BUDUNION INCOMPATIBILITIES AND ASSOCIATED DECLINES OBSERVED IN FLORIDA AMONG TREES ON SWINGLE CITRUMELO AND OTHER TRIFOLIATE ORANGE-RELATED ROOTSTOCKS

S. M. GARNSEY, W. S. CASTLE, AND D. P. H. TUCKER
University of Florida, IFAS
Citrus Research and Education Center
Lake Alfred, FL

R. E. ROUSE
University of Florida, IFAS
Southwest Research and Education Center
Immokalee, FL

H. K. WUTSCHER
USDA, ARS (retired)
Winter Haven, FL

M. C. KESINGER
Bureau of Citrus Budwood Registration
Div. of Plant Industry, FDACS
Winter Haven, FL

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Abstract. **Stunting and decline of 'Roble' sweet orange [*Citrus sinensis* (L.) Osb.] trees propagated on Swingle citrumelo rootstock [*C. paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.] were observed in commercial groves in several locations. Affected trees showed pronounced budunion incompatibility symptoms. The incompatibility first appears in trees 4 to 5 years old, and a brown stain or groove can be seen by removing bark patches across the budunion. Symptoms occur later in some trees, and initially, only a portion of the union may be affected. Symptoms in the canopy occur several years later and vary in severity. The incompatibility was not associated with a known virus or virus-like agent and is apparently physiological in nature. Budunion incompatibilities of varying severity were observed in experimental plantings of 'Roble' on several rootstocks, including trifoliate orange, Carrizo and C-35 citranges (*C. sinensis* × *P. trifoliata*), and several other citrumelos. Some citranges and citrumelos have remained free of symptoms suggesting that a segregating genetic factor may be involved. Incompatibilities between Swingle and other scions have also been reported. Notable examples in Florida include 'Murcott' (*C. sinensis* × *C. reticulata* Blanco), 'Pera' sweet orange, and several mandarin (*C. reticulata*) hybrids. Growers should be cautious in the future use of Swingle rootstocks with scions where incompatibilities have been observed. Scion-rootstock compatibility should also be investigated for all new cultivars, although delayed expression of symptoms and marked differences between closely related cultivars pose significant challenges for making rapid and thorough evaluations.**

Positive attributes such as tolerance to tristeza, blight, citrus nematodes and foot root, as well as cold hardiness and high fruit quality led to the enthusiastic adoption of Swingle citrumelo as the predominant citrus rootstock for new citrus plantings in Florida (Castle and Stover, 2000; Castle et al. 1988). Even though some precautions were indicated (Castle et al., 1993), Swingle was rapidly planted in a wide variety of situations and used with a diverse array of scions. Not surprisingly, some problems have eventually surfaced (Castle and Stover, 2000). These include unexplained declines of trees in certain locations and several forms of stunting (Garnsey, 1998; Rouse and Wutscher, 1985).

Several investigations have been initiated to determine causes for the performance problems observed with Swingle, especially those that could not be readily attributed to unfavorable soil types. One of the problems investigated was an unexpected decline of trees of 'Roble' sweet orange on Swingle citrumelo in several commercial plantings. Preliminary observations indicated that this decline was associated with a budunion incompatibility that begins when trees are about 5 years old. 'Roble' is an early-maturing variety that apparently was introduced from Spain in the 1850s as seed and has been propagated commercially in the Tampa Bay area since that time with gradually expanding grower interest (Kesinger, pers. comm.). Sour orange (*C. aurantium* L.) was frequently used as a rootstock in early plantings, but numerous propagations have been made on Swingle since the late 1980s.

Although no scion incompatibilities were noted in the original release notice for Swingle (Hutchison, 1974), budunion incompatibilities between Swingle and other scions have been observed. These include 'Pera' (Carlos and Donadio, 1996; Pompeu, 1980), 'Shamouti' (Ashkenazi, 1988), 'Tomango' (Barry, 1993) and 'Hong Jian' (Su, pers. comm.) sweet oranges, grapefruit (Rouse and Wutscher, 1985), and some mandarin (*C. reticulata* Blanco) hybrids such as 'Murcott' (Castle and Stover, 2000).

Occurrence of budunion incompatibilities with Swingle is a reminder that they are an ongoing and complex problem in citrus that involves a wide range of species and cultivars (Bridges and Youtsey, 1968; McClean, 1974; Olson, 1958; Olson and Frolich, 1968; Russo, 1969; Salibe, 1965; Schneider and Pehrson, 1985; Weathers et al., 1955). In addition to reports dealing specifically with graft incompatibilities, information on incompatibility reactions is often also included in reports on rootstock tests or other studies.

Some incompatibilities become apparent soon after grafting .and rapidly affect growth and vigor. Others do not become apparent for some years, and trees may grow vigorously for long periods before showing any effects (Fernandez-Valiela et al., 1965; Schneider and Pehrson, 1985).

Some incompatibilities are associated with infection by virus or virus-like agents and include diseases such as those caused by tristeza and tatterleaf viruses (Miyakawa and Tsuji, 1988; Timmer et al., 2000), and several other transmissible agents (McClean, 1974; Navarro et al., 1984). Other incompatibilities occur in the absence of any apparent pathogen and have been classified as localized (Mosse, 1962). Localized incompatibilities do not occur

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when the scion and stock are separated by a mutually compatible interstock.

When the incompatibility reaction is severe, trees are frequently stunted or show deterioration of canopy health, and may be susceptible to breakage at the budunion. Some incompatibilities are manifested by an obvious overgrowth or benching at the budunion. In many cases, the evidence of incompatibility may not be apparent until a bark patch is removed across the budunion area to reveal a groove and/or brown stain.

Our objective was to describe the incompatibility reactions we observed in commercial plantings of 'Roble' sweet orange on Swingle, and observations of incompatibility between 'Roble' and other rootstocks in experimental plantings. Several other observations on rootstock-scion compatibility problems in Florida are also reported. Problems associated with evaluating scion-rootstock compatibility and the complexity involved are discussed.

Methods and Materials

Field observations. The Florida Citrus Production Research Advisory Council funded a project to investigate causes for decline and stunting syndromes associated with Swingle citrumelo. Surveys were made of more than 20 commercial plant-ings in which trees propagated on Swingle citrumelo were reported to exhibit various types of problems. Among these plantings there were eight groves in central and west central Florida of 'Roble' sweet orange trees ranging in age from 5 to more than 14 years. Observations were also made in several experimental plantings established and maintained by the Florida Citrus Budwood Registration Bureau of the Florida Department of Agriculture and Consumer Services. These plantings contained propagations of 'Roble' on an array of rootstocks.

An apparent incompatibility between Bittersweet sour orange (BSO) and trifoliate orange was investigated based on a severe budunion crease exhibited by a tree in a Budwood Registration Program indexing test. Further testing of the incompatibility involved seedlings of BSO grown from seed harvested from a parent tree which we coded as FS583. Buds taken from the seedlings were subsequently propagated on several rootstocks.

Tree canopies were rated for vigor and decline, including twig die back and leaf chlorosis. Observations for budunion incompatibilities were made by removing patches of bark approximately 1 × 2 inches from across the budunion. At least one additional patch on the opposite side of the trunk was examined if no symptoms were observed on the first patch. Trunks from several trees with early and advanced stages of incompatibility were harvested and cut longitudinally.

Greenhouse indexing. Budwood was collected from selected trees of 'Roble' and navel orange on Swingle that showed budunion symptoms, and from a BSO tree on trifoliate orange. This tissue was used to inoculate S1 Etrog citron (*C. medica* L.) indicator plants to test for the presence of viroids, and Rusk citrange to test for citrus tatterleaf. Indexing for tatterleaf was also done by mechanical inoculation to the herbaceous hosts *Chenopodium quinoa* Willd. and Red Kidney bean (*Phaseolus vulgaris* L.) using tender leaf tissue from field- and glasshouse-grown plants. Indicator plants were held in a glasshouse cooled by evaporative coolers.

Laboratory testing. Double antibody sandwich indirect ELISA was used for detection of infection by citrus tristeza virus (CTV). General procedures were as previously described (Garnsey et al., 1996). A combination of monoclonal antibodies was used to detect all CTV isolates and MCA 13 was used to detect severe isolates. Tissues tested were taken from field trees and greenhouse-grown propagations. Tests for citrus leaf blotch virus (CLBV) were done at the Instituto Valenciano de Investigaciones Agrarias, Moncada, Spain. Extracts prepared from freeze dried tissue samples were tested by RT-PCR using primers to CLBV sequence (Vives et al., 2001).

Results and Discussion

Field observations in 'Roble' plantings. Association of a tree decline syndrome with budunion incompatibility between 'Roble' and Swingle citrumelo was first observed in a 10-year-old planting near Haines City that had originally been propagated from a virus-free source of 'Roble' budwood. Over 80% of the trees in this block showed some evidence of decline (Fig. 1a). All unthrifty trees of 'Roble' on Swingle that we examined showed obvious signs of a budunion incompatibility when a bark patch was removed from across the budunion. There was a pronounced groove at the budunion that extended into the wood and a matching ridge on the inner surface of the bark patch. A brown gum or a brown stain was often visible on the trunk and on the inner face of the bark patch (Fig.1b). Some scattered trees that were vigorous and markedly larger than the majority of the trees had no budunion symptoms. No mature fruit were present at the time of the initial survey, but information provided by the owner (and our subsequent fruit observations) revealed that the vigorous trees were actually 'Valencia' trees on Swingle that had been accidentally mixed in with the 'Roble' trees when the block was planted. This further indicated that the decline condition observed was associated with a specific stock-scion combination.

Seven additional plantings of 'Roble' sweet orange on Swingle citrumelo rootstock, and several plantings on other rootstocks were observed. The trees on Swingle ranged in age from 4 to 10 years and had been propagated from old line and shoot-tip-grafted sources of budwood. Evidence of budunion incompatibility was found in at least some trees in all 'Roble' plantings on Swingle when bark patches were removed from the budunion. Some of the younger trees were still free of visual budunion symptoms and even some of the older (8-10 years) trees were affected only in one portion of the union (Fig. 1c). Trees free of budunion symptoms, or with only partial or mild budunion symptoms, were generally vigorous in appearance. Decline symptoms were more common in plantings 8 to 10 years old, but we did find some trees as young as 5 years old in decline. A longitudinal section of the trunk of a 10-year-old tree in decline indicated a cyclic pattern in abnormal tissue differentiation at the budunion. Pockets of gummy tissue interspersed between bands of apparently normal tissue could be traced back for at least four seasons (Fig. 1d).

It appears that 'Roble' trees on Swingle grow normally for at least the first 4 or 5 years. Evidence of budunion incompatibility can often be found on some trees at 5 years by examining bark patches, but canopy symptoms may not become apparent for several more years. Onset and progression of budunion and decline symptoms may vary among trees in the same planting. Several growers reported heavy crops just prior to the onset of visible decline and this may have been an indication of the girdling effect the incompatibility can produce. Decline was less severe and slower to appear among trees in groves receiving optimal care. Symptoms were similar in trees propagated from old line and shoot-tip-grafted sources of budwood. Propagations of seedling sources of 'Roble' on Swingle have also shown budunion incompatibility.

Budunion symptoms have been observed in 'Roble' propagated on Carrizo (Fig. 1e), but, to date, this has not been accompanied by development of visual canopy symptoms. No budunion symp-

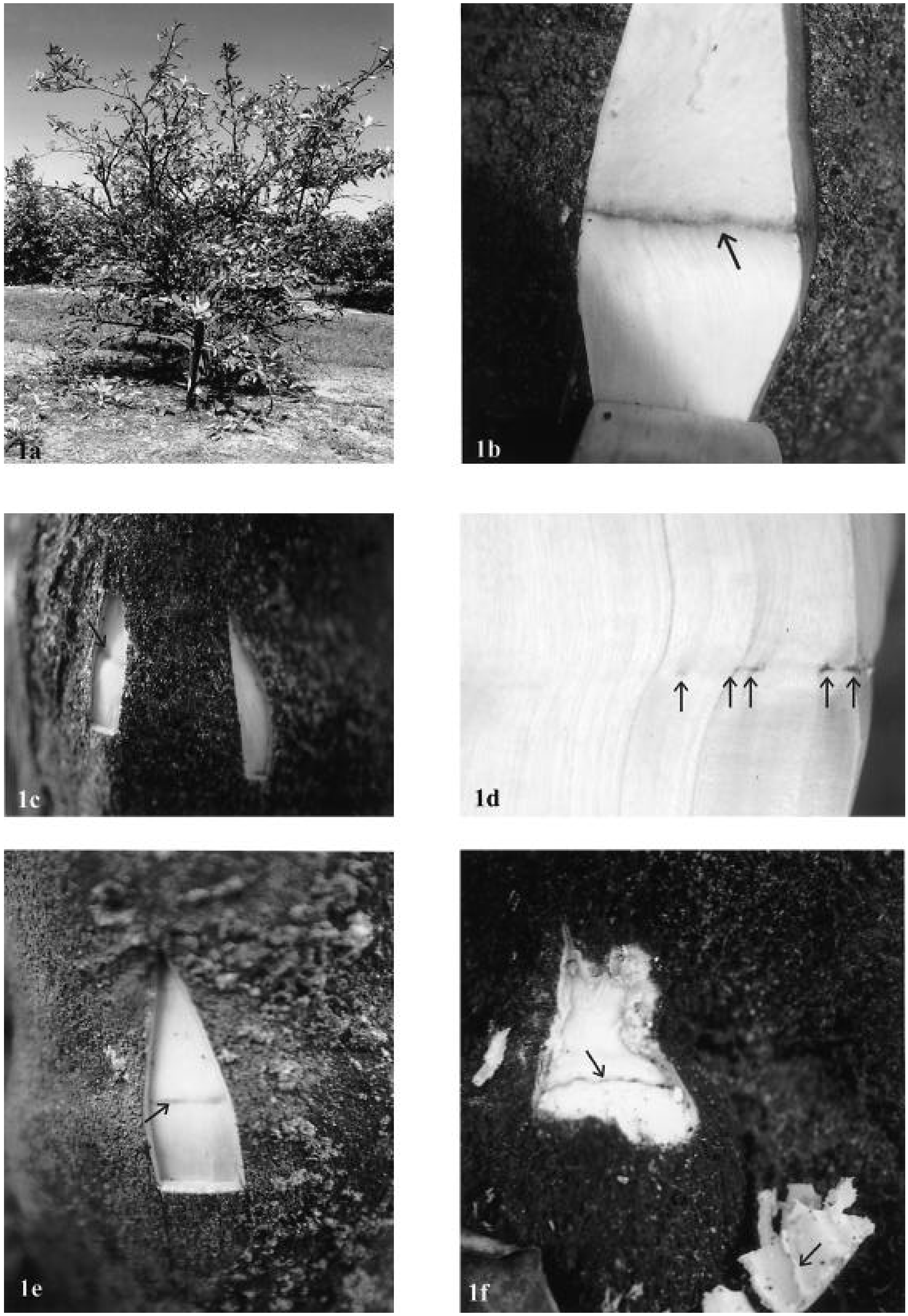

Figure 1. a. Decline symptoms in a 10-year-old tree in a planting of 'Roble' sweet orange on Swingle citrumelo. Declining trees all exhibited prominent budunion crease/browning symptoms (see Fig. 1b). b. Budunion crease and stain symptoms at the budunion of a declining 10-year-old 'Roble' on Swingle tree (Fig. 1a). c. Budunion of a 6-year-old 'Roble' on Swingle tree showing irregular distribution of budunion incompatibility symptoms. Symptoms are present in the window on the left, while none are present in the window on the right. d. Longitudinal section through the budunion area of a 10-year-old 'Roble' on Swingle tree showing cyclic occurrence of abnormal tissue development at the union (arrows). Note gummy areas of increasing intensity. e. Budunion incompatibility symptoms in a 'Roble' on Carrizo tree in foundation planting at Immokalee. No decline was noted in this tree. f. Budwood incompatibility symptoms in an 18-year-old 'Washington' navel on Swingle tree in a central Florida planting. Mild decline symptoms were present in the canopy of this tree, and some nearby trees had been removed previously.

toms were observed in 'Roble' trees propagated on Cleopatra mandarin or sour orange rootstocks.

Observations on 'Roble' budunion incompatibility in experimental plantings. A shoot- tip-grafted source of 'Roble' on a range of rootstocks was included in a foundation planting established by the Citrus Budwood Registration Program at Immokalee in 1989. 'Roble' was also included in a rootstock trial for nine mid-season varieties established at Budwood Registration Program facilities at Dundee in 1992. These two trials involved 22 rootstocks including trifoliate orange, seven citrumelos, four citranges, four other hybrids with trifoliate orange parentage, Cleopatra, Changsha, and Sun Chu Sha mandarins, *C. amblycarpa*, Calamandarin (*C. reticulata* hybrid), Smooth Flat Seville (sour orange hybrid), and Gou tou (sour orange hybrid) (Table 1). There were only two to four replications of each scion-rootstock combination, but both trials contained some rootstocks in common, including Swingle.

Budunion incompatibilities were present when 'Roble' was propagated on trifoliate orange, and on seven of 14 hybrids with trifoliate orange parentage (Table 1). Although we observed only a limited number of replications, there did seem to be quantitative differences in the severity of incompatibility with 'Roble'. Trees on trifoliate orange were the most severely affected and several had already died. The reaction of Swingle appeared to be approximately mid range in severity and was less than that observed in citrumelos 80-5, 80-6, and 80-7. The citrumelos 80-8 and 80-18 (which originated from the same cross that produced citrumelos 80-5, 80-6, and 80-7) were free of budunion symptoms. While these combinations may still show an incompatibility when older, it appears that a genetic factor associated with 'Roble' incompatibility may segregate in crosses involving trifoliate orange. Similar differences were noted among the citranges tested although these did not come from one hybrid population. Incompatibility was not observed between 'Roble' and any of the rootstocks without trifoliate orange parentage (Table 1).

Limited observations were also made in the Dundee planting of other scion cultivars growing on Swingle and other citrumelos that had showed an incompatibility with 'Roble'. One tree of 'Parson Brown' on citrumelo 80-5 and one tree of 'Midsweet' on citrumelo 80-6 showed initial symptoms of an incompatibility in one of three bark patches cut. Several 25-yr-old trees of 'Parson Brown' on Swingle had clear budunion creases, but did not exhibit visual canopy symptoms.

Other field observations. Budunion incompatibility symptoms were observed in several plantings of 'Murcott' trees propagated on Swingle, and in some cases, were associated with a tree decline. A similar budunion crease and tree decline had been noted in 'Murcott' trees on Carrizo citrange (Castle et al., 1993).

Budunion incompatibility symptoms were observed in a planting of navel orange trees on Swingle near Haines City. Trees began declining in this planting as it reached 12 years of age and tree loss has continued. Declining trees showed budunion grooving and staining similar to that observed in the 'Roble' on Swingle combination (Fig. 1f). After 18 years, nearly all trees had some degree of budunion incompatibility symptoms, but a number of these still remained free of canopy symptoms. The pattern of tree loss in this planting was somewhat suggestive of the introduction of an infectious agent, but no conclusive evidence for this has been developed. Slowly developing incompatibilities between navel orange and trifoliate orange rootstocks were previously reported elsewhere (Fernandez-Valiela et al., 1965; Schneider and Pehrson, 1985).

Table 1. Budunion incompatibility observations in experimental plantings with 'Roble' sweet orange budded on different rootstocks.[z]

Rootstock	Location	Budunion symptoms	Canopy affected
Trifoliate orange (TO)	IM	strong	yes
Citrumelos			
Swingle	D, IM	strong	yes
W-2	D	none	no
80-5	D	strong	yes
80-6	D	strong	yes
80-7	D	strong	yes
80-8	IM	none	no
80-18	D, IM	none	no
Citranges			
Carrizo	IM	moderate	no?
Benton	D, IM	no	no
Koethen × Rubidoux	D	mild	no
C35	D, IM	strong	yes
Other TO hybrids			
x639 (Cleo. × TO)	D	none	no
Minneola × TO	D	none	no
Rangpur × Troyer	IM	none	no
Non TO rootstocks			
Cleopatra mandarin	D	none	no
Changsha mandarin	D	none	no
SunChu Sha mandarin	D	none	no
Calamandarin	D	none	no
Smooth Flat Seville	D	none	no
Gou tou	D	none	no
C. amblycarpa	D	none	no

[z]Readings made in FDACS, Division of Plant Industry test plantings at Immokalee (IM) and Dundee (D) Florida. All trees were propagated from a shoot-tip-grafted source of 'Roble' (504-4-2). Budunion condition was determined by removing at least two bark patches across the budunion. Trees at Immokalee were examined at 9 years after planting and those at Dundee were read at 7 and 9 years after planting.

Budunion incompatibilities (but not canopy symptoms) were noted in 10-year-old 'Page' orange (*C. reticulata* hybrid) trees on Swingle citrumelo and Troyer rootstocks as trees were removed from an experimental planting. Marked budunion incompatibility was also noted in several selections of 'Pera' orange trees propagated on Swingle in a test planting near St. Cloud. Symptoms generally did not occur until the trees were about 8 years old. Tree decline was associated with the budunion symptoms and continued over several years. These observations are consistent with earlier reports from Brazil (Pompeu, 1980). Trees with a sweet orange interstock between the 'Pera' scion and the Swingle rootstock remained vigorous and free of incompatibility symptoms.

While the incompatibilities observed on Swingle with 'Pera', 'Roble', 'Tomango', 'Shamouti', and 'Hong Jiang' sweet oranges appear somewhat similar, it is not clear if these are associated with a single factor or have multiple causes. Tests involving a matrix of these scions and rootstocks that have shown differential reactions, such as the 80 series citrumelos in this test, could provide further clarification.

No visual incompatibility has been observed between Swingle and 'Valencia' or 'Hamlin' scions. A syndrome in which variable numbers of trees on Swingle citrumelo in a planting fail to grow at a normal rate has caused grower concern in several areas (Garnsey, 1998). There is no obvious association with soil or cultural practices, and there was also no evidence of budunion incompatibility found in these stunted trees, or in trees in several plantings suffering from declines of undetermined cause.

Incompatibility reactions observed with Bittersweet sour orange (BSO). Glasshouse propagations of BSO from a field tree on trifoliate orange showing a strong incompatibility showed pronounced budunion incompatibility within 1 year on trifoliate orange, Swingle, and Carrizo seedlings. Propagations of standard sour orange on the same rootstocks formed normal unions. Budlings from nine seedlings from the Bittersweet tree also developed budunion incompatibilities when budded on trifoliate orange. When propagations were made with a standard sour orange interstock between the BSO scion and the trifoliate orange rootstock, no incompatibility developed. A similar disorder among sour orange scions and Troyer citrange was reported by Russo (1969) who also noted variation among sources of sour orange. While the symptoms of the Bittersweet incompatibility were similar to those observed with 'Roble', it forms at an earlier age.

Virus indexing results. An early goal in virus testing was to see if citrus tatterleaf virus (TLV) could be implicated in the budunion incompatibility symptoms observed in the 'Roble' and navel scion combinations with Swingle, or with those observed in the Bittersweet -trifoliate orange combination. These budunion symptoms were all similar to those induced by TLV (Miyakawa, 1988; Timmer et al., 2000). TLV is symptomless in lemons, oranges, grapefruit, and mandarins, but causes a striking budunion incompatibility when infected budwood is propagated on trifoliate orange or most trifoliate orange hybrids, including Swingle. While TLV has rarely been found in common commercial cultivars in Florida, isolates of tatterleaf have been recovered from some 'Meyer' lemon trees (*C. limon* hybrid) in Florida. The infections in 'Meyer' are presumed to originate in the original introductions of 'Meyer' lemon from China where TLV is common.

Graft inoculations to Rusk citrange indicators with tissues from 'Roble', navel, and Bittersweet trees with incompatibility symptoms did not induce foliar symptoms of TLV while inoculations with the standard TLV 4 isolate produced typical reactions. Glasshouse sub-propagations of 'Roble', and navel orange scions on Swingle seedlings did not show budunion symptoms after several years, while sweet orange scions infected with TLV and propagated on Swingle produced a clear bud union crease within 6-12 months under glasshouse conditions. Similarly, mechanical inoculation of Red Kidney bean and *Chenopodium quinoa* with tissues from 'Roble', navel, and Bittersweet sources also failed to induce symptoms while similar inoculations with TLV4 produced typical symptoms. Group III viroid symptoms were detected in citrons inoculated with several old line sources of 'Roble', but viroids were not found in trees originating from shoot-tip-grafted sources of budwood.

ELISA testing for CTV revealed that most 'Roble' and navel orange field trees tested were infected with mild or decline isolates of CTV, but there was no correlation between presence of either isolate type and budunion incompatibility. Some trees in one 'Roble' planting that had been propagated originally from shoot-tip-grafted sources of budwood still indexed negatively for CTV, yet showed a typical incompatibility.

A citrus virus originally discovered in Nagami kumquat [*Fortunella margarita* (Lour.) Swing.] trees in Spain (Navarro et al., 1984) was subsequently recovered from other trees in Spain with budunion incompatibility symptoms. This virus, which is called citrus leaf blotch virus (CLBV), has been characterized and sequenced recently (Vives et al., 2001). Tissue samples collected from four 'Roble' and three navel trees with budunion incompatibilities in Florida were freeze-dried and sent to the Instituto Valenciano de Investigaciones Agarias in Moncada, Spain. Primers based on CLBV sequence yielded a RT-PCR amplification product in one navel and three 'Roble' samples (P. Moreno, pers. comm.). This indicates that CLBV may be present in Florida, but a causal association between CLBV and budunion incompatibility has yet to be established in either Spain or Florida. To infer a virus etiology in the 'Roble' and Bittersweet incompatibility complexes, one must assume that the agent is efficiently seed transmitted, and that the effect is highly specific among closely related cultivars. In the case of Bittersweet, the effect is also not translocated through an interstock.

Implications for developing new rootstocks. Broad compatibility between scion and rootstock is important for the long-term success of new cultivars. However, while this trait may be important, it often receives less attention than other factors in the germplasm development process. Incompatibilities are difficult to predict and often are slow to develop. The basic causes for formation of many incompatibilities remain undetermined and it is unclear how many distinct types of incompatibility actually exist.

Undetermined genetic factors can be present in either the scion or rootstock that affect localized (non-pathogen associated) incompatibility. For example, sweet orange cultivars essentially arose by mutation and are, thus, genetically closely related. Nevertheless, sweet orange cultivars can vary markedly in compatibility with a single rootstock such as Swingle. At the same time, variation in compatibility among closely related rootstocks with a single scion also occurs. Evidence includes our observations with different citrumelos and 'Roble', and variation among trifoliate oranges sources for compatibility with navel orange scions (Schneider and Pehrson, 1985).

The lack of clear patterns for incompatibility reactions indicates that testing of a few representative selections from each group of commercial cultivars may not be sufficient. For example, early trials with Swingle did not forecast the variety of incompatibilities that have now been revealed. While a number of incompatibilities have been reported that involve trifoliate orange and trifoliate hybrid rootstocks, incompatibilities occur with a diverse array of germplasm. In fact, one of the first incompatibility problems observed in Florida was associated with sweet orange on rough lemon (*C. jambhiri* Lush.) rootstock (Bridges and Youtsey, 1968).

The long delay that often occurs before expression of an incompatibility occurs is further confounded by irregular initial manifestation of the incompatibility along the circumference of a single budunion. When an incompatibility forms quickly after propagation, such as is the case with BSO, it is easier to detect than slowly forming incompatibilities, such as those observed with 'Roble' and navel oranges.

While the task is clearly not easy, experiences with Swingle should reaffirm the need to carefully consider compatibility issues when developing and introducing new scions or rootstocks. Some success in more rapid prediction of incompatibility was reported by Bevington et al. (1978). They exchanged rings of bark between scions and rootstocks and found that anatomical disruptions at the junctions of the bark ring were predictive of future incompatibilities. This approach and other cytological studies could speed detection of compatibility problems prior to expression of visual symptoms. However, until better knowledge of the specific factors involved is obtained and predictive screening methods are well developed, screening will continue to involve propagation of extensive ranges of scion-stock combinations and lengthy observations. Even so, it will not be feasible to test all possible combinations of scion and rootstock for long periods prior to making a release. Use of multiple rootstocks for budwood increase plantings is a practical step that can reveal unsuspected problems. More pilot test plantings of new citrus germplasm combinations involving cooperation between citrus breeders, nurserymen, and growers could also help identify potential problems before large scale commitments are made.

Virus-induced incompatibilities make the situation even more complicated since scion-rootstock combinations that may not manifest localized incompatibilities can still become incompatible when they become virus-infected. In addition to known virus problems such as tristeza and tatterleaf, other viruses or virus-like agents that currently do not cause a problem may become a factor in a new combination of scion and rootstock.

A better understanding of the basic cause of budunion incompatibilities is clearly needed. While it is apparent that abnormal differentiation or development of tissue at the budunion is associated with the creasing and gumming symptoms observed, the physiological changes that cause these abnormalities are poorly understood. It appears that several distinct physiological factors may induce or result in similar anatomical changes and symptoms. The BSO incompatibility factor is not commercially significant, but may provide a good model system for future investigation of budunion incompatibilities simply because the reaction forms so rapidly. Virus-induced incompatibilities, such as those induced by TLV, also provide a system that has some advantages for studying how incompatibilities are created. Inoculating an appropriate scion-rootstock plant combination with TLV changes a tolerant condition to an intolerant one and the changes must be associated with a virus-induced factor that was triggered by one of the limited number of genes in the TLV genome. Isolates of TLV apparently also differ in their ability to induce the incompatibility response (Miyakawa and Tsuji, 1988). This could also be useful in pinpointing the inducer of this incompatibility.

Recommendations for growers. It is clear that propagation of 'Roble' sweet orange should not be continued on Swingle, trifoliate orange or other rootstocks that show clear incompatibility problems. Although decline has not yet been observed in trees on Carrizo in commercial plantings, caution would certainly be advised in using it as a rootstock for 'Roble'. Limited observations indicate that Benton citrange, x639 citrandarin, and the citrumelos 80-8 and 80-18 may be acceptable rootstocks for 'Roble'.

It is possible that use of an interstock such as 'Valencia' between Swingle and 'Roble' would avoid formation of an incompatibility as has been observed with 'Pera' but this has not been verified experimentally. Even if successful, this would raise costs for propagation of nursery trees.

Young trees of 'Roble' on Swingle in existing field plantings could be inarched with a tolerant rootstock, such as Cleopatra mandarin, to prevent future development of decline, however, this may not be practical or cost effective.

The most practical approach for growers with existing plantings of 'Roble' on Swingle may be to anticipate when tree decline will likely begin, and to interset the grove with tolerant trees several years in advance of this time. In this manner, some production can be obtained from the existing block while the new trees are growing. The older, declining trees can be removed as production loss occurs. A precise prediction of the onset of decline may be difficult, but it is likely that significant decline will not occur until several years after initiation of the first budunion symptoms. This can be determined by periodically checking bark patches across the budunion of suspect trees. Once a clear creasing, and gum impregnation are observed, decline can be anticipated, although the tree may still look healthy.

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