# CENTRAL VALLEY POSTHARVEST NEWSLETTER

**COOPERATIVE EXTENSION** **UNIVERSITY OF CALIFORNIA**

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## SOUR ROT CONTROL


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Sour rot of peach, caused by *Geotrichum candidum* (sexual stage: *Galactomyces geotrichum*), has only been infrequently reported to cause problems of traditionally handled and marketed fruit. Sour rot-like infections may also be caused by other yeasts and possibly other organisms that have not been well characterized. Although the following discussion specifically deals with decay caused by *G. candidum*, decays by these other organisms may have similar requirements. Postharvest handling and marketing practices that minimize injuries and utilize sanitation and immediate cold temperature management of harvested fruit (32ºF, 0ºC) generally eliminate the occurrence of the disease. In fruit lots that reach the market and develop the disease, the incidence of sour rot is usually less than 3%. Occasionally, fruit decay can also occur during transportation if temperatures are above 36ºF (>2ºC). Sour rot is associated with fruit injuries or bruises and fruit with split pits. Furthermore, the disease mainly occurs on ripe fruit but may also occur on severely injured immature fruit. Symptoms include a dark-brown, watery, soft decay with a thin layer of white mycelial growth on the fruit surface. The decay may reach the pit and consume the entire fruit. Rotted fruit have a characteristic yeasty to vinegary odor; however, other odors may develop with bacterial contamination that commonly occurs in the watery decay.

In recent years, pre-conditioning or pre-ripening of fruit has become a more widely used practice to improve the quality of fruit bound for distant markets. Specifically, pre-conditioning of fruit reduces internal breakdown from chilling injury. Internal breakdown results in dry, mealy textured fruit with pit cavity browning and mesocarp translucency, as well as loss in fruit flavor. The pre-conditioning process involves a 48-hour storage treatment of harvested fruit at 68ºF (20ºC) prior to cold temperature storage at 32ºF (0ºC). Senescent fruit are very susceptible to decay. Laboratory treatments that block wound healing and lead to fruit senescence increase the incidence of the disease. Pre-conditioned fruit are closer to senescence and thus, more prone to fungal decays, including sour rot, because of the ripening of fruit. Postharvest fungicides can effectively control all the major stone fruit decays such as brown rot, gray mold, and Rhizopus rot. No fungicide, however, has ever been registered for postharvest use on stone fruit that is effective against sour rot. Thus, increases in the incidence of sour rot in recent years have been associated with changes in temperature management (i.e., pre-conditioning) and poor sanitation, as well as harvest and postharvest handling practices that lead to fruit injuries or bruises.

*Epidemiology and management practices*

*Geotrichum candidum* is a wound pathogen that decays fruit after spores are deposited into injuries. The organism is widespread on organic material in the soil and is commonly found in dust or dirt on fruit surfaces. Spores of the fungus may be spread by vinegar flies from decayed fruits to cracks or bruises in healthy fruit. The spores may also be disseminated in picking boxes and handling equipment. During harvest micro-wounds occur on the fruit and these injuries may function as infection sites. When the fruit is washed, the wash water may carry the spores of the fungus into the wounds.

The minimum temperature for spore germination, growth of the fungus, and infection is about 36°F (2ºC), the optimum 77-80ºF (25-27ºC), and the maximum 101ºF (38ºC). At above 60ºF (15.5ºC), the rot spreads very rapidly in ripe peaches. Decay will essentially stop developing if fruit is maintained below 41ºF (5ºC), however, if the fruit was already infected the decay develops quickly once the fruit are marketed at higher temperatures. Rapid cooling of the fruit and refrigeration at low temperature will reduce losses from sour rot. If fruit are pre-conditioned, then fruit must be stored at 32ºF (0ºC) to arrest any incipient decay and maintain fruit quality.

Proper sanitation practices are critical for effective decay control. Fruit should not be picked up from the orchard floor, and should be carefully sorted at the packingline to remove fruit with obvious injuries**.** Care in handling should be taken to prevent injuries and fruit should be washed using a disinfectant such as chlorinated water and all equipment should be periodically sanitized. To be effective, chlorinated washes need to be monitored and maintained at 50-100 ppm free chlorine (hypochlorous acid + hypochlorite ion) at near neutral. For sanitizing equipment, quaternary ammonia compounds are among the most effective treatments. In studies where *G. candidum* spores were directly exposed to selected sanitizers, a complete kill of the spores was obtained with 10-ppm solutions of chlorine or quaternary ammonia during 60-sec or 30-sec exposures, respectively. On contaminated fruit, however, not all decay propagules could be removed using 100-ppm solutions of chlorine but approximately 80% reduction was obtained. In addition, chlorine washes (50-100 ppm available) were more effective when a neutral detergent (neutral cleaner, sooty mold cleaner) was added to the wash solution and when washing times were for at least 30 sec. Furthermore, the decay can be managed with proper temperature management after harvest. If pre-conditioning is used, then sanitation practices to remove injured fruit and to sanitize wash water and fruit surfaces are essential to prevent sour rot from developing. Furthermore, all fruit handling equipment should be cleaned thoroughly after each day. Quaternary ammonia and chlorinated wash water are EPA-approved materials for sanitizing equipment used in food handling. Bin dumps, brush beds, and other equipment not in contact with sanitizing washes of fruit should also be cleaned more frequently based on usage. Labels of specific products should be followed for rates, contact time, and water rinse duration. If chlorinated water is used to clean equipment, higher rates can be used as compared to rates used for sanitizing fruit but higher concentrations of chlorine (higher oxidation potential) may be more harmful to equipment.

Previously, registered pre- and postharvest fungicides were not effective against the sour rot pathogen. The fungicides tebuconazole (e.g., Elite 45WP) and propiconazole (e.g., Break 3.6EC or Orbit 3.6EC), are somewhat effective, but they are registered only for preharvest and not for postharvest use on stone fruit crops. Preharvest applications of these fungicides are effective in reducing the incidence of sour rot.

Five aspects of sour rot that need to be considered for proper management of the disease include:

- Incipient infections cannot be easily observed by graders and infected fruit are often packed with healthy fruit.
- Sour rot spreads rapidly at temperatures above 41°F (5°C).
- The disease is not controlled by any registered postharvest fungicide and requires proper harvesting and handling practices to minimize wounds and soil contamination. Additionally, sanitation washes, preferably with a neutral detergent, that prevent further spread of inoculum and inoculation of fruit during postharvest cleaning and low-temperature storage (<41°F or 5°C) are required for effective control. Pre-conditioned fruit should ideally be stored at 32°F (0°C) with a practical range of 32°F to 36°F (0 to 2°C) and should not be held above 36°F (2°C).
- Picking and packaging equipment should be regularly disinfected with sanitizing solutions such as quaternary ammonia or chlorinated washes. Treatments should be done regularly, especially between fruit lots from orchards with a history of the disease.
- Fruit planned for pre-conditioning should be pre-harvest treated with a SBI fungicide such as propiconazole (e.g., Break 3.6EC or Orbit 3.6EC) or tebuconazole (e.g., Elite 45WP). Two pre-harvest applications within 10 days of harvest may help to reduce the incidence of postharvest sour rot but proper sanitation and temperature management should be used in an integrated approach.

## HYDROCOOLER WATER SANITATION IN THE SAN JOAQUIN VALLEY STONE FRUIT INDUSTRY

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Most packing house operators in the San Joaquin Valley use chlorine in their hydrocoolers to kill pathogens in the water and on fruit surfaces. Such practices prevent the buildup of pathogens in the water and can greatly reduce fruit infections during subsequent storage and transportation. Chlorination is also advantageous because it leaves no residue on the fruit for human health concerns. Further, in our research we have not seen any damage of fruit treated with up to approximately 500 ppm sodium hypochlorite. However, because chlorination leaves no residue on the fruit, pathogens which land on the fruit surface after treatment will not be killed.

The main forms of chlorine used include sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine gas ($Cl_2$). Sodium hypochlorite comes in a 5.25% solution (household bleach) and 12.75 or 15% solutions available through laundry and swimming pool chemical suppliers. Calcium hypochlorite usually comes as a powder or tablets in formulations of 65%. However, it does not dissolve readily (especially in cold water) and undissolved particles can cause phytotoxic chlorine burns on the fruit. To prevent this, one should first dissolve the powder or granules in a small amount of warm water before adding to the hydrocooler water. If using tablets for continuous, slow-release of chlorine, ensure that the tablets are placed so that water circulates well around them. Chlorine gas comes in pressurized gas cylinders and should be handled cautiously according to label instructions.

**Factors Controlling Sanitation Activity**

There are several factors that influence available chlorine levels and how effectively pathogens are killed:

pH: When sodium hypochlorite is added to water, it forms sodium hydroxide (NaOH) and hypochlorous acid (HOCl) (Reaction #1).

Reactions:

1) $NaOCl + H_2O \leftrightarrow NaOH + HOCl$ (active form)
2) $HOCl \leftrightarrow H^+ + OCl^-$
3) $HOCl + HCL \leftrightarrow H_2O + Cl_2$ (gas)

All three forms of chlorine produce hypochlorous acid (also called available chlorine, free chlorine or active chlorine) which is what kills the pathogens. In solution, the hypochlorous acid can disassociate to form hypochlorite ion ($OCl^-$) (Reaction #2). Hypochlorite ions are relatively ineffective against pathogens. At low pHs, most of the chlorine is in the hypochlorous acid form while at high pHs, most of the chlorine will be in the ion form (Fig. 1). However, at pHs below 6 available chlorine activity is lost rapidly because another reaction is favored which produces toxic chlorine gas (Reaction #3). Therefore, maintaining a pH of around 7 will maintain about 80% of the chlorine in the hypochlorous acid (active) form with very little in the gaseous form.

Adding either sodium hypochlorite and calcium hypochlorite will increase pH, while adding chlorine gas will decrease pH. After adding commercial chlorine, adjust the pH of the water to 7 by adding either acid or base. One can determine the pH of water by using an electronic pH meter or color-changing paper indicator. Muriatic (HCl) or citric acid are commonly used to lower pH while sodium hydroxide (lye) will raise pH. Typically, in this area we may need to decrease pH of our hydrocooler water. To lower pH, one can determine the amount of acid to add by taking a sample of the water, adding acid to the sample until the pH drops to 7, and then multiplying the amount of acid added per gallon of sample by the total number of gallons in the tank. For example, if 1 fl oz of acid added to a 5 gal. water sample reduces the pH to 7 and the tank holds a total of 300 gal., then (1 fl oz/5 gal. sample) x (300 gal. tank) = 60 fl oz or about 1.9 quarts of acid to lower the tank to pH 7. After adding acid to the hydrocooler tank and allowing about 10 minutes for thorough mixing, verify its pH and “fine tune” it if necessary.

Chlorine concentration: Although low concentrations of hypochlorous acid (<40 ppm) have been reported to kill most pathogens within 1 minute, higher concentrations (50-100 ppm) are commonly used to compensate for various losses of available chlorine in the tank.

Exposure time: High available chlorine concentrations kill pathogens after short exposure times (< 1 min.). At lower concentration, more contact time is required to kill the pathogens.

Amount of organic matter in the water (e.g. fruit, leaves and soil): Organic matter in the water will inactivate hypochlorous acid (HOCl) and can quickly reduce the amount of available chlorine. Chlorine which combines with organic matter no longer is active against pathogens but will still be measured by total chlorine testing kits.

Water temperature: At higher temperatures, hypochlorous acid (HOCl) kills pathogens more quickly but is also lost more rapidly due to chlorine gas formation and reactions with organic matter.

Type and growth stage of the pathogens: Although germinating spores and mycelium are relatively easy to kill, spores are much more resistant to chlorine and pathogens growing inside the fruit (inside wounds or as quiescent infections) are shielded from the chlorine and not killed.

**San Joaquin Valley Hydrocooler Water Survey**

During the 1995 stone fruit season, we surveyed both total and available chlorine levels in several commercial hydrocoolers. We found that available and total chlorine levels started out high in the morning, but then quickly declined by about 50% during the first 48 bins. Under these conditions, pH was not an important factor because both total and available chlorine levels dropped so quickly. Therefore, frequent monitoring (~ every load) of available chlorine levels is essential to control pathogens in hydrocooler water.

Kits for measuring total and available chlorine can be easily purchased. Those that measure available chlorine are preferred because chlorine ions or "combined chlorine" may give high readings in total chlorine kits.

When using sodium hypochlorite, sodium ions are released (Reaction #1) and can accumulate to levels which may damage the fruit (Table 1). Sodium levels are cumulative and rise each time more sodium hypochlorite is added. Because of this and accumulating dirt, it is important to drain the tank daily and add fresh, clean, potable water. Drained water can usually be applied to nearby farmland. However, check pollution control regulations and local restrictions before disposing of the water.

**Recommendations:**

- Check available chlorine levels often (~every load). Total chlorine measurements may be adequate when water is clean and pH is near 7.0. Installation of automated systems to monitor and adjust available chlorine and pH levels may be worth consideration.
- Maintain available chlorine levels between 50 and 100 ppm.
- Maintain pH around 6.5 - 7.5.
- Ideally, drain the tank at the end of a busy day and refill with clean water.
- Use all chemicals according to their labels (e.g. chlorine, muriatic acid, citric acid, lye, etc.).
- Use self cleaning screens in hydrocoolers to remove large debris.

Table 1.

| pH | Ounces of 65% $Ca(OCl)_2$ per 100 gal. of water | Resulting ppm $Ca(OCl)_2$ | Pints of 5.25% NaOCl solution per 100 gal. of Water | Pints of 12.75% NaOCl solution per 100 gal. of Water | Resulting ppm NaOCl | ppm Na | Estimated ppm of available chlorine (HOCl) at specified pH |
|---|---|---|---|---|---|---|---|
| 6 | 2.1 | 104 | 1.6 | 0.7 | 108 | 33 | **75** |
| | 2.8 | 139 | 2.2 | 0.9 | 144 | 45 | **100** |
| 7 | 2.5 | 120 | 1.9 | 0.8 | 125 | 39 | **75** |
| | 3.3 | 160 | 2.5 | 1.0 | 167 | 51 | **100** |
| 8 | 5.8 | 282 | 4.5 | 1.8 | 294 | 91 | **75** |
| | 7.7 | 376 | 6.0 | 2.5 | 392 | 121 | **100** |
| 9 | 38.9 | 1892 | 30.0 | 12.4 | 1970 | 608 | **75** |
| | 51.8 | 2523 | 40.0 | 16.5 | 2627 | 811 | **100** |

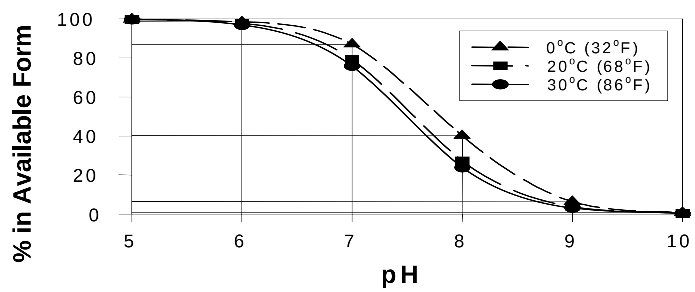


Fig. 1. Percent of chlorine in the available (HOCl) form at different pHs and temperatures.

## THE TOP TEN TIPS FOR DECAY CONTROL

**J. E. Adaskaveg, H. C. Förster, and C. H. Crisosto**

The 2006 stone fruit packing season has started with major challenges in the management of decays. The unusually high rainfall and long cold bloom period have created ideal conditions for decay fungi. These fungi thrive in wet environments at moderate temperatures with spore formation, germination, and growth at their optimum. Spores of *Monilinia* species (brown rot) are produced on infected blossom parts and previous year's fruit mummies. These spores are wind- and rain-disseminated, and can infect fruit through the intact cuticle and epidermis. On mature fruit, decays develop either in the field or soon after harvest. On immature fruit, quiescent infections are established that can develop into active decay at fruit ripening later in the season. Thus, the spring rains will also affect decay incidence of fruit that is maturing later in the season. Rain cracks and split pits are direct entry points for *Monilinia* species and *Botrytis cinerea* (gray mold), as well as for fungi that are usually of minor importance such as *Geotrichum*, *Alternaria*, *Cladosporium*, and *Penicillium* species.

Decay management in this current situation cannot depend on any postharvest fungicide alone. Fludioxonil (Scholar) and fenhexamid (Elevate), are now fully registered as postharvest fungicides on all stone fruits in California. It is a wound-protection treatment that effectively inhibits brown rot, gray mold, Rhizopus decay, and other fruit rots when applied up to 18 hours after inoculation. Any established infections especially those in split pits, however, cannot be eradicated or managed effectively with any postharvest treatment except by strict sorting practices. Thus, an integrated decay management approach is the only option to get high-quality fruit to the consumer in a high-risk disease year like this. This includes preharvest fungicide treatments to inhibit new infections on the highly susceptible maturing fruit, careful sorting to remove any injured fruit, and then a postharvest fungicide treatment. In our research we have identified preharvest fungicide treatments that effectively reduce postharvest brown rot and gray mold decays even after fruit is washed and sanitized in the postharvest handling process. The most effective treatments include mixtures of SBI fungicides such as Elite (tebuconazole), Orbit (propiconazole), and Indar (fenbuconazole) with either Elevate (fenhexamid), Vangard (cyprodinil), or Pristine (pyraclostrobin + boscalid). In the mixtures, the SBI fungicide was used at the low label rate (4 oz/100 gal/A). Elevate was used at the only rate registered (1.5 lb/100 gal/A) and Vangard at the 5 to 10 oz/100 gal/A rate. For best efficacy, two treatments should be applied between 14 days and 1 day before harvest in a 7-day interval (e.g., 14 and 7, or 7 and 1 days before harvest). Treatments with Elite or other SBI fungicides alone are also very effective against brown rot, but control against gray mold is reduced.

For postharvest treatments with Scholar or Elevate follow label recommendations. Be sure that fruit is well covered. This is even more important in high-disease years. Thus, low-volume spray application systems need to be accurately calibrated and should be used on a brush bed. Alternatively, high-volume applications can be used to improve fruit coverage. With a CDA system, use higher recommended volumes of 20 to 25 gal/200,000 lb. One of the most difficult areas of stone fruit crops to reach is the concaved stem end. Water may accumulate in this area of the fruit and allow spores of the brown rot pathogens to germinate and infect the fruit in both pre- and postharvest environments. Thus, be sure that the fungicide covers the stem end well by checking treated fruit immediately after application.

The following 10 guidelines are suggested for this season:

1. Identify orchards with a history of brown rot. They will be at greater risk in a wet year such as this year.
2. Monitor orchards for any fruit with brown rot during fruit development. Decayed fruit on the tree is an indication of high inoculum levels in the orchard.
3. Use preharvest treatments within 14 days of harvest as described in the text above.
4. Use SBI fungicides (e.g., Elite, Orbit, Indar) for best results against brown rot.
5. Minimize injuries during harvest and transportation to the packinghouse.
6. Hydro-cool fruit with chlorinated water. Be sure to change the water in the hydro-coolers daily to prevent buildup of organic load (organic material and soil directly inhibit the activity of active chlorine on microbial populations including fruit pathogens such as *Monilinia* species).
7. Be sure to use chlorinated water (and possibly detergents) on the brush beds to minimize contamination of equipment and subsequent inoculation of fruit.
8. Treat fruit with postharvest fungicides (e.g., Scholar) at **registered rates** within 18 hours of harvest. Lower rates than 8 oz/200,000 lb are ineffective on peaches, plums, and nectarines to maintain commercial decay management standards for all major decays and may result in the development of resistant populations of postharvest pathogens.
9. Sort fruit to remove off-grades and fruit with obvious injuries.
10. Carefully use temperature management practices throughout packing and transportation of fruit to market.

## FUTURE DATES

**2006 Variety Displays and Research Update Seminars at the Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA.** Sponsored by University of California Cooperative Extension and the Kearney Agricultural Center.

| | |
|---|---|
| 8:00 – 9:00 a.m. | Variety display by stone fruit nurseries, breeders and the USDA |
| 9:00 – 10:00 a.m. | Research Update Topic and discussion in the field |

***Mark your calendars for these dates:***

- Friday, June 9 — Rootstock Options for Stone Fruit
- Friday, July 14 — Mechanical Topping to Control Tree Height
- Friday, September 8 — Soil Fumigation Considerations

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**Other upcoming events posted on the Postharvest Calendar at the ANR website can be found at:** http://ucce.ucdavis.edu/calendar/calmain.cfm?calowner=5423&group=w5423&keyword=&ranger=3650&calcat=0&specific=&waste=yes

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