The Effects of Virus and Viruslike Diseases on Citrus Production in Florida

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Summary

Florida has not experienced as much devastating injury from virus diseases as many citrus-growing areas; however, tristeza, psorosis, exocortis, and xyloporosis have all been damaging. Tristeza continues to be a major problem, but psorosis, xyloporosis, and exocortis are now controllable. Several other viruses have been described, but are not widely distributed. New diseases, including a stem-pitting disorder of 'Milam' (*Citrus jambhiri* Lush. hybrid?) and some tangerine hybrids (*Citrus paradisi* Macf. X *Citrus reticulata* Blanco), are appearing. Several viruses have been discovered by inoculating herbaceous plants, but relationship of these viruses to specific diseases has not been established. Introduction of new citrus varieties, rapid shifts in rootstocks, and rapidly changing production practices will contribute to future problems. Vigorous research and regulatory programs will be needed in response to existing and future problems.

Introduction

Strictly defined, virus diseases are caused by small, infectious nucleoproteins. Commonly, however, infectious citrus diseases not obviously caused by fungi, bacteria, or nematodes are called "virus" diseases, although the identity of the causal agent is often unknown. This broader definition will be retained in this paper so that the necessary topics can be covered. Emphasis will be placed on disease effects, not on properties of the causal agent. Some diseases that will be covered, have been called virus diseases, but are now known to have other causal agents. Examples are exocortis, caused by a small, naked, infectious nucleic acid, provisionally called a viroid or pathogene (41, 42), and stubborn, which has been associated with a mycoplasmalike organism much larger and more complex than a true virus (3, 17). Young tree decline (YTD) and sandhill decline (SHD), which are very similar to the older and also unsolved decline problem called blight (30), are covered specifically by other authors and will be treated only briefly in this paper.

Regardless of nomenclature, virus and viruslike diseases have caused serious problems in most citrus-producing regions of the world. These diseases often limit the production of certain types of citrus in some areas. In addition, "latent" virus infections can cause widespread but less obvious losses (43, 44).

For several reasons, Florida has had less serious virus problems than most major citrus areas. In Florida, oranges and grapefruit (*C. paradisi*) have been grown mostly on rough lemon (*C. jambhiri*) and sour orange (*C. aurantium* L.) rootstocks. Exocortis and xyloporosis, although common in most mature plantings, do not cause obvious symptoms on these trees. Psorosis has been under increasingly effective control for a number of years by budwood registration. Tristeza virus has become widespread, but severe injury to sour orange-rooted trees has occurred only in localized areas. Natural infection of grapefruit trees by tristeza has been uncommon.

Despite past good fortune, concern about citrus virus diseases in Florida is increasing. Tristeza has spread rapidly into existing plantings on the east coast of Florida in recent years, and evidence of tristeza decline is increasing in this area. In spite of tristeza damage, sour orange is being widely used in new plantings.

New virus or viruslike diseases are appearing. Some, such as the new stem-pitting disease in 'Milam' (a probably rough lemon hybrid) and in tangerine hybrids such as 'Robinson', 'Page', and 'Lee' (*C. reticulata* X *C. paradisi*) (49), threaten to be large problems in the future.

Damage to rough lemon-rooted plantings in recent years by YTD and SHD is causing a rapid shift to other rootstocks. These are largely untested commercially in Florida, and many are susceptible to exocortis and/or xyloporosis. New scion varieties, which may harbor unsuspected susceptibility to virus diseases, are also being propagated.

Production practices continue to change rapidly in Florida. Many of these changes probably will not affect the citrus virus disease situation; but the effects of herbicides, permanent irrigation, hedging and topping, abscission agents, and mechanical harvesting devices are undetermined and may affect virus spread and disease symptoms.

This paper will review the various virus and viruslike diseases in Florida and will discuss, where possible, the problems that lie ahead. Some discussion of the possible beneficial use of citrus viruses for cross protection and tree-size control will also be included.

Major Viruses

Tristeza. Tristeza remains a major threat to Florida citrus growers, in spite of its past failure to cause more widespread damage to sour orange-rooted trees. The presence of tristeza in Florida was confirmed in 1951 (34), but it was undoubtedly introduced much earlier (20). Significant natural spread occurred first in central Florida, and then later in all major citrus areas in the State (5, 34). It has just recently spread rapidly into existing plantings on the east coast and lower interior (5). These plantings are largely on sour orange and were nearly free of tristeza until recently.

The most efficient vector of tristeza, *Toxoptera citricidus* Kirk., has not been reported in Florida; but the 3 aphid vectors present (35) can cause considerable natural spread when inoculum is plentiful and vector populations are high.

The effect of tristeza on sour orange-rooted trees in Florida has been variable. Quick decline symptoms have been observed (Fig. 1), but a slower decline is more typical. Even more common are large numbers of tristeza-infected trees on sour orange that show no obvious signs of infection. The absence of symptoms is probably due to a predominance of mild strains of tristeza and mild climatic conditions.

Florida isolates of tristeza often produce mild vein-clearing and stem-pitting symptoms in 'Mexican' lime (*C. aurantifolia* [Christm.] Swing.) indicators, but some isolates cause severe symptoms. Some isolates, especially from 'Meyer' lemon (*C. limon* [L.] Burm. f. hybrid), can cause seedling yellows in 'Eureka' lemon (*C. limon*) (20). Tristeza stem-pitting in grapefruit or sweet orange has been rare. Natural infection of grapefruit trees has been uncommon, but does occur and may be increasing (5). Tristeza decline in mature grapefruit trees on sour orange has recently been observed in central Florida.

Fig. 1. Tristeza quick decline symptoms in 'Valencia' tree on sour orange root. Tree is approximately 20 years old. Photo taken 8/7/73, at Winter Garden, Fla.

Tristeza will continue to be a problem in Florida citrus for a long time. The use of sour orange rootstocks is increasing, partly because of its YTD tolerance. Some locally severe damage seems certain to continue as it has in the past. The extent of future damage probably depends on the proportion of new trees that become infected with severe and mild strains and whether trees infected with mild strains will resist subsequent inoculation by severe strains (33, 47). It is probable that there is some natural cross-protection at work in Florida, although this is difficult to prove. There is considerable interest in deliberate use of cross-protection, and this approach is being studied here. One difficulty with cross-protection tests in Florida is lack of rapid means to subject plants infected with mild strains to natural challenge by severe strains to determine the "protection" given by the various mild strains. While natural spread is occurring, young plants in the field do not all become rapidly infected and do not necessarily get challenged by severe isolates.

Some strains of tristeza are transmitted more readily than others in Israel (2). The relative transmissibility of Florida strains of tristeza has not been studied, but this factor could have an effect on the relative distribution of different tristeza strains in new plantings.

The large numbers of uninfected grapefruit trees on sour orange in Florida appear vulnerable to further and more rapid spread of tristeza isolates capable of causing decline. Our grapefruit trees, regardless of stock, are also vulnerable to severe stem-pitting forms of tristeza that exist in many parts of the world. Pitting has been induced in experimentally inoculated plants (24) and could be a problem if pitting strains become widespread.

Reports of tristeza-related problems with citranges (*Poncirus trifoliata* [L.] Raf. X *C. sinensis* Osbeck) and trifoliate orange (*P. trifoliata*) from other areas (8, 36) suggest that tristeza will be a continuing problem in rootstock selection. However, no tristeza problems have been reported to date on 'Carrizo' citrange- or trifoliate orange-rooted trees in Florida.

Exocortis. Citrus exocortis virus (CEV) is present in most old-line Florida citrus trees. However, typical CEV symptoms, are rare, because CEV-sensitive rootstocks have been used sparingly until recently. The CEV isolates found in Florida vary widely in their effect on trees grafted to trifoliate-orange rootstocks and on 'Etrog' citron (*C. medica* L.) indicators. Many CEV isolates cause severe tree stunting and bark scaling on trifoliate-orange rootstocks. These also cause severe symptoms in citron indicators. Other isolates cause little stunting or scaling in trees on trifoliate orange, but cause definite, although mild, symptoms in citron indicators. Intermediate forms are also found.

There are indications from the budwood certification program indexing tests that symptoms of stunting and bark scaling in trifoliate orange-rooted trees are not always linked (G. D. Bridges, personal communication). Severe scaling is not always accompanied by severe stunting and, conversely, severe stunting may occur with little scaling. This suggests the presence of a "stunting factor," perhaps distinct from CEV. CEV sources that cause stunting but little scaling have been reported in Australia (6). Further experiments with mechanically transmitted sources of CEV free of other viruses should help clarify this situation.

The recent widespread use of 'Carrizo' citrange and other CEV-sensitive rootstocks in new plantings has prompted greater concern about CEV. Fortunately, CEV-free selections of all important scion varieties, except 'Temple' orange (*C. reticulata* hybrid?) and 'Thompson' grapefruit, are available through the budwood certification program.

CEV can be transmitted mechanically as a contaminant on cutting tools and hands (22). This hazard must be carefully avoided in nursery operations, where contamination of budwood-source trees or young nursery trees can be disastrous. Contamination can be readily avoided by use of sterilants such as dilute (5-10%) solutions of household bleach (23, 38).

There is a hazard of spreading CEV in the grove during hedging and topping operations, but the potential for damage to mature groves on CEV-sensitive rootstocks may not be too great. First, some scion varieties, such as grapefruit and tangelos, have been resistant to infection via contaminated tools in experimental tests (22). Secondly, infection of mature trees is unlikely to have any sudden, drastic effect. There may be reduction in growth after several years, but this would not be harmful where trees are pruned periodically to limit size. Pruning and/or removal of root sprouts from young trees might be more hazardous because of stunting before trees reach the desired size.

Natural spread of CEV (7) and apparent seed transmission (39) were reported before the discovery that CEV can be spread as a contaminant. It now appears that contamination is the cause for the natural infections of CEV observed.

Future damage from CEV can be largely avoided by using clean budwood and simple sanitation procedures. However, increased use of sensitive stocks, coupled with inattention to selection of budwood and contamination, may result in more CEV damage than we have previously experienced.

A beneficial use of citrus viruses to control tree size has been proposed (32), and this is being tested with CEV (6, 11, 13, 26). While CEV infection usually reduces tree size and yield of trees on sensitive stocks, the effect on fruit quality may be beneficial. Reduction in yield per tree can be compensated for by increasing the number of trees per unit area, if the sizing potential of the tree is known at time of planting. This approach has been on trial for some time in Australia (6, 26), and experiments are being conducted in Florida. It appears that accurate and successful use of CEV for tree-size control will ultimately require information on the stock-scion combination used, the virus isolate, and the tree age at the time of inoculation. The beneficial use of a virus such as CEV is intriguing, but obviously, this requires a full understanding of the virus and its effects.

Xyloporosis (cachexia). Severe symptoms of xyloporosis are encountered infrequently in Florida. Although a considerable acreage of 'Orlando' tangelo (*C. reticulata* X *C. paradisi*) and other mandarin hybrids susceptible to xyloporosis (30, 48) is grown in Florida, these trees usually have been propagated from xyloporosis-free budwood. A common cause for the xyloporosis damage observed has been topworking symptomless varieties to a susceptible scion (48).

Xyloporosis symptoms have been seen on satsuma mandarins (*C. reticulata*) in several instances (30). These symptoms develop slowly, becoming apparent at 8 to 10 years after budding. Xyloporosis can apparently cause mild pitting and gum-pocket formation in rough lemon and affect tree growth and yield (44).

Fovea, a disease similar to xyloporosis in 'Murcott' oranges (*C. reticulata* hybrid), has caused some injury in Florida (31), but is generally avoided by the use of clean budwood.

Sweet lime (*C. aurantifolia*), *C. macrophylla*, and 'Rangpur' lime (*C. reticulata* var. *austera* hybrid) rootstocks are being used more widely. These are susceptible to xyloporosis, and budwood sources free of xyloporosis and fovea should be used in propagation. Topworking with sensitive varieties should be avoided, unless the virus status of the trees is known. Several unexplained, apparently natural infections of xyloporosis have been observed (G. D. Bridges, personal communication), but extensive natural spread is not indicated now (9).

Psorosis. Psorosis symptoms are found in many older groves in Florida. Sometimes severe bark-scaling symptoms are present, and the debilitating effect on the tree is obvious. More commonly, the presence of the virus is marked only by scattered, ephemeral leaf patterns in the young, spring-flush leaves. The effect of the latter type of infection on tree condition or production is not obvious. Psorosis infection has been associated with a decrease in vitamin C content (44).

Psorosis is uncommon in younger plantings, because one of the first dividends from Florida's budwood certification program was identification of many sources of major scion varieties free from psorosis.

Psorosis can be seed-transmitted in 'Carrizo' and 'Troyer' citranges (45), but this hazard has been overcome by certifying rootstock seed-source trees. No natural spread of psorosis has been documented in Florida, and future effects of this virus should be minor.

Other Viruses

Florida citrus has other viruses in addition to the 4 common viruses already discussed. Generally, these have limited distribution or they affect varieties of minor importance. Some could cause serious damage if they should become widely distributed. Several viruses have been discovered only recently, and their potential for damage to citrus has not been evaluated.

Tatter leaf-citrange stunt complex (TL-CSV). Many 'Meyer' lemons in Florida are infected with a virus complex that causes symptoms in plants of citrange and *C. excelsa* Wester and a disabling stock-scion incompatibility in orange trees on citrange or trifoliate orange stocks (18, 20, 37, 46). The above symptoms were observed in plants inoculated experimentally, and the TL-CSV complex is known to occur naturally only in 'Meyer' lemon. It should not become a problem unless a vector appears. 'Meyer' lemon sources free of the TL-CSV complex (20, 37, 46) should be used in new plantings to limit the inoculum potential.

Citrus variegation virus (CVV). Citrus variegation virus occurs in Florida (25), but it is rare in the field. It is a hazard mostly to acid lemons, a relatively minor crop here. CVV causes severe variegation symptoms in 'Etrog' citron indicator plants (unpublished), and can be readily detected in an indexing program using that indicator.

Citrus leaf rugose (CLRV). This virus, originally reported as a crinkly-leaf-type virus (19), is related to CVV, but has some different properties. CLRV is limited in its present distribution, but has some potential for damage. It causes severe stunting in young grapefruit plants under cool conditions, some stunting on lemons and tangelos and a leaf distortion in 'Mexican' lime (19). Natural spread in the field is indicated (21).

New Virus Problems

New stem-pitting disease. Recently, stem-pitting symptoms of unknown cause have been observed in several citrus varieties in Florida (49). These symptoms vary in severity from scattered, inconspicuous pits, visible only when the bark is removed, to severe pitting that deforms even the external appearance of trunks of affected trees. The most severe symptoms have been observed on 'Milam' (Fig. 2), 'Robinson', and 'Page' trees. Symptoms are most severe on the trunk and lower limbs. Pits are rare in limbs less than 1 inch in diameter.

Pitting symptoms were first detected in June 1972, and full information on host range and effects is not yet available. Severely pitted 'Milam' trees continue to grow vigorously, although these are still less than 10 years old, and no controlled comparisons with healthy plants are available. Pitting on 'Milam' is especially severe, and there may be some debilitation eventually. However, pitting symptoms do not extend below groundline, and there may be less effect on this variety as a rootstock.

Natural spread is indicated, but the means is unknown. Pitting symptoms have been reproduced in greenhouse propagations of pitted 'Milam' trees. 'Milam' plants inoculated with tissue from a pitted 'Robinson' tree have shown some gum-impregnated streaks in the cambial region, but distinct pits have not formed yet. A mechanically transmissable virus was discovered in 1 pitted 'Robinson' tree, but this virus was not found in other pitted 'Robinson' trees or pitted trees of other varieties; and its causal role in the pitting disease is questionable (unpublished). Some, but not all, pitted trees are infected with tristeza (49). While tristeza apparently is not responsible for the pitting observed, severe isolates of tristeza can cause pitting on 'Milam' and complicate diagnosis in that variety.

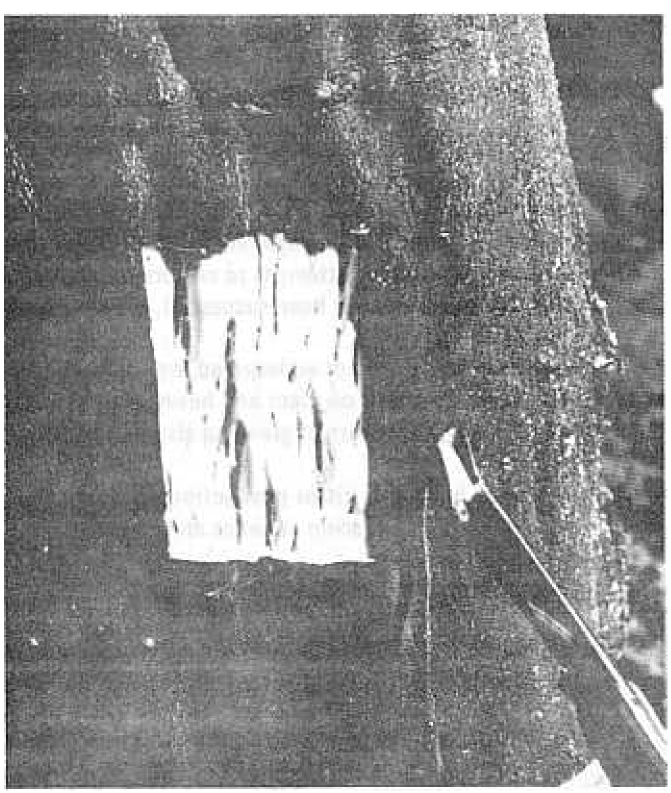

Fig. 2. Stem pitting symptoms in trunk of 8-year-old 'Milam' tree near Haines City, Fla.

A stem-pitting factor that causes symptoms in 'Madam Vinous' sweet orange has been reported recently (15). Its relationship to the stem pitting in 'Milam' and the tangerine hybrids is unknown at this time.

Miscellaneous. Recently, additional viruses have been found in Florida by use of herbaceous assay plants (unpublished). These viruses are sap-transmitted, but their identity and properties are undetermined. Two were found in citrus introductions from Algeria. One is apparently latent and has not caused detectable symptoms in citrus indicators. The other causes symptoms similar to those described for citrus ring spot virus (46). Inoculated plants show severe shock symptoms initially, but later recover.

A mechanically transmitted virus has also been found in a tree affected with a severe bark-scaling form of psorosis, but its relationship to psorosis has not been determined.

Associated Problems

Stock/scion incompatibilities. Some virus-induced incompatibility problems have already been discussed. Virus or viruslike agents are suspected in several others. Bud-union-crease symptoms (4) are often encountered in trees on rough lemon rootstock. The cause of this problem is not known, but apparently it is graft-transmissible, and not caused by the viruses discussed above or YTD. Podagra, a stock/scion problem between 'Nagami' (*Fortunella margarita* [Laur.] Swing.) and 'Meiwa' (*F. crassifolia* Swing.) kumquats and rough lemon (29), also occurs in Florida.

Recently, some apparent compatibility problems with mandarin or mandarin-hybrid scions on trifoliate-orange hybrid rootstocks have been observed. (Bridges, unpublished; Hutchison, Hearn, and Garnsey, unpublished.) Symptoms consisted of creasing with or without gum deposits at the bud-union. These symptoms did not always extend completely around the trunk and may be transitory and recurring. The cause and final effects are unknown, but further observation is warranted.

Viruslike diseases. Several viruslike diseases have been described in Florida, including lime blotch, measles, leprosis, crinkle scurf, cancroid spot, and sphaeropsoid knot, but none has been proven infectious (28).

Young tree decline. The pattern of spread in the field of YTD and associated diseases suggests that an infectious agent is involved (14). However, all attempts so far to transmit or perpetuate the disease have failed. Many of the more recent experiments are not old enough yet to be conclusive, but they do indicate that if an infectious agent is involved, it is difficult to transmit and/or requires a long incubation period to produce symptoms. The initial symptoms of decline suggest a xylem dysfunction. This type of symptom is not ordinarily associated with virus or mycoplasmalike diseases.

Mycoplasmalike diseases

Symptoms of stubborn and greening diseases have been described in Florida (10, 27). However, presence of either stubborn or greening in Florida has not been demonstrated by graft transmission. These diseases, once considered virus diseases, are now thought to be caused by mycoplasmalike or similar organisms (3, 17). Electron-microscopic observation of tissues from YTD-affected trees that showed leaf symptoms similar to greening symptoms failed to reveal mycoplasmalike agents (Purcifull, Garnsey, Storey, and Christie, manuscript in preparation). Attempts to culture mycoplasmalike organisms from trees suspected of being stubborn and from YTD-affected trees have not been successful.

If stubborn and greening are present in Florida, they currently are not widespread, nor do they cause readily detectable symptoms. Past reliance on old-line budwood sources, with emphasis on vigor and heavy fruit production, has probably forestalled spread of these problems by propagation. The psyllid vectors of greening also do not occur in Florida.

Continued avoidance of stubborn and greening is a must in Florida citrus production. Greening and related diseases are destructive where vectors are present, and no tolerant or resistant scion varieties are available.

Need for Further Research and Control

Virus and viruslike diseases will continue to be a problem in Florida. Research work has eliminated or controlled some problems. However, some solutions, such as development of tristeza-resistant rootstocks, may not be permanent; and new diseases have arisen.

Basic information in a number of areas is need to provide better control of citrus virus diseases. Some examples are cited below.

We need more rapid and precise methods of detecting citrus viruses. Serological techniques (21), electron microscopy (1), and chromatographic techniques (16, 40) have been promising in some situations, but wider application is needed. We need to know more about vectors of citrus viruses. The physiology of citrus virus diseases also needs more intensive study. Virus-induced stock/scion incompatibilities and stem pitting are major problems; yet, we don't know how these symptoms develop or how to detect sensitivity to these problems in new citrus cultivars. Sources of resistance to some virus diseases have been identified, but inheritance of these factors has not been defined. Breeding for virus-resistant varieties is still haphazard. Therapy of plants affected by virus and mycoplasmalike agents (38) also deserves more attention.

Regulatory and certification programs have eliminated or avoided many serious disease problems, and their need will be undiminished in the future. Greening, stubborn, woody gall, impietratura, and cristacortis, among others, should be excluded from Florida. The efficient aphid vector of tristeza and the psyllid vectors of greening could also be serious problems if introduced.

The budwood certification program in Florida has developed many valuable sources of scions and rootstocks free of damaging viruses for the grower. Information on virus diseases developed by the program has also been invaluable to research on virus diseases and identifying and solving new problems. Continuation and wide use of this program by growers is essential if virus diseases in Florida are to be controlled.

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