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Diseases of Citrus in Arizona

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Introduction

Although citrus is indigenous to southeast Asia, oranges were first planted commercially in central Arizona in the late 1800s. Today commercial production is centered in several warm and low-frost-risk areas of central and southwestern Arizona. A great number of citrus varieties are also widely planted in home gardens. Many diseases of citrus have been described world wide and have colorful and descriptive names such as: blue mold, green mold, gray mold, pink mold, pink nose, brown rot, black spot, black rot, black pit, yellow vein, yellow spot, rubbery wood, lumpy rind, curly leaf, corky bark, slow decline, spreading decline, and stubborn. Other names are rooted in the many international languages of citrus such as: Italian (impietratura and mal secco), Portuguese (tristeza), or Greek and Latin (cachexia, psorosis, exocortis, xyloporosis, cristacortis, and leprosis). Fortunately, most of the more serious, widespread diseases do not occur or are of little importance in Arizona. Diseases of importance here include several caused by fungi or fungal-like organisms: foot rot gummosis (*Phytophthora* root rot) caused by *Phytophthora nicotianae* (syn. *Phytophthora parasitica*) and *P. citrophthora*, *Hendersonula* branch wilt (caused by *Hendersonula toruloidea*), brown heartwood rot of lemons caused by species of *Antrodia* and *Coniophora*, and black rot of fruit caused by *Alternaria* sp. Bacterial diseases such as citrus canker that require wet environments do not occur in Arizona. Symptoms often may be confusing (Figure 1).

Of the many virus and virus-like diseases that have been described world wide, only tristeza, psorosis and a mycoplasma disease, stubborn, are presently known to occur in Arizona. Tristeza and stubborn disease have been extensively studied in Arizona and in other citrus areas of the world. In 1956, research in Arizona identified tristeza virus in Meyer lemon, and psorosis, a virus-like disease, in several old line citrus varieties including Marsh grapefruit, Valencia orange, and Washington navel. These two diseases were probably introduced into Arizona in infected budwood and planting material prior to 1930. Stubborn disease was first identified in Arizona in 1965.

One of the most important diseases found in citrus in Arizona is caused by the citrus nematode (*Tylenchulus semipenetrans*). This disease has become more widespread and important because present control options are limited.

Figure 1. Non-specific symptoms in citrus of general tree decline with tip die back and sparse foliage. This condition could be caused by several factors including Phytophthora crown and root rot, citrus nematode, or nutrient deficiencies or excesses.

Many serious and widespread diseases in citrus grown in Arizona are nonparasitic in nature. These diseases are not the result of infection by living microorganisms but are caused by factors such as: excessive sun and heat, excesses of certain elements including boron or lithium, excess soil salts, mineral deficiencies, water stress, freeze injury, hail, lightning, and genetic disorders. Two excellent publications that discuss diseases of citrus are: Compendium of Citrus Diseases and Citrus Health Management both published by the American Phytopathological Society and Integrated Pest Management for Citrus, published by the University of California (publication 3303).

Parasitic Diseases

Diseases caused by fungi and fungal-like organisms

Phytophthora foot rot (Phytophthora gummosis)

Phytophthora foot rot or gummosis of citrus in Arizona is caused by two fungus-like soil microorganisms, *Phytophthora nicotianae* (syn. *P. parasitica*) and *P. citrophthora*. This disease is relatively common in citrus groves in the Salt River Valley and Yuma areas. Loss of individual trees in home gardens occurs in all of

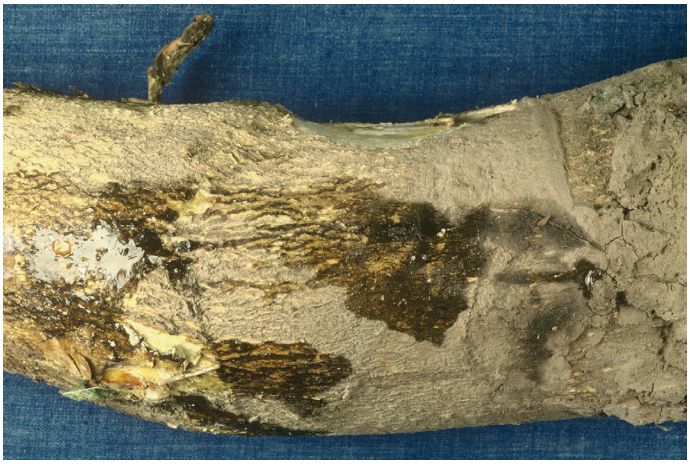

Figure 2. Typical gummy lesions caused by *Phytophthora nicotianae* in citrus bark.

Figure 3. Bark removed from sample shown in previous photograph.

southern Arizona. Disease incidence is especially high in trees established with the graft union at or below the soil surface, exposing susceptible scion tissue to the two pathogens. Severe losses also can occur in groves subjected to flood irrigation if trees are planted on susceptible rootstocks.

Symptoms: The most diagnostic symptoms of *Phytophthora* foot rot are found at or below the soil level. Longitudinal cracking of bark, accompanied by profuse gumming, usually is positive evidence of infection (Figure 2). Soil removal around affected trees reveals bark that is water soaked, slimy, reddish-brown, or in late stages, black (Figure 3). Diseased bark may be easily removed if pathogen activity is recent, and wood is discolored (Figure 4). Advanced stages of infection will result in yellow, sparse foliage. Trees may later collapse and die due to the girdling action of the pathogen infection.

Fruit infections, although not common in southern Arizona, may occur during or shortly after warm rainy periods during summer and fall. These infections are caused by motile spores being splashed onto fruit. This stage of the disease is called brown rot, since the diseased areas on the fruit are brown in color. Active growth of trunk lesions occurs during May and June, declines somewhat during the hot summer months of July and August, and resumes during September and October.

Figure 4. Typical discoloration under the bark of the trunk of an active lesion caused by *P. nicotianae.*

Disease cycle: Both *P. citrophthora* and *P. nicotianae* are soil-borne microorganisms. They complete their life cycles in the soil. In our dry desert conditions infection by these two pathogens occurs, for all practical purposes, only on roots and lower bark tissue at the crown of the tree. In humid, wet areas of the world, however, these plant pathogens can infect fruit and upper trunk tissue. Recent surveys determined that *P. nicotianae* is the more common of the two species, in soils in the lower elevation, higher temperature areas of Yuma County. This may be because *P. nicotianae* has a higher optimum temperature for growth (85°-90°F) than *P. citrophthora* (75°-80°F). However, both species are commonly found in central Arizona. These species have been recovered from soil and infected plant tissue in over 85 percent of 60 different citrus plantings in Maricopa and Yuma counties. Both of these fungus-like organisms produce motile, swimming zoospores when soils are saturated from irrigation or rainfall. These spores are attracted to root tips. After attachment they germinate and infect cortical root tissue. Infected feeder root cortical tissue becomes rotted and dark in appearance.

Physical removal of this decayed tissue (by rubbing between your fingers) reveals the whitish, central root tissue. This is a simple diagnostic technique that can be used in the field. Proof that a *Phytophthora* sp. is the cause of the decay requires the isolation and identification of the organism on *Phytophthora* specific media in the laboratory. Both species produce survival structures in decayed root tissue that permits indefinite survival in soil. Studies in Arizona have shown that isolates of *P. nicotianae* from other hosts (tomato, for example) are not pathogenic to citrus. Interestingly, in contrast, isolates of *P. nicotianae* from citrus are highly pathogenic to tomato.

Control: Most citrus trees are budded on to a rootstock. Most of these rootstocks are more resistant to *Phytophthora* diseases than the scions (tops), so it is necessary to keep the bud union at least four to six inches above the soil line at planting. In general, water should not be allowed to stand around the crown of citrus during irrigation. This is particularly true when rootstocks susceptible to *Phytophthora* disease, such as some selections of rough lemon or sweet orange, are used. Moderately resistant rootstocks include

Figure 5. Symptoms of sooty canker caused by *Hendersonula toruloidea.*

Figure 6. Branches with the black "soot" of sooty canker disease.

Citrus macrophylla, Cleopatra mandarin, and Troyer citrange. Over-irrigation resulting in soil saturation is detrimental to normal feeder root development even in the absence of *Phytophthora*. It is important to dig a planting hole as deep as necessary to obtain good drainage. Caliche layers, commonly found in our low rainfall, alkaline soils, should be opened up to allow water drainage and unrestricted root development.

Control of *Phytophthora* diseases in citrus has been enhanced by the availability of highly active, systemic fungicides specific for control of *Phytophthora*. These chemicals are applied to the soil and the crown and trunk areas of affected trees. Studies in Arizona indicated that isolates of *P. nicotianae* and *P. citrophthora* pathogenic to citrus do not occur naturally in Arizona soils. This fact suggests that these fungal-like pathogens were most likely introduced into Arizona on imported planting material prior to our present inspection and certification programs.

Hendersonula Branch Wilt

Also known as sooty canker or limb wilt, this disease is caused by the fungus, *Hendersonula toruloidea*, a wound pathogen that invades citrus bark that has been damaged by freezing injury, sunburn, or mechanical injury. The fungus does not infect uninjured bark tissue. *H. toruloidea* has a wide host range and causes disease in many plants unrelated to citrus.

Symptoms: The most common symptom of sooty canker is the sooty, black growth that develops beneath bark tissue. This black canker is due to the presence of masses of black, fungal spores that appear under the bark and on the surface of the canker. Because the fungus grows into and kills sapwood, the leaves on branches with cankers wilt, turn brown, and die (Figure 5). Branches die back to the cankered area (Figure 6). Scattered branches are usually affected. Most cankers develop on trunks or limbs that face toward the sun and are not shaded. Sunburned trunks and limbs are highly susceptible to infection.

Biology of the pathogen: In Arizona, *H. toruloidea* produces only conidia and thus has a very simple life cycle. The small conidia, produced in black, powdery masses under bark, are easily wind disseminated. These spores, which arise from segmented hyphae, are carried to damaged bark where they germinate and initiate infection. The mycelium grows into living tissue. Infected sapwood is stained gray to black in color.

Control: Sooty canker can be controlled when infections are confined to limbs and upper branches. Smaller infected branches should be removed when symptoms appear. Since sunburned bark is the primary infection site, large limbs should be pruned only when trees are dormant.

When removing infected limbs, cut back to at least one foot below the canker. The cut area and pruning tools should be treated with a solution of one part household bleach and nine parts water. Pruning wounds should be painted with a copper fungicide to prevent infection. Reapply the copper compound to the wound each spring to insure adequate protection against infection. Control becomes increasingly difficult as the disease progresses into the scaffold branches and is virtually impossible once the main trunk is infected.

Tree vigor should be maintained through proper fertilization and deep watering on a regular schedule. Severe pruning of larger branches and limbs of trees should be avoided. Whitewash, applied to exposed lower trunk areas, will reduce the possibilities of infection. This material reflects radiation and reduces bark temperature.

Brown Heartwood Rot of Lemons

Two different wood rot fungi have been shown to cause decay and death of branches of lemon trees in the Yuma area. The fungi, *Antrodia sinuosa* and *Coniophora eremophila*, initially invade branch tissue through wounds resulting from fractured or partially broken limbs. These wounds usually result from tractor damage, heavy fruit load and wind damage. The aerially dispersed spores of the fungi are deposited in these wounds, where subsequent colonization of wood tissue and development of wood decay in living heartwood occur. These infections result in death of branches above the infection site.

Symptoms: The first obvious symptom is death of a lemon tree branch that often is partially broken from the tree. The fractured infected wood is light brown in color. No evidence of fungal growth is observed on wood infected

Figure 7. A broken branch in lemon caused by infection by the wood decay fungus *Antrodia.*

with *Coniophora*, whereas white fungal mycelium can be observed within the brown decayed wood infected with *Antrodia* (Figure 7).

Biology of the pathogens: *Antrodia* and *Coniophora* both produce aerially dispersed spores. *Coniophora* has not been found sporulating on infected lemon wood, so infected wood in lemon plantings is not producing spores that could infect other lemon trees. On the other hand, *Antrodia* has been observed sporulating on lemon wood, so that additional infections could arise from spores produced from decayed lemon wood.

Control: Broken or dying branches should be removed with a flush, clean cut close to the main branch to minimize development of wood rot at wound sites. If the wood rot decay is caused by *Antrodia*, removal of wood debris will eliminate this potential source of spores and minimize the threat of new infections. Maintaining tree vigor with adequate irrigation and proper fertilization should promote wound healing and minimize development of wood rot. No fungicides currently available for use on citrus will control this disease.

Dry Root Rot

Dry root rot of citrus occurs sporadically, attacking trees that usually are weakened by some other factor. The most susceptible rootstocks include citranges, citrumelo, *Citrus macrophylla*, rough lemon and Cleopatra mandarin. The general symptoms of dry root rot resemble those caused by *Phytophthora* and other pathogens that damage roots or girdle the trunk, such as reduced vigor, leaves dull green in color, restricted new growth and twig dieback. If root damage is severe, leaves may suddenly wilt and dry on the tree during summer and early autumn.

Symptoms: Examination of infected trees usually reveals a dry decay of fibrous roots, larger roots and trunk at or below the soil surface. The wood below the bark is not decayed but may be stained a dark color. A soil-borne plant pathogenic fungus, *Fusarium solani*, can be recovered from infected root tissue. Dry root rot may advance and develop for years with a slight wilt under dry conditions being the only symptom. However, once enough root tissue has been destroyed, leaves on infected trees may suddenly wilt and turn yellow; at this stage the tree may die with the leaves still attached. In addition to direct destruction of root tissue, the symptoms of *Fusarium* dry root rot are caused by inhibition of water transport in root tissue and production of toxins by the pathogen.

Biology of the pathogens: *Fusarium solani* is a common soil and root-inhabiting fungus which is associated with the roots, stem and bark of healthy as well as diseased citrus trees. The transformation of the fungus into a pathogen is correlated with stress factors, such as root damage caused by *Phytophthora*, over-watering, under-watering, poor soil drainage, excess fertilizer, heat stress and root injury due to plowing, herbicides or nematodes.

Control: Since stress factors like those listed above can trigger disease development, prevention of these stress factors can minimize the occurrence and severity of dry root rot. To date, control of *Fusarium* dry root rot with fungicides has not been successful.

Blue and Green Fruit Molds

Blue and green molds are common postharvest diseases of citrus. All types of citrus fruit are susceptible to these two mold diseases.

Symptoms: The initial symptom of blue and green mold is the appearance of a soft, watery and slightly discolored spot from 1/4 to 1/2 inch in diameter. This spot enlarges to 1 to 2 inches in diameter after 1 to 1.5 days at 75°F. White mycelium appears on the surface, and when the growing fungus is about 1 inch in diameter, blue or olive green spores are produced. The entire fruit surface is rapidly covered with the blue or olive green spores, which are easily spread if the fruit is handled or exposed to air currents.

Biology of the pathogens: The fungi that cause blue mold and green mold are both in the genus *Penicillium*. Spores of the fungi are produced in chains in massive quantities on infected fruit. The fungi survive in the orchard as spores. Infection occurs by airborne spores entering the fruit rind through injuries. The infection and sporulation cycle can occur many times during the season in the packinghouse. Blue and green mold develop most rapidly at around 75°F; on the other hand, rot is virtually stopped at a temperature of 34°F.

Control: Careful picking, handling, packing and storage of fruit minimize injuries to the fruit rind and the risk of blue or green mold development. Sanitary packinghouse practices, including the use of disinfectants such as chlorine or other materials help reduce the concentration of fungal spores

Figure 8. Internal Alternaria infection in lemon fruit.

Figure 9. Alternaria infection on the blossom end of orange fruit.

capable of causing infection. Post-harvest application of selected fungicides can help delay the development of blue and green mold, especially in combination with immediate cooling of fruit after packing.

Alternaria Fruit Rot

Alternaria fruit rot, also called black rot, is a fungal disease caused by *Alternaria*. The disease occurs occasionally in lemons and navel oranges in Arizona (Figure 8). Alternaria attacks only citrus fruit. *Alternaria* rot is primarily a problem in storage, but it sometimes occurs in the orchard where it can cause premature fruit drop. In other parts of the world the disease has been reported on citrus fruit other than navels and lemons. *Alternaria* fruit rot is most important in areas where citrus is processed for juice because of juice contamination by masses of black fungal mycelium found in the interior of the infected fruit.

Symptoms: Fruit infected with *Alternaria* may turn light in color several weeks before the color break in healthy fruits. Some infected fruit may prematurely drop while others may remain on the tree.

Infected fruit may appear normal. The simple method of diagnosis is to cut the fruit in half, exposing the stylar or "blossom" end and the central cavity. Diseased fruit have a brown to blackish discoloration at the "blossom" end (Figure 9). The discoloration and decay may be restricted to the "blossom" end or it may extend deep into the central cavity. Observations of infected tissue in the laboratory reveal the presence of *Alternaria*. Fungal spores are unique in appearance. There may be little or no external evidence of infection. In lemons the disease is most common during storage. In Arizona, splitting, caused by environmental factors, often predispose navel oranges to infection by *Alternaria*. Large navel fruit may split and drop in the fall during hot, dry weather. The incidence of splitting is higher in sunburned fruit, and in trees stressed by drought and frost injury.

Biology: *Alternaria* is an active saprophyte. The fungus grows on dead citrus tissue during wet weather. Airborne conidia are produced during these periods. These spores germinate and the fungus establishes itself in the button or stylar end of the fruit. Entrance into the fruit is facilitated when splits or growth cracks occur. The fungus grows into the central core of the fruit and causes a black decay. *Alternaria* produces large numbers of conidia in infected fruit. The fruit may dry and become black and mummy-like in appearance. This fruit becomes one of the survival mechanisms for the fungus.

Control: Proper fertilization and irrigation will reduce the incidence of this disease. There are no chemicals that are presently recommended for control.

Sweet orange scab

Sweet orange scab (SOS) is a disease that affects citrus fruit and to a much lesser extent leaves and twigs. It is caused by the fungus *Elsinoe australis,* a new pathogen to citrus in the United States, and was detected on tangerine in Arizona in 2010. SOS is an established disease in humid citrus growing areas of South America where it causes damage to sweet orange and tangerine fruit. Damage is superficial on the fruit and does not affect quality, but reduces marketability. It is similar to citrus scab, a different disease caused by *Elsinoe fawcettii*, a distinct species.

Symptoms: SOS causes corky pustules on fruit. It generally does not cause lesions on stems and twigs. However, because of its similarity to other citrus scab diseases, it is very difficult to distinguish the scab diseases by fruit symptoms.

Biology: *E. australis* is a fungus that attacks the young fruit of susceptible hosts. When sufficient moisture is present, the fungus produces spores that are spread by splashing rain and wind. The fungus is spread long distances, i.e. between citrus growing regions or countries, by human movement of infected fruit.

Control: Sweet orange scab can be controlled by fungicide applications. Timely application prevents infection, but does not eradicate the disease. Quarantine measures are in effect for many citrus growing regions, and prevention of introduction is much easier and efficient than long term chronic treatments. Since detection of sweet orange scab on tangerine in Maricopa County and lemon in Yuma County, costly quarantines have been in effect that restrict out of state movement of all susceptible fruit.

Rio Grande Gummosis

This name has been given to a gumming disease of mature citrus, particularly grapefruit, thought to be caused by several fungi, but no particular pathogen has been identified.

Symptoms: Symptoms begin as narrow cracks in the bark of limbs and trunk in which a yellow, water soluble exudate accumulates. Gum formation on the trunk or branches and gum exudation from blisters on the trunk continues and forms gum pockets under the bark. The advancing margin of infection is orange to pink. Once sapwood is exposed, wood decay may begin. In later stages of disease, heart rot may also be prevalent.

Control: Several factors have been identified as contributing to disease including freeze damage, poor drainage, and salt accumulation. Weakened and injured trees seem to be predisposed the disease. There is no control other than cultural practices that keep trees in vigorous condition. Good pruning practices that remove freeze damaged wood and encourage fast healing are the best way to prevent disease.

Virus Diseases

Citrus tristeza virus

Introduction: *Citrus tristeza virus* (CTV) is one of the most destructive viruses that affect citrus. The impact of CTV infection spans from the destruction of South American citrus industries built on the sour orange rootstock in earlier 1900s, to present day limits on citrus production in many countries. Observations in the late 1800s and early 1900s of declining sweet orange trees on sour orange rootstocks led scientists to conclude that tree failure was due to an incompatibility between certain scion varieties and sour orange roots. American and Brazilian plant pathologists almost simultaneously, in 1946, reported that tree failure was caused by a viral disease. The Brazilians demonstrated that an aphid, *Toxoptera citricida,* was a vector of the virus. The disease was named "tristeza," a Portuguese word meaning sadness, an appropriate name for a viral disease that had killed 6 million trees in Argentina and 10 million trees in Brazil. The virus was identified in California in the late 1940s. Severe losses occurred in Southern California in a number of citrus varieties that were budded to sour orange rootstocks. Studies in California demonstrated the existence of several variants or strains of CTV. These strains varied in severity, vector specificity, and host range. It was proven that several distinct diseases (tristeza, stem-pitting, seedling-yellows, and lime dieback) were caused by strains of CTV. In Arizona CTV was first identified in 1956 in Meyer lemon. Later surveys discovered the virus in mature trees of Clementine mandarin, Dancy tangerine, and Marsh white grapefruit.

Symptoms: Symptoms of CTV in citrus are extremely variable and depend on the isolate of the virus, host, environment, and scion/rootstock relationships. Common symptoms include reduced fruit size, leaf vein-clearing, yellowing and cupping of leaves, and stem pitting. Depending on the symptoms on different hosts, isolates of CTV can be categorized into four categories. Mild strains cause very mild symptoms and slight yield reductions on a variety of citrus. Quick decline strains are most severe in

Figure 10. Advanced symptoms of citrus tristeza virus.

citrus on the sour orange rootstock and cause rapid death of the host. Infection of sweet orange, mandarin, or grapefruit trees on sour orange rootstock by the quick decline strains causes necrosis in the phloem of the sour orange rootstock just below the bud union. This girdling causes eventual decline and death of the infected tree (Figure 10). Stem-pitting strains cause stem pitting in either sweet orange or grapefruit, resulting in severe yield reduction and loss of plant vigor. Seedling yellows strains induce chlorosis and stunting in sour orange, acid lemon and grapefruit.

Transmission: CTV is not transmissible by seed or mechanical means. The virus is disseminated only in infected bud wood, planting materials, and by several species of aphids. The cotton aphid, *Aphis gossypii*, is a vector of certain strains of CTV in California and Florida. There is no evidence that the cotton aphid is involved in the spread of CTV in Arizona. The most efficient vector, *T. citricida* (the brown citrus aphid) is currently not present in Arizona. This species, prevalent in South America, played a key role in the early epidemics of CTV. *T. citricida* was introduced into Florida in 1995, but it has not been found in other citrus-producing states. Since the introduction of the brown citrus aphid, growers in Florida have reported annual loss of trees on sour range rootstock at a rate of up to 25%.

Present Situation in Arizona: Surveys conducted in the late 1990's did not find any CTV infection in commercial citrus in Arizona, and at that time, all citrus trees in the Citrus Budwood Certification Program tested negative for CTV. However, CTV was found in about 0.5% of the dooryard citrus trees in Maricopa, Pinal, Pima, and Yuma counties. Infected trees included lemon, Meyer lemon, orange, and grapefruit. The fact that CTV is not presently a factor in commercial plantings of citrus on sour orange roots is due to a number of factors: the Arizona Citrus Budwood Certification Program has been effective in preventing the introduction of infected budwood and planting material into Arizona; the cotton aphid (*A. gossypii*), which occasionally feeds on citrus in Arizona, apparently does not transmit the strains of CTV present in Arizona; old line citrus varieties carrying the virus have been eradicated; and quarantine regulations on imported citrus have been effective. The establishment of the brown citrus aphid in the Yucatan region of Mexico in 2000 should be a concern to Arizona citrus growers.

Psorosis

Psorosis is an occasional problem in old citrus plantings in Arizona. The disease, which occurs primarily in orange and grapefruit trees, is characterized primarily by the scaling and flaking of the bark on the scion cultivar. Because of these symptoms, the disease is sometimes referred to as scaly bark. Symptoms do not occur until the tree is usually over ten years in age. First symptoms of scaly bark consist of small flecks of gum on the trunk and main branches. These areas become dry and scaly. As they enlarge, the tree becomes stressed and less productive. Twig and limb death may occur.

Causal agent: The cause of bark scaling in citrus has frustrated plant pathologists since symptoms were first observed in Florida and California in the late 1890s. Initially, in the 1930s, bark scaling in citrus was named psorosis. In the late 1970s, a number of graft-transmittable diseases that caused bark scaling were lumped together and referred to as psorosis. They included psorosis A, psorosis B, citrus ringspot, concave gum, cristacortis, and impietratura. The causal agent of these diseases was listed as virus or virus-like. The first of these diseases to be identified as caused by a virus was the citrus ringspot disease. The causal virus was named the Citrus Ringspot Virus (CRV).

In the 1990s plant pathologists from Argentina, South Africa, Spain, and the U.S. identified a virus, Citrus-psorosis-associated Virus (CPsAV) as a probable cause of certain strains of psorosis. All of the psorosis diseases, including the two caused by viruses, are disseminated only by infected bud wood. No vectors of these diseases have been identified. The strains of psorosis that occur in Arizona have not been studied.

Control: These diseases have been controlled by eradication and effective citrus certification programs in Arizona and California. The disease is not common in Arizona.

Mycoplasma Diseases

Stubborn Disease

Stubborn disease is a major disease of citrus in North Africa and in the middle-eastern and Mediterranean citrus areas including Israel, Egypt, and Turkey. In North America the disease is known to occur only in the hot, dry citrus areas of Arizona and California. For unknown reasons, the disease has not been found in citrus in Florida or Texas. Prior to the 1970s, it was thought the disease was caused by a virus. In the early 1970s, however, research in several areas determined the disease was caused by a unique mycoplasma-like organism that was named *Spiroplasma citri*. Presently, stubborn is an important disease in Arizona and California. In Arizona, stubborn disease is especially prevalent in Washington navel trees but may occur in Valencia and sweet oranges as well as grapefruit.

Symptoms: The disease may appear at any time during the life of the tree, and severity and symptoms vary from year to year. Symptoms consist of stunted growth; misshapen, flat-topped trees; proliferation of shoot development resulting in witches'-brooms; twig die-back; small, stiff, upright foliage showing marked Zn or Mn deficiency-like symptoms; occasional diffuse yellow and green mottling of leaves; small leaves sharply pointed, cupped, and having marginal chlorosis; fruit malformed, "acorn shaped" with rind thick at stem end and thin at stylar end (Figure 11); many aborted seeds found in seedy varieties; progressively decreasing yields of small fruits having insipid flavor; "off-season" bloom. In some instances, only part of the tree shows these described symptoms. Stubborn disease does not normally cause death in citrus. Stunting is most common in trees that are infected when young. Symptoms are accentuated during hot weather.

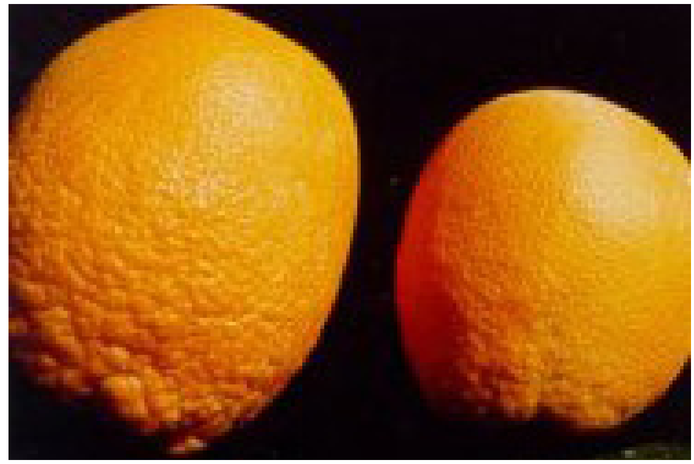

Figure 11. Symptoms of stubborn disease in citrus fruit. Note the small malformed fruit (right) taken from a diseased tree in comparison with a healthy fruit (left).

Field diagnosis of stubborn is difficult because many of the variable symptoms caused by stubborn may also be the result of freezing damage, insect infestations, wind, and improper irrigation or nutritional factors. Several laboratory tests are currently available for diagnosis. They include serological techniques (including ELISA) and indexing.

Situation in Arizona: The causal organism of stubborn, *Spiroplasma citri*, has been isolated from ten different cultivars of citrus in Arizona. Some naturally infected plants other than citrus include: wild turnip, *Brassica* sp; London rocket, *Sisymbrium irio*; *Zinnia* sp.; marigold, *Tagetes* spp.; *Viola* sp.; periwinkle, *Vinca rosa*; onion, *Allium cepa*; squash, *Cucurbita pepo*; *Plantago* and *Malva* sp. Two leafhoppers, *Circulifer tenellus* and *Scaphytopius nitridus* are vectors of the disease in the southwestern United States. Recent studies demonstrated that *Spiroplasma citri* reproduces in the sugarbeet leafhopper *C. tenellus*. The cells of *Spiroplasma citri* are injected into plants via salivary secretion during leafhopper feeding.

Causal agent: *Spiroplasma citri* is one of the few mycoplasma-like organisms that can be grown in laboratory media. The microscopic cells of the organism are wall-free, filamentous, motile or spiral-shaped. The organism can be cultured from infected tissue. Isolates from infected citrus in Arizona have been obtained by passing the sap of leaves, bark, and seed through small microbiological filters into specific media. *S. citri* was thought to be restricted to the southwestern United States but was identified in the early 1980s as the cause of brittle root of horseradish in Illinois and Maryland. This fact has prompted a reevaluation of the potential threat of this organism to non-citrus crops in areas far removed from the southwestern United States.

Control: Nursery trees should be propagated from Stubborn-free budwood. Infected trees should be removed from the orchard and replaced with healthy replants.

Nematode Diseases

Citrus nematode

More than 40 nematode species have been described worldwide on citrus. In Arizona, however, only one species, the citrus nematode, *Tylenchulus semipenetrans,* is important and damaging. This nematode has become of increasing importance since the withdrawal of the soil fumigant, DBCP, which was previously used as a post plant fumigant for control. The citrus nematode was first found infecting citrus in California in 1912. The nematode was described from Arizona in 1926. Today, the citrus nematode has been reported in all citrus producing regions of the world. Surveys made in the United States indicate that infestations of citrus areas range from approximately 50 to 60 percent in California and Florida to 90 percent in Texas and Arizona.

Symptoms: Symptom development depends on overall tree vigor. Infected trees growing under optimum conditions may appear healthy for many years. For this reason, the disease is often referred to as "slow-decline." Heavily infected root systems eventually cause a reduction in yield and quality of fruit. Trees in early stages of decline, however, may have relatively vigorous root systems. Above ground symptoms of nematode damage are non-specific. Root feeding and subsequent damage reduces the overall vigor of infected trees. Symptoms include leaf yellowing, sparse foliage, small, non-uniform fruit, and defoliated upper branches (Figure 12). Dieback is particularly noticeable in the upper portion of trees. Affected trees appear similar to stress conditions caused by *Phytophthora* root rot, poor nutrition, and inadequate irrigation. Tree decline, which depends upon care of the grove and overall tree vigor, may not occur for three to five years after heavy infection. Infected roots may appear coarse and dirty. Female nematodes are found in small groups on the root surface. Soil adheres to the gelatinous matrix in which eggs are embedded. Positive identification requires the extraction of the nematodes from soil samples taken in the feeder root zone between the trunk and the drip line of the tree. The nematodes may also be identified microscopically on infected roots in the laboratory.

Biology: The citrus nematode, an obligate parasite, reproduces only on living roots of host plants. Early researchers in Arizona proved that populations of nematodes in roots were highest in the early stages of tree decline and lowest in roots of declining trees. They found that nematode populations and root systems were almost in equilibrium. Low nematode populations in dead or dying root systems allowed new root development. New root development resulted in increased nematode populations. This repeating cycle, however, eventually resulted in tree decline. Four races or biotypes of the citrus nematode have been described worldwide. A "citrus" biotype has been described from populations of the nematode from Arizona. This biotype reproduces on *Citrus* spp. and on the hybrids "Carrizo" and "Troyer" citrange as well as on grape, olive, and persimmon.

Control: No chemicals are presently recommended for post-plant control of the citrus nematode.

Figure 12. Slow decline of citrus infected with citrus nematode.

Nonparastic Diseases

Major Nutrients

In general, citrus trees do not have to be fertilized heavily, but regular applications of nitrogen in one form or another are needed. Usually nitrogen is the only major nutrient required. Potassium and phosphorous generally are adequate in central Arizona soils, but all soils require nitrogen. On the Yuma Mesa, citrus has responded to phosphate applications.

Nitrogen deficiency, showing up as yellow-green leaves, normally develops over a period of two or four years on unfertilized trees but can be quickly corrected with proper fertilization.

Pale green leaves are normal in two situations. A heavy drop of old leaves normally occurs in March and April. Before leaf drop, nitrogen is removed from these leaves and migrates to new leaves, leaving old leaves pale green. Leaves on shoots produced on grapefruit during the summer and fall normally turn yellow in the winter, but regain their green color in the spring.

In southern Arizona, a mature grapefruit tree in good, healthy condition will need an annual application of one pound of actual nitrogen each year. Oranges and other mature citrus will require two pounds. Apply half of this in February and the remainder as a split application in May/August. Manure may be applied periodically in the fall, but should be supplemented with commercial fertilizer in the spring. On the sandy Yuma Mesa soils, an annual application of two to three pounds of actual nitrogen is needed for mature trees.

Nitrogen can be supplied to the soil in the form of animal manures, commercially prepared chemical fertilizers or a combination of the two. Commercial fertilizers are generally preferred because research indicates that excessive use of animal manure may induce iron chlorosis in citrus and increase salts.

Micronutrient deficiencies: The most common micronutrients that are deficient for normal citrus growth in Arizona are iron, zinc, and manganese. These elements are normally not needed before trees are three to five years old. Diagnosis of specific micronutrient deficiencies is dependant on the location of the symptoms on the tree, the pattern of leaf discoloration, and tissue analysis.

Iron: Iron chlorosis (yellow-white leaves with green veins) is common in Arizona because iron is less available for root uptake in our alkaline soils. Symptoms normally appear on young, rapidly growing leaves. Mild symptoms may disappear with aging of leaves. The entire young leaf appears yellow-green with exception of the tissue surrounding leaf veins which remain green.

Leaves may turn almost white with green tissue remaining only around the leaf veins. Lime induced iron chlorosis is a common nonparasitic disease in many plants grown in Arizona, including citrus. The disease is more common in home plantings than in commercial groves because ornamentals and lawns are often planted near citrus in back yard plantings. These nearby plants need frequent irrigation. Iron chlorosis in citrus is exacerbated by overwatering. Shallow-rooted ornamentals that require frequent watering should not be planted in tree basins. Grapefruit trees normally turn yellow during the winter months but re-green as new leaves appear in the spring. Do not apply iron to correct this "winter chlorosis" condition.

To correct iron chlorosis chemically, treat trees with iron sulfate or an iron chelate compound. Place iron sulfate in a shallow circular trench around the tree trunk or broadcast it around the entire tree basin from the trunk to outside the drip line, and apply four to six inches of water. An average-size tree requires 20 to 30 pounds of iron sulfate. When using iron chelate, apply according to label directions to the tree basin area and irrigate thoroughly.

Trees do not respond to chelate applications in winter but will respond well from April through September.

Zinc: Zinc is a common deficiency in Arizona. The symptoms appear, as with iron deficiency, on recently expanded, young leaves. A "mottle-leaf" pattern occurs in leaf tissue. Yellowing develops in areas between the leaf veins. Severe deficiency causes small leaves and short internodes. Defoliation and dieback may occur in stressed trees. Zinc deficiency is more of a problem on sandy soils or where manure has been frequently applied. Optimum leaf concentration is 25-100 ppm (parts per million) zinc. Deficiencies may be corrected by foliar or soil applications of zinc salts or zinc chelates.

Manganese: Deficiency symptoms also occur on young leaves. Symptoms overlap with those of iron deficiency. If leaf tissue concentration of manganese is below 25 ppm a foliar application of manganese sulfate may be helpful. Soil applications of manganese sulfate in our alkaline soils are less effective than foliar applications.

Environmental Factors

Water stress: A slight wilting of leaves indicates that a tree does not have enough water and irrigation is needed. New leaves show leaf rolling, the first sign of water stress. Long droughts may cause defoliation and dieback. In Arizona, hot dry winds may accentuate moisture stress and cause leaves to dry up on the tree. In young leaves, chlorosis may occur on the leaf blade between the midrib and the leaf margins. These chlorotic (yellowish) areas may later turn gray to light brown. This condition is referred to as "mesophyll collapse." Damage to surface roots by disking or plowing during water stress situations may accentuate this symptom.

Figure 13. Freeze damage in lemon. Young trees may be killed.

High daytime temperatures and dry winds may cause heavy leaf drying in October and November. Grapefruit trees seem most susceptible to this type of injury. In severe cases, small twigs may crack, gum and die. Adequate water during these hot windy periods is the only practical method of reducing injury.

Freezing damage: Freezing can damage both tree and fruit of all citrus varieties, but some are more sensitive than others (Figure 13). Limes and lemons are the most tender, oranges, and grapefruit are of intermediate hardiness, and mandarins are the most hardy. Older orange and grapefruit trees are quite tolerant to cold, and seldom need to be protected. The fruit is usually damaged when temperatures fall below 26°F for a period of several hours.

In the desert areas of Arizona, nighttime temperatures can drop below freezing from mid-November to late March, most often in December and January. In most areas of southern Arizona where citrus is grown, some type of frost protection is necessary from November through March during the first two or three years. Palm fronds give effective protection, but corn stalks also work well. Protect the trunk and main branches of young trees, leaving one-third of the leafy area exposed to sunlight and air, by placing and tying four to six fronds or 12 to 15 corn or sorghum stalks around the tree.

Young trees can be successfully protected from frost by running water under the tree during below-freezing hours, covering them with a large cardboard box, placing a burlap bag over the tree, or covering with cloth. Do not use plastic unless you build a frame to keep the plastic away from tree foliage. Plastic does not hold in much heat compared to other materials. Remove heavy cloth coverings after each frost period. Burlap may be left in place for the entire winter.

Figure 14. Sunburn damage on citrus fruit.

Hanging a light bulb in the branches on cold nights provides additional heat.

If a tree is frozen, do not prune frozen parts until new growth emerges in spring. After new growth begins, the exact portions killed by frost can be more clearly seen and pruned off.

Sunburn: Temperatures above 110°F usually burn some leaves and fruit (Figure 14) and may damage any exposed bark on young or old trees. Protect any exposed bark areas with tree wraps or white, water-base paint.

When lower branches or tops of old trees have been pruned, exposed bark usually is sunburned and may be killed. Fungal infection may follow and destroy larger areas. Such trees must be protected by painting trunks and scaffold limbs with whitewash or any white, water-base paint. Heavy paper tree protectors or cardboard should be applied to young trees after painting.

Leaf and Fruit Drop: Two conditions, leaf drop and fruit drop, are poorly understood problems in citrus. Leaf drop appears to be a normal phenomenon. Citrus is an evergreen plant and sheds leaves gradually throughout the year. Replacement of leaves occurs naturally. Leaf drop is heaviest during the spring months but occurs to some extent all year. Fruit drop may also be a normal physiological event. Only a small percentage of the blossoms on a tree develop into fruit. Although most of the developing fruits will drop soon after flower petal fall, some fruit will drop in later May and June. In most years, this June drop allows crop thinning. If it did not happen, the tree would break down under the load and fruit would be small and inferior.

The amount of June drop depends on variety. Seedless oranges have greater drop than ones with many seeds; tangerines with many seeds have a small amount of drop. Cross-pollination of Tangelo and Tangerine varieties causes many more seeds to develop and thus reduces the drop. With Valencia oranges and grapefruit, a heavy crop of mature fruit reduces the food supply to the young fruit and this increases the drop.

In some years, high temperatures in May help induce heavy drop. Maintaining an even watering schedule and adequate nutrient level for tree use will minimize small fruit drop in most varieties.

Salt Toxicity: Salinity is measured and reported in terms of EC (electrical conductivity) of a soil-saturation extract (ECe) or water (ECw). Citrus is moderately salt tolerant provided that levels of boron or lithium are not toxic.

The units of ECe measurement are mhos per centimeter (mhos/cm). A soil analysis report will usually contain a column for ECe x 103, the electrical conductivity of a saturation extract of the soil multiplied by 1000 and reported as mmhos/cm. The soil sample should be taken in the root zone. Water analysis will report ECw x 103. It is interesting to compare the sensitivity of citrus to some of the major crops grown in Arizona. Citrus is sensitive to soil salinity at ECe values in excess of 1.8. This sensitivity is similar to other crops grown in Arizona such as potatoes, corn, peppers, lettuce, grapes, almonds, and plums.

The threshold for salt damage in citrus is an ECe of 1.8 (approximately 1152 ppm total salts). At ECe 3.0 (approximately 1920 ppm salts) there is approximately a 20 percent reduction in yield. Symptoms of salt injury consist of irregular brown necrotic (dead) areas along the leaf margins and near the leaf tip. Defoliation, dieback, and fruit drop and yield reductions occur in acute cases. Excessive fertilization may cause these symptoms. Heavy irrigation may reduce salt concentrations. Most commonly these problems occur in backyard situations where frequent, light irrigations and soil water evaporation move salts into the upper root zone.

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