College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Plant Disease
August 2014
PD-103

Anthracnose of Papaya in Hawai'i

Colby Maeda and Scot Nelson
Department of Plant and Environmental Protection Sciences

Papaya (*Carica papaya*) is a major food and export crop for Hawai'i. In 2011, the United States Department of Agriculture reported that papaya production in Hawai'i comprised 172 papaya farms cultivated on 526 ha (1,300 acres) at a value of $9.7 million (USDA 2012). A majority of the papayas grown in Hawai'i are exported to the mainland U.S., Japan, and other countries, as well as being sold in local markets. In addition, papaya is one of the most popular residential fruit crops grown in Hawai'i, and when ripe the fruit commonly appear for sale at farmer's markets.

Symptoms of papaya anthracnose.

Common GMO (genetically modified) papaya cultivars grown in Hawai'i include Rainbow, SunUp, and Laie Gold. These cultivars were genetically modified to resist the *Papaya ringspot virus*. Other, non-GMO papayas grown locally include 'Kapoho Solo', 'Kamiya', 'Kapoho', 'Sunrise', 'Sunset', and 'Waimanalo'.

A disease of papaya that still causes significant yield losses is anthracnose. The plant-pathogenic fungus *Colletotrichum gloeosporioides* causes papaya anthracnose, recognized globally as a major post-harvest disease. Hawai'i, as a major papaya exporter, suffers losses of marketable fruit due to anthracnose, and post-harvest losses to the disease are common for residential growers and local consumers. Anthracnose is an important disease in tropical and subtropical regions having high humidity and ample amounts of rainwater. The disease can significantly affect fruit that is refrigerated and exported out of the state (Dickman 1994). Whereas fungicide-treated fruits that are not refrigerated and are sold in local markets may not display disease symptoms, organically grown fruits at local markets often show symptoms of anthracnose as they ripen.

In this article we describe the host, the disease symptoms, and the pathogen and suggest integrated practices for the successful management of anthracnose of papaya in Hawai'i.

The Host: Papaya

Papayas generally thrive in tropical regions at elevations below 152 m (500 ft). However, in Hawai'i there is a significant papaya production up to 457 m (1500 ft) in the Kona district and other areas where 102 to 152 cm (40 to 60 in) of rain falls evenly throughout the year. In areas where rainfall is greater, the soils should be porous and well drained.

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, under the Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

Papaya plants grow to a height of about 9 m (30 ft) and produce fruit varying in size and weight, depending on the cultivar. In Hawai'i, 'Solo' produces fruit weighing about 340 to 850 gm (12 to 30 oz), whereas other cultivars can produce fruit weighing up to 9 kg (20 lb) (Crop Knowledge Master 2014). Papayas are short-lived perennials with hollow, herbaceous stems that rarely form branches.

Papaya plant gender may be male, female, or hermaphrodite. The gender status of plants is distinguished by the flower structure. Male flower buds are thin and tubular and contain only stamens; female flower buds are larger and cone-shaped and contain only pistils. Hermaphrodite plants have flowers with both stamens and pistils. Seeds from 'Solo' usually produce plants that are 1/3 female and 2/3 hermaphrodites. Although both female and hermaphrodite plants bear fruit, the female plants are less desired due to their need to be pollinated, their tendency to have lesser yields than the self-pollinated hermaphrodites, and their more rounded fruit shape. The flowers of the plants can be found in the leaf axils at the top of the tree. The flowers are whitish to cream colored and have five petals, and they sometimes have a fragrance. When female flowers require pollination by male flowers on different plants, wind and insects are the primary pollinators (Crop Knowledge Master 2014).

The Disease and Its Symptoms

Anthracnose is an important disease worldwide. Along with papaya, the pathogen affects banana, mango, avocado, passion fruit, citrus, coffee, and various other tropical fruits (Nelson 2008a). Although all anthracnose pathogens on these crops are classified as the same pathogen species, in the case of mango anthracnose the pathogen is highly host-specific (Ploetz 1999). Considering these data, it is possible that the papaya anthracnose pathogen is also host-specific.

Anthracnose can infect papaya leaves, but the fruit is much more severely affected (Dickman 1993). As

Papaya anthracnose. Photos by Scot Nelson (left and right) and Wayne Nishijima (center)

a fruit matures, the first symptoms are small, light-colored spots. As the spots enlarge they become sunken and take on a water-soaked appearance. Single spots can grow to 5 cm in diameter, or merge (see photos) and rapidly destroy a fruit. As a fruit continues to ripen and as disease progresses, pinkish-orange or salmon-colored "cordial masses" of *C. gloeosporioides* typically form concentric ring patterns in the sunken lesions. Another common symptom is "chocolate spot lesions." These are sharply defined reddish-brown, irregular or circular spots about 1–10 mm in diameter. As a fruit continues to ripen, these spots quickly enlarge, forming circular, sunken lesions up to 20 mm in diameter. The reason the same pathogen causes two different symptoms is unknown (Dickman 1994).

Disease Cycle and Epidemiology

Spread of this pathogen among fruits and plants and infection of papaya depend heavily on moisture provided by rainfall. Thus, anthracnose reaches highest disease incidence and severity in areas where relative humidity and rainfall are highest and the air temperature is warm and conducive for fungal development. Optimum air temperatures for the pathogen occur between 18 and 25°C (64.4 and 77°F).

Spores produced on fungal structures called acervuli are dispersed in splashing water, rain droplets, and wind-blown rain. The spores can germinate and form germ tubes if deposited on immature green fruit and if there is free water and a minimum relative humidity of at least 97%. Appressoria, or specialized fungal cells used to infect their hosts, form at the ends of the germ tubes on the fruit surface. The appressorium penetrates the host cuticle and epidermal layer with a "penetration peg" to establish infection. The infection remains latent until the post-climacteric stage of the fruit (Dickman 1994).

As the fruit starts to ripen, the pathogen resumes growth and the typical anthracnose symptoms appear. The fungus absorbs nutrients from the fruit as it

Papaya anthracnose. Photos by Scot Nelson

colonizes it, then again forms acervuli and spores to complete the life cycle (Nelson 2008a).

In tropical and subtropical areas the growing seasons is continuous and the disease cycle is perpetually repetitive. In the absence of its host plant, *C. gloeosporioides* can survive as a saprophyte in dead infected papaya tissue or other organic matter.

Pathogen

Colletotrichum gloeosporioides is the imperfect or asexual stage of the fungus. It was later determined that its perfect or sexual stage was *Glomerella cingulata*. Because its perfect stage is rarely seen and the name of the imperfect stage is so commonly used, *C. gloeosporioides* is regarded as the correct name to describe this pathogen (JGI 2014). The perfect stage, *G. cingulata*, and the imperfect stage, *C. gloeosporioides*, may be present on the stem of the papaya fruit. However, *G. cingulata* does not produce either the symptoms on the fruit or the pinkish spores on agar typical of *C. gloeosporioides* (Dickman 1994).

Disease Management

The goal of anthracnose disease management in Hawai'i is to minimize damage and fruit losses rather than to eradicate the pathogen. A program of Integrated Pest Management (IPM) uses the methods described below. By the application of various management tactics simultaneously, the pathogen can be targeted at different points in its life cycle. These tactics combine both pesticidal and cultural practices.

- ***Site selection.*** Sites having lower annual rainfall amounts, such as Kahuku, O'ahu, have much less severe epidemics of papaya anthracnose than do high-rainfall locations such as regions in the Puna district of the Big Island. Therefore, by selecting a cultivation site in a low-rainfall area, one can avoid anthracnose.
- ***Cultivar selection.*** In Hawai'i, there are no cultivars highly resistant to papaya anthracnose. 'Sunrise Solo,' however, is considered more resistant than 'Kapoho Solo' (Dickman 1994).
- ***Intercropping, polycropping, and agroforestry.*** Planting papaya as a multicrop that is interspersed with non-hosts of C. gloeosporiodes such as citrus, coffee, or breadfruit can help to minimize anthracnose disease incidence and severity. Such planting configurations interfere with splash dispersal of the pathogen spores and thereby reduce the population size of the pathogen.
- ***Sanitation.*** Sanitation in this instance is the removal of diseased fruits from the ground and field to reduce the number of spores available to cause infection. Furthermore, removing dead leaves, weeds, and debris in and around the trees removes organic matter upon which the pathogen can survive saprophytically.
- ***Moisture management.*** A well-drained, porous soil will reduce standing water that can lead to higher humidity levels that favor infection. Increase the space between plants to reduce relative humidity in the canopy and to promote air circulation and rapid drying of fruit surfaces after rainfall events.
- ***On-time harvest.*** Harvest papaya fruits promptly by picking them from papaya plants before fruits dehisce and fall to the ground. Ripe, rotting fruits left on the ground contribute spores to the epidemic.
- ***Post-harvest management.*** These practices include immersing fruits in water heated to 48°C (118°F) for 20 minutes, using postharvest fungicides, or both. The fungicides are applied as sprays or dips in combination with a food-grade wax (Dickman 1994). Store fruits in a well-ventilated environment to encourage lower levels of relative humidity. Ship and store fruits at temperatures below 18°C (64°F) to inhibit disease development. Cull infected fruits to prevent spread of the disease to other fruits.
- ***Fungicide applications.*** In areas highly prone to anthracnose, fungicides are usually necessary. There are many fungicides available for use in Hawai'i that have different active ingredients, timing of applications, and application rates. Almost all of the fungicides are preventative and must be applied before the fungus reaches the plant. Some are applied before rainfall and some when flowers first appear. It was recommended by Dickman (1994) that preventative fungicides be applied at two- to four-week intervals. Most of these fungicides have different application rates, so always check the label before applying. Read the complete label and follow all of its requirements.

Table 1. Fungicides Registered for Use on Papaya in Hawai'i. Source: Pesticides Registered for Use in Papaya in Hawaii 2013.

Product Name	Active Ingredient(s)	Formulation	Type of Control
Abound® Flowable Fungicide	Azoxystrobin	Flowable suspension	Preventative
Double Nickel 55™ & Double Nickel™ LC	*Bacillus amyloliquefaciens* strain D747	Aqueous suspension bioherbicide	Preventative
Serenade® ASO & Serenade® MAX	*Bacillus subtilis* QST713	Dry bioherbicide for mixture w/water	Preventative
Basic Copper 50W HB, Basic Copper 53, Cuproxat® Flowable Copper Fungicide, Cuprofix® Ultra 40 Disperss®	Basic copper sulfate	Solid dry flowable, soluble concentrate, dry formulation, liquid concentrate	Preventative
Bravo Ultrex®, Bravo Weather Stik®, Chloronil® 720, Chlorothalonil® 720 SC, Initiate® 720 Flowable	Chlorothalonil	Liquid concentrate, water dispersible granule	Preventative
Champ® Formula 2 Flowable, Champ® WG Agricultural Fungicide, Dupont™ Kocide® 101 Fungicide/Bactericide, Dupont™ Kocide® 2000 Fungicide/Bactericide, Dupont™ Kocide® 3000 Fungicide/Bactericide, Dupont™ Kocide® 4.5LF Fungicide/Bactericide, Dupont™ Kocide® DF Fungicide/Bactericide, Griffin Kocide® LF Fungicide/Bactericide, Kentan® DF, Agri Star® NU-COP® 3L (DISC.), Agri Star® NU-COP® 50 DF (Disc.), Agri Star® NU-COP® 50WP (Disc.), Agri Star® NU-COP® HB	Copper hydroxide	Dry flowable, flowable concentrate, liquid concentrate, water-dispersible granules, wettable powder	Preventative
Dupont™ ManKocide® Fungicide/Bactericide	Copper hydroxide + mancozeb	Water-dispersible granules	Preventative
DelCup L, Mastercrop Fungicide/Bactericide	Copper sulfate pentahydrate	Liquid concentrate	Preventative
Nordox 75	Cuprous oxide	Wettable granules	Preventative
Badge® SC, Badge® X2	Cuprous oxychloride + copper hydroxide	Dry flowable, suspension concentrate	Preventative
Dithane® 75DF Rainshield®, Dithane™ DF Rainshield® (Agricultural) Fungicide, Dithane F-45® Rainshield® Fungicide, Dithane™ M-45 Agricultural Fungicide, Fungicide (Disc.), Dupont™ Manzate® Flowable Fungicide, Dupont™ Manzate® Pro-Stick™ Fungicide (Disc.), Griffin Manzate® 75DF Fungicide (Disc.), Griffin Manzate® Flowable Fungicide, Manzate® Max Fungicide, Manzate® Pro-Stick™ Fungicide, Roper DF Rainshield®	Mancozeb	Dispersible granules, dry flowable, liquid concentrate	Preventative—begin at flowering
Manco-Phite® DF	Mancozeb + Phosphorous acid	Dry flowable	Preventative—begin at flowering
Regalia® Bioprotectant Concentrate	*Reynoutria sachalinensis*	Biofungicide concentrate	Initiate and strengthen plant defenses

Table 2. Papaya: Number of Farms, Acreage, Utilization, Farm Price, and Value in the State of Hawai'i, 2007–2011

Year	Number of Farms	Total Area (in Acres)	Production Area (in Acres)	Utilization (in Thousands of Pounds)			Farm Price (in Cents per Pound			Value of Sales (in Thousands of Dollars)
				Processed	Fresh	All	Processed	Fresh Market	All	
2007	178	2,065	1,310	2,200	31,200	33,400	3.8	41.7	39.2	13,094
2008	177	2,190	1,380	2,000	31,500	33,500	3.0	45.5	43.0	14,393
2009	177	2,025	1,325	1,200	30,300	31,500	3.0	46.7	45.0	14,186
2010	173	2,075	1,350	900	29,200	30,100	3.0	38.0	37.0	11,123
2011	172	2,000	1,300	900	27,700	28,600	3.0	35.0	34.0	9,722

Source: USDA 2012.

References

Pesticides Registered for Use in Papaya on Hawaii. 2013. College of Tropical Agriculture & Human Resources, University of Hawai'i, Extension Pesticides Programs. http://pesticides.hawaii.edu/hipmrinn/papaya_licensed_products201309.pdf (accessed February 28, 2014). Website provided by Dr. Michael Kawate.

Crop Knowledge Master. Papaya: General Crop Information. http://www.extento.hawaii.edu/kbase/crop/crops/i_papa.htm#PRODUCTION (accessed February 28, 2014).

Dickman, M.B. 1993. *Colletotrichum gloeosporioides*. In: Wayne Nishijima's Papaya Compendium. Department of Plant Pathology. CTAHR. University of Hawai'i at Hilo. http://www.extento.hawaii.edu/Kbase/crop/Type/c_gloeo.htm (accessed February 28, 2014)

Dickman, M.B. 1994. Papaya Anthracnose. pp. 58–59 In: R.C. Ploetz, G.A. Zentmyer, W.T. Nishijima, K.G. Rohrbach, and H.D. Ohr (eds.), Compendium of Tropical Fruit Diseases. American Phytopathological Society, Minneapolis, MN.

Hawaii Grown Papayas. http://www.hawaiipapaya.com/choices.html (accessed February 28, 2014)

JGI. *Glomerella cingulata* 23 (*Colletotrichum gloeosporoides* 23) v1.0. http://genome.jgi-psf.org/Gloci1/Gloci1.home.html (accessed February 28, 2014)

Nelson, S. 2008a. Mango Anthracnose (*Colletotrichum gloeosporioides*). CTAHR Department of Plant and Environmental Protection Sciences, UH-Mānoa. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/pd-48.pdf (accessed February 28, 2014)

Nelson, S. 2008b. Anthracnose of Avocado. CTAHR Department of Plant and Environmental Protection Sciences UH-Mānoa. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-58.pdf (accessed February 28, 2014)

Ploetz, R. 1999. Anthracnose: The most important disease in much of the mango-producing world. *PLP News, the Newsletter of the Plant Pathology Department, University of Florida-Gainesville* (3) 9: 1–2.

USDA. 2012. 2011 Hawaii Papaya Utilization and Price Down. http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Fruits_and_Nuts/annpapFF.pdf (accessed February 28, 2014)

Acknowledgements

The authors thank Michael Kawate of UH-CTAHR for providing pesticide information. We also recognize the thoughtful reviews of this manuscript provided by Fred Brooks (UH-CTAHR) and Ken Love (Hawaii Tropical Fruit Growers Association).