World Citrus Rootstock Situation

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Introduction

A number of different citrus rootstocks are used in the various citrus-producing areas of the world. The performance of each has been selected as best adapted to the area in which it is used. This variation in usage is understandable in view of the differences in soil types, environment, water relationships, nutrition, the miscellaneous disease complexes involved and other factors. Rootstocks once established are not very susceptible to change; however, occasionally something happens which requires a change. Rootstocks do change. Sometimes the change is slow and gradual, and at other times it is sudden and almost catastrophic. The slow, evolutionary changes we are not worried about as the industry has time to adjust to them with little consequence. The sudden or catastrophic changes occur right now, and unless the industry is prepared, have dire consequences.

Many of the rootstock problems faced by citrus growers the world over are the same regardless of the country or area in which they live. However, in a few cases, what has been a catastrophe in one area seems to be of little economic importance in another. For example, tristeza almost overnight wiped out citrus planted on sour orange rootstock in Africa, South America and California; yet it seems to be of little importance in some of the Mediterranean countries. However, it is probable that this disease, and many others, will become more widespread and disastrous in areas where they are now minor in nature.

The ravages of tristeza in Spain at the present time are a good example. It has also been true in the past and will undoubtedly be true in the future that organisms causing disease can mutate to more virulent forms, or new diseases appear which necessitate finding or developing new rootstocks which will be better suited to meet new threats, whatever they may be.

A review of the various citrus areas and their current rootstock situation is thus very much in order.

Spain

Spain is the world's largest exporter of fresh citrus fruit and is exceeded only by Japan and the United States in citrus production. Because of the prevalence of *Phytophthora*, nearly all Spanish citrus has been planted on sour orange stock. However, tristeza is rapidly spreading in Spain, and present estimates are that as many as a million to a million and a half trees may now be infected particularly in the area around Alcira and the Rio Jucar river. Much of the mandarin acreage in recent years has been planted on 'Cleopatra', and experimental plantings are being made on 'Troyer' and 'Carizzo' citrange, sweet orange and trifoliate. However, most of the soils along the Mediterranean coast of Spain are too calcareous for the successful growing of trifoliate. However, it may prove useful in the interior of the Guadalquivir Valley between Sevilla and Cordoba where new plantings are being established.

Almost all scion wood in Spain is infected with exocortis, and a budwood virus indexing program is being established. Success of this program will be necessary before some of the newer rootstocks can be used. Psorosis and xyloporosis are also widespread. However, the most prevalent disease is *Phytophthora*, and in some areas earth ridges are thrown up in a circle around the trunk to keep irrigation water away from the foot of the tree.

Recently, because of the threat of tristeza, the Ministry of Agriculture has licensed nurseries and prohibited the selling of trees budded on sour orange. However, this does not prevent the private grower from raising his own sour rootstock. Many of the growers still prefer sour and do not believe that tristeza is a problem.

Italy

Italy is the world's fifth largest producer of citrus, the second largest grower of lemons and the major supplier of citrus in the European Common Market. Citrus areas are located in southern Italy and Sicily.

All varieties of citrus in Italy are grown on sour orange. Because of the fear of what tristeza could do to the orange and mandarin industry, research workers have been stimulated to search for and test new rootstocks.

Tristeza has not become an economic threat in Italy, but it has been found in backyard plantings of 'Meyer' lemon and Satsuma. Eradication of these trees has hopefully removed or delayed the threat. An indexing program for exocortis and psorosis is now underway, and a virus-screening program has been established.

Research is taking place at Acireale to develop nucellar lines of local orange varieties. When sufficient virus-free budwood becomes available, 'Troyer' citrange may become a recommended rootstock for oranges. Other trials are being carried on to develop lemon varieties and rootstocks more resistant to mal secco. 'Monachello' has been recommended because of its resistance to this disease, but bud union overgrowth limits tree life when used on sour rootstock.

Tests with *Citrus volkameriana* have shown advantages in vigor and resistance to mal secco over sour, and it is being recommended as a rootstock for lemons.

The general practice in Italy is to bud at a height of about 1 meter, or 40 inches. This height is used because of an extreme fear of gummosis, which practically wiped out the citrus industry before the turn of the century, when most trees were propagated on their own roots from cuttings.

Corsica

Corsica, with very limited citrus acreage, has a fine rootstock program underway, perhaps the best in the Mediterranean area. It has fairly extensive rootstock trials with most of the world's existing or potential rootstocks and has complimented it with the introduction of numerous nucellar lines. Their problem is to find a replacement stock for sour orange, one with both tristeza and *Phytophthora* tolerance. Cold resistance is a rootstock asset which cannot be overlooked for Corsica.

Israel

Israel, with slightly over 100,000 acres, is the fourth largest citrus-producing country in the Mediterranean area. 'Palestine' sweet lime and sour orange are the principal rootstocks. Soil types range from sandy loams along the coast and in the northern Negev to heavy clay in the Jezreel Valley. In some areas, light, alluvial soil overlays heavier soil.

It is common practice in light soils to bud on sweet lime for early production and to inarch with sour, usually before the trees are 10 years of age. This is done because trees left on sweet lime invariably decline from xyloporosis. In heavy soils, trees may be planted on sour from the beginning.

Tristeza now occurs in Israeli citrus orchards. So far the plan has been to eradicate affected trees as they appear and some indexing is being done for symptomless carriers. This plan would delay the onslaught of tristeza but is not practical for controlling it. They will have to switch to tolerant rootstocks. Some work has been done on nucellar lines but they are not in general use as they have not been as fruitful and are more prone to alternate bearing.

An extensive research program is being carried on in Israel in all phases of citrus culture, rootstocks included. It is felt that more information is needed on the nutritional requirements of different rootstock-scion combinations, and research on this is being expanded. Other research is directed toward predicting the compatibility and performance of rootstock-scion combinations from juvenile characteristics or chemical analysis of tissue. If this should prove successful, it would help eliminate the long wait now necessary to evaluate mature trees. A close watch is being kept on disease problems which could become a threat to the industry.

Greece

In 1963, Greece had approximately 85,000 acres of citrus, of which about 48,000 were oranges, 19,000 were lemons and 18,000 were mandarins. A great deal of Greece's citrus production is used for home consumption, and that which is exported goes to eastern European markets and does not compete with the western European economic community. The major orange

variety planted in Greece since 1955 has been the 'Washington' navel. Many of the older, common orange plantings have been topworked to navel varieties.

The predominant rootstock in Greece for all citrus is sour orange. Attempts have been made in the case of lemons to use an interstock of sweet orange in the hope that this will give resistance to mal secco. Such attempts have been unsuccessful. As in the rest of the Mediterranean area, psorosis and exocortis are also present. Since all plantings are on sour, tristeza could rapidly become a major problem. No major rootstock trials are underway. Frost can be a problem and water is somewhat limited and of poor quality.

Lebanon

Lebanon has between 25 and 30 thousand acres of citrus. Areas suitable for citrus are limited, and little expansion is expected. As in Israel, the principal rootstocks are sweet lime and sour orange. Important diseases are *Phytophthora*, xyloporosis and psorosis. No rootstock trials are underway.

Algeria

Citrus plantings in Algeria increased rapidly after World War II and reached 84,000 acres by 1960. However, during the civil strife of the 1960's, few plantings were made and some groves were abandoned so that citrus acreage declined. During the past few years, however, citrus acreage has again increased. Algerian soils are mostly heavy loams, although there is a small coastal lemon area north of Algiers which has light, sandy loam soil. In some areas, the water table is only a few feet from the surface, and drainage ditches and tiling are used. Many commercial varieties have been introduced into Algeria. These include the 'Hamlin', 'Washington' navel, 'Cadenera', 'Thompson' navel, 'Shamouti' and many Portuguese and Spanish varieties. 'Marsh' grapefruit has been introduced as have the 'Eureka' and 'Berna' lemons. There are smaller plantings of 'Lisbon', 'Meyer' and Italian varieties of lemons.

Sour orange is the predominant rootstock. However, 'Clementine', which is the second largest citrus crop in Algeria, is often planted on trifoliate orange in heavier soils where high water tables exist. *Phytophthora* and foot rot are present in most Algerian groves, and trees are budded about 2 feet above ground level. No rootstock trials are evident.

Morocco

In Morocco, citrus acreage has grown at an increasing rate during the past few years, with production mainly concentrated on oranges. Varieties are similar to those in Algeria. The most important mandarin is the 'Clementine'. Grapefruit plantings are primarily 'Marsh', and lemons are the 'Eureka' type. Most Moroccan citrus soils are light, well-drained loams. Salinity is a problem in some areas. Diseases are psorosis, *Phytophthora*, Rio Grande gummosis, stubborn disease, xyloporosis and exocortis. Tristeza has been identified but has not reached economic significance. Present citrus acreage is estimated to be 180,000 acres.

In 1969, a Moroccan Agricultural Service Society, which is an advisory bureau containing research and extension personnel, was established. Purpose of the society is to carry out research work which will benefit Moroccan citrus culture. The principal rootstock is sour orange; however, new rootstocks are being introduced and tried.

Egypt

Egyptian citrus acreage is now estimated to be between 85 and 90 thousand acres. The principal orange varieties grown are local selections called 'Beladi'.

Egyptian citrus soils are fertile and consist of deep, alluvial silt and clay loams. Groves are irrigated by permanent basins or sprinkler systems. The principal rootstock used is sour orange, although sweet lime is used in lighter soils. Diseases include *Phytophthora*, foot rot, psorosis and xyloporosis. It might be expected that tristeza also exists, since it is present in other areas

in the Mediterranean basin. However, tristeza has not become an economic problem. There are no major rootstock trials underway.

Cyprus

Major varieties in Cyprus are the 'Shamouti' and 'Valencia' orange, 'Marsh' grapefruit and the local sour lemon which resembles the Lisbon. The 'Clementine' mandarin, 'Temple' orange and some varieties of satsuma have also been introduced. Soils are generally light in texture in citrus areas, and the major rootstocks are the sour orange and sweet lime. There is a major problem with *Phytophthora.* Water is scarce and of rather poor quality. A few new rootstock types have recently been introduced.

Tunisia

While citrus has been grown in Tunisia for a long time, it has only been within the past few years that a sizeable commercial industry has become established. Even this is small by present day standards.

When budded, trees are usually on sour orange; however, most of the native groves are seedling trees which are densely planted, 200 to 400 trees per acre, small in size and heavily pruned.

The climate in Tunisia is arid with low humidity and great extremes in temperature. Irrigation water is limited and salinity is a problem. Periods of drought often occur. Tunisian soils are light textured and cover crops are grown in some areas to prevent wind erosion. It is reported that few virus diseases occur in seedling groves. However, both *Phytophthora* and *Armillaria* are present and psorosis is present in vegetatively propagated orchards. No real rootstock trials exist.

Turkey

In Turkey, the citrus industry is being modernized, and today there are over 100,000 acres of citrus in this country. Oranges are the most important, followed by mandarins, lemons, and grapefruit. Nearly all budded citrus in Turkey is grown on sour orange rootstock, with the exception of satsuma mandarin which is grown on trifoliate. Major diseases are *Phytophthora* on all citrus and mal secco on lemons. Psorosis, stubborn, xyloporosis, and exocortis are present. Tristeza-like symptoms have been observed, indicating the virus may be present and a threat to Turkish orange plantings. No rootstock plantings are in evidence.

Middle East

In Iran, oranges are grown on their own roots or are budded on sour orange, rough lemon, or sweet lime. Sour limes and lemons are grown entirely from seedlings. A similar situation exists in Iraq, and nematodes have been mentioned as a serious problem. The Ministry of Agriculture has imported large quantities of 'Troyer' citrange seed for trial. No nucellar budlines are available.

India

India, which is second only to China in being the oldest citrus-growing area in the world, has provided the industry with several important commercial rootstocks. Among these are rough lemon, sour orange, 'Rangpur' lime (which is really an acid mandarin) and mitha the sweet lemon. Gajanimma, also called *Citrus moi* and *Citrus pennivesiculata,* 'Kharna Khatta' *(Citrus kharna)* and nasnaran, *Citrus amblycarpa* are also rootstocks of lesser importance.

There are about 250,000 acres of citrus under cultivation in India, most of which is in small plantings and much of which is double-cropped or more.

Citrus diseases affecting rootstocks in India include *Phytophthora,* tristeza, psorosis, xyloporosis and citrus canker. A serious threat is citrus dieback which is a complex problem maybe due to a mycoplasm such as greening but which is terribly complicated by nematodes, fungi and nutritional problems.

Rough lemon or *Citrus jambhiri* is the most widely used rootstock for oranges and mandarins in India. 'Rangpur' lime is also used as a rootstock, especially in Bombay State where it is used with the 'Mosambi' orange. *C. Kharna* is also used extensively except under blood oranges with which it is incompatible. 'Malta red' is also incompatible on rough lemon stock. A vigorous rootstock of some local importance is 'Gajanimma' or *C. pennivesiculata.* It has also attracted some attention in California, but is very susceptible to tristeza, stem-pitting severely. It is also extremely susceptible to cold. The 'Kharna Khatta' is very susceptible to gummosis. The rough lemon is susceptible to gummosis to about the same degree or perhaps a little less than sweet orange or grapefruit. Rough lemon is also susceptible to *Armillaria* or oak root fungus. It is tolerant to tristeza, cachexia and exocortis. It is susceptible to nematodes. Rough lemon will grow fairly well on all soils but is particularly adapted for use in light sandy and sandy loam soils. It is average as to salt tolerance but will not do well in poorly drained soil as it will not stand "waterlogging" for any length of time. It is more drought resistant than either sour or sweet orange. As a replant in former citrus soils its growth has been average to good. Fruit quality is poor.

Many rootstock trials have been conducted in India. Their results are somewhat inconclusive and rough lemon remains the rootstock of note. There are many forms of the rough lemon and variable performance in part can be attributed to the genetic differences between these cultivars. Of all the varieties coming out of India the nasnaran or *C. amblycarpa* has shown the most interest and best performance in California. More will be said about the 'Rangpur' lime later.

Pakistan

About 92 per cent of the 40,000 acres of citrus grown in Pakistan is in west Pakistan. Rootstocks, varieties and disease problems are similar to those in India. Fairly extensive rootstock trials have been conducted in Pakistan but in general they were of the same nature as those conducted in India and the conclusions are similar.

China

Certainly major citrus diseases such as *Phytophthora,* tristeza, psorosis, exocortis and xyloporosis are present in China. In the past, *Citrus sunki* has been the principal rootstock in China. *C. sunki* is mentioned in the literature as being a dwarfing stock. However, in trials in California where *C. sunki* has been grown on rich, loam soils, it has not proved to be dwarfing. It is, therefore, probable that the cultural conditions under which citrus is grown in China are responsible for the dwarfing effect of sunki. In southeastern Asia, sunki is close-planted on ridges only a few feet above the water table. Principal varieties grown on *C. sunki* are the 'Swatow' orange, also known as the 'Ponkan', and another mandarin orange, the 'Tankan'.

Citrus sunki is a sour mandarin in Swingle's classification.

In China, sunki is reported to be slow growing and similar to ponki, which is similar to the 'Cleopatra' mandarin.

Sunki is tolerant to tristeza and, if like 'Cleopatra', tolerant of exocortis and susceptible to xyloporosis and *Phytophthora.* Sunki is short-lived, about 10-12 years, in the Orient, and fruit size and quality are average from trees grown on it.

The Satsuma mandarin is also grown, usually on trifoliate rootstock *(Poncirus trifoliata).*

While a large part of the southern plantings in mainland China are near the sea in heavy soils, inland citrus-growing areas, which are usually in river valleys, have sandy, alluvial and loam soils.

In addition to native citrus, a number of western varieties such as 'Washington' navel, 'Valencia' and 'Shamouti' orange have been introduced, as well as 'Marsh' grapefruit, 'Eureka' and 'Lisbon' lemon.

Although budding and grafting are common, propagation by marcotting and cuttings is also used. No rootstock trials are known.

Thailand

In southeastern Asia marcottage (aerial layering) is the common method of propagation. This is true in Thailand where 95 per cent of the citrus, whether pummelos or mandarins, is grown this way. One of the reasons marcotting is so popular is that it avoids any unfavorable reaction often experienced when the scion wood is virus-infected and susceptible rootstocks are used.

However, in recent years Thailand, more than any other country in southeast Asia, has been experimenting with modern methods of production which includes rootstock trials as well as fertilization trials and the introduction of modern pesticides.

A considerable number of pummelos are grown in Thailand, principally on their own roots. Pummelos have a high resistance to *Phytophthora* and are grown on soil beds a few feet above the water table under conditions where brackish water is a problem. It is questionable whether few other stocks would tolerate this type of environment as long as the pummelo does.

In northern Thailand there tends to be drought at certain seasons. All of Thailand is characterized by rather heavy cover crops.

Pummelo has never been successful as a rootstock in trials in California because of its susceptibility to tristeza. Yields also tended to be light in relation to tree size.

Rootstocks in Japan

Japan is the world's largest producer of mandarin-type citrus. Satsuma is widely grown, and the 2 major varieties are the 'Wase', an early type, and the 'Owari', a late type. A summer orange, called 'Natsudaidai', is also grown. Ninety per cent of the satsumas are on *P. trifoliata.* The remainder are on 'Yuzu'. In many cases, 'Yuzu' is used as an inarching stock for satsuma on trifoliate after the trees are about 10 years of age and begin to decline.

While tristeza, psorosis, exocortis and other diseases are recognized, they do not seem to be a serious problem. A virus-indexing program for scion budwood sources is administered on a national basis in Japan.

Trifoliate orange, the number 1 rootstock in Japan, is also the world's third most widely used rootstock. Trifoliate is an excellent stock for mandarins, particularly on heavier soils. It is resistant to *Phytophthora* and *Armillaria* and tolerant of tristeza and cachexia (xyloporosis). Trifoliate is, however, susceptible to exocortis. It is tolerant of nematodes and does well in heavy, poorly drained soils. It is very resistant to cold and makes good growth as a replant in old citrus soils but has a low tolerance to salt and calcareous soils. Fruit quality of oranges and mandarins grown on trifoliate is excellent. Trifoliate is not compatible with lemons and is a poor stock for grapefruit.

'Yuzu' is used extensively in Japan as a rootstock for oranges and as a secondary stock for satsuma. 'Yuzu' has been used in Japan for centuries and was their principal stock prior to the acceptance of trifoliate. Trees on trifoliate are more precocious in bearing and initially grow more rapidly than trees on 'Yuzu'. However, in Japan trees on trifoliate stock sometimes begin to decline after 10 to 20 years, and it is the practice to inarch these trees with 'Yuzu' as soon as growth seems to be retarded. The declining trees recover and become long-lived and productive.

'Yuzu' does best on deep, rich soils, since it produces an extensive taproot. Gummosis resistance of 'Yuzu' is comparable to sour orange or better. It is not affected by citrus canker and shows considerable resistance to oak root fungus. It grows relatively well as a replant. In California, its replant growth is comparable to sour, but it does not show resistance to the citrus nematode as does trifoliate. Trees on 'Yuzu' are nearly as resistant to frost as trees on trifoliate orange. Since 'Yuzu' does well in Japan where tristeza is widespread, one may assume that it is tolerant of this disease.

Indications in California are that 'Yuzu' would probably be a good stock to try in calcareous soils, since it picks up more iron and less calcium. On the other hand, it picked up more boron and sodium than other rootstocks and should not be used under saline conditions.

In general, Japan seems to have very little in the way of rootstock problems. They have escaped the ravages of tristeza, primarily because of their widespread use of tolerant rootstocks. Poor results have been attained with 'Yamamikan', 'Girimikan' and 'Tachibana'.

Taiwan

Taiwan is another important citrus-producing country in Asia. Since citrus is a valuable export commodity, the industry has been expanding and will probably continue to do so since production efficiency is increasing.

'Ponkan' and 'Tankan' make up 83 per cent of the commercial citrus production. *C. sunki,* which we have already discussed, is the principal rootstock for these varieties. Satsuma mandarins are grown, with trifoliate orange being the favored stock. Some pummelos are grown, and these are propagated by marcotting and are planted on their own roots.

Phytophthora is 1 of the principal diseases, although all of the common virus diseases are present. Likubin, or yellow shoot is also prevalent. A nursery-tree certification program is operated by the Taiwan Department of Agriculture. Mother trees are selected for yield performance and are virus indexed as pedigreed sources of propagating material. Nurseries are registered and inspected. Little rootstock work is conducted.

Philippines

In general, citrus plantings in the Philippines are small, and many trees are grown on their own roots. However, there has been some interest in trying new rootstocks, and these are principally the rootstocks that have developed and tried elsewhere in the world. At the present time, many of the trees that are budded in the Philippines are on calamondin *(Citrus mitis).*

Major citrus diseases are *Phytophthora,* foot rot, psorosis, xyloporosis (cachexia), tristeza, citrus canker and leaf mottle yellows. *Phytophthora* has caused the loss of many trees during recent years and has spurred the use of rootstocks. Because of *Phytophthora,* the height of budding has been increased to 12 to 18 inches above ground level. Cover crops also increase the incidence of *Phytophthora.*

Australia

In 1966 it was reported that there were 76,000 acres of citrus in Australia, and that acreage was increasing at an annual rate of 4 per cent. Australian citrus consists of about 50 per cent 'Valencia' oranges, 30 per cent navels, 10 per cent lemons and limes and 10 per cent grapefruit, mandarins and other minor citrus.

The climate in which citrus is grown in Australia ranges from humid tropical to arid subtropical with the greater part of the acreage being in the latter zone. In general, soils in the citrus areas are calcareous, alkaline, high in natural salinity and range from sand to sandy loam in texture.

In the past, rough lemon has been the main rootstock because of its vigor and drought resistance. However, other rootstocks are now under trial and are being used in commercial practice. These include sweet orange, 'Carizzo' citrange and trifoliate. Rootstocks under trial in experimental plantings include 'Cleopatra' and 'Emperor' mandarins, 'Sampson' and 'Orlando' tangelos and 'Troyer' citrange.

Phytophthora root rot is present and its spread is mainly blamed on faulty irrigation practices. Virus diseases such as exocortis and psorosis occur but are avoided by a scion selection program. Tristeza virus is also present in Australia, but lack of susceptible rootstocks makes it of little economic importance.

New Zealand

Total citrus acreage in New Zealand is relatively small, being about 2,000 acres. However, citrus plantings have increased by over 50 per cent during the past 5 years, primarily because of the introduction and use of trifoliate as a rootstock.

Because of unfavorable climatic conditions and the use of rough lemon as rootstocks, soluble solids in oranges tended to be low and acid high, giving a poor quality fruit. However, the use of trifoliate as a rootstock caused a marked improvement in the soluble solids content and improved fruit quality. As a result, this fruit has found a market and there has been an upsurge of orange plantings.

Southern and Central Africa

In the Republic of South Africa, almost all budded citrus trees are on rough lemon because of the devastating influence of tristeza. Recently a number of test plantings have been made with new rootstocks which include sweet orange, 'Empress' mandarin, 'Troyer' citrange, and trifoliate orange. There is recent interest in a hybrid of 'Troyer' citrange and 'Cleopatra' mandarin #639. In addition to tristeza, exocortis and xyloporosis are widely distributed in most old-line citrus varieties. So far, they have been of minor economic importance because of the tolerance of most scion-rootstock combinations.

Psorosis has been almost completely eliminated in South Africa because of an efficient eradication program carried out by the South African Department of Agriculture. This program was started in 1927, and at the present time hardly any psorosis-infected citrus trees are to be found.

In southern Rhodesia, rough lemon is again the primary rootstock, although experimental plantings have been made with trifoliate orange and 'Troyer' citrange. Trifoliate orange may prove to be of value, particularly in view of the heavier soils and extensive rainfall which occur in many citrus-growing areas.

Citrus is grown for local consumption in many of the newly created African countries. In almost all cases, the principal rootstock is rough lemon. Ghana supported a lime industry, the trees of which were almost entirely on their own roots. In 1941, tristeza virus decimated the industry, and these trees have gradually been replaced with healthy scion material on rough lemon rootstock. This was also true of the Gold Coast (Ghana). *Phytophthora* and tristeza have been the 2 limiting diseases in most instances in lime culture.

South America

The wide-scale commercial development of citrus which began at the turn of the century in South America was based on citrus budded on selected rootstocks. Since then, the citrus industry of South America has experienced several setbacks, most of which have been related to rootstock problems.

In 1900, almost all plantings made in South America were on sweet orange rootstock. However, losses from *Phytophthora* were immense, and by 1915 sour orange was recommended and being planted as the best rootstock for citrus. For the next quarter of a century, sour was almost universally used. The onslaught of tristeza in the mid-1930's caused the loss of more than 20 million trees in Argentina, Brazil, Paraguay, and Uruguay. While badly hurt, the citrus industry was not wiped out. New plantings were established on rootstocks tolerant to the tristeza virus. In Brazil, the 'Rangpur' lime has become the major stock. Sweet lime and trifoliate orange are also used, particularly in Argentina and Uruguay, respectively.

In Peru, sour rough lemon and 'Cleopatra' mandarin are being used in the drier coastal areas where sandy soils prevail, and 'Rangpur' lime and 'Troyer' are used in the more humid tropic regions.

Major rootstock research studies were started in the late 1920's when trials were installed simultaneously in Brazil, Argentina, and Surinam. Since then over 100 rootstock trials have been established in these and other South American countries, principally Brazil.

In using tristeza-resistant rootstocks, it has become very important that virus-free budwood be used, and constant indexing programs are necessary. For example, tristeza-tolerant, 'Rangpur' and other mandarin limes are intolerant of exocortis and xyloporosis (cachexia). Trifoliate and most of its hybrids are susceptible to exocortis. Most tangerines and tangelos are susceptible to xyloporosis. Thus, there has been an increasing trend toward the use of nucellar lines of budwood.

Original trials in the search for tristeza-resistant rootstocks were mainly interested in disease resistance with little regard to fruit quality. Now that tolerant stocks have been found, attention has been turned to resistant stocks with improved fruit quality.

In South America, a greater diversity of tristeza-resistant rootstocks are in use than in perhaps any other part of the world. This is primarily because such rootstocks are chosen for their best performance under a variety of climatic and ecological conditions.

'Rangpur' lime, which we have said before is really an acid mandarin, is used extensively in South America and very little elsewhere in the world.

In trials in California, with 'Valencia' scion, it was the most prolific bearer of 25 rootstocks in the test. However, fruit quality was low, being only slightly better than fruit grown on rough lemon. Fruit size was good. 'Rangpur' is susceptible to exocortis and xyloporosis, a little less susceptible to *Phytophthora* than sweet orange, and resistant to tristeza. Its salt tolerance is moderate, and it is similar to sweet in cold hardiness. It has had no observed compatibility problems with oranges and mandarins but should not be used with lemons. All in all, it has been a good backup stock for use in South America where tristeza has become endemic.

British Honduras - Jamaica - Trinidad

In British Honduras, Jamaica, and Trinidad, as in many tropical areas of high rainfall, foot rot caused by one or more species of *Phytophthora* is the major disease problem connected with rootstocks. Sour orange is the principal rootstock, although some sweet orange is used. In some of the heavier Jamaican soils, a local shaddock known as "Hog Shaddock" serves as a rootstock.

Mexico

Sour orange is the major stock used in Mexico. However, sweet is also used and in some areas numerous seedling trees are grown on their own roots. Seedling orchards are numerous in the state of Veracruz where citrus is interplanted with coffee. Production from such orchards is low, ranging from 60 to 125 boxes per acre.

Some of the best cultural practices are said to occur in the state of Nuevo Leon. New plantings there are mainly 'Valencia' orange budded on sour. Again, foot rot and other diseases caused by *Phytophthora* are serious, particularly in the areas of high rainfall and humidity. The 'Cleopatra' mandarin and the 'Troyer' citrange were recently introduced and as yet there is no report on their performance.

United States

In the United States, the main citrus producing states are Florida, California, Arizona, and Texas.

Many of the early orange groves in California were seedling trees on their own roots, and a few of these orchards remained until World War II. However, many of the early California orchards were planted on sweet orange. When *Phytophthora* became a problem, sour orange became a dominant stock and remained so until the advent of tristeza.

Most of the diseases which attack rootstocks of citrus are present in California. For example, during the wet years of 1938, 1941, and 1943, Klotz estimated that almost a million trees in California were infected with brown rot gummosis or foot rot. Other types of gummosis are also present.

Psorosis and exocortis also infect California orchards, but xyloporosis is not a problem.

Sweet orange grows well on fairly heavy soils, but is best adapted for growth on rich, sandy loams. It does not do well on extremely sandy soils or extremely heavy or calcareous soils. On heavy, poorly drained soils it may show iron chlorosis symptoms, as it also does on calcareous soils. It does not develop a well-differentiated taproot as does sour, and is moderately shallow-rooted. It does develop an abundant system of lateral roots which generally are deeper than those of rough lemon.

Scions budded on sweet orange produce large, vigorous trees with all commercial varieties. The trees are larger than when similar scions are budded on sour orange. Yields on sweet orange are good -- the highest with all scion varieties except when navel oranges are budded on sour or 'Morton' citrange which outyields sweet. Trees budded on sweet orange are not as precocious in bearing as trees on trifoliate orange or *Citrus macrophylla,* but trees on sweet are long-lived and bear well into advanced age of 50 or 60 years. Fruits from trees on sweet are thin-skinned, juicy, and of high quality, hold up well on the tree, and also store well. Per cent juice, soluble solids, and citric acid are essentially identical to those obtained on sour orange and are better than from fruits grown on rough lemon. However, fruit quality is not as good as when scions are grown on trifoliate orange or 'Savage' citrange. Granulation of fruit from trees on sweet orange is not a serious problem. Fruit sizes from trees on sweet tend to run somewhat smaller than average, although they are larger than when 'Cleopatra' mandarin is a rootstock but smaller than when rough lemon and sour orange is used.

Trees on sweet orange are extremely susceptible to gummosis. This is true even when the trees are budded high, planted high, and the best cultural practices are used. This is the greatest disadvantage that sweet orange has. It seems remarkable, considering the susceptibility of sweet orange to *Phytophthora,* that so many seedling orchards survived in the early history of California and Florida. Sweet orange is the most susceptible commercial stock to this disease, being somewhat worse than rough lemon and not nearly as tolerant as sour orange, *C. macrophylla,* or 'Troyer' citrange.

Sweet orange performs very poorly as a replant in old citrus soil, even though the soil has been fumigated and good cultural practices are used. Sweet orange stock is especially prone to collar rot and has poor root regeneration capacity once infected with *Phytophthora.* There is some variation in susceptibility to *Phytophthora* between various cultivars, and 'Indian River' sweet seems more resistant than others. However, this may be of little practical importance. A sweet orange rootstock resistant to *Phytophthora* would be a great asset to the citrus industry.

Sweet orange rootstocks are resistant to sour orange scab and to mal secco which are not problems in California. Psorosis or scaly bark is more serious on sweet orange than it is on the resistant sour orange stock. Lemon trees on sweet do not express shell bark symptoms with the same severity that trees do on sour orange or rough lemon. Sweet orange is not affected by exocortis, cachexia (xyloporosis), or woody gall. Reaction of sweet orange to tristeza inoculations have generally been negative, so that most cultivars of sweet are tolerant of tristeza. Sweet orange stock is very susceptible, however, to citrus nematode, although certain selections like the 'Pineapple' and 'Sanguine Grosse Ronde' have shown resistance to the burrowing nematode which does not exist in California but is present in Florida.

Sweet orange is not an answer to the world's rootstock problems, but it has so many good qualities that its germ plasm should be perpetuated in other rootstocks such as in hybrids with trifoliate orange which have resulted in citranges such as 'Troyer' and 'Carizzo'.

In California, almost all plantings of oranges being made today are on 'Troyer' or, in some cases, 'Carizzo'. There is some interest in trifoliate orange in the heavier soils of the San Joaquin Valley. Almost all lemons being planted are on *C. macrophylla.* However, there is some use of rough lemon for grapefruit and lemons in the sandy soils in the desert areas.

The reason for the switch to 'Troyer' citrange as a primary rootstock for oranges is its tolerance to tristeza, coupled with resistance to *Phytophthora*. It is, however, susceptible to exocortis, and it must be used with budwood free from this virus.

'Troyer' is susceptible to *Armillaria* and to nematodes. Fruit quality and production are good with oranges, mandarins, and grapefruit. Most lemons, with the exception of 'Lisbon', suffer from bud union difficulties when grown on 'Troyer'.

'Troyer' is above average as to cold hardiness, low in salt tolerance, and does not stand up well under conditions of poor soil drainage. Its replant growth in old citrus soils is good, as is its longevity.

'Carizzo' citrange, which came from the same series of crosses that gave rise to 'Troyer', is very similar to 'Troyer', although in some tests it shows more resistance to citrus nematode. For this reason, it is now being planted in preference to 'Troyer' in some areas of California.

Research trials on rootstocks indicated that *C. macrophylla* might be a good rootstock for lemons under California conditions, and most of the lemons now being planted in California and Arizona are on this rootstock.

While macrophylla buds well to all varieties of citrus, its susceptibility to tristeza and cachexia rule it out for use in most areas except for lemons and limes.

Macrophylla is highly resistant to *Phytophthora* and tolerant of exocortis. It does well on all soil types from sandy to heavy clay loams and has a high degree of resistance to calcareous and saline soils. It shows perhaps the highest boron tolerance of all citrus rootstocks, and it is also capable of absorbing certain other micronutrients in slightly greater quantities than other citrus. Hence, trees on macrophylla are deep green in color and seldom show leaf patterns that denote micronutrient deficiencies.

Young lemon trees on macrophylla are vigorous and precocious in bearing. One problem is that fruiting is so heavy that severe limb breakage occurs. Bud unions have been good with all scion varieties tested, and yields have been heavy with navels, 'Valencias', 'Dancy' tangerine, grapefruit, 'Eureka' and 'Lisbon' lemons, and lime. Fruit from trees grown on macrophylla are larger than average. However, fruit quality is below average and with some varieties can even be classified as poor. 'Dancy', for example, granulates badly when macrophylla is used as a rootstock. Soluble solids and citric acid from fruit of trees grown on macrophylla are low, being comparable to fruit grown on rough lemon. However, as mentioned before, recommendations are for use only with lemons and limes.

Tree vigor is good while the trees are young, but older trees show no more, and perhaps even less, vigor than trees budded on rough lemon. Lemon trees on macrophylla are relatively short lived. 'Eureka' on this stock has a productive life of 20 to 25 years, and the life of 'Lisbons' may be only slightly longer.

Macrophylla is very sensitive to cold, and trees on this rootstock do not fare as well as trees on rough lemon when subjected to freezing temperatures.

Macrophylla is an interesting rootstock, and hybrids with trifoliate orange may combine the good qualities of both. Testing of such hybrids is in progress in California rootstock trials.

Arizona

Citrus growing in Arizona is centered in 3 districts. The lower Colorado River Valley near Yuma, the Wellton-Mohawk area east of Yuma and the Salt River Valley area near Phoenix.

Arizona now has over 50,000 acres of citrus and rough lemon is and has been the primary rootstock used for oranges, lemons and grapefruit in the Yuma and Wellton-Mohawk areas. Otherwise sour orange was used. Recently 'Troyer' and macrophylla have been tried for oranges and lemons respectively. Some 'Cleopatra' mandarin has also been used as a rootstock.

Diseases which affect rootstocks include *Phytophthora*, psorosis, exocortis, tristeza and a severe type of gummosis known as Rio Grande gummosis. So far this disease has primarily attacked grapefruit trees. Rio Grande gummosis also exists in the desert areas of California and has been a problem in recent years in some grapefruit orchards. Tristeza, while present, has caused no serious problems.

Soils in citrus growing areas of Arizona range from sand and silt along the Colorado River areas near Yuma to sandy, clay loam soils in the Phoenix district. Salt accumulation and iron chlorosis are problems in some areas. Small rootstock trials exixt at Yuma and Phoenix.

Texas

The citrus industry of Texas has been badly hurt several times during the past century by severe freezes. Each time, however, the industry has rebounded with increased plantings of both oranges and grapefruit. The principal rootstock has been sour orange for both grapefruit and oranges. Texas grapefruit is of high quality and the fruit has been sold at a premium on the market.

Plantings since the 1962 freeze, which nearly destroyed the industry, have been about two-thirds red ('Ruby') grapefruit and about one-third of other varieties of citrus. The oranges grown are primarily varieties from Florida.

Salinity is frequently a problem in Texas orchards and considerable research has been done toward finding more salt tolerant rootstocks.

Rio Grande gummosis and foot rot are serious disease problems in Texas. Psorosis, cachexia, and other virus diseases are also present.

Florida

Florida is now the largest citrus-growing area in the world. It produces almost 2/3 of the world's grapefruit and about 25 per cent of the world's oranges. Also, most limes, tangelos and tangerines which are produced in the United States are grown in Florida.

You will see much of Florida citrus and its problems on the field tours so I will spend very little time on the rootstock situation here, since there are others present who are certainly more qualified to talk about local conditions than I.

The predominant rootstock in Florida is rough lemon which is believed to have reached here early in the 19th century. On deep, well-drained, sandy soils it produces larger and more productive trees in a shorter period of time than any other rootstock. Sour orange is the second most important rootstock and is preferred for low hammock and flatwood soils. Other rootstocks coming into use include 'Cleopatra' mandarin, 'Rangpur' lime, trifoliate orange, and 'Troyer' and 'Carizzo' citrange.

Major citrus diseases include psorosis, exocortis, brown rot gummosis, tristeza, *Armillaria, Clitocybe* root rot as well as others.

ROOTSTOCK SHORT COURSE

11:15 Discussion
Monday, September 24

Questions for Dr. W. P. Bitters

question: I would like to ask Dr. Bitters to give us his experience on lemons on rough lemon rootstock in California. How much does scaly bark and psorosis reduce the overall performance?

answer: Depending upon the soil type and the area in which they are growing, such trees may begin to decline at 10 or 12 years of age and may be out of production by the time they are 20 years of age. They are generally very short-lived. Shell bark has been a very serious problem on them. Shell bark of trees on rough lemon is perhaps severe as it is on any rootstock combination.

question: The trees we have now are 6 years old. We are experiencing some severe shell bark and gummosis. Would you say that they will grow to be 20 years old?

answer: They could survive this long with the shell bark but I don't know with the gummosis.

question: What is the best way of keeping the greening disease out of Florida and California?

answer: Dr. E. C. Calavan answering: We will need continued quarantine and a very careful enforcement of regulations.

question: I hear that lemon trees on sour orange root are not affected by tristeza. wonder if you had observed that.

answer: I think this is correct. Lemon trees are not affected by tristeza on sour orange roots. I think one of the principal reasons is that the vector itself does not feed on the lemon foliage at least under California conditions and the second thing is that the lemon is not a very favorable host for the build-up of the virus.

question: You mentioned that in Israel that they eradicate trees to the point of eliminating tristeza. thought that was a hopeless task.

answer: I think it may be a hopeless task but I do think it is a delaying action until they can at least establish a new rootstock program. We have faced a similar situation in the central valley of California where we had an eradication program for removal of trees showing symptoms or adjacent trees which have been indexed and discovered to be symptomless carriers. So far the spread has been held down in the central valley. I would expect this program to continue.

question: You mentioned that lemon should not be used with Rangpur lime. Is that right?

answer: We have had a little difficulty with Rangpur lime and I would like to see a little more experience with them.

question: On trifoliate orange, how critical is the calcium level and what is the proper pH range?

answer: I couldn't tell you what the proper pH range is. I think it is primarily a calcium problem because we run into problems where we have calcareous soils where trifoliate orange just becomes so hard that we cannot grow it. We may have to treat with iron chelate at least twice a year to keep the trees growing. At one of our field stations where the pH is around 7.3 to 7.5 we have this problem in the nursery but once we get a scion variety on it we can continue to grow the trees even though we do have some chlorosis showing on them.

11:15 Discussion (cont.)
September 24

question: In Spain and Portugal and in that area the pH is very high. was wondering if that was one of the reasons why they put the bud union so high.

answer: Not as far as I know.

question: How will trifoliata work on tropical conditions?

answer: To the best of my knowledge, trifoliata has not been tried successfully under tropical conditions. I have some reservations as to whether it will do satisfactorily under tropical conditions.

question: Would you expect trifoliata to be more cold sensitive if it were grown under tropical conditions?

answer: I think it would. I say this because even in California where we have had warm falls and then experienced a sudden cold spell in the fall, I have actually seen worse frost damage on trifoliata orange then I have on rough lemon in the same orchard at the same time. I suspect its hardiness is due to the fact that as the temperature is lower it gets a chance to harden off and become more resistant to cold. If it doesn't have this factor it doesn't have the resistance to cold.

question: Is there any difference in lemon quality (I am referring to California lemon growers) with lemon on macrophylla as far as fresh quality is concerned as opposed to sour or rough lemon?

answer: Quality wouldn't be as good but it is still acceptable.

question: What is the relative tolerance or resistance of grapefruit to tristeza on sour orange as compared to sweet oranges on sour oranges?

answer: Grapefruit on sour orange in California is very slow in showing symptoms of tristeza. Under field conditions your trees of sweet orange and sour orange would probably be showing severe symptoms and many trees would probably be dead before the grapefruit trees on sour begin to show symptoms. When we inoculated grapefruit trees on sour orange in the field we got symptoms rather soon. But under field conditions it takes quite a while for symptoms to appear so they are more resistant. This is also true for mandarins. Mandarins on sour orange are more resistant to tristeza than sweet orange on sour orange.

question: Is stock-scion incompatibility a problem of any significance and if so has very much research been done?

answer: It is a matter of significance because while we generally haven't found it on the older rootstocks, by this I mean rootstocks like sweet and sour, but this is a problem with the trifoliate orange group and in our recent rootstock trials where we have about 200 new rootstocks under test we find that about 10% of these will show very severe incompatibilities when they have trifoliate parentage in them. Even with trifoliate orange, we have found bud union crease to be fairly common. I think it is something to consider particularly in the trifoliate orange or trifoliate hybrid group.