Background Material For A Study of Rootstocks

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The basic element in any attempt to advance knowledge is the ability to communicate. Each area of study requires a special language of definitions and facts that enable those involved to discuss a subject intelligently. The purpose of the following material is to present a ready reference of facts and terminology for use in this course. The material is presented in brief form to serve the immediate interests of the participants.

Classification and Nomenclature of Plants

Classification. - Scientists have classified plants, (placed them into groups based on their relationship to each other) and then affixed names to these groups according to accepted rules of nomenclature. Classification is inexact because there is no way to determine the precise relationship of plants. Thus, plants may be grouped differently by equally able scientists who interpret available information differently. Perhaps fortunately, not many scientists are inclined to undertake the tremendous task of classifying large groups of plants. Walter T. Swingle, a U.S. Department of Agriculture scientist who worked in Florida, is the universally accepted authority for the large family of plants that includes the genus *Citrus.*

All life is divided into that which is animal and that which is plant and then into groups decreasing in size and increasing in closeness of relationship.

The position of citrus in the Plant Kingdom is:

Division	-	*Embryophyta Siphonogama*
Subdivision	-	*Angiospermae*
Class	-	*Dicotyledoneae*
Subclass	-	*Archichlamydeae*
Order	-	*Geraniales*
Suborder	-	*Geraniineae*
Family	-	*Rutaceae*
Subfamily	-	*Aurantioideae*

The subfamily *Aurantioideae* is a rather large category but worthy of mention because it contains not only the various kinds of commercial citrus but wild relatives, some which hybridize with citrus and some which have potential as rootstocks. Swingle has divided the subfamily *Aurantioideae* into tribes, subtribes, subtribal groups and genera as follows:

Subfamily	-	*Aurantioideae*
Tribe I	-	*Clauseneae*
Subtribe 1	-	*Micromelinae*
Genus I	-	*Micromelum*
Subtribe 2	-	*Clauseninae*
Genus I	-	*Glycosmis*
Genus II	-	*Clausena*
Genus III	-	*Murraya*
Subtribe 3	-	*Merrillinae*
Genus I	-	*Merrillia*
Tribe II	-	*Citreae*
Subtribe 1	-	*Triphasiinae*
Genus I	-	*Wenzelia*
Genus II	-	*Monanthocitrus*
Genus III	-	*Oxanthera*
Genus IV	-	*Merope*
Genus V	-	*Triphasia*
Genus VI	-	*Pamburus*
Genus VII	-	*Luvunga*

Genus VIII - *Paramignya*
Subtribe 2 - *Citrinae*
Genus I - *Severinia*
Genus II - *Pleiospermum*
Genus III - *Burkillanthus*
Genus IV - *Limnocitrus*
Genus V - *Hesperethusa*
Genus VI - *Citropsis*
Genus VII - *Atalantia*
Genus VIII - *Fortunella*
Genus IX - *Eremocitrus*
Genus X - *Poncirus*
Genus XI - *Microcitrus*
Genus XII - *Citrus*
Subtribe 3 - *Balsamocitrinae*
Genus I - *Swinglea*
Genus II - *Aegle*
Genus III - *Afraegle*
Genus IV - *Aeglopsis*
Genus V - *Balsamocitrus*
Genus VI - *Feronia*
Genus VII - *Feroniella*

Nomenclature. - The ordinary layman defines citrus as the sweet oranges, tangerines, grapefruit, lemons and lime fruit, commonly found on the grocery shelf under the citrus label. Growers, more knowledgeable of citrus technology, include unpalatable species and close relatives such as sour orange, trifoliate oranges, kumquats, and others in their definition of citrus. Scientists use the term citrus in several ways as follows:

A. The subtribe *Citrineae* has been divided into 3 citrus groups.

Subtribe - *Citrineae*
1. Primitive Citrus Fruit Trees
   Genus I - *Severinia*
   Genus II - *Pleiospermum*
   Genus III - *Burkillanthus*
   Genus IV - *Limnocitrus*
   Genus V - *Hesperethusa*
2. Near-Citrus Fruit Trees
   Genus I - *Citropsis*
   Genus II - *Atalantia*
3. True Citrus Fruit Trees
   Genus I - *Fortunella* (kumquats)
   Genus II - *Eremocitrus*
   Genus III - *Poncirus* (trifoliate orange)
   Genus IV - *Clymenia*
   Genus V - *Microcitrus*
   Genus VI - *Citrus* (includes common commercial citrus types)

Thus, the scientist may use the term citrus in a broad sense to mean the commercial types of the genus *Citrus*, the inedible types of *Citrus* and certain *Citrus* relatives.

B. The term *Citrus*; ie, citrus spelled with a capital C and underlined or italicized indicates the generic name of that group. All of the fruit marketed commercially as citrus is included in this genus. The kumquat, in the genus *Fortunella*, is a minor exception.

Scientists and well-informed growers often use scientific botanical names, such as *Citrus sinensis* (L.) Osbeck. The scientific name can be divided into 3 parts the genus, *Citrus*, the species epithet *sinensis* and the author citation, (L.) Osbeck. The common name of this species is sweet orange or orange.

The advantage of the scientific name is that each species, the basic taxonomic unit, can have only one name and that name is formed according to specific rules. The unfortunate fact, however, is that those who classify plants may differ as to which plants should belong to a given group. This situation borders on the ridiculous in the genus *Citrus* which Swingle divided into only 16 species. Tyosaburo Tanaka from Japan, on the other hand, divided the same genus or group of plants *(Citrus)* into over 145 species! Tanaka's classification is too unwieldy to be functional. Swingle's is more usable than Tanaka's because it is simple, but it is obviously in error in some cases. Scientists and professional horticulturists generally use Swingle's system modified at times to include some of Tanaka's system when modifications appear appropriate. A brief summary of Swingle's system with occasional comparisons with Tanaka's system is presented below:

Genus - *Citrus*

1. Subgenus *Citrus,* includes those species with edible fruit and pulp not containing drops of acrid or bitter oil. This subgenus contains the following species:
   a. *C. medica* (citrons), a species valued primarily for the use of its peel. The 'Etrog' variety or cultivar is used in certain religious ceremonies by Hebrews and some selections of the 'Etrog', such as Arizona 861 and USDA 60-31, are commonly used as indicator plants to detect the exocortis virus.
   b. *C. limon* (lemons), a species used by Swingle to include all lemons, both acid and acidless. His classification is probably too inclusive and certain exceptions are commonly made, with *C. limon* primarily including the acid lemons of commerce. Tanaka's classification includes the following types commonly used as rootstocks:
      (1) *C. jambhiri* - rough lemon
      (2) *C. limonia* - Rangpur lime
      (3) *C. volkameriana* - Volkameriana lemon

      The 'Meyer' and 'Ponderosa' lemons are considered hybrids by Swingle but separate species by Tanaka.
   c. *C. aurantifolia* (acid limes), a species including all acid limes according to Swingle. Some commonly used exceptions by Tanaka are:
      (1) *C. aurantifolia* - the 'Key', 'West Indian', 'Mexican' or 'Gallego' lime. The 'Key' lime is used as an indicator plant for the tristeza virus.
      (2) *C. latifolia* - the 'Tahiti', 'Persian' or 'Bearss' lime.
      (3) *C. macrophylla* - the Alemow. Tanaka described this species as a lime-like fruit. Some feel it is lemon-like and others that it is a hybrid of *C. celebica.* This species has become an important lemon rootstock in recent years.
      (4) *C. limetta* - the limmetas, a group of lemon-like fruit with both acid and acidless forms.
      (5) *C. limmetoides* - the Indian or Palestine sweet lime that is widely used as a rootstock in some parts of the world. The Columbian sweet lime is indistinguishable from the standard Palestine sweet lime.
   d. *C. aurantium* (sour orange), a species used widely as a rootstock where the tristeza virus doesn't prevent its use. There are numerous forms of sour orange including a low acid type called bittersweet.
      (1) *C. taiwanica* - is a sour orange-like fruit with resistance to certain forms of tristeza.
      (2) Australian sour orange - is a hybrid of unknown origin that is reputedly tolerant of tristeza; however, this selection has few if any characteristics that resemble sour orange. Calling this fruit a sour orange is misleading.
   e. *C. reticulata* (mandarins), a species with loose-peeled fruit that includes the common tangerines and satsumas (Unshiu, Mikan) oranges. Tanaka divides this species into several as indicated in the table below.

Common Name	Swingle	Tanaka
	C. reticulata	*C. unshiu*
	C. reticulata	*C. tangerina*
	C. reticulata	*C. reticulata*
	C. reticulata	*C. reshni*
	C. reticulata	*C. clementina*

cont.

Common Name	Swingle	Tanaka
'Willowleaf'	*C. reticulata*	*C. deliciosa*
'King'	tangor?	*C. nobilis*
'Temple'	tangor?	*C. temple*
'Calamodin'	*C. reticulata* var. *austera* x *C. ichangensis*	*C. madurensis*
Yuzu	(tangerine x *C. ichangensis*	*C. junos*

(1) The Cleopatra mandarin is important as a rootstock throughout the world and the Yuzu is used to some extent as a rootstock in Japan.
(2) Most of the mandarins are used for their fine quality as fresh fruit.
(3) The tangerines have been hybridized with grapefruit to form tangelos such as 'Orlando', 'Minneola' and 'Nova'.
(4) The 'Clementine' and 'Temple' are used widely in breeding programs because they are monembryonic and of high quality.

f. *C. grandis* (pummelo or shaddock), is little used in the United States but important for its fruit in the Far East. The fruit and tree are similar to grapefruit in many respects but the flesh of pummelo is sweeter and less juicy than that of grapefruit and the peel of pummelo is generally thicker. The cultivars in this species are monoembryonic and therefore the pummelo is used in grapefruit breeding programs. The Cuban shaddock is sometimes mentioned as a rootstock.
g. *C. paradisi* (grapefruit), a species valued more for its fruit in the Western than the Eastern world, is used primarily as a fresh fruit. Grapefruit has been used occasionally as a rootstock in Florida but without any apparent advantages.
h. *C. sinensis* (sweet oranges), is the most widely grown species of *Citrus.* There are many horticultural or commercial types that can be placed into 3 groups: the common or round oranges, the navel oranges and the blood oranges. This species is most important for its fruit but sweet orange is also commonly used as a rootstock. Some sweet oranges have tolerance or resistance to the spreading decline nematode. The 'Ridge Pineapple' is the best known example.
i. *C. tachibana* and *C. indica* are 2 other species of little importance included in the subgenus *Citrus.*

2. Subgenus - *Papeda,* includes those species with numerous droplets of acrid oil that make them inedible. Also, the leaf petioles of species in this subgenus are long and broadly winged. The *Papeda* group is of little value except for its potential in a breeding program.
   a. *C. ichangensis,* a cold-hardy, monoembryonic species that hybridizes readily.
   b. *C. celebica,* is thought by Swingle to be one parent of the Yuzu, which is used as a rootstock in Japan.
   c. *C. latipes, C. micrantha, C. macroptera, C. annamensis* and *C. hystrix* are of little value.

Genus - *Poncirus*

The trifoliate orange is in a separate genus with only 1 species, *Poncirus trifoliata.* Unlike *Citrus, Poncirus* is deciduous, inedible and very cold-resistant. The trifoliate orange has many characteristics that make it useful as a rootstock, such as resistance to *Phytophthora* sp., tristeza, xyloporosis, cold and the citrus nematode. It is, however, sensitive to exocortis and grows poorly on coarse sands. Trifoliate orange has been hybridized with several species of *Citrus.* A few of the more important hybrids are:

P. trifoliata x *C. sinensis* (sweet orange) - citrange
P. trifoliata x *C. reticulata* (tangerines) - citrangedin
P. trifoliata x *C. paradisi* (grapefruit) - citrumelo
P. trifoliata x *C. aurantium* (sour orange) - citradia.

The most important hybrids are those with sweet orange, such as 'Rusk', 'Carrizo' and 'Troyer'. 'Carrizo' and 'Troyer' are rootstocks of major importance. None of the citranges are edible. At least one of the citrumelos now being tested shows promise as a rootstock.

Genus - *Fortunella*

The kumquats are often called citrus and they have been hybridized with both *Citrus* and *Poncirus* but neither the kumquats nor its hybrids are of major significance.

Nomenclature of Horticultural Varieties - The above discussion has dealt primarily with species and categories larger than species. Horticulturists are interested in plant material with minor botanical differences but differences that influence their commercial value. There are several terms of interest in this regard.

Variety - the horticultural unit, such as 'Valencia' sweet orange, 'Marsh' grapefruit or 'Dancy' tangerine. Such plant material differs very little within the species but the difference of the 'Marsh' grapefruit from the 'Duncan' grapefruit is very important commercially. The horticultural variety differs from the botanical *varieta*, a term sometimes used to indicate a unit below the level of species.

2. Cultivar - is a term synonymous with variety and is being used quite frequently in professional and scientific language. The term means a cultivated variety. The cultivar or varietal name is generally written with the first letter capitalized and the entire word in single quotes. Example, 'Hamlin' sweet orange. Cultivars may also be written *C. sinensis* cv. Hamlin. The single quotes are eliminated because the term Hamlin is preceded by the abbreviation for cultivar, cv.

3. Group names - such as satsuma and navel are often erroneously used. They should be written just as any common name without capitalization or quotes. The satsumas and navels each include several cultivars or varieties. Some feel the 'Valencia', commonly considered a cultivar, should be given group status because there are several selections of 'Valencia' that differ sufficient to be given cultivar status. Terms such as sour orange, rough lemon and so forth are common names that require no special designation.

Rootstock and Related Nomenclature

1. Rootstock - is the rootsystem portion of a tree propagated by budding or grafting. The rootstock may furnish part of the trunk when budded high, a practice followed in many areas, but not in Florida, to reduce the damage often occuring to the basal part of the tree trunk by *Phytophthora* sp.

2. Scion variety - is plant material used as the source of budwood for producing the aerial, crop-producing portion of the tree.

3. Interstock or Splice - is a portion of a budded tree between the rootstock and the fruit producing top. This is uncommon in citrus but common in apples where the interstock material and the length of the interstock are used to dwarf or control the tree size.

4. Budding - is the process of placing a single bud with a small piece of bark or bark and wood into a specially prepared wound or the rootstock (*the matrix*) which then unites. The bud is *forced* or caused to grow by removing the rootstock portion above the bud.

5. Budeye - is a term used to indicate a bud and the area immediately surrounding it.

6. Grafting - is the process of propagating by inserting a short piece of stem with 2 or more buds into the wound or matrix on the rootstock.

7. Graftage - is a term sometimes used to include budding and grafting.

8. Topworking - is a term restricted to replacing the canopy of a relatively large tree through budding or grafting as opposed to budding or grafting seedling rootstocks in the nursery.

9. Suckers - are shoots arising from the roots and are used to identify the rootstock where it is unknown. Citrus roots sucker readily when the soil is removed and the roots exposed to light (see watersprouts).

10. Watersprout - is a term used to indicate a shoot arising from dormant or adventive buds of the trunk or framework branches. The terms watersprouts and suckers are often used synonymously, resulting in some confusion. Both watersprouts and suckers are often excessively vigorous and the leaf and petiole may not be precisely typical of the normal shoots.

11. Fluting - is a term applied to ridges and valleys in the trunk at the base of the tree. The ridges are extensions of the major roots. Trifoliate orange and its hybrids are often fluted when used as rootstocks.

12. Crown - this term is used to indicate both the base of the tree and the upper portion or crown of the leafy canopy.

13. Foot - indicates the base of the tree, as in foot rot.

14. Scion Rooting - refers to root formation of the scion top and therefore rooting above the bud union.

15. Bud Union - is the plane of union of the scion top and the rootstock. The area of union is often very noticeable as a result of an overgrowth or undergrowth of the stock or scion variety. Some bud unions are very smooth but there is always some difference of growth disparity, bark texture or bark color.

16. Tap root - the primary, central root(s) that extend straight down into the soil. There are often several tap roots.

17. Feeder Roots - small, branched roots that apparently form the absorbing surface of the root system.

18. Root Hairs - unicellular extensions near root tips that form an important part of the absorbing surface of the root system.

Nucellar Seedlings

Most plants produce only seedlings that are the result of sexual union and have only one embryo per seed. Such seedlings resemble each of the parents to a certain degree but are unlike either one. They result from a sexual combination of genetic material.

This same sexual union and seedlings resulting from a combination of genetic material also occurs in citrus. In addition, however, most kinds of citrus produce additional embryos from a tissue called the nucellus, a tissue which surrounds the embryo sac containing the sexual or gametic embryo. The nucellar embryos arise solely from maternal tissue and the seedlings that arise from them are essentially the same as the mother plant. Such seedlings are called nucellar seedlings. The nucellar embryos generally develop faster than the sexual embryos and often crowd them out. Thus, most of the seedlings of a 'Valencia' sweet orange or a 'Marsh' grapefruit are genetically the same as the parent tree. Such varieties are also called polyembryonic varieties because they contain more than one embryo per seed. A few varieties, such as 'Temple', 'Clementine' and the pummelo are monoembryonic and produce only sexual seedlings.

The nucellar seedlings are used advantageously in 2 ways.

1. Very uniform rootstocks are obtained by roguing out or discarding the very small and unusually large seedlings of a given rootstock variety, such as rough lemon, in the nursery row. The remaining seedlings will be essentially the same genetically, with all the good and poor characteristics of the species. This is not possible with most fruit species, such as apples, pears, grapes and pecans, and one must resort to vegetative propagation, such as stem cuttings to get genetically uniform rootstocks. Vegetative propagation is also called asexual propagation.

2. Viruses, with rare exceptions, are not transmitted through seeds. Thus, a cultivar, such as 'Valencia' sweet orange, grown as a nucellar seedling will be true-to-type (a true 'Valencia') and free of viruses. This budwood is usable on rootstocks that are sensitive to budwood-transmitted viruses, such as exocortis and xyloporosis that may be contained in the parent 'Valencia' tree.

Unfortunately some nucellar seedlings vary slightly from the parent so they must be tested for a number of years to be certain they are at least the equal of the mother parent. Trees that have been propagated by budding for many generations are called old-line trees. Trees propagated from material that has recently been developed from nucellar seedling sources are called nucellar trees or nucellar varieties. These terms are vague and there is not a set period after which a nucellar variety becomes an old-line variety.

Juvenility

Citrus seedlings exhibit a pronounced juvenility; ie, seedlings pass through a juvenile stage characterized by upright growth, extreme thorniness, and absence of flowering. The seedlings gradually grow out of this juvenility, with the newer wood becoming less thorny and more productive of flowers. The basal portions of seedlings remain juvenile throughout the life of the tree. Flowering occurs only on the later growth flushes. Thus, budwood from nucellar seedlings should be obtained only from the older flowering and fruiting portions of the trees. This juvenility greatly lengthens the time to produce nucellar varieties of sweet oranges and grapefruit and new hybrids.

The length of the juvenile period varies with the species approximately as follows:

Sweet Orange	- 6 - 15 years
Grapefruit	- 6 - 15 years
Mandarins	- 5 years
Lemons	- 2 - 3 years
Limes (Key)	- 1 - 2 years
Trifoliate Orange	- 3 - 4 years

Growth conditions that slow growth, prolong the juvenile period. Conditions promoting growth reduces the juvenile period.

Nematodes

Nematodes are small worm or worm-like animals that are commonly found in the soil. They differ from insects and mites in many important ways.

The 2 most damaging nematodes of citrus are:

1. *Tylenchulus semipenetrans* (citrus nematode) - is of worldwide importance. The citrus nematode is immobile and it is transported primarily through infested nursery stock. The trifoliate orange and some of its hybrids offer protection against this pest but all other *Citrus* is susceptible to it.

2. *Radopholus similis* (burrowing nematode) - is a tropical region nematode that has been very damaging in Florida, causing the spreading decline disease. The life cycle of this nematode and the coarse sands of Florida have made its elimination possible in certain sites. 'Milam' lemon, 'Estes' rough lemon and 'Ridge Pineapple' afford some protection from this nematode.

There are several significant terms related to nematodes:

(1) Immune - is that form of resistance where the nematode neither penetrates nor feeds upon the root tissues of the plant.

(2) Resistance - indicates a situation in which plant growth is not retarded, even though invaded by the nematode, and the nematode population gradually diminishes to a low level or completely disappears.

(3) Tolerance - denotes a situation in which the nematode population is retained at a high level but, even so, the growth is retarded no more than 20 percent.

The terms immune, resistant and tolerant cannot be transferred to virus and other diseases. They are arbitrary terms used to describe the reactions of plants to nematodes.

(4) Biotype - denotes a slight biological variant such as often occurs in living matter. For example, some citrus nematodes have evolved, either through mutations or the sexual process, that damage trifoliate orange but which cannot be distinguished in any other way from other citrus nematodes that do not damage this species. By the same token, slight changes in the rootstock can take place that enable them to tolerate a pest other rootstocks of the species won't tolerate. The 'Estes' rough lemon, for example, is tolerant of the burrowing nematode but indistinguishable in any other manner from the common Florida rough lemon. Biotypes can occur in all living material, not just rootstocks and nematodes.

(5) Chemical Barrier - denotes a relatively plant-free zone surrounding a spreading decline area that is periodically fumigated to prevent spread of both roots and nematodes into adjacent nematode-free areas.

(6) Biological Barrier - is applied to a zone of immune or highly resistant plants surrounding a nematode infested area. Nematode spread is prevented by the inability of the nematode to live and produce in the plants separating the infested zone from a nematode-free zone. Citrus on 'Milam' rootstocks have been used experimentally as barrier plants.

Virus and Virus-Like Diseases

Virus Diseases

Virus diseases are less completely understood than fungus and bacterial diseases. The latter 2 types of organisms have been known for many years and can be identified on the basis of their sexual forms and the morphological features of their vegetative structures as seen under the standard light microscope. Viruses, on the other hand, have been recognized only recently. They are without sex and their particle size is so small the electron microscope is generally necessary for their study. Viruses reproduce in host cells by altering the nucleic acid metabolism of the infected cell. Viruses, unlike fungi and bacteria, generally cannot be grown on artificial media.

There is no completely satisfactory definition of a virus. Viruses generally consist of ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) surrounded by a thin protein coat. This definition fits the citrus tristeza virus but not the exocortis virus, which lacks the thin protein coat. Citrus virologists have not yet resolved problems of classification and nomenclature. Such names as tristeza, exocortis, xyloporosis and psorosis identify disease symptoms, each of which could be caused by one or more closely related viruses.

Transmission of some viruses may be achieved by mechanical means (knives, pruning shears, etc.), buds and grafts, insects, nematodes, fungi, bacteria, parasitic plants and through seeds. In citrus, however, transmission through seeds is rare and mechanical transmission is limited to exocortis and certain minor viruses. Tristeza is the only major insect-transmitted virus. All major citrus viruses can be transmitted through the use of infected budwood. Psorosis and xyloporosis are transmitted only through infected budwood and exocortis is transmitted largely in this manner.

Some viruses cause damage regardless of the rootstock-scion variety combination while others are rootstock-scion, rootstock or scion-dependent.

Some useful terms or definitions related to viruses are:

1. Registered Budwood - is budwood registered free of one or more viruses.

2. Indexing - is determining the presence or absence of a virus in a plant that may carry, but not express or only slowly express a symptom response to the virus, by infecting an *index plant* (one which expresses the symptom relatively rapidly following infection). For example, exocortis is carried in sweet orange on rough lemon without symptom expression. Certain selections of citrus budded with exocortis infected material soon express the presence of the virus with distorted or epinastic vegetative growth. The plant grows normally when the virus is not present.

Virus-Like Diseases

Stubborn or acorn disease and the greening disease of citrus were once thought to be virus diseases because of their mode of transmission and because no fungal, bacterial or physiological disorder could be found. These diseases are now diagnosed as mycoplasma or mycoplasma-like in nature.

Mycoplasma are extremely small organisms without cell walls that cannot be grown on artificial media. Plants injected with tetracyclene recuperate at least partially. Plants with stubborn and greening respond to tetracyclene and have been found to contain mycoplasma. Both diseases are insect transmitted.

Mycorrhiza

Mycorrhiza are fungi living on and in the roots of plants in a symbiotic (mutually beneficial) relationship. The mycorrhizal fungi need the carbohydrates produced by the leaves of the plant while they (the fungi) take up nutrients from the soil and transfer them into the plants. In effect the mycorrhizal fungi serve as roots that are in some ways more effective than citrus roots in taking up mineral elements, such as phosphorous.

The role of the mycorrhizal relationship has long been established for certain forest trees but it has only recently received attention in citrus as a result of methyl bromide fumigation of citrus nursery sites. Methyl bromide kills the mycorrhizal fungi as well as the harmful organisms. Research has indicated the presence of mycorrhizal fungi on all rootstocks examined to date.