Overview: Phytophthora brown rot is a fruit disease of citrus fruit that is caused by several species of fungal-like organisms in the genus *Phytophthora*, including *P. citrophthora*, *P. syringae*, *P. hibernalis*, and *P. parasitica*. These species can also cause root rot, foot rot, and gummosis of citrus. Brown rot develops mainly on fruit growing near the ground. Symptoms include olive-brown discoloration of the rind and a distinctive, pungent, aromatic odor of the fruit. Infectious propagules of the pathogen depend on water and temperature but for any one species, temperature requirements and length of continuous wetness periods are the most important predictors of brown rot epidemics. Damage of citrus fruits from the disease may occur especially in the winter in many citrus-growing areas of California.

Observations and research have indicated that:

- *Phytophthora* species are present in all citrus growing areas in California.
- *Phytophthora syringae*, a quarantine pathogen, and some other *Phytophthora* species are only active during the cooler months of the year.
- The soil/root and fruit disease phases of the pathogens are connected; thus, brown rot management also requires root rot management.
- The *Phytophthora* pathogens can infect healthy tissue and do not need injuries for infection.
- At 20°C the pathogens require approximately 18 h to 24 h of wetness to form sporangia that produce the infectious propagules, the zoospores.
- Wetness (from rain or irrigation) during cool weather is the most important environmental factor determining disease outbreaks.
- Disease develops on mature or nearly mature fruit and mainly on fruit near the ground where spores from the soil are splashed onto the tree.
- Symptoms develop after 6 to 28 days, depending on the temperature and species involved.
- Harvested fruit may be symptomless and disease develops during shipment and storage.
- Detection of brown rot and differentiation of the four pathogens can be done by culturing the organism, or more rapidly, by molecular PCR-based methods using species-specific primers.
- Effective registered preharvest and postharvest fungicide treatments are available and new compounds have been identified and are being developed for use in California.

I) Management of the disease: Efficacy of preharvest cultural practices and pre- and postharvest chemical treatments is cumulative and warrants a “systems approach” for control of Phytophthora brown rot of citrus.

A) Cultural practices:

1) Planting scions on resistant rootstocks (from UC Publ. No. 21477). Ratings for root rot:
   - **Orange**: Sweet - susceptible, Sour - intermediate, Trifoliate hybrids - intermediate (e.g. Carrizo, Troyer) to tolerant (C-35, C-32, Swingle), and trifoliate - tolerant
   - **Mandarine**: Cleopatra and Rangpur - susceptible
   - **Lemon**: Volkameriana – rough lemon - susceptible, Macrophylla and Yuma ponderosa - tolerant

2) Planting on berms for adequate drainage.

3) Removal of lower branches or “skirt pruning” by mechanical or manual methods to remove any fruit exposed to water splashing from the soil surface that might carry
inoculum of Phytophthora spp. from rainfall or sprinkler irrigation events. This practice should be utilized and maintained over the course of the year.

4) Adjusting irrigation systems to minimize water splashing onto lower fruit and avoid excess soil moisture (long irrigation sets).

5) Fruit planned for export to China should be harvested above 50 cm from the ground. This can be done in the field using various measuring methods such as marking ladders, hanging ribbons, or other types of measures. Growers should have a system in place to prevent mixing of fruit from 50 cm and below from fruit above 50 cm.

B) Fungicide treatments for direct application to fruit or soil surface for brown rot control:

1) Fungicide treatments can protect fruit from infection by Phytophthora spp. Foliar treatments should be applied to the lower half of the tree. When rainfall is excessive, multiple treatments may have to be applied during the harvest season (e.g., January, February, March, etc.). Spraying the ground underneath the trees with systemic fungicides such as mefenoxam (e.g., Ridomil Gold) also reduces brown rot infections.

2) The first protective fungicide application must be a registered copper compound. The application is mandatory and must be done after the first rain to all citrus planned for exportation to China. Historically, this application is made between October 15 and November 30.

3) Possibly, second and third applications may be needed and will be based on rainfall and temperature conditions experienced in each county. Industry-wide forecasting of favorable conditions for brown rot is planned for the main citrus growing regions (Fresno, Tulare, and Kern Co.) (see below).

4) Registered fungicides include fixed coppers (e.g., basic copper sulfate, copper hydroxides, copper oxides, copper oxychloride/copper hydroxide mixtures), Bordeaux mixtures including copper sulfate-lime or zinc sulfate-copper sulfate-lime mixtures, and mefenoxam (this latter fungicide is used as a soil treatment) can be used. Foliar and fruit applications of phosphonate fungicides (fosetyl-Al, potassium phosphite) and fertilizers containing phosphorus acid or phosphate salts should not be used because MRLs are not established in China.

5) Foliar applications of copper sprays are effective for approximately 6 weeks. New fungicides with much longer persistence are in development.

6) Pesticide Use Reports should be available if needed by regulators.

C) Specific details for fungicide treatments:

**Zinc-copper-lime treatments:** When using zinc sulfate (neutral and acidic forms) and copper hydroxide, copper oxide, or basic copper sulfate (i.e., fixed or basic coppers), the rate of metallic zinc equivalent (mze) should be a minimum of 2.5 lb mze per acre (Table 1). The rate of metallic copper equivalent (mce) per acre should be a minimum of 1.65 lb mce per acre. A minimum of 2 lb hydrated lime should be added when using 1.65 lb copper (mce) and a minimum of 4 lbs hydrated lime when using 3 lb copper (mce) per acre. The material should be applied as a dilute application of no less than 200 gallons per acre.

Higher rates of zinc, copper, and lime may be used as local conditions warrant or if higher disease levels were experienced last season.
Good Agricultural Practices (GAPs) for the Management of Phytophthora Brown Rot of Citrus in California

Bordeaux sprays: If zinc-copper Bordeaux applications are used, 3.3 lb metallic zinc, 1.65-2.45 lb metallic copper, and 20-67 lb hydrated lime per acre in dilute application of no less than 200 gal/acre will meet the minimum requirement.

Registered alternative fungicides Mefenoxam (e.g., Ridomil Gold) should be applied to the soil surface under trees (see label). MRLs have been established in many countries, however, some countries do not have MRLs established for these fungicides. Please check with the export country before making pre-harvest fungicide treatment/application decisions.

3) The mix order for preparing Bordeaux or zinc-copper-lime treatments: first add zinc, then copper, followed by lime.

4) Spray requirements for young trees (6 years old or younger). If the trees have been planted less than or equal to six years ago, applications should be done to the lower part of the tree at 100 gallons/acre. Use the lower rates according to the fungicide label.

5) The spray should cover the lower half of the tree. Skirt sprays are not acceptable. All active ingredients in the spray mix (i.e., zinc, copper, and lime) are required to be reported to the county.

D) Timing of additional fungicide applications based on environmental conditions and copper residues –

1) Timing of additional fungicide applications (e.g., second and third fungicide treatments) will be based on the duration of wetness periods at selected temperatures after copper residues are significantly depleted. A model for copper persistence based on rainfall and time after application is being developed for the timing of additional fungicide treatments after the mandatory first application (e.g., copper). This model is based on a model used in Florida (http://edis.ifas.ufl.edu/pp289) and is shown in Fig. 1.

2) A preliminary empirical forecasting model that provides a numerical risk based on published cardinal temperatures (i.e., minimum, optimum, and maximum temperatures) and wetness periods for growth and sporulation of \( P. \ syringae \) is as follows (Fig. 2):

![Fig. 1. Agroclimate - Citrus Copper Application Scheduler (A) and overview (B). Weather station or uploaded weather data (C) can be used for different citrus crops with their bloom date (D). Application attributes are entered for dates of application, amount of copper, volume of application (E).](image-url)
**Good Agricultural Practices (GAPs) for the Management of Phytophthora Brown Rot of Citrus in California**

### Fig. 2. Preliminary numerical risk model for forecasting brown rot caused by *Phytophthora syringae* based on cardinal temperatures and wetness periods for growth.

<table>
<thead>
<tr>
<th>Temperature range (°F)</th>
<th>Temperature range (°C)</th>
<th>&lt;10</th>
<th>10-18</th>
<th>18-25</th>
<th>&gt;25</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤41</td>
<td>≤5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt;41-50</td>
<td>5-10</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&gt;50-68</td>
<td>&gt;10-20</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
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<tr>
<td>&gt;68-77</td>
<td>&gt;20-25</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&gt;77</td>
<td>&gt;25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**II) Monitoring guidelines:**

A) All grower lots must be evaluated by field scouting. Fruit samples with symptoms described above can be identified in the field.

Risk assessment should be based on scouting of orchards:

**Risk categories are as follows:**

- Low risk: <10 fruit with brown rot per acre (Can be shipped to China)
- Moderate risk: 10-20 fruit with brown rot per acre (Caution in shipping to China)
- High risk: >20 fruit with brown rot per acre (Ship to other markets)

B) Monitoring frequency: Fields should be monitored monthly or within 14 days after every major rainfall, and one week before each harvest.

**III) Postharvest Management Guidelines:**

A. Fruit treatments – Potassium phosphite has been registered for postharvest use on domestic fruit and for countries that have MRLs for postharvest usage. China is currently registering potassium phosphite for postharvest use. **At this time, fruit should NOT be treated with a postharvest packing line treatment of potassium phosphite or other phosphonate fungicide.** Fruit treated with this fungicide are not acceptable for export to China at this time.

B. Fruit may be treated with registered postharvest fungicides for the management of green and blue mold (Penicillium decays). Aqueous treatments of imazalil (e.g., Fungazal, Deccoci, Freshgard, etc.), pyrimethanil (Penbotec), sodium bicarbonate, TBZ (Alumni), or other registered fungicide with approved MRLs in China should be applied prior to a fruit coating or wax. Fungicides may also be applied in a fruit coating and may include either imazalil, pyrimethanil, and/or TBZ. **Note: Currently, MRLs for azoxystrobin and fludioxonil have not been established in China.**

C. **Grading - All fruit destined for China should be graded.**

1. Fruit found with symptoms of brown rot should be identified and reported to packinghouse managers. If any brown rot decayed fruit are found at this stage, the fruit lot should be considered for other export markets.

2. Remove any other types of decay found during grading.

D. **Phytosanitary inspection prior to export –**

1. APHIS will apply a 0% tolerance for any type of decay during inspection.
2. Any grower lot in a shipment displaying decay of any kind (brown rot, green mold, sour rot, etc.) will be rejected and not certified for the Chinese market.

3. All fruit lots that pass inspection shall be provided with a Phytosanitary Certificate and state the additional declaration: “This shipment complies with ‘The Protocol of Phytosanitary Requirements of California Citrus exported to China’ and ‘Supplementary Inspection and Quarantine Requirements for California Citrus to be Exported to China’.”

E. Fruit Storage – Recommendations for fruit destined for the China market are as follows:

1. Fruit should be stored at the lowest temperature recommended for each citrus species for example, oranges at 3-9°C (37-48°F) and lemons 10-13°C (50-55°F).

2. Fruit should not be stored more than one week following packing.

3. Packed fruit destined for China Export should be stored separate from domestic or other Export shipments to avoid mixing of the load.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>First Application 2014-15 Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc-Copper-Lime Applications</td>
<td>Fixed coppers (e.g., copper hydroxide and copper oxide)</td>
</tr>
<tr>
<td>Application Volume</td>
<td>Metallic Zinc/100 gal</td>
</tr>
<tr>
<td>200 gal/A</td>
<td>1.25-2 lb</td>
</tr>
<tr>
<td>400 gal/A</td>
<td>0.63-1 lb</td>
</tr>
<tr>
<td>600 gal/A</td>
<td>0.42-0.67 lb</td>
</tr>
<tr>
<td>Total* lb/A</td>
<td>2.5-4</td>
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</table>

* - If brown rot was observed in a grower lot last season, use a higher rate of each spray component within the range provided.

** - Note that other fungicides can be used in rotation with copper.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>First Application 2014-15 Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc-Copper Bordeaux Applications</td>
<td>(Zinc monohydrate + Copper pentasulfate)</td>
</tr>
<tr>
<td>Application Volume</td>
<td>Metallic Zinc/100 gal</td>
</tr>
<tr>
<td>200 gal/A</td>
<td>1.65 lb</td>
</tr>
<tr>
<td>400 gal/A</td>
<td>0.83 lb</td>
</tr>
<tr>
<td>600 gal/A</td>
<td>0.55 lb</td>
</tr>
<tr>
<td>Total* lb/A</td>
<td>3.3</td>
</tr>
</tbody>
</table>

* - If brown rot was observed in a grower lot last season, use a higher rate of each spray component within the range provided.

** - Note that other fungicides can be used in rotation with copper.