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Phytophthora Diseases of Citrus[1]

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Phytophthora spp. cause the most serious and economically important soilborne diseases of citrus in Florida. Tree and crop production losses occur from damping-off of seedlings in the seedbed, root and crown rot in nurseries, foot rot and fibrous root rot, and brown rot of fruit in groves. Foot rot results from infection of the bark near the ground level producing lesions on the trunk or crown roots that can girdle and kill the tree. *Phytophthora* spp. also attack and cause the decay of fibrous roots, especially on susceptible rootstocks in nurseries. In bearing groves, fibrous root rot damage causes tree decline and yield losses. *Phytophthora* spp. infect fruit causing brown rot that leads to fruit drop in the groves and postharvest decay. The most important species include *P. nicotianae* and *P. citrophthora*.

DISEASE SYMPTOMS

Damping-off

Damping-off can affect newly germinated seedlings of all citrus cultivars. Typical symptoms of damping-off result when the soil or seed-borne fungus penetrates the stem just above the soil line and causes the seedling to topple. *Phytophthora* spp. also

decay of fibrous roots.

cause seed rot or preemergence rot. Infected seedlings are killed rapidly when moisture is abundant and temperatures are favorable for fungal growth. Plants usually become resistant to damping-off once the true leaves have emerged and the stem tissue at the soil line has matured.

Foot Rot and Gummosis

The most serious diseases caused by *Phytophthora* spp. are foot rot and gummosis. Foot rot results from an infection of the scion (Plate 2, Plate 3) near the ground level, producing lesions which extend down to the budunion on resistant rootstocks. Scaffold root rot or crown rot (Plate 4, Plate 5, Plate 6) below ground may occur when

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susceptible rootstocks are used. Infected bark remains firm with small cracks through which abundant gum exudation occurs. Citrus gum, which is water-soluble, disappears after heavy rains but is persistent on the trunk under dry conditions. Lesions spread around the circumference of the trunk, slowly girdling the tree. Badly affected trees (Plate 7, Plate 8) have pale green leaves with yellow veins, a typical girdling effect. If the lesions cease to expand or the fungus dies, the affected area is surrounded by a callus tissue.

Plate 2.

Plate 3.

Plate 4.

Nursery trees and young orchard trees of small trunk circumference can be rapidly girdled and killed. Large trees may be killed likewise, but typically the trunks are partially girdled and the tree canopy undergoes defoliation, twig dieback, and short growth flushes. On susceptible rootstocks, lesions may occur on the crown roots below the soil line and symptoms

Plate 5.

Plate 6.

Plate 7.

Plate 8.

in the canopy develop without obvious damage to the trunk aboveground.

Fibrous Root Rot

Phytophthora spp. infect the root cortex and cause a decay of fibrous roots. The cortex turns soft, becomes somewhat discolored, and appears watersoaked. The fibrous roots slough their cortex leaving only the white thread-like stele, which gives the root system a stringy appearance.

Root rot can be especially severe on susceptible rootstocks in infested nursery soil. Root rot also occurs on susceptible rootstocks in bearing orchards where damage causes tree decline and yield losses. In advanced stages of decline, the production of new fibrous roots cannot keep pace with root death. The tree is unable to maintain adequate water and mineral uptake, and nutrient reserves in the root are depleted by the repeated fungal attacks. This results in the reduction of fruit size and production, loss of leaves, and twig dieback of the canopy.

Brown Rot of Fruit

Phytophthora infection of fruit produces a decay in which the affected area is light brown, leathery, and not sunken compared to the adjacent rind. White mycelium forms on the rind surface under humid conditions. In the orchard, fruit near the ground become infected when splashed with soil containing the fungus. If favorable conditions of optimum temperature (75-82°F) and long periods of wetting (18 plus hours) continue, the disease spreads to fruit throughout the canopy. Most of the infected fruit soon abscise, but those that are harvested may not show symptoms until after they have been held in storage a few days. If infected fruit is packed brown rot may spread to adjacent fruit in the container. In storage, infected fruit have a characteristic pungent, rancid odor. Brown rot epidemics are usually restricted to areas where rainfall coincides with the early stages of fruit maturity. All cultivars are affected, especially lemons.

CAUSAL ORGANISMS

The most widespread and important *Phytophthora* spp. are *P. nicotianae* and *P. citrophthora*. *P. nicotianae* is more common in subtropical areas of the world and causes foot rot and root rot, but usually does not infect far above the ground. Occasionally, *P. nicotianae* attacks aerial parts of the tree and is most commonly the cause of brown rot of fruit. *P. citrophthora* also causes brown rot but outbreaks during the fall and winter are restricted to cooler weather sites in coastal areas of Florida.

Disease Cycle

The disease cycle of *P. nicotianae* (Figure 2) and *P. citrophthora* begins with the production of sporangia which release large numbers of zoospores. *P. nicotianae* produces chlamydospores in abundance while most isolates of *P. citrophthora* do not. *P. citrophthora* rarely produces oospores, whereas *P. nicotianae* commonly produces oospores. With time and appropriate conditions zoospores encyst and germinate to form mycelia. The optimum temperature for mycelial growth are 86°-90°F for *P*. nicotianae and 75°-82°F for *P. citrophthora*.

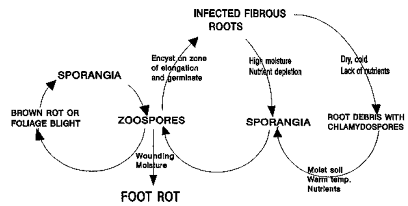


Figure 3.

Sporangial production by *P*. nicotianae and *P. citrophthora* is favored by small deficits in matric water potential (=-5 to -70 KPa), but not by saturated conditions (=0) unless sporangia are produced on citrus root pieces. The optimal for sporangium formation probably represents a compromise between requirements for free water and aeration. Nutrition depletion and light also stimulate sporangial production from mycelium.

Indirect germination of sporangia to produce zoospores requires free water and is stimulated by a drop in temperature. Under moist conditions sporangia may also germinate directly by growth of germ tubes, but the correlation between soil saturation and severity of Phytophthora root rot suggests that indirect germination is more important in the root disease cycle.

Chlamydospore production by *P. nicotianae* occurs under unfavorable conditions for fungal growth, ie. nutrient depletion, and low oxygen levels and temperatures (59-64°F). Water requirements for germination of chlamydospores are similar to those for sporangia. Chlamydospores of *P. nicotianae* appear to become dormant below 59°F, so exposure to temperatures of 82-90°F is used to stimulate germination. Nutrients that are acquired from soil extracts and excised citrus roots are known to stimulate chlamydospore germination.

The requirements for oospore germination are thought to be nearly identical to those of chlamydospores. Oospore maturation appears to be an important factor in germinability of *Phytophthora* spp. Periods of alternating high and low temperatures may also be a prerequisite for uniform germination.

Soil and Environmental Factors

Phytophthora spp. are parasites but are poor competitive saprophytes (an organism that lives off any dead or decaying organic matter) in soil. The fungus grows well on nutrients obtained from the living plant and, under favorable conditions, undergoes repeated cycles of mycelium to sporangia, zoospores, and more mycelium. *P. nicotianae* (Figure 1) is most active during the warmer seasons of the year and forms chlamydospores and oospores for survival during unfavorable periods. *P. citrophthora* is active during cooler periods and is believed to survive as resistant sporangia and possibly chlamydospores and oospores. Because less is known about the life cycle of *P. citrophthora* discussion of the spore forms in relation to soil environmental factors will be limited to *P. nicotianae*.

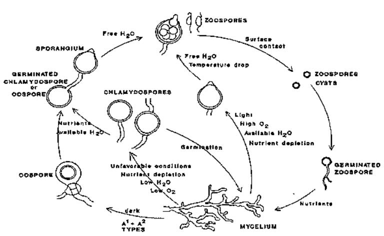


Figure 1.

Chlamydospores of *P. nicotianae* may form when soil moisture is limiting, conditions are cool or where the host roots are not actively growing and producing susceptible tissue. Formation of chlamydospores may also be stimulated by poor aeration and high carbon dioxide concentrations in the soil atmosphere. Chlamydospores can survive several months under unfavorable conditions.

Optimal germination of chlamydospores occurs in well-aerated, moist environments when temperatures are favorable for root growth. Chlamydospores require nutrients in the form of root exudates for germination. Oospores which occur in low numbers, are thick walled and probably resistant to desiccation and cold temperature. They may mature more slowly than chlamydospores, but once matured they germinate in response to nutrients from roots. Oospores form when the opposite mating types are present, which may occur infrequently in some citrus soils. Thus, the importance of oospores in the disease cycle is not known, except that they provide new sources of variation in the population when sexual recombination occurs between the different mating types.

Under well-aerated, moist conditions, chlamydospores and oospores can germinate immediately to form a sporangium that liberates zoospores. Zoospore release for *Phytophthora* spp. is optimal in saturated soils. Diurnal soil temperature changes may serve to synchronize zoospore release. Zoospores are motile and can swim short distances by flagellar movement or can be carried long distances by soil water. Zoospores are attracted to roots and swim to the root and encyst upon contact. Zoospore cysts then germinate and penetrate the root cortex.

Soil Moisture

Host susceptibility is affected when roots are stressed or damaged in saturated or in dry soil. Root exudates released by living, but damaged or stressed roots attract zoospores. Soils with drainage restricted by hardpans or clay layers or those with shallow water tables that temporarily rise into the root zone provide ideal conditions for fibrous root infection and rapid buildup of Phytophthora propagules. Also, the frequency and duration of irrigations can influence fungal activity and predispose roots to rot. If soils become saturated during an irrigation zoospores are released which can then infect roots to form more sporangia. When soils do not dry sufficiently between irrigations sporangia can survive until the next irrigation and zoospores will be released again. Citrus roots do not grow in saturated soil due to low oxygen availability. Thus, new roots will not develop if the soil is not allowed to adequately dry between irrigations.

Soil Aeration

Oxygen availability in the soil is closely related to soil moisture because the amount of pore space occupied by water directly determines the remaining pore space occupied by air. When roots are subjected to low oxygen (anoxia), they are damaged by reduced forms of minerals and by toxic metabolites produced by microorganisms on the roots themselves. Root regeneration is restricted and root exudation increases under flooded conditions. Prolonged oxygen deprivation makes roots more attractive to zoospores and increases infection. Moreover, chronic anoxia due to flooding of the root system will in itself damage roots even in the absence of *Phytophthora*.

Soil Temperature

Populations of *P. nicotianae* do not drop significantly in Florida because soil temperatures rarely fall below 59°F. In Florida, the increase in *P. nicotianae* populations coincides with a spring flush of roots that occurs when soil temperatures rise above 68-73°F. This population response is probably not temperature dependent, but due to the greater abundance of roots available for infection.

Resistance

Trunk Resistance

Although most commonly planted scion cultivars are susceptible to bark infection, most rootstocks are at least moderately tolerant. Nevertheless, rootstocks vary in their susceptibility to diseases caused by *Phytophthora* (Table 1). Although the use of resistant rootstocks is the best solution for control of Phytophthora disease, some highly resistant rootstocks are susceptible to other diseases or are horticulturally unacceptable. Furthermore, there is not always a good correlation between tolerance to foot rot and to root rot. For example, Carrizo citrange and sour orange are tolerant to foot rot, yet are susceptible to root rot. The mechanisms of resistance of different citrus tissues to *Phytophthora* are poorly understood. Because of the great differences in the type of tissue affected and the response of different citrus species to infection, there is probably more than one resistant and/or tolerance mechanism involved.

Little is known about the host specificity of *P. nicotianae* and *P. citrophthora* and the relative aggressiveness of different isolates within each species. *P. nicotianae* has a broad host range. The virulence of *P. nicotianae* isolates from tomato and other noncitrus hosts toward citrus is low, but all isolates of *P. nicotianae* are pathogenic on tomato. Aggressiveness of *P. nicotianae* on sweet orange seedlings varies widely, but that does not appear to be the case for *P. citrophthora*.

Root Rot Resistance

Quantitative evaluations of root rot susceptibility has indicated trifoliate orange and Swingle citrumelo as tolerant, and a wide range of rootstocks that are susceptible, including sour orange, Carrizo citrange, Cleopatra mandarin, Ridge Pineapple sweet orange and Volkamer lemon. This classification of rootstocks generally agrees with the results of zoospore inoculation tests except that Carrizo citrange and sour orange, which are usually considered moderately tolerant, are grouped with sweet orange and Cleopatra mandarin as susceptible. The field tolerance of Carrizo citrange and sour orange to foot rot confirms that there is not necessarily a correspondence between root rot tolerance and foot rot resistance. However, trifoliate orange and Swingle citrumelo are both tolerant to root rot and resistant to stem infection.

Trifoliate orange and Swingle citrumelo, a hybrid of trifoliate orange, have the ability to regenerate roots in the presence of *P. nicotianae*. Their roots are not immune to infection because they support populations of *P. nicotianae* in greenhouse and field soils, but these populations are lower than on susceptible rootstocks. Tolerant rootstocks apparently have the ability to grow new roots subtending infected root tips. The resistance factors that limit infection to the root tip are not known but may be related to coumarin phytoalexins found in woody tissue of citrus infected with *P. citrophthora*.

EPIDEMIOLOGY

Phytophthora spp. are already widespread in most citrus groves. Thus, in many situations, we are dealing with a naturally occurring (endemic) pathogen rather than a newly introduced (epidemic) situation existing in virgin soils, where *Phytophthora* is introduced with trees from the nursery.

Fungal populations in the soil are maintained by repeated infection of the fibrous roots. Under favorable conditions of high moisture and temperature infected roots produce sporangia which in turn release motile zoospores. Zoospores are attracted to the zone of elongation of new roots by nutrients in exudations. Upon contact with the root zoospores encyst, germinate and then infect in the area of the zone of root elongation. Once the fungus has entered the root tip the infection may advance in the cortex resulting in rot of the entire rootlet. The cycle can repeat itself as long as conditions are favorable and susceptible tissue is available. In the case of *P. nicotianae*, the fungus most likely survives unfavorable periods in root debris. The rotted cortex is sloughed and the fungus produces chlamydospores which may persist in the soil for long periods. When favorable conditions return chlamydospores germinate indirectly to produce sporangia and zoospores or directly to produce mycelium. When both mating types are present oospores may also be produced which aid survival of the fungus. With *P. citrophthora*, which often does not produce chlamydospores or oospores, the mechanism of survival is uncertain. However, both species may be able to persist as mycelium in infected, living roots or as sporangia.

Foot rot or gummosis of the trunk occurs when zoospores or other propagules are splashed onto the trunk above the bud union. A wound and moisture on or around the base of the trunk are necessary for infection. Wounds are susceptible to infection for up to 14 days. Foot rot lesions do not usually produce inoculum for subsequent infections and, thus, are of no epidemiologic significance.

Even though *Phytophthora* spp. in citrus are usually present, epidemics can develop in certain cases. When *Phytophthora* spp. are first introduced into a grove or nursery spread to other plants may be epidemic. However, epidemics of foliage blight and brown rot are much more common, especially on highly susceptible hosts such as lemons. When conditions are favorable, fruit and young foliage may become infected by propagules splashed from the soil. Secondary infections may then be caused by inoculum from the above-ground parts of the plant which is dispersed by rain splash or wind-blown rain. This seldom occurs with *P. nicotianae* which does not readily produce aerial sporangia, but is more common in *P. citrophthora* and other species which produce abundant sporangia on fruit and leaf surfaces. Brown rot is most common in areas where these species are present and when prolonged winter rains occur.

MEANS OF SPREAD

The primary means by which *Phytophthora* spp. are spread through citrus orchards is by use of infested nursery stock. The pathogen may be present in soil or infected roots even though disease symptoms are not readily apparent. The fungus is also carried in soil on equipment when vehicles move from infested to non-infested groves or nurseries. Propagule densities decline sharply when soil is air-dried, reducing the probability of spread.

Irrigation water may also move the pathogen from area to area. Within groves, dispersal by irrigation water occurs especially where furrow or flood irrigation is used. Surface water following heavy rains may carry the fungus as it drains from the grove. More serious problems can arise in irrigated citrus areas where run-off water carries the pathogen into canals, or ponds. Use of water from these sources may then contaminate previously noninfested areas.

Wind is not a major factor in dispersal of *Phytophthora* spp. However, wind-borne soil carries *Phytophthora* spp. and may recontaminate fumigated soils. Windblown rain can disseminate sporangia produced on the surface of aboveground plant parts.

DETECTION METHODS

For disease management purposes, it is frequently desirable to know whether *Phytophthora* spp. are present and, if so, at what level. Fruit and leaf baiting methods were developed many years ago for detection of *Phytophthora* spp. These are usually considered qualitative tests, but propagule densities can be quantitated by use of more complex techniques. They are relatively simple and require minimal equipment and supplies.

Subsequently, media have been developed for the selective isolation of *Phytophthora* spp. from soil to determine propagule densities. Methods for sample collection and handling have been developed. Propagule densities are highest where fibrous root densities are greatest. Thus, populations diminish with depth and with distance from the tree.

It is also important to recognize that Phytophthora populations are not uniform across the orchard. Spatial distribution studies in Florida indicate a more random distribution of the fungus in a grove. For routine propagule density determinations, samples should be collected at random in the orchard. About 20-40 composite soil cores per 10 acre grove provide a reliable estimate of the propagule density when populations are moderate to high. Propagule densities vary considerably between sample times and populations may show seasonal trends of abundance.

Genus specific polyclonal and monoclonal antibodies have been produced against *Phytophthora*. Diagnostic kits using enzyme-linked immunosorbent assay (ELISA) have been developed for detection of *Phytophthora* spp. in roots and in soil debris. The ELISA method is highly sensitive and can detect the presence of *Phytophthora* at lower population densities than dilution plating onto selective media. Theoretically, the tissue baiting and the ELISA soil assay should be the most sensitive since they utilize larger volumes of soil. However, in one study the leaf baiting and selective media were about equally sensitive.

Although it is possible to quantify *Phytophthora* spp. populations, the significance of those populations remains to be determined. Populations may vary considerably during a season suggesting a need to sample repeatedly through the year as well as from year to year. Propagule densities in most Florida groves range from 1-20 propagules/cm^3, but occasionally range as high as 100-200 propagules/cm^3. Threshold densities have not been established, but populations of less than 5 propagules/cm^3 have been considered insignificant. Increases in fibrous root densities and, in some cases, yield have been observed following fungicide treatment of orchards with 10 propagules/cm^3 or higher.

DISEASE MANAGEMENT

Nurseries

Ideally, citrus nurseries should be maintained free of *Phytophthora* spp. to avoid moving the fungus into the orchard. Citrus seed should be treated at 122°F for 10 minutes prior to nursery planting to avoid fungus introduction. Previously, seed was planted in raised beds in a field nursery and consequently many problems occurred due to the damping-off of seedlings by *Phytophthora* spp. Seed planted into sterilized, soilless media in greenhouse containers will eliminate most Phytophthora problems at the seedbed stage.

Optimally, the site selected for a field nursery or seedbed should be a virgin site and located at some distance from existing plantings free of *P. nicotianae*. If sites must be used repeatedly for citrus nurseries, they should be fumigated, especially if disease problems have been observed in previous crops. Preplant application of methyl bromide at 446-535 lb/a or metam-sodium at 45 gal/a will reduce pathogen populations substantially and, in some cases, eliminate these fungi completely. However, fumigation eliminates beneficial mycorrhizal fungi and may result in stunting of seedlings due to poor uptake of phosphorus, zinc and copper. This problem may be partially overcome by adjusting the fertilization program. Trifoliate orange and its hybrids are generally less susceptible to fumigation-induced stunting than sour orange, Cleopatra mandarin and other rootstock species.

stunting of seedlings.

Field nurseries and greenhouse production facilities can be maintained free of *Phytophthora* spp. by following certain sanitary practices. Plant material from sources not known to be free of *Phytophthora* spp. should not be introduced into clean facilities. Implements, machinery and personnel which have been in the grove should not enter nursery facilities. Care must be taken not to allow run-off water from contaminated areas to enter Phytophthora-free zones. If portions of nurseries become infested, trees may be destroyed and the site fumigated if the area is small. If not destroyed, they should be isolated from other areas of the nursery and no traffic should be allowed between clean and infested areas.

The systemic fungicides metalaxyl and fosetyl-Al are highly effective against *Phytophthora* spp. and provide effective field disease control (see the *Florida Citrus Pest Management Guide*: Phytophthora Foot Rot and Root Rot). However, they are often used routinely by nurserymen to suppress Phytophthora populations and reduce root damage in nursery stock. If these materials are routinely used they should be alternated so as to minimize the risk of developing fungicide resistant Phytophthora populations. It should also be recognized that application of fungicides to Phytophthora-free nurseries is not necessary. In infested nurseries, fungicides may suppress populations temporarily, but populations may rise sharply after nursery trees are transplanted to the orchard. Phytophthora-free stock should be used when planting sites not previously used for citrus. However, infested trees with only minor root loss can be used when replanting orchards with existing populations of the fungus.

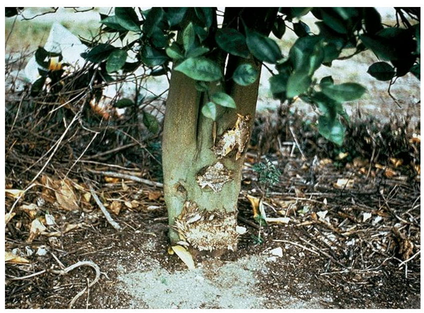
Control of Foot Rot in Young Groves

Most of the rootstocks used commercially for citrus are tolerant to bark infection by *Phytophthora* spp. However, in groves with a previous history of foot rot replanting with Swingle citrumelo should be considered. Swingle citrumelo is resistant to foot rot and roots do not support damaging populations of *P. nicotianae* in established trees. Use of Cleopatra mandarin should be avoided since it is prone to develop foot rot when roots are infected in the nursery and planted in fine-textured flatwood soils with high water tables.

The majority of foot rot problems can be solved by manipulation of cultural practices. For example, fallowing of the planting site for 6-12 months will not only effectively reduce Phytophtora populations but also those of other soilborne pests such as citrus nematode. In new plantings on virgin soils only Phytophthora-free trees should be used. Although undesirable, Phytophtora-infected trees may be suitable for replanting within existing groves.

Only trees which have been inspected for proper budding height (4 to 6 inches above soil line) and freedom of obvious root rot or taproot lesions should be used. Trees should then be planted so that the budunion remains well above the soil line since the bark of all commercially available scion varieties are susceptible to foot rot (particularly sweet orange, grapefruit, and lemons) and burial of budunions allows direct contact of bark with infested soil.

Once the trees are planted the soil surface under the tree must be kept clean and dry. Injuries to the trunk bark must be avoided since they provide entry points for infection. Use of herbicides in citrus groves has helped reduce foot rot damage by reducing humid conditions under the trees and by eliminating wounds produced by hoes, mowers, and other implements.



Injuries to the trunk bark.

Water-absorbent trunk wraps used for freeze protection often create conditions highly favorable for foot rot development. These wraps also serve as ideal nesting sites for fire ants which not only damage the bark but also provide points of entry for *Phytophthora*. By removing trunk wraps or soil banks when not needed for freeze protection Phytophthora problems, and those from ants, can be reduced. This is especially true when irrigation wets the trunk area for long periods or when young trees are overwatered due to frequent irrigations.

Oftentimes, foot rot damage can also be reduced by redirecting sprinklers so that the trunk remains dry and by irrigating during morning hours so that the bark has opportunity to dry during the day. In some situations, improvement of surface drainage to eliminate standing water is helpful in minimizing damage.

Even when appropriate cultural practices are used foot rot may remain a potentially serious problem thereby requiring some form of preplant or postplant fungicide treatment. For example, preplant fumigants should be considered, particularly when the planting site has a combined history of problems with *Phytophthora*, citrus nematode, root sprouting and weeds. Likewise, use of postplant fungicides in young groves should be based on rootstock susceptibility, likelihood of Phytophthora infestation in the nursery, and history of Phytophthora disease problems at the grove site. For susceptible rootstocks such as Cleopatra mandarin and sweet orange, fungicides may be applied to young trees on a preventive basis. For other rootstocks, fungicide treatments should commence only after foot rot lesions develop.

In previous years, foot rot lesions were treated by carving out infected bark tissue and painting the wound with copper fungicides. However, this procedure has never been highly successful and is laborious and time-consuming. With the introduction of the systemic fungicides metalaxyl and fosetyl-Al curative treatments are much more feasible. Trunk paints and sprays with systemic fungicides have been shown to be highly effective without the surgical treatments.

Trunk applications of systemic fungicides as well as copper fungicides can be highly effective preventive treatments and a single application can last for many months (see the *Florida Citrus Pest Management Guide*: Phytophthora Foot Rot and Root Rot). It should be recognized, however, that once a fungicide program is initiated it should be continued for at least 1 year for tolerant rootstocks, but may be continued beyond for susceptible stocks if necessary. Where foot rot incidence is high, it may be necessary to use fosetyl-Al to protect remaining healthy trees. Either fungicide may be applied through a microsprinkler irrigation system. Foliar or soil surface applications are less effective against foot rot.

Control of Root Rot in Mature Groves

Once a grove matures and begins to bear a regular crop of fruit foot rot usually ceases to be a serious problem. Loss of fibrous roots due to Phytophthora infection may still produce mild tree decline and reduced yields.

Prior to the development of the systemic fungicides it was not possible to determine the importance of fibrous root loss due to Phytophthora infection on mature trees. Application of fungicides has routinely increased fibrous root densities from 20-40%, and in some cases increases of 100% have been observed. Thus, it may be necessary to control *Phytophthora* in a grove with high populations even on tolerant rootstocks to maximize yields. Fibrous root losses and Phytophthora populations may be reduced by installation of tile drainage or improvement of surface drainage. Regular foliar applications of fosetyl-Al and soil applications of metalaxyl may reduce fibrous root rot severity but increased yield and fruit size has not always been consistently demonstrated.

In mature groves, fungicide applications should be based on yearly soil sampling to indicate whether damaging populations of Phytophthora occur in successive growing seasons. Once initiated, a fungicide program should be continued for at least 3 years and seasonal applications made during periods of susceptible root flushes in the spring (after the spring leaf flush) and fall (October to November). Soil application methods with either fungicide shouldbe targeted to areas of highest fibrous root density. Fosetyl-Al and metalaxyl can be highly effective for root rot control when applied at recommended rates so alternation of materials should be considered to minimize the risk of fungicide resistance.

Brown Rot and Canopy Blight

Where *P. nicotianae* is the primary species present, these diseases are seldom of much importance. Only occasional losses of fruit near the soil are incurred. However, where *P. citrophthora* and other species occur in rainy areas, these diseases may be severe. Usually, the primary problem is loss of fruit to brown rot which may continue to develop and spread in packing boxes during storage and transport. Leaf and twig blight are seldom serious, but if the fungus infects large branches, cankers may be formed and entire branches may be girdled, especially on highly susceptible species such as lemons.

Sometimes brown rot losses can be reduced by changing from overhead to under tree sprinklers for irrigation. However, most of the problem stems from fall and winter rains and fungicides must be applied. Copper fungicides applied prior to the beginning of the rains are effective. Preharvest applications of the systemic fungicide fosetyl-Al to the canopy provide effective control of brown rot preharvest and postharvest. Most of the standard postharvest fungicides used in packinghouses are ineffective against brown rot, but the systemic fungicides control the disease.

Table 1.

Cultivars	Response
Scions	
Lemons, limes, sweet oranges, grapefruit	Very Susceptible
Mandarins, tangerines and their hybrids	Susceptible
Rootstocks	
Trifoliate orange, Swingle citrumelo	Resistant
Sour orange, *Citrus macrophylla*	Moderately resistant
Cleopatra mandarin, Troyer and Carrizo citrange, most rough lemon selections, Rangpur, Volkamer lemon	Tolerant
Sweet orange, some rough lemon selections	Susceptible