material in order to have seeds, a source of plants for further testing. Seedlings are screened for diseases and pests. Rootstock candidates that survive the early screening are then used for horticultural field evaluations. The entire process can easily take 15 years or longer. The inability of the rootstock researcher to shorten the time required to evaluate all rootstock candidates dictates that much information will have to come from cooperative trials with growers. Rootstocks that are not fully evaluated but are suitable for small scale grower trial are described in Table 2.

Table 2. Rootstocks suitable for small scale grower trial.

Rootstock	Seed source; availability[z]	Comments
Nasnaran (*C.amblycarpa*)	DPI; A	Small fruited, acid mandarin. Similar to Cleopatra mandarin in performance. Foot rot and tristeza tolerance. Blight tolerance unknown. No commercial experience; only field trials. Nursery seedlings are bushy.
Shekwasha mandarin (*C. depressa*)	DPI; A	Average performance in Texas field trials but good tolerance to alkaline (calcareous) soils, cold and tristeza. Included in some Florida trials.
Changsha mandarin (*C. reticulata*)	DPI,CREC; B	Trees on this stock are small but not dwarf and very cold hardy. Tristeza tolerant. Included in Florida field trials that are 10 years of age and younger.
Sunki mandarin (*C. sunki*)	DPI; A	Sunki is tristeza but not exocortis tolerant. Not widely tested but of considerable interest in Brazil as a blight-tolerant replacement for Rangpur. Salt tolerant.
Sun Chu Sha mandarin (*C. reticulata*)	USDA, DPI; B	Limited testing by the USDA in a cooperative flat-woods trial. Tristeza and apparently blight and foot rot tolerant. May be suitable for calcareous sites.
<u>Trifoliate oranges</u>		
Flying Dragon	C, DPI, CREC; B	A selection with standard trifoliate orange rootstock traits except trees on this stock are dwarfed. Suitable for dooryard trees.
<u>Citranges</u> (hybrids of trifoliate orange and sweet orange)		
Benton	DPI; B	Developed in Australia and selected for foot rot tolerance. Still under trial in Australia but promising. Data from young Florida trials are encouraging. Tristeza tolerant. Blight unknown.
C-32	C; A	Developed in California. A hybrid of trifoliate orange and Ruby sweet orange. Early performance in California with navel, Valencia, Minneola scions has been very good. Seed-lings are variable. Tolerant to *Phytophthora* spp., citrus nematode and tristeza. Included in young Florida trials.
C-35	C; A	Same as C-32 except rootstock fruit are seedier and seedlings more uniform.
Koethen sweet orange x Rubidoux trifoliate orange	CREC; B	Under trial in Florida since 1968. Moderate cold tolerance. Not affected by tristeza. Very good yield. No field loss from foot rot.
Morton	C, CREC; B	Excellent performance in old California trials and more recently in Texas. One of the leading rootstocks in a 6-year-old CREC trial of Murcott, Hamlin, Valencia and Redblush trees planted at 800 trees/acre. Rootstock fruit produce few seed. Under trial in several Florida sites. Some pitting from tristeza virus but with little or no apparent effect.
Norton	DPI; B	Good yield with navel scions at DPI Foundation Farm. Limited commercial experience. Should not be confused with Morton citrange. Tristeza tolerant.

[z] Seed sources: DPI - Bureau of Citrus Budwood Registration, Winter Haven; CREC - Citrus Research and Education Center, Lake Alfred; USDA - U. S. Department of Agriculture, Orlando; C - California.
Availability: A - one quart quantities; B - one quart or less; C - small quantities only.

Table 2.(continued)

Rootstock	Seed source; availability[z]	Comments
Citrumelos (hybrids of trifoliate orange and grapefruit)		
F80-3	DPI; B	Under trial in Florida. Appears promising but some trees have blight.
F80-5	DPI; B	Under trial in Florida. Good cold tolerance.
F80-6	DPI; B	Under trial in Florida. Good cold tolerance.
F80-8	DPI; B	Under trial in Florida. Good cold tolerance.
F80-18	DPI; B	Under trial in Florida. Very good survival and performance in a USDA cooperative trial on an organic flatwoods soil.
F80-19	DPI; B	Under trial in Florida. Good cold tolerance and yield.
Hybrids		
Rangpur x Troyer citrange	DPI, CREC; B	Evaluated in Florida since 1968. Suitable for close spacing. For full description see 1986 Proc. Fla. State Hort. Society.
639	DPI; C	South African hybrid of Cleopatra mandarin and trifoliate orange. Promising for blight tolerance but untested in Florida. Included in young field trials.
Changsha mandarin x English Large trifoliate orange	DPI; B	Hybrid that has survived and performed well in a USDA cooperative trial on a flatwoods site.
Ford nematode hybrids	DPI, CREC; B	Hybrids between Milam, Ridge Pineapple and trifoliate orange produced by H. W. Ford. Controlled screening test has indicated that these selections each have good tolerance to both citrus and burrowing nematodes. Included in young field trials. Limited data available.
Other		
Gou tou	DPI; C	Probable sour orange hybrid from China with apparent tristeza tolerance; otherwise untested in Florida. Included in young field trials.
Smooth flat Seville	DPI; A	Possible sour orange or grapefruit hybrid known in Florida as Australian sour orange. Limited commercial use. Apparently blight tolerant. Controlled tests have indicated that SFS is less susceptible to citrus tristeza virus than sour orange. No clear advantages over sour orange.
Orlando tangelo	DPI; A	Data from several trials indicated that Valencia performs on Orlando similar to Valencia on Carrizo. Blight and xyloporosis susceptible but blight rate of loss is unknown. Tristeza and cold tolerant.
Murcott	DPI; A	Limited data indicate that trees on Murcott are very cold tolerant and are also tristeza tolerant. They yield less than trees on Carrizo but better than trees on Cleopatra. Blight susceptibility unknown. Fruit quality excellent.

[z] Seed sources: DPI - Bureau of Citrus Budwood Registration, Winter Haven; CREC - Citrus Research and Education Center, Lake Alfred; USDA - U. S. Department of Agriculture, Orlando; C - California.
Availability: A - one quart quantities; B - one quart or less; C - small quantities only.

Appendixes

Appendix A. Establishing a registered rootstock seed source planting.

Contact the Citrus Budwood Registration Bureau for specific information. Additional information is given below.

Rootstocks for Seed Source Trees

1. Avoid using the same rootstock as the scion, e.g., do not produce sour orange seed using sour orange propagated on sour orange. This prevents confusion when a tree is damaged and rootstock sprouts develop.
2. Do not use seedlings if possible. This prevents problems associated with characteristics unrelated to visible difference in plants. For example, a Carrizo citrange seedling that has not been tested, may not be burrowing nematode tolerant.
3. For Swingle citrumelo, satisfactory rootstocks have been Cleopatra mandarin, Carrizo citrange and trifoliate orange. Rough lemon, Volkamer lemon and Palestine sweet lime may be incompatible with Swingle.
4. Rough lemon and Volkamer lemon trees on trifoliate orange, Swingle citrumelo and Carrizo citrange produce incompatible, weak bud unions.
5. Select rootstocks for seed sources trees using the same criteria as in choosing a rootstock for grove trees except that fruit quality is not important.

Table A.1. Number of seeds/quart for various rootstocks.[z]

Rootstock	California	Florida
Rough lemon	6000	5500
Volkamer lemon	7000	5000
Citrus macrophylla	4800	4500
Milam	5700	6500
Palestine sweet lime	----	5000
Sour orange	2700	2500
Smooth flat Seville	----	2500
Sweet orange	2700	2500
Ridge Pineapple	2700	2300
Cleopatra mandarin	6000	5000
Carrizo citrange	2600	2100
Swingle citrumelo	3500	3000
Trifoliate orange	3500	3500

[z] The variation in approximate number of seeds/quart between California and Florida may be the result of extraction, cleaning and grading procedures.

Appendix B. Choosing a rootstock for citrus.

Step 1. Gather the facts about your site.

A. Soil — texture, depth, restrictive layers, pH, drainage, etc.
B. Water supply and quality; type of irrigation system.
C. Elevation and air drainage.
D. Nematode survey — the results may help to define rootstock choices.
E. Historical — past experience is valuable.

Step 2. Know your objective.

A. Scion cultivar — a choice not easily changed after planting.
B. Market — fresh or processed.
C. Time — short-range or long-range.

Step 3. Know the rootstocks.

There are two readily available sources of information:

A. Experience.
B. Research data from field experiments.

Step 4. Identify suitable rootstocks.

This is usually accomplished most easily by reviewing a list of possible choices and then eliminating those that seem to be the least acceptable for a given set of circumstances.

Appendix C. Nomenclature and classification of citrus.

Each scion cultivar — such as Valencia orange — and rootstock — such as sour orange — must have a name in order to communicate accurately. Also, it is valuable for the grower to know how scion and rootstock cultivars are related among themselves and to each other. For example, certain types of citrus are grouped as sweet oranges, others as grapefruit and so on, lumping all of them under the general heading of citrus fruit. The grouping of plants on the basis of their relationship is termed classification and the assignment of a name in an orderly fashion according to accepted rules is nomenclature.

Scientists have recognized the importance of classification and nomenclature almost since the beginning of time and called the science taxonomy. The scientific aspects of taxonomy are complex and can be confusing and boring while the common classification and naming of plants used in the field varies so much from place to place that it is often misleading. Australian sour orange is an excellent example. It was introduced as a tristeza-tolerant sour orange rootstock but it is clearly not a sour orange. The nomenclature of the grower and the buyer is filled with such errors.

Science has done better but here, too, there is confusion. Scientists have divided plants into categories based on the closeness of their relationship. Thus, plants are placed into groups such as orders, tribes, families, genera and species. The species is the smallest unit, the genus is a broader group, and the relationships get wider as one ascends to tribes, family, order and division.

Citrus fruits belong to the sub-family *Aurantioideae* of the family *Rutaceae*. This sub-family contains two tribes, 33 genera, and 203 species according to Walter Swingle, a USDA scientist who classified citrus and its relatives many years ago.

The basic unit is the species, of which sour orange, sweet orange and grapefruit are examples of groups or units called species. Their scientific names are *Citrus aurantium*, *C. sinensis* and *C. paradisi* respectively. Note the scientific name is composed of the genus (*Citrus*) and the species epithet (*aurantium*), in the case of sour orange. The name of the person who classified and named the species is a proper part of the scientific name but it serves no purpose here.

Some species of commercial value are not in the genus *Citrus*. The trifoliate orange, *Poncirus trifoliata*, an important rootstock, particularly in Japan, Australia and Argentina, and the kumquats, *Fortunella* spp. are examples.

Citrus is somewhat unique in that species of the genus *Citrus* can be satisfactorily budded on closely related genera such as *Eremocitrus*, *Clymenia*, *Fortunella*, *Microcitrus* and *Poncirus*, some of which have promise as rootstocks, and on certain genera that are more distantly related.

Unfortunately, the scientific system is not as orderly as would be liked. This is because everyone does not agree with Swingle as to his classifications. Tanaka, from Japan, divided the genus *Citrus* into more than 145 species while Swingle divided it into only 16.

They did not differ in the case of certain species such as sweet orange (*C. sinensis*) and grapefruit (*C. paradisi*), but they differed widely in others such as the mandarins or tangerines and lemons. Tanaka's classification is too extensive and Swingle's also has faults. Thus, part of both are in common use. Rootstocks frequently used in world citrus production and others that are uncommon, but which have potential use or some meaningful rootstock relationship, are listed in Table C.1. by their common and scientific names.

Table C.1. Rootstock names.

Common name	Scientific name[z] Swingle	Scientific name[z] Tanaka
Carrizo citrange	*Citrus sinensis*(L.) Osbeck x *Poncirus trifoliata*(L.) Raf.	Same
Cleopatra mandarin	*C. reticulata* Blanco	**C. reshni* Hort. ex Tan.
Grapefruit	*C. paradisi* Macf.	Same
Macrophylla (Alemow)	*C. aurantifolia*(Christm.)Swingle	**C.macrophylla* Wester
Milam	*C. limon*(L.) Burm.f.	**C. jambhiri* hybrid or variant
Palestine sweet lime	*C. aurantifolia*	**C. limettioides* Tan.
Rangpur	*C. reticulata* var. *austera* Swingle	**C. limonia* Osbeck
Rough lemon	*C. limon*	**C. jambhiri* Lush.
Rusk citrange	(See Carrizo)	
Smooth flat Seville (Australian sour orange)	(Probable sour orange hybrid)	
Sour orange	*C. aurantium* L.	Same
Bittersweet	*C. aurantium*	Same
Sweet orange	*C. sinensis*	Same
Swingle citrumelo	*C. paradisi* x *P. trifoliata*	Same
Trifoliate orange	*P. trifoliata*	Same
Volkamer lemon	*C. limon*	**C. volkameriana* Ten. and Pasq.

[z] According to the classification scheme of W. T. Swingle or T. Tanaka.
* Most commonly used scientific name.

Appendix D. Rootstock identification.

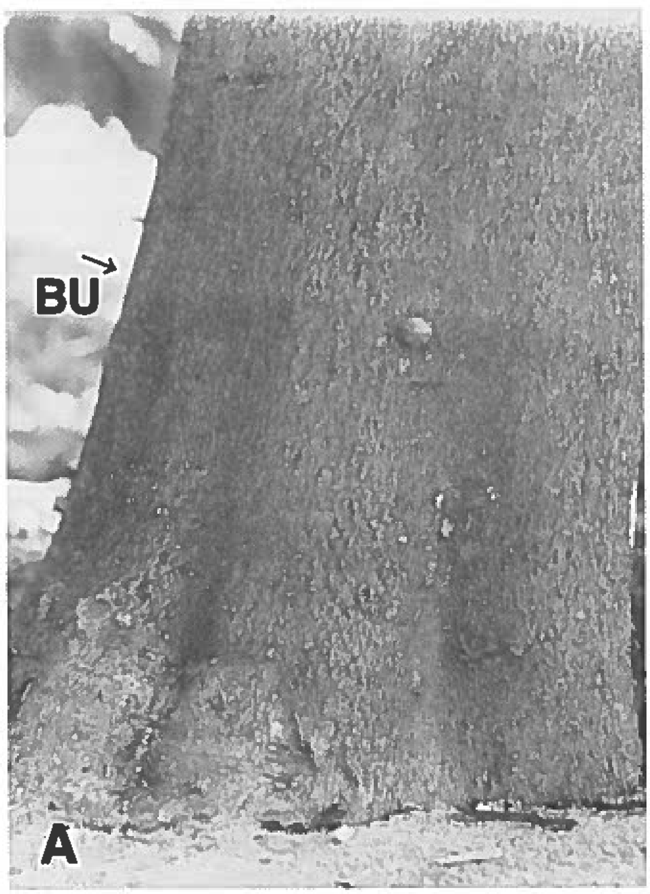
The ability to identify a rootstock is an important skill useful in a number of circumstances such as verifying the rootstock in a grove for sale or one recently purchased. Also, trees injured by cold, for example, may develop a rootstock sprout which in time dominates or becomes the tree canopy. Early recognition of the sprout would prevent the tree space from being wasted because of continued culturing of an undesired plant. Nursery personnel must recognize rootstocks to avoid propagation and shipping errors. Correct rootstock identification would also be helpful in diagnosing the possible cause of various diseases and declines.

Correct rootstock identification involves experience and knowledge of various diagnostic characteristics and of those factors which can alter them. Among the common commercial rootstocks, the bud union for budded trees, or leaf, fruit, or shoot characteristics of rootstock plants are useful for identification. One or more of these are usually diagnostic for a given rootstock. Many times only a non-fruiting sprout or seedling is available and thus, leaf or shoot morphology must be used for identification.

Bud Union
(Figure 5)

- Most rootstocks are difficult to identify by this characteristic. Once the scion has healed over the rootstock and a straight trunk has formed, most cultivars on **rough lemon, Milam, Rangpur, Palestine sweet lime, Volkamer lemon,** *C. macrophylla*, **Cleopatra mandarin,** or **sweet orange** generally have a smooth trunk and the bud union is not readily apparent. The differences in trunk diameter above and below the bud union would be slight to none.

- Trees on **sour orange** also have a smooth trunk; however, citrus tristeza virus (CTV) and the scion can influence the bud union appearance. Tristeza causes starch to accumulate above the union and stimulate growth in this region. This results in a visibly enlarged trunk above the bud union. A similar effect can occur in grapefruit trees even without CTV.



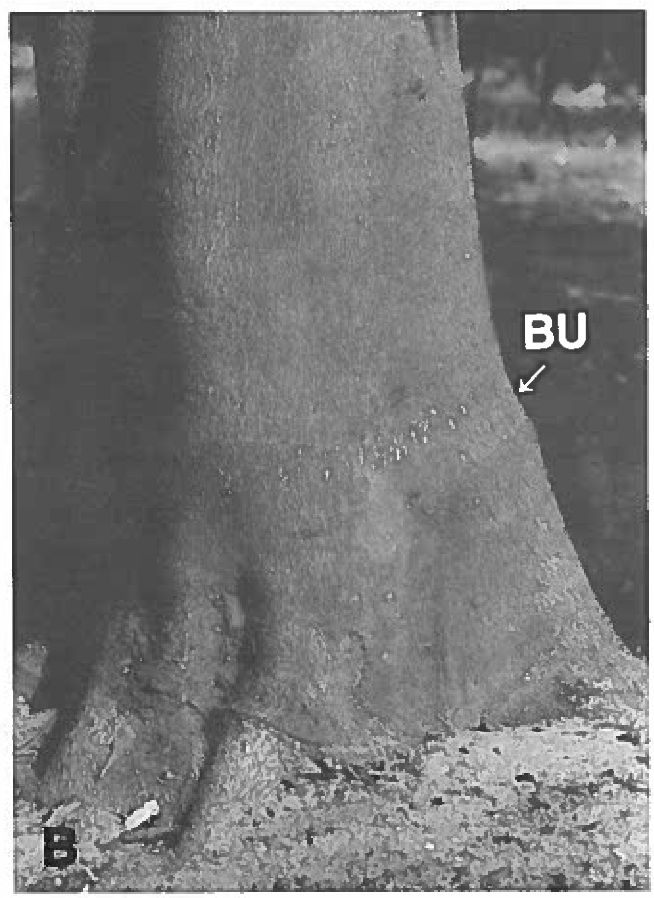


Figure 5. Bud unions (BU) of 7-year-old Valencia orange trees on several rootstocks. The trees were propagated from a mild tristeza virus infected Hughes nucellar budline. The trees are part of a rootstock field trial planted in central Florida. (A) rough lemon, (B) Volkamer lemon.

- Trees on **trifoliate orange, citranges** and **citrumelos** are easily identified by their bud union. Trees on trifoliate orange have a marked difference in trunk diameter above and below the bud union. The stock can enlarge to the extent that it becomes nearly flat (horizontal) in the vicinity of the union. This feature is commonly referred to as a "bench." The bench can be reduced by the presence of exocortis viroid. The rootstock is also considerably fluted.
- Trees on **Carrizo** and other citranges often display little or no benching, but the indentations in the trunk (fluting) are fewer as compared to trifoliate orange. These characteristics are consistent regardless of the scion.
- Trees on **Swingle citrumelo** have a marked bench which varies with the scion but fluting is usually absent. The trunk is quite smooth and uniform in diameter below the union. Exocortis does not apparently affect the magnitude of the bench.

The appearance of the bud union may vary from those shown in Figure 5 because of the effect of scion cultivar, tree age, tree vigor and budding height.

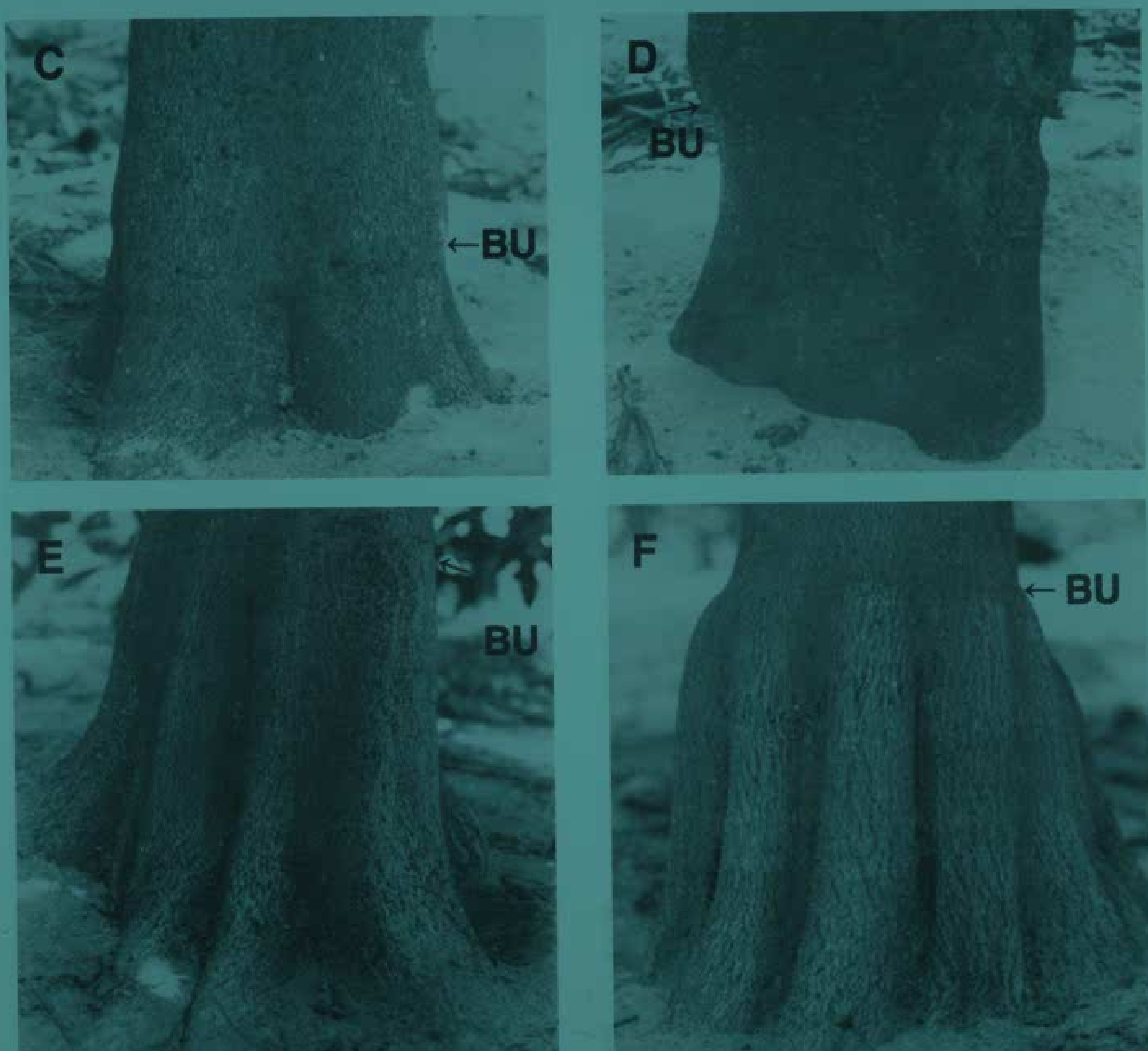


Figure 5. (Continued) (C) sour orange, (D) sour orange with citrus tristeza virus (CTV) demonstrating enlarged trunk effect above bud union; (E) Carrizo citrange showing fluting and (F) trifoliate orange showing more pronounced fluting.

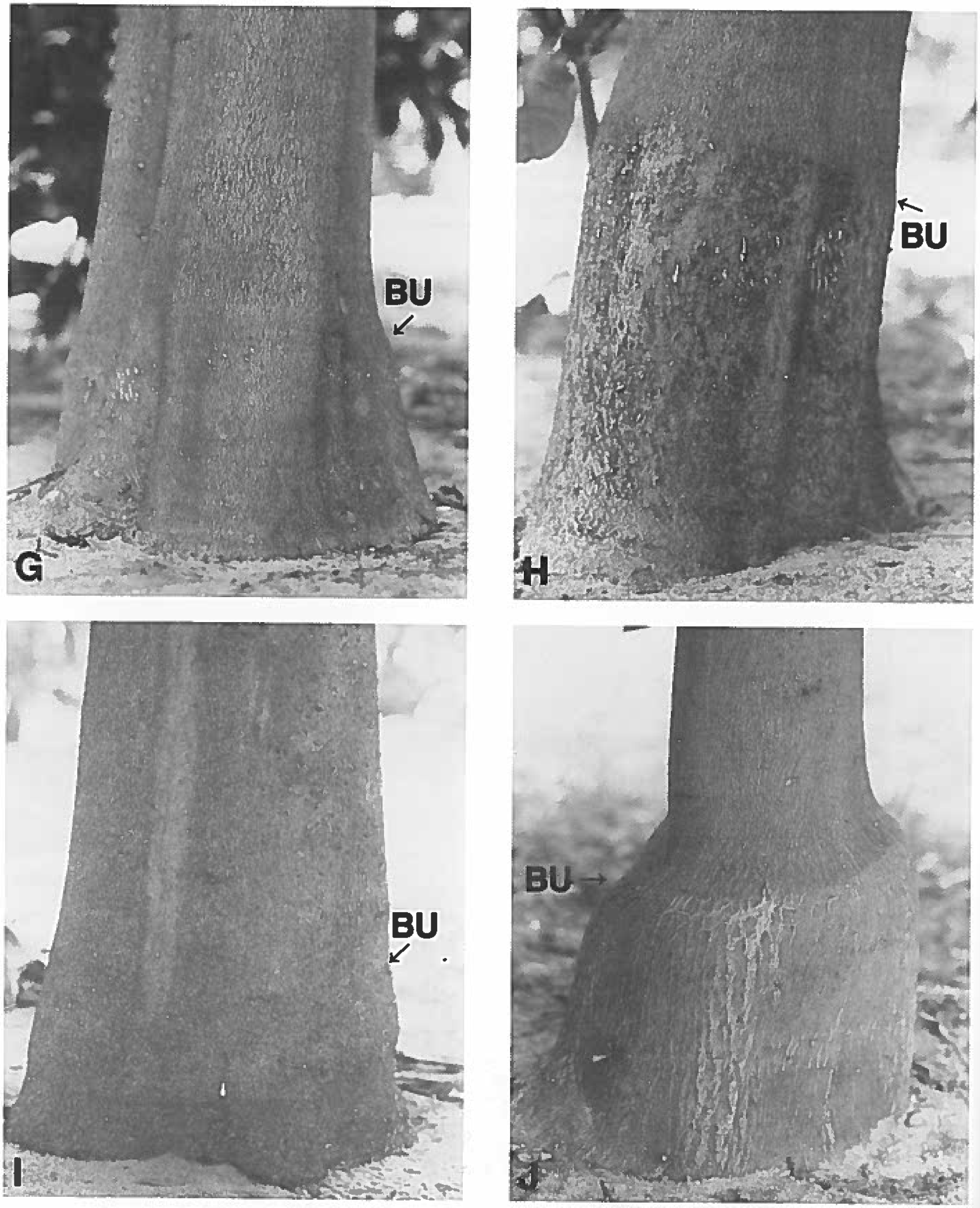
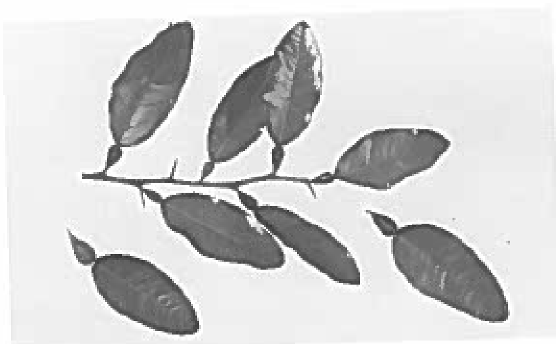


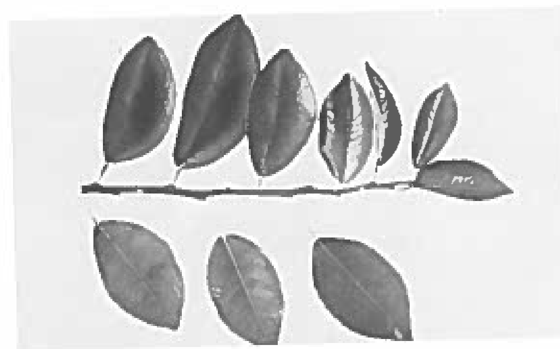
Figure 5. (Continued) (G) Palestine sweet lime, (H) *Citrus macrophylla*, (I) Cleopatra mandarin and (J) Swingle citrumelo showing bench effect characteristic of this rootstock.

Leaf and Shoot
(Figure 6)

- *Citrus macrophylla* is one of the easiest rootstocks to recognize. The leaves are pale green, have a narrow elongated (straplike) shape with a blunt apex and a moderate-sized petiole wing. **Milam** shoots are usually thick with stout thorns and pale green leaves that are distinguished by their broad apex which gradually tapers to a point.
- **Volkamer lemon** leaves are relatively small, light colored and broad with wavy margins. They are boat-shaped unlike the flat leaves of **rough lemon** and **Rangpur**. The leaves of the latter two rootstocks are pale green to green, elongated, and gently tapering to a point. Rangpur leaves are generally somewhat longer with a more prominent tip and the veins on the leaf underside often seem rather pronounced. The presence of *Alternaria citri* lesions can be diagnostic for these two stocks (Fig. 6, 7).
- **Palestine sweet lime** leaves are usually light colored and are nondescript. The leaf apex is blunt and the leaf blade is frequently slightly rolled as if the plant was being subjected to a mild water stress. The leaves of all of the above rootstocks have a relatively short petiole and an inconspicuous petiole wing except *C. macrophylla* (Fig. 6).

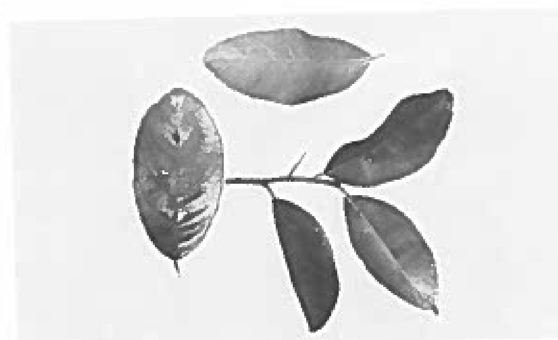


Citrus macrophylla

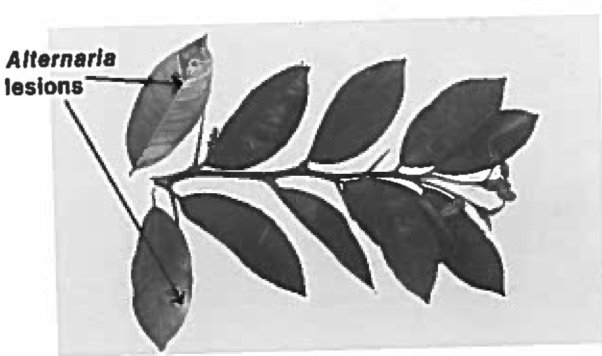


Milam

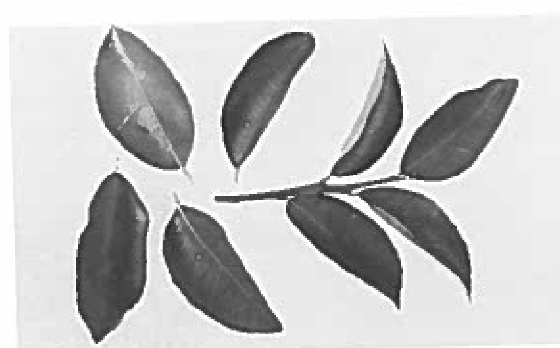
Volkamer lemon



Rough lemon



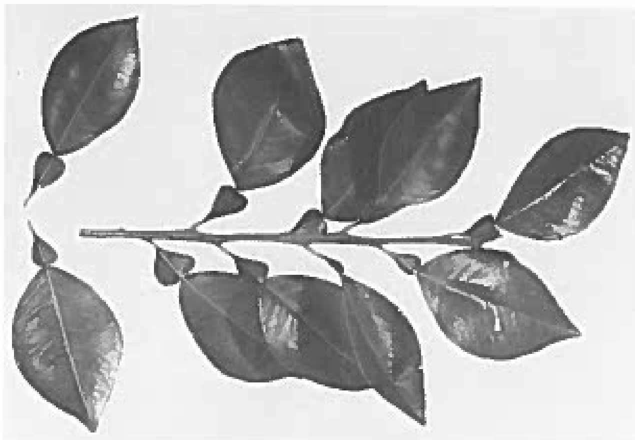
Rangpur



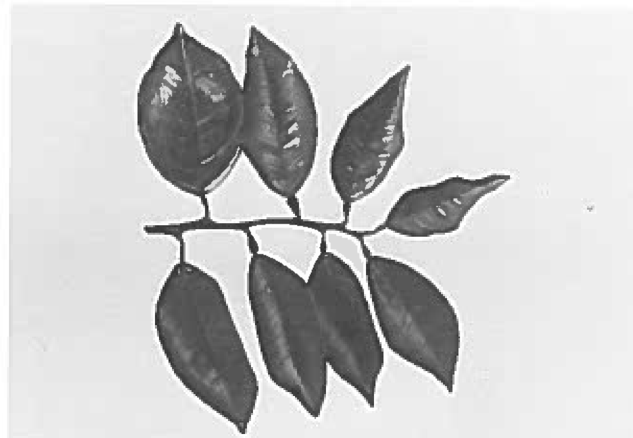
Palestine sweet lime

Figure 6A. Appearance of various rootstock leaves and shoots as grown under central Florida environmental conditions. Note the *Alternaria* lesions on the rough lemon and Rangpur leaves.

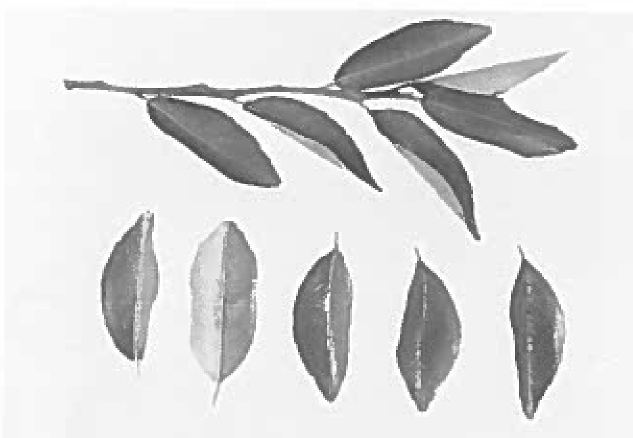
- **Sour orange** leaves are medium to large in size, dark green with a distinctive petiole wing that does not usually overlap the leaf blade. Sour orange is very susceptible to scab caused by *Elsinoe fawcetti.* Sweet orange leaves are very similar to those of sour orange except they lack the petiole wing, are not affected by sour orange scab, and are broader and not so acutely pointed at the apex.
- **Cleopatra mandarin** leaves are small and dark green with rounded teeth at the edges like Murcott leaves. Cleo leaves are closely spaced (short internodes) along the stem and appear to point toward the shoot apex.
- **Grapefruit** leaves are large, dark green, bluntly tipped and very broad with wide petiole wings that unlike sour orange leaves, touch or slightly overlap the leaf blade.
- **Flying Dragon trifoliate orange** is simple to identify from its wavy stem and recurved thorns.



Sour orange

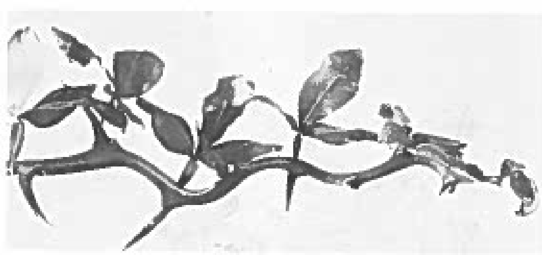


Ridge Pineapple sweet orange



Cleopatra mandarin

Duncan grapefruit



Flying Dragon trifoliate orange

Figure 6B. Appearance of various rootstock leaves and shoots as grown under central Florida environmental conditions.

- The differences in **trifoliate orange, Swingle citrumelo** and **Carrizo citrange** leaves are best noted when the leaves are compared together (Fig. 6C). The leaves of these three stocks are correctly described as trifoliolate indicating that there are three leaflets attached to a common axis. The trifoliate orange leaflets are nearly round and equal in size while the center leaflet of the Carrizo citrange leaf is the largest and has a broad, rounded apex. The citrange leaf is larger than the trifoliate orange leaf. Swingle citrumelo leaves are the largest of the three stocks. The center leaflet of the citrumelo leaf is commonly about twice the size of the lateral ones; also, the middle leaflet is more elongated and elliptically shaped than the middle Carrizo leaflet.

Leaf and shoot characteristics can be reliably used for rootstock identification when the diagnostic traits are clearly evident; however, there are circumstances when the differences given above are less obvious. Leaf and shoot morphology are easily altered by environment. Leaf appearance and shoot length may change when rootstock sprouts develop within a canopy as compared to seedlings grown in full sunlight. It is best to first carefully examine all the available leaves and shoot before rendering a decision.

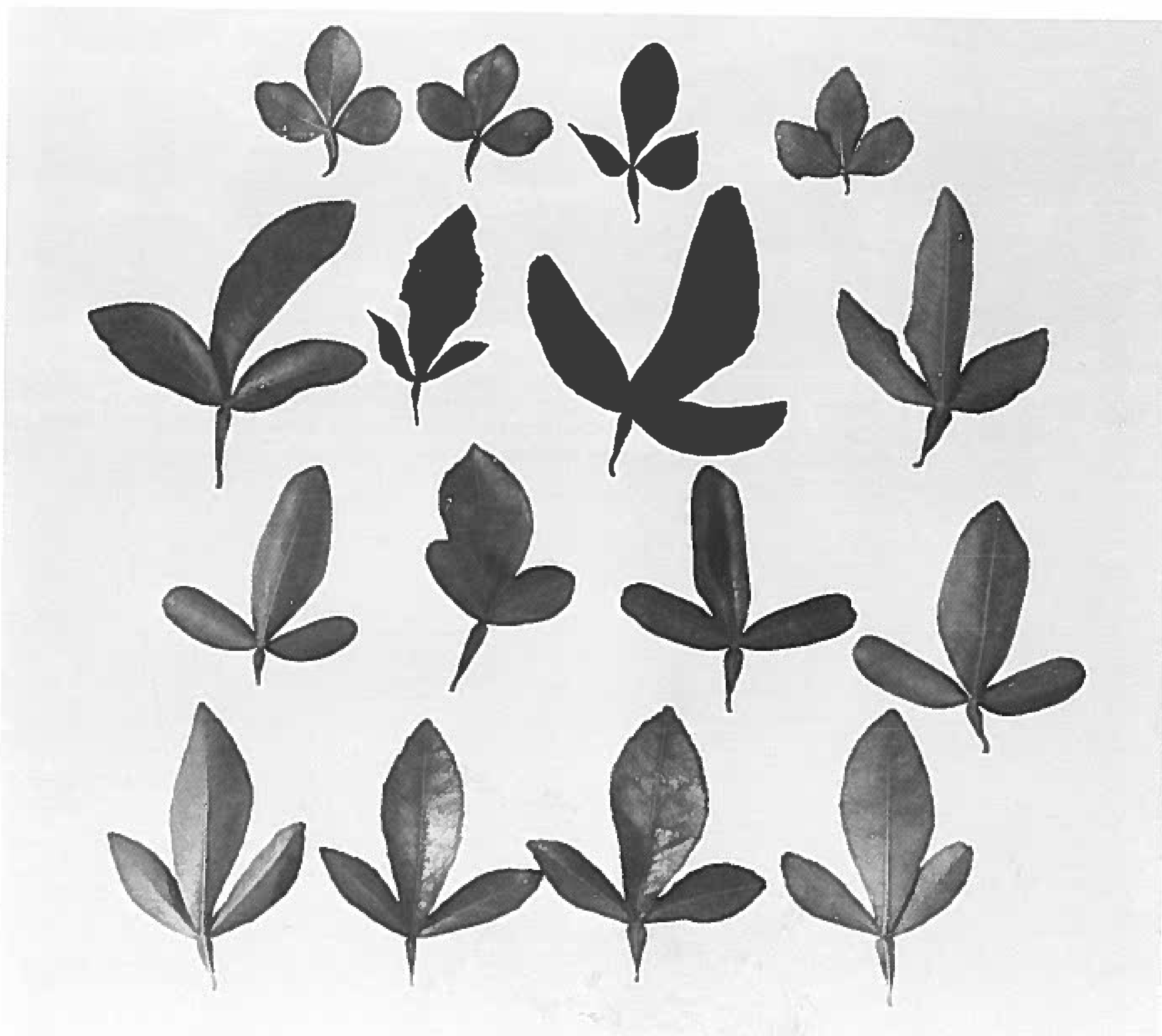


Figure 6C. Leaves of trifoliate orange (top row), Swingle citrumelo (second row), Rusk citrange (third row), and Carrizo citrange (bottom row) showing differences described in the text.

- The differences in **trifoliate orange, Swingle citrumelo and Carrizo citrange** leaves are best noted when the leaves are compared together (Fig. 6C). The leaves of these three stocks are correctly described as trifoliolate indicating that there are three leaflets attached to a common axis. The trifoliate orange leaflets are nearly round and equal in size while the center leaflet of the Carrizo citrange leaf is the largest and has a broad, rounded apex. The citrange leaf is larger than the trifoliate orange leaf. Swingle citrumelo leaves are the largest of the three stocks. The center leaflet of the citrumelo leaf is commonly about twice the size of the lateral ones; also, the middle leaflet is more elongated and elliptically shaped than the middle Carrizo leaflet.

Leaf and shoot characteristics can be reliably used for rootstock identification when the diagnostic traits are clearly evident; however, there are circumstances when the differences given above are less obvious. Leaf and shoot morphology are easily altered by environment. Leaf appearance and shoot length may change when rootstock sprouts develop within a canopy as compared to seedlings grown in full sunlight. It is best to first carefully examine all the available leaves and shoot before rendering a decision.

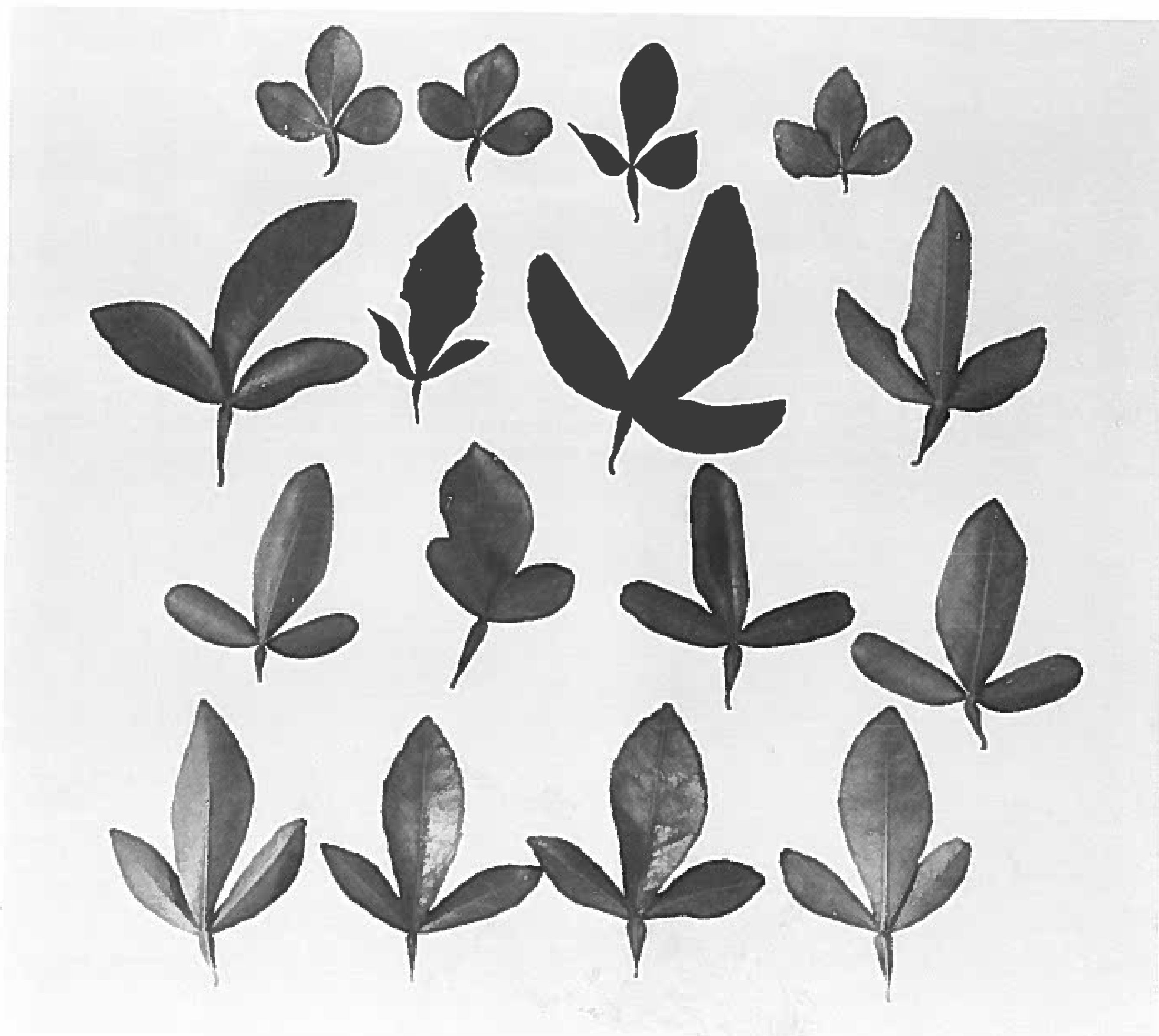


Figure 6C. Leaves of trifoliate orange (top row), Swingle citrumelo (second row), Rusk citrange (third row), and Carrizo citrange (bottom row) showing differences described in the text.

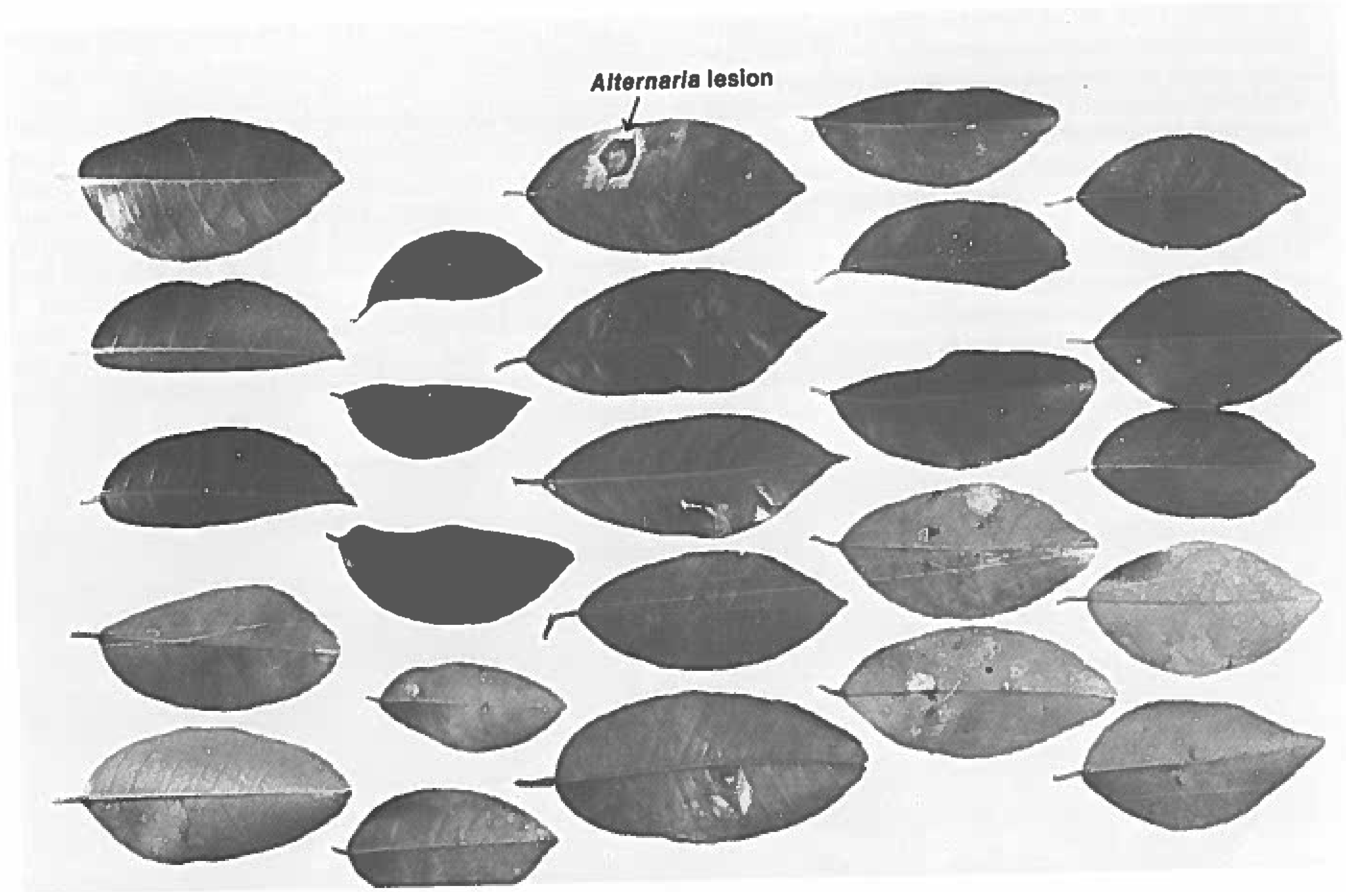


Figure 7. Comparison of (left to right) Palestine sweet lime, Volkamer lemon, Rangpur, rough lemon and Milam leaves grown under central Florida environmental conditions. The top three leaves in each vertical row show the upper leaf surface and the bottom two leaves the lower surface. The top leaf in the Rangpur row shows an *Alternaria* lesion.

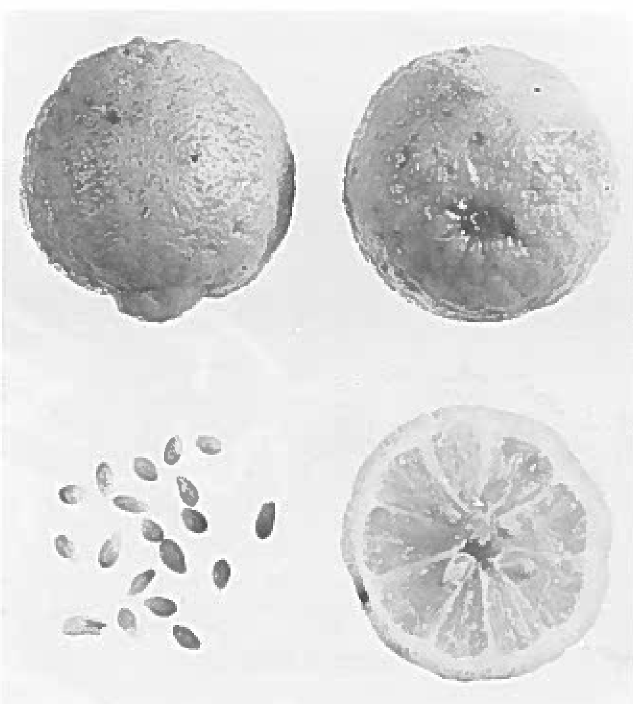
Seeds and Fruit
(Figure 8)

Seeds have little value in identification other than to assist placing a rootstock into a general group.

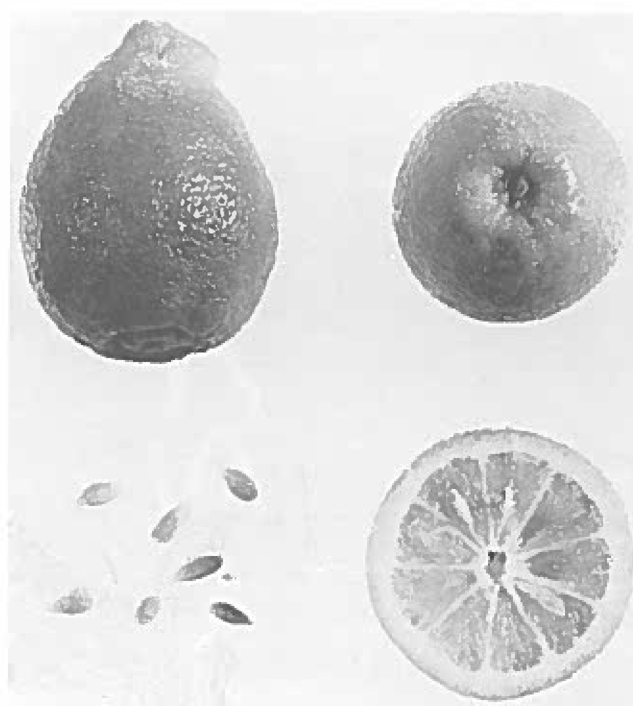
- **Rough lemon, Rangpur, Milam, Volkamer lemon,** *Citrus macrophylla* and **Palestine sweet lime** seeds are teardrop shaped, and small. The outer seed coat (testa) and cotyledons are usually cream to yellow colored. **Sour orange** seeds are larger, elongated and flat. The testa extends beyond the cotyledons forming a "beak" at both ends of a seed. **Sweet orange** seeds are about the same size as those of sour orange but they are generally plumper and rounder in shape. **Cleopatra mandarin** seeds are characteristic of many mandarins, i.e., they are very small with green cotyledons.
- The ovate-shaped **trifoliate orange** seeds have a smooth testa that is completely filled by the cotyledons. The seeds are medium-sized and yellow to brownish in color. **Carrizo citrange** and **Swingle citrumelo** seeds are large but can vary in size and shape. The testa is cream colored and often wrinkled.
- **Grapefruit** seeds are among the largest. They are variable in size and shape but generally are broad and flat with a white testa and a prominent beak.

Although seed color, size and shape are characteristic for certain groups of cultivars, these traits are not consistent. Seed color can vary depending on whether the seed coats are dry or wet. Seed size varies annually and with the number of seeds per fruit. Fruit characteristics are usually more useful in rootstock identification but they are also subject to environmental and other influences.

- **Rough lemon** fruit are medium-sized and variable in color and shape. The fruit are commonly yellow and oblate to oblong in shape. They often have a broad nipple at the stylar end surrounded by a furrow. The rind is medium-thick and bumpy or "rough." The flesh is a light yellow to yellow color. **Milam** fruit are similar but without such a protruding nipple; also, they have a smoother rind, are more elongated and are frequently necked. Milam fruit rarely contain more than about 10 seeds and often few or none.
- Unlike its leaf, the fruit of **Rangpur** is clearly different from that of rough lemon. Rangpur fruit are small to medium-sized with a thin, smooth skin that is easily removed and is bright orange to reddish in color. The fruit are round to teardrop shaped and may be slightly necked. The flesh is orange colored and strongly acid.
- **Volkamer lemon** fruit are medium-sized, oval to ellipsoid in shape with a coarse to smooth, yellow to orange colored rind and flesh. The stylar end has a broad, low nipple surrounded by a shallow furrow. The juice is acid.



Rough lemon

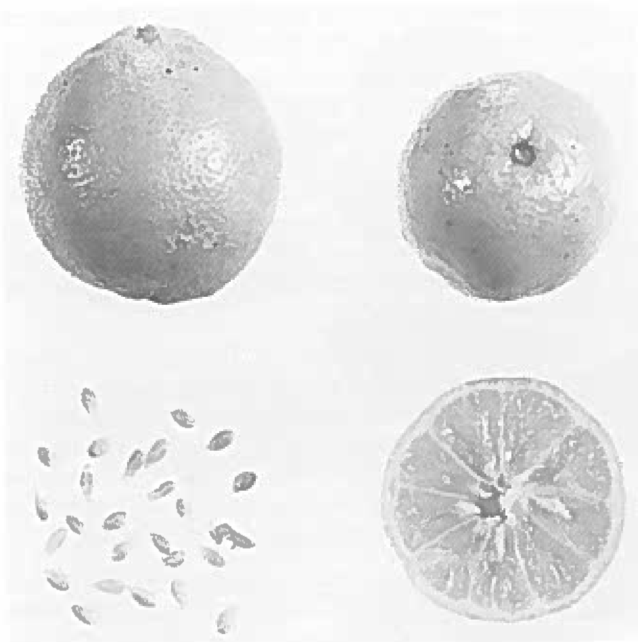


Milam

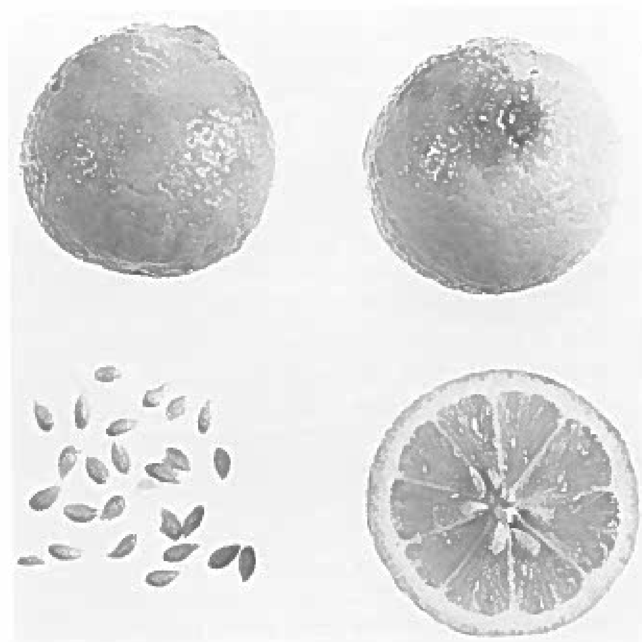
Figure 8. Fruit and seed of various rootstock cultivars collected in central Florida.

- *Citrus macrophylla* fruit are medium large, ovate-shaped, yellow at maturity and very seedy. The stylar end has a circular furrow. The flesh is white to greenish yellow colored and has a dry appearance. The juice is acid and bitter.

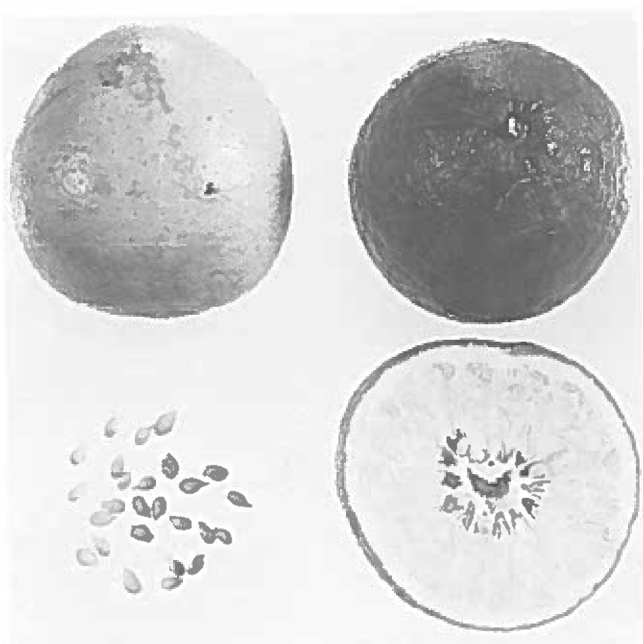
- **Palestine sweet lime** fruit are easily recognized by their subglobose (nearly spherical) to slightly elliptical shape, medium size, and smooth, thin yellow peel. The flesh is pale yellow to white and has an insipid taste.



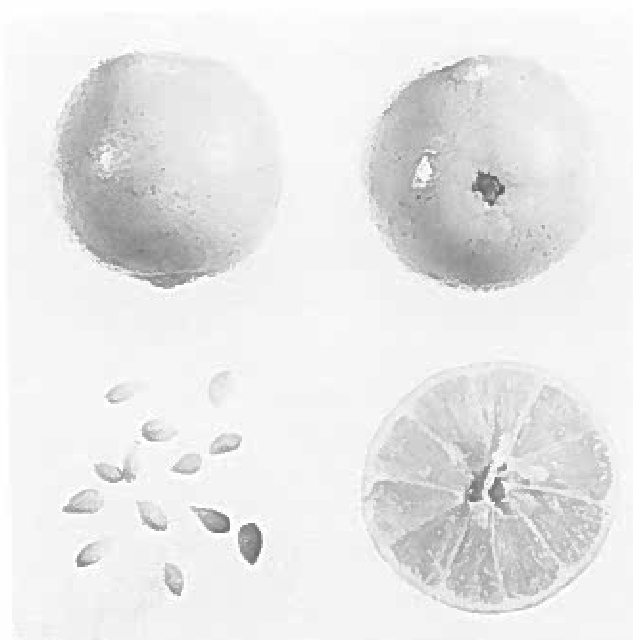
Rangpur



Volkamer lemon



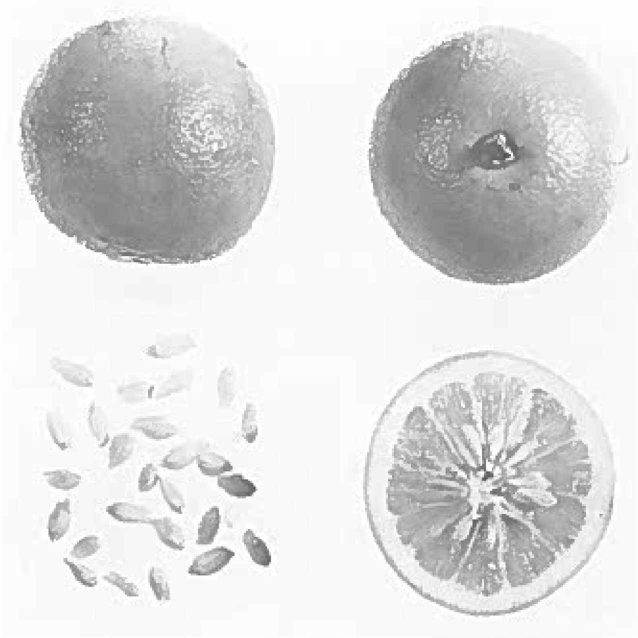
Citrus macrophylla



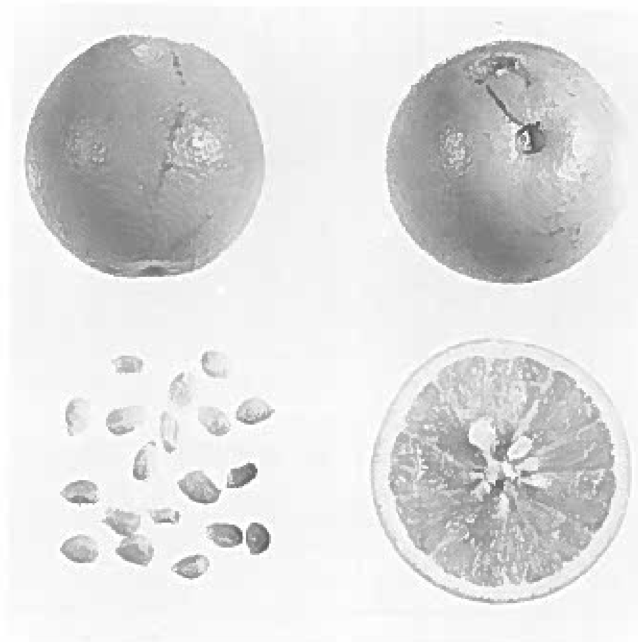
Palestine sweet lime

Figure 8. (Continued)

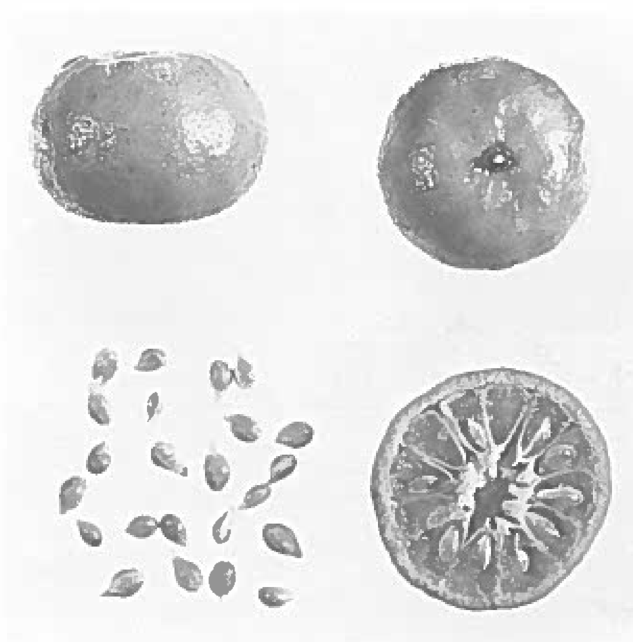
- **Sour orange** fruit are well-known because of their numerous seeds and high acidity. The fruit are medium to large-sized, round but slightly flattened at the poles often giving the fruit a box-like appearance, and have a thick, orange colored rind. The rind can be relatively smooth or rough but not like rough lemon. The fruit often have a large calyx (button). **Sweet orange** fruit have a sweeter juice, a thinner, usually smoother rind and are oval-to oblong-shaped. Cultivars vary in appearance and seediness, some producing virtually no seeds.
- **Cleopatra mandarin** fruit are small with a loosely adhering orange to reddish peel. The fruit are oblate, depressed at the stylar and stem end and very seedy.



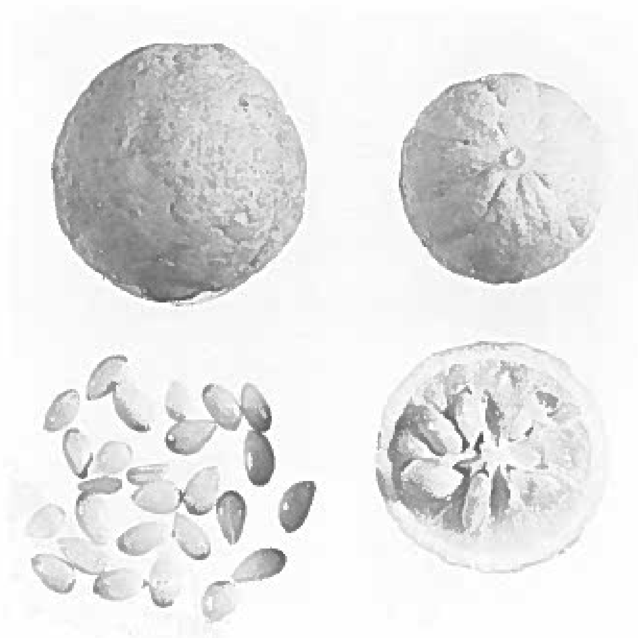
Sour orange



Ridge Pineapple sweet orange



Cleopatra mandarin

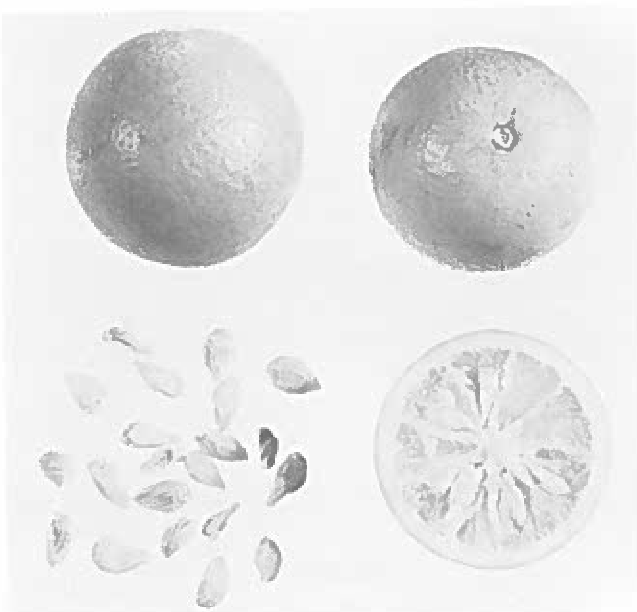


Trifoliate orange

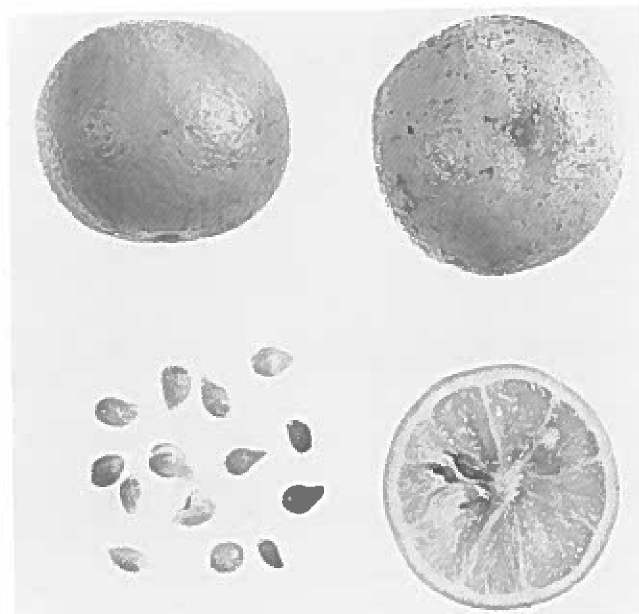
Figure 8. (Continued)

- **Trifoliate orange** fruit are round, small with a dull yellow-lemon color and thick rind that is densely pubescent (hairy). The fruit are very seedy and have a rough, coarse appearance. **Carrizo citrange** fruit are oblate to round, orange colored at maturity, and seedy. Fruit size is small but larger than that of trifoliate orange fruit. The rind is relatively smooth. Flesh color is greenish yellow. **Swingle citrumelo** fruit are yellow, medium-sized, pyriform with a collared stem end. The fruit are lightly pubescent with a medium thick rind and numerous seeds.

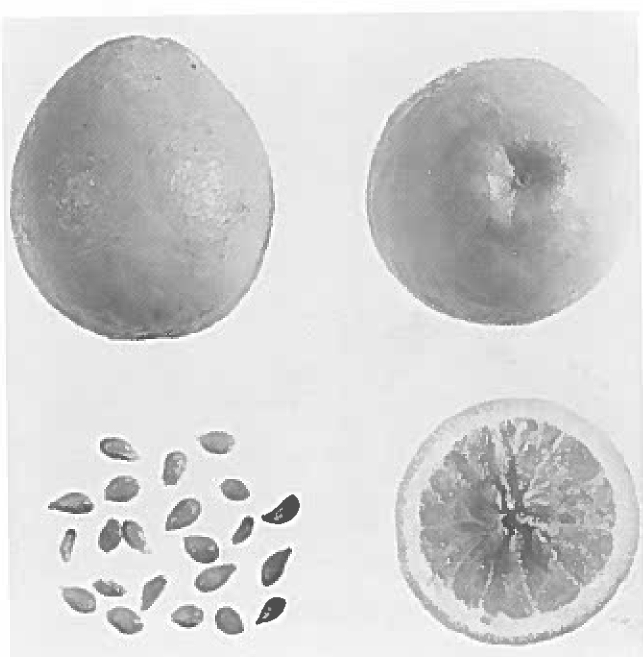
- **Grapefruit** characteristics are also widely known particularly their oblate (flattened) shape, large size, and yellow color. There are many cultivars, therefore, certain characteristics may vary and like the sweet oranges, some cultivars are seedless.



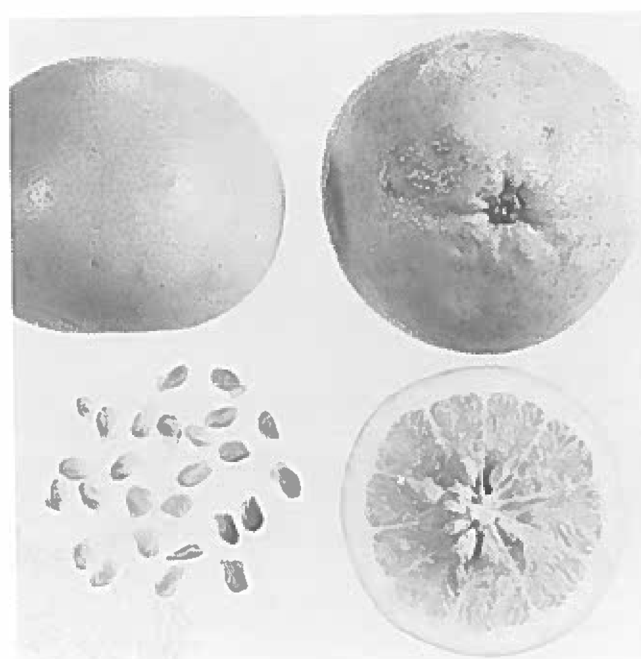
Carrizo citrange



Rusk citrange



Swingle citrumelo



Duncan grapefruit

Figure 8. (Continued)

Appendix E. Quick reference chart.

This chart summarizes in a general way, across all scion cultivars, the relative ranking of various rootstocks for the listed characteristics. The chart is helpful for learning or reviewing basic rootstock responses but should not be relied upon for rootstock selection without consulting the more detailed descriptions and discussion presented under Rootstock Characteristics and Rootstock Selection, or reading pertinent articles listed in Appendix F. The chart is only intended to serve as a guide.

Rootstock \ Characteristic	Phytophthora tolerance	Flood tolerance	Drought tolerance	Cold tolerance	Blight tolerance	Tristeza tolerance	Exocortis tolerance	Xyloporosis tolerance	Burrowing nematode tolerance	Citrus nematode tolerance	Yield/tree	Brix	Fruit size	Tree vigor	High calcium tolerance	Salt tolerance
Rough lemon	S	G	G	P	P	T	T	T	S	S	H	L	LG	H	H	I
Volkamer lemon	S	G	G	P	P	T	T	T	S	S	H	L	LG	H	H	?
Citrus macrophylla	R	G	G	P	P	S	T	S	S	S	H	L	LG	H	H	G
Palestine sweet lime	S	G	G	P	P	T	S	S	S	S	H	L	LG	H	I	P
Rangpur	S	?	G	P	P	T	S	S	S	S	H	L	LG	H	H	G
Milam lemon	S	G	G	P	P	T	T	T	R	S	H	L	LG	H	?	?
Sour orange	T	I	I	G	G	S	T	T	S	S	I	H	I	I	H	I
Cleopatra mandarin	T	P	I	G	G	T	T	T	S	S	L-I	H	SM	H	I	G
Sweet orange	S	P	P	I	G	T	T	T	S	S	I	I	I	I	L	I
Ridge pineapple	S	P	P	I	G	T	T	T	R	S	I	I	I	I	L	I
Carrizo citrange	T	P	G	I	P	T	S	T	T	T	H	I	I	H	L	P
Swingle citrumelo	R	G	I	G	I?	T	T?	T	S	R	I	H	I	I	I?	I
Trifoliate orange	R	I	P	G	P	R	S	T	S	R	L-I	H	SM	L	L	P
Rusk citrange	T	?	P	G	?	T	T?	T	S	T	L-I	H	I	I	L	P
Grapefruit	S	?	P	I	?	T	T	T	S	S	H	L	SM	H	L	I

Key to symbols:
- G - good
- H - high
- I - intermediate
- L - low
- LG - large
- P - poor
- R - resistant
- S - susceptible
- SM - small
- T - tolerant
- ? - inadequate information or rating unknown

Appendix F. Suggested reading.

Books

1987 **Citrus rootstocks.** W. S. Castle. In: R. C. Rom and R. F. Carlson (eds.). *Rootstocks for Fruit Crops*. J. Wiley and Sons, N.Y.

1979 **Citrus rootstocks.** H. K. Wutscher. In: J. Janick (ed.). *Horticultural Reviews*. AVI Publications.

Magazines

Citrograph

1986

Dec **Test with eureka, lisbons, and new citrange rootstocks.** R. M. Burns, N. J. Sakovich, and J. B. Carpenter.

Nov **Citrus tree size control with dwarfing agents.** P. Broadbent, et al.

Sep **The potential for dwarfing rootstocks for citrus.** M. L. Roose.

1983

Sep **Dwarf citrus moves from theory to field.** Anonymous.

1981

Mar **Performance of rootstocks inoculated with virus.** J. B. Carpenter, R. M. Burns and R. F. Sedlacek.

Feb **Flying dragon: a potential dwarfing rootstock.** D. Cole and C. D. McCarty.

1980

Oct **Phytophthora resistant rootstocks for lisbon lemons in California.** J. B. Carpenter, R. M. Burns and R. F. Sedlacek.

1979

Jun **Facts about dwarf citrus trees.** W. P. Bitters, D. A. Cole and C. D. McCarty.

1973

Jul **Comparisons between Troyer and Carrizo citrange.** C. D. McCarty, W. P. Bitters and D. A. Cole.

1967

Mar **Valencia orange rootstock trial at south coast field station.** W. P. Bitters.

Citrus Industry

1986

Jul **Nurserymen hear presentation on own-rooted citrus.** J. Fisher.

1985

Oct **Navel orange growing in Florida.** F. S. Davies.

Oct **Citrus basics: of scions and such.** J. M. Bulger, L. K. Jackson and R. M. Davis.

Sep **Citrus basics: citrus rootstocks.** L. K. Jackson, J. M. Bulger and R. M. Davis.

Sep **Flying dragon rootstock may prove favorable for Florida citrus.** J. Fisher.

1984

Jan **Choosing a rootstock for citrus.** W. S. Castle.

1983

Jul **What you should know before buying citrus nursery trees.** J. Race.

1982

Jun **Origins and early history of Florida citrus**
Jul **citrus budwood program.** J.F.L. Childs.

1965

Feb **The origin and history of Troyer and Carrizo citranges.** E. M. Savage and F. E. Gardner.

Citrus & Vegetable

1963

Feb **Effect of freeze injury on root distribution of citrus.** H. W. Ford.

Florida Grower & Rancher

1979

Jul **Rootstocks: their relation to virus disease and blight.** A. H. Krezdorn.

Jun **Citrus rootstocks: tolerance of environmental and disease problems.** A. H. Krezdorn.

May **Rootstocks: how they affect yield.** A. H. Krezdorn.

Apr **Selecting citrus rootstocks for fruit size and quality.** A. H. Krezdorn.

Proceedings

First International Citrus Short Course — Citrus Rootstocks

1973 **World citrus rootstock situation.** W. P. Bitters.

Citrus rootstock improvement. W. P. Bitters.

Florida State Horticultural Society

1987 **The Fallglo citrus hybrid in Florida.** (Data presented for six rootstocks) C. J. Hearn.

1986 **Tree spacing and rootstock affect growth, yield, fruit quality, and freeze damage of young Hamlin and Valencia orange trees.**

1986 **Tree spacing and rootstock affect growth, yield, fruit quality, and freeze damage of young Hamlin and Valencia orange trees.** T. A. Wheaton, J. D. Whitney, W. S. Castle and D. P. H. Tucker.

Rangpur lime x Troyer citrange, a hybrid citrus rootstock for closely spaced trees. W. S. Castle, C. O. Youtsey and D. J. Hutchison.

Incidence of citrus blight in Florida's citrus budwood foundation grove. C. O. Youtsey and F. J. Rosenthal.

Tristeza and blight influence fruit quality and yield of Valencia orange trees on seven rootstocks. D. J. Hutchison.

1983 **Growth, yield, and cold hardiness of seven-year-old 'Bearss' lemon trees on twenty-seven rootstocks.** W. S. Castle.

1982 **Development of the root system of young Valencia orange trees on rough lemon and Carrizo citrange rootstocks.** K. B. Bevington and W. S. Castle.

Rates of blight incidence in trees on Carrizo citrange and other rootstocks. R. H. Young, L. G. Albrigo, M. Cohen W. S. Castle.

1981 **Performance of Queen orange trees on 15 citrus rootstocks.** D. J. Hutchison.

Preliminary performance on 7-year-old Valencia orange trees on 21 rootstocks. D. J. Hutchison and F. W. Bistline.

Cold hardiness of citrus trees during the 1981 freeze in Florida. G. Yelenosky, R. Young, C. J. Hearn, H. C. Barrett and D. J. Hutchison.

1980 **A survey for citrus tristeza virus in registered budwood sources commercially propagated on sour orange rootstocks in Florida.** S. M. Garnsey, R. F. Lee, C. O. Youtsey, R. H. Brlansky and H. C. Burnett.

Incidence of citrus blight on Carrizo citrange and some other rootstocks. R. H. Young, L. G. Albrigo, D. P. H. Tucker and G. Williams.

The blight susceptibility of Pineapple orange trees on Citrus macrophylla rootstock. H. K. Wutscher and F. W. Bistline.

Citrus rootstocks for tree size control and higher density plantings in Florida. W. S. Castle.

1978 **Higher density plantings for Florida citrus — concepts.** T. A. Wheaton, W. S. Castle, D. P. H. Tucker and J. D. Whitney.

1977 **Root system characteristics of citrus nursery trees.** W. S. Castle and C. O. Youtsey.

The performance of Robinson and Page citrus hybrids on 10 rootstocks. C. J. Hearn and D. J. Hutchison.

Cold hardiness of orange and grapefruit trees on different rootstocks during the 1977 freeze. G. Yelenosky and R. Young.

The performance of Nova and Orlando tangelos on 10 rootstocks. D. J. Hutchison and C. J. Hearn.

1976 **Field performance of several common citrus scions on Milam rootstock.** W. S. Castle.

Cold hardening young Valencia orange trees on Swingle citrumelo (CPB 4475) and other rootstocks. G. Yelenosky.

1974 **Rootstock effects on root distribution and leaf mineral content of Orlando tangelo trees.** W. S. Castle and A. H. Krezdorn.

Swingle citrumelo — a promising rootstock hybrid. D. J. Hutchison.

1972 **Variation in <u>Phytophthora</u> resistance of Florida rough lemon and sour orange clones.** D. J. Hutchison and G. R. Grimm.

Rootstock effects on tree size and yield of Tahiti lime (<u>Citrus</u> <u>latifolia</u> Tanaka). C. W. Campbell.

Sweet orange rootstock in experimental trials on the east coast of Florida. M. Cohen.

Reaction of selected citrus rootstocks to footrot, burrowing and citrus nematodes. D. J. Hutchison, J. H. O'Bannon and G. R. Grimm.

1971 **Sweet lime, its performance and potential as a rootstock in Florida.** A. H. Krezdorn and W. S. Castle.

1970 **Rangpur lime as a citrus rootstock in Florida.** M. Cohen.

The influence of rootstocks on tree growth, fruiting and fruit quality of Orlando tangelos. A. H. Krezdorn and W. J. Phillips.

1968 **Exocortis virus as a possible factor in producing dwarf citrus trees.** M. Cohen.

Footrot and tristeza tolerance of smooth seville orange from two sources. G. R. Grimm and S. M. Garnsey.

1967 **<u>Poncirus</u> <u>trifoliata</u> and some of its hybrids as rootstocks for Valencia sweet orange.** F. E. Gardner and G. E. Horanic.

Growth and productivity of virus-infected Valencia orange trees on 25 rootstocks. F. E. Gardner, D. J. Hutchison, G. E. Horanic and P. C. Hutchins.

1966 **Growth, yield, and fruit quality of Marsh grapefruit on various rootstocks on the Florida east coast — a preliminary report.** F. E. Gardner and G. E. Horanic.

1964 **The effect of rootstock, soil type, and soil pH on citrus root growth in soils subject to flooding.** H. W. Ford.

1963 **Cold tolerance and vigor of young citrus trees on various rootstocks.** F. E. Gardner and G. E. Horanic.

Rootstocks for Valencia orange and Ruby Red grapefruit: results of a trial initiated at Fort Pierce in 1950 on two soil types. M. Cohen and H. J. Reitz.

1961 **A comparative evaluation of rootstocks for Valencia and Parson Brown oranges on Lakeland fine sand.** F. E. Gardner and G. E. Horanic.

1959 **Relative wilting of orange trees on various rootstocks.** G. E. Horanic and F. E. Gardner.

1958 **Influence of various rootstocks on the cold resistance of the scion variety.** F. E. Gardner and G. E. Horanic.

1954 **Root distribution in relation to the water table.** H. W. Ford.

1952 **Citrus rootstock trials. A nine-year progress report on seven rootstocks on Lakeland fine sand.** J. A. Cook, G E. Horanic and F. E. Gardner.

1946 **Root systems of various citrus rootstocks.** E. M. Savage, W. C. Cooper and R. P. Piper.

1924 **Some observations on citrus rootstocks.** R. E. Skinner.

International Society of Citriculture

1978 **Citrus root systems: their structure, function, growth and relationship to tree performance.** W. S. Castle.

Selection of rootstocks for salinity and disease resistance. D. A. Newcomb.

1977 **Citrus relatives are not irrelevant as dwarfing stocks or interstocks for citrus.** W. P. Bitters, D. A. Cole and C. D. McCarty.

Potentially dwarfing rootstocks for Florida citrus. W. S. Castle and R. L. Phillips.

Influence of rootstocks on mandarin cultivars. A. H. Krezdorn.

The effects of rootstocks on citrus cold hardiness. R. H. Young.

Influence of rootstock on the performance of Valencia sweet orange. D. J. Hutchison.

The influence of rootstocks on yield and quality of red grapefruit in Texas. H. K. Wutscher.

University of Florida Circular S-151

1964 **Three citrus rootstocks recommended for trial in spreading decline areas.** H. W. Ford and W. A. Feder.

Appendix G. Glossary.

Adventitious bud. A bud not arising from its usual place (the axil of a leaf) but from a root or other place. Such buds are also called adventive. Dormant or latent buds imbedded in old limbs are not adventitious in origin.

Asexual propagation. See vegetative propagation.

Biotype. Species of living organisms gradually change through the sexual process and mutation. Slight changes often occur in which a strain of an organism becomes either more or less resistant to a disease. Also, a disease agent, insect or nematode may develop an ability to attack a plant previously resistant to it, even though there are no visually observable changes. Organisms that have undergone such changes are called biotypes.

Bud. A protuberance normally arising in the axil of a leaf and consisting of a greatly compressed stem with its growing point.

Budeye. A term used commonly in propagation which refers to an axillary bud and the area of the stem immediately surrounding it.

Budding. A propagation procedure which involves inserting a single bud with a small amount of bark and wood, or with bark only, into a cut on the rootstock seedling followed by wrapping to secure the bud firmly in place. Most citrus trees are propagated in this manner using a T-bud.

Budline. A specific source of propagation material within a cultivar. Florida examples are the Hughes nucellar valencias (e.g. V-S-SPB-1-12-7, V-S-SPB-1-21-30, etc.) and the nucellar navels (e.g. N-S-F-56-11).

Bud union. The point of connection between the scion and the rootstock.

Budwood or bud stick. A short piece of stem with buds used as a source of buds during propagation.

Budwood source tree. A tree maintained by nurserymen, growers or others as a source of budwood for producing nursery trees.

Calcareous. Generally refers to a soil condition resulting from the presence of enough calcium carbonate (usually from marl, shells, or limerock) to cause release of CO_2 when the soil is treated with cold dilute hydrochloric acid.

Certification. A program of the Division of Plant Industry. A nursery site that has been inspected and declared free of certain nematodes particularly the burrowing and citrus nematodes is called a **certified site**. The term also applies to citrus **nursery trees** raised on approved (certified) sites. Such trees are commonly referred to as BN (burrowing nematode) certified but they also have been inspected for apparent freedom from other pests and diseases.

Clone. An asexually reproduced cultivar; a group of genetically uniform plants that have been propagated vegetatively from a single, original plant. A cultivar, such as Redblush grapefruit or Hamlin sweet orange, propagated in this manner, is referred to as having been **clonally propagated** and the cultivar itself is a clonal cultivar.

Cultivar. A group of cultivated plants (thus, the term cultivar from <u>culti</u>vated <u>var</u>iety) that can be distinguished from others by some morphological, physiological or other characters that are of practical significance and are retained through sexual or asexual reproduction. For example, Marsh and Redblush grapefruit are the same species, *Citrus paradisi*, but are different cultivars. Redblush is distinguished from Marsh by its peel blush and flesh color. These characteristics are maintained through vegetative propagation (budding).

Flatwoods land. Broad, nearly level, poorly drained areas in Florida primarily in coastal locations and characterized by dominantly sandy soils. Usual vegetation is open pine forest and saw palmetto. These areas must be drained and bedded in order to grow citrus.

Fluting. The trunks of some rootstocks are ridged and furrowed rather than being smooth and uniform. When these grooves are present, the trunk is commonly described as fluted.

Grafting. A method of asexual progapation that differs from budding in that a short piece of stem with two or three buds instead of a single bud, is inserted into a cut on the stem.

Hammock land. Relatively small land units which occur within both well-drained and poorly drained areas of Florida. Hammock sites are usually slightly elevated compared to the surrounding land and support a dense growth of hardwood vegetation. Drainage in hammocks is also slightly better and the soil somewhat richer.

Interstock. A third part of a citrus tree inserted between the scion and rootstock usually by budding during propagation. The interstock can be a short piece of trunk or most of the trunk and the primary framework branches. Interstocks often arise inadvertently when trees are topworked or intentionally when an interstock is desired for a specific purpose. Interstocks are not commonly used in citrus propagation.

Juvenility. The physiological state of immaturity expressed in citrus seedlings. Citrus plants in the juvenile phase of their life cycle do not produce flowers, usually have pronounced thorns and are vigorous, often with a marked upright growth form. The length of the juvenile period varies

from one to two years for Key lime, two to three years for lemons, five years for tangerines or mandarins, to 8 to 12 years for sweet oranges and grapefruit.

Latent buds. Dormant buds that become imbedded in the bark because of their failure to grow for many years. Their location is indicated by small bumps or raised areas on old limbs. They are forced to grow when the limb is cut back to a point just above the bump or bud.

Leaf blade. The main, broad, flattened portion of the leaf.

Leaf petiole. The stalk with which the leaf blade is attached to the stem.

Leaf petiole wing. The leaf blade-like outgrowth or margin attached to the petiole.

Marcottage or air layerage. A propagation process which involves wounding a stem attached to a plant and wrapping it with material that retains moisture. Roots develop from above the wounded area. The stem above the wound with its newly found roots is cut off, and planted. Tahiti limes are often propagated in this manner. Such plants (marcotts) are on their own roots, i.e., no rootstock is involved.

Monoembryonic. Describes seeds which contain only one embryo that is sexual in origin; also used in reference to certain cultivars, like Temple, Robinson and Clementine mandarins and all of the pummelos (*C. grandis*), which produce seeds with only one embryo.

Nematodes. Small worm-like microscopic organisms that attack roots causing tree decline and debilitation.

Nucellar embryony. A phenomenon common in many citrus cultivars in which embryos arise from a maternal tissue, the nucellus. These embryos are asexual in origin and are in addition to the one embryo that results from the normal fertilization (sexual) process. In some cultivars, the sexual embryo often does not develop because of the more rapid growth of the nucellar embryos. These cultivars then produce virtually 100% nucellar seedlings.

Nucellar seedling. A seedling that has developed from a nucellar or vegetative embryo. Such seedlings are genetically uniform and, with rare exception, free of viruses and viroids. They are initially juvenile but eventually produce adult or fruiting portions that are a source of budwood for propagating nursery trees. Rootstock seedlings are largely nucellar and thus, are free of viral agents and are genetically identical to the parent tree, two important horticultural advantages.

Nucellar cultivar or variety. A cultivar that has been propagated, usually clonally, from a nucellar seedling of that cultivar. Such cultivars should be free of budwood transmitted viruses and viroids and they often exhibit greater vigor and thus, yield better than old line cultivars.

Old line cultivar or variety. A cultivar long past its juvenile phase that has been propagated for many years, usually clonally, without any apparent recent reproduction of the original tree by seed.

Polyembryonic. A seed or cultivar that produces seed with more than one embryo per seed regardless of their origin, i.e., sexual or nucellar.

Registration. A voluntary program of the Division of Plant Industry, Bureau of Citrus Budwood Registration. It is designed to provide horticulturally sound, true-to-type, virus and viroid free budwood and seeds. Both scion budwood and rootstock seed sources can be registered and when used for propagation entitle the resulting nursery plants to be sold as **registered trees.** Registered sources of budwood and seed are coded with letters and numbers designating the cultivar, tree location and the results of the virus/viroid testing. For example, H-1-4-1 is a Hamlin clone free of psorosis. If free of psorosis and xyloporosis, it is designated H-1-4-1-X; and, if also free of exocortis, then it is H-1-4-1-XE. Budwood is not registered free of tristeza virus because of its widespread occurrence in Florida and transmission by aphids.

Reset. A plant used to replace another that has died or been removed for other reasons in a grove.

Resistance. Refers to a level of relationship between a host and a disease agent or pest in which the organism may penetrate the host but does not reproduce. The host is unaffected.

Ridge land. A general term used within the citrus industry to describe areas of central Florida characterized by high sand ridges of non-calcareous sands over beds of acid sandy clays. The soils are deep, well-drained and acid. They support a native vegetation of pine and oak.

Rootstock or stock. Citrus is normally a two-parted tree. The part below the bud union consisting of the roots and lower trunk is the rootstock.

Scion. The portion of the citrus tree which produces the desired fruit and arises from the bud inserted in the rootstock seedling. It is pronounced SIGH-ON, not SKY-ON.

Sexual embryo. A sexual embryo is a miniaturized plant in the seed formed by fusion of an egg cell of the female parent with gametes from the pollen tube of the male parent. The resulting seedling will have a mixture of the characteristics of the parent. It is also called a gametic embryo.

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Sprout. A general term given to vigorous shoots arising from roots, trunks and main framework branches. Removal of sprouts is called sprouting.

Susceptibility. Refers to a level of host-pathogenic organism relationship in which the disease agent or pest invades the host and reproduces readily. The host is adversely affected and may ultimately die.

T-Budding. A type of budding which involves inserting a bud attached to a shield-shaped piece of bark and sliver of wood, into a T-shaped cut on the rootstock. An inverted T is usually used in Florida.

Tolerance. Refers to a level of host-pathogenic organism relationship in which the host is invaded but the pathogen reproduces only modestly with slight effects on the host.

Topworking. Replacing the canopy of a tree with another cultivar. The top is cut back to main framework branches (buckhorning) and each of the branches is budded or grafted.

Trueness-to-type. A key concept in preserving genetic identity during vegetative propagation of clones. It involves assurance that the source of propagation material is correctly named and that the source has not changed in any significant way.

Variety. A synonym for cultivar which is the preferred term. Variety is less precise but is commonly used.

Validation. A voluntary program of the Division of Plant Industry, Citrus Budwood Registration Bureau, which assures correct identification, timely indexing and authentic plantings of new scion and rootstock cultivars released through state and federal agencies. Validation precedes registration.

Vegetative (asexual) propagation. Propagation without the sexual process that is involved in gametic or sexual seedling production. The plants produced are genetically the same. This includes producing plants by budding, grafting, cutting, layers, nucellar embryony and tissue culture.

Viroid. A virus-like or naked virus particle that does not have the protein sheath of a virus. Examples of citrus viroids are exocortis and xyloporosis.

Virus. A virus is a particle composed of a nucleic acid nucleus surrounded by a protein sheath that caused diseases. Tristeza and psorosis are examples of viruses.