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

Plant Disease
May 2015
PD-108

Black Pod Rot of Cacao Caused by *Phytophthora palmivora*

Benjamin Vanegtern[1], Michael Rogers[1], and Scot Nelson[2]
[1]Department of Tropical Plant and Soil Sciences
[2]Department of Plant and Environmental Protection Sciences

Introduction

Cacao is the most economically important species in the genus *Theobroma* (Acebo-Guerrero 2012). It is an upright evergreen tree that can grow to 15 m but is usually kept below 5 m for ease of harvesting. The tree has a polymorphic habit: the seedling grows 1 to 2 m in height as a single stem and then separates into the jorquette, a whorl comprised of 3 to 5 branches. Two to three years after planting, flowers begin to grow from pads or cushions beneath the bark. Under optimal conditions these pads will continue to produce flowers for 60 to 100 years. In Hawai'i, less than 1% of the flowers set fruit (Bittenbender 2011). Pollination of cacao requires a pollinator; in Hawai'i, pollination is by midges (Bittenbender 2011). Some self-incompatible varieties of cacao require cross-pollination, while others are fully self-compatible. The cacao fruit, better known as a pod, is cut from the tree without damaging the flower pad below the surface. Damaged flower pads will no longer bear fruit. The pods are harvested for the seeds, known as beans, inside the pod. Each pod contains about 30 to 60 beans, which are covered with white mucilage that is high in sugar content. Pods are picked at maturity for their primary use, the production of chocolate. Cacao can be grown only within the tropical belt (Acebo-Guerrero 2012). The largest cacao-producing region is the Ivory Coast on the west coast of Africa, where 68% of the world's cacao is harvested. The Amazon Basin is believed to be the origin of *Theobroma cacao* but makes up only a portion of the 15% of world production from the Americas (World Cocoa Foundation 2014).

Figure 1. Incipient infections (arrows) occurring on a ripe cacao pod caused by *Phytophthora palmivora*.

Cacao in Hawai'i

Hawai'i is the only state in the United States where cacao can be commercially grown. It was introduced in the mid-19th century but is newly commercialized and is gaining a foothold throughout the Islands. Cacao was grown on approximately 28 acres in 2013. An additional 18 acres have been planted since then but are not yet in production. A majority of these plantings, 35 acres, are on O'ahu, with 68 additional acres expected by the end of 2018 (Bittenbender 2013). However, Hawai'i doesn't produce enough dry bean weight commercially to compete with other cacao-growing regions of the world. The University of Hawai'i and the United States Department of Agriculture (USDA) are

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.

Figure 2. Unripe cacao pod showing signs of black pod rot caused by *Phytophthora palmivora*.

Figure 3. Unripe cacao pod showing increased signs of black pod rot caused by *Phytophthora palmivora*.

Figure 4. Severely infected cacao pod covered with the white sporangia of *Phytophthora palmivora*. This pod is in the beginning stage of becoming mummified.

currently testing new cacao varieties. They are evaluating specific genotypes for high bean quality, increased yield per acre, and resistance to diseases and pathogens such as *Phytophthora palmivora*, a devastating fungus-like pathogen that is already established in the state. This paper discusses *P. palmivora*, the cause of black pod rot, and other methods of combatting black pod rot in Hawai'i in addition to resistance.

Environmental Factors and Cacao

Cacao can grow in soils ranging from acidic to slightly alkaline, with a pH of 6.5 optimal for nutrient uptake by the trees. In high-rainfall areas, increased soil moisture can increase the potential for black pod rot.

The Pathogen

Black pod rot of cacao is caused by a pathogen in the genus *Phytophthora*, literally translated as the "plant destroyer." This is the same genus responsible for the Irish potato famine of 1845–1852. These pathogens were originally classified as fungi but have since been reclassified into the kingdom Stramenopila. There are more than 80 species of *Phytophthora* that cause plant diseases, of which several, including *P. palmivora*, *P. megakarya*, *P. citrophora*, and *P. capsici*, are responsible for black pod rot of cacao. *Phytophthora* spp. are responsible for pod loss of 20 to 30% of the total cacao crop annually, though some plantations have lost up to 90% of their pods due to the disease. Cankers caused by the pathogen may kill up to 10% of all trees each year (Acebo-Guerrero 2012). In Hawai'i, it is *P. palmivora* that causes the disease. This species attacks over 150 host plant species in the tropics, although strains *of P. palmivora* may infect only one or several host plants.

Morphology and Life Cycle of *P. palmivora*

P. palmivora has four types of spores that may directly or indirectly cause infection: sporangia, zoospores, oospores, and chlamydospores. Sporangia are produced on infected fruit, leaves, stems, or roots. They can germinate directly on the plant surface or in the soil and are capable of producing zoospores. Zoospores can swim in soil water or in water on a plant surface until they find entry into the plant. When the two mating types of zoospore,

Figure 5. A cacao pod consumed by *Phytophthora palmivora*. Note the infected bean mass.

A1 and A2, are present, oospores are formed. This sexual cycle can produce genetic variations with the possibility of overcoming host resistance. Fortunately, the two mating types are not usually found together. Chlamydospores are produced asexually and can survive for months in soil or dead plant material in the absence of their host. The spores germinate when host plants are again present under favorable weather conditions.

Symptom Development

Symptoms of pod rot of cacao caused by *P. palmivora* appear below. Note that these symptoms may be confused with Cherelle wilt, an unrelated, physiological disease in which no specific plant pathogen is involved.

- **Brownish spots on fruit**. When cacao is infected by *P. palmivora,* the pathogen penetrates the waxy cuticle and attacks the epidermis. A small brownish spot appears at the point of infection (Figure 1). Such infections can begin at the stem- or blossom-ends of fruits.
- **Spread of infection and symptoms on fruit**. Infection spreads rapidly across the outer surface, covering the entire pod in a few days (Figures 2 and 3). Infected areas turn from brown to black and, if conditions are favorable, clusters of white sporangia appear on outer surfaces of the pod (Figures 3 and 4).
- **Infection of cocoa beans**. As visible symptoms progress, the pathogen moves deeper into the pod, infecting and destroying the beans (Figure 5). Infected beans quickly deteriorate and rot, rendering the pod useless. The pods then dry up and mummify on the tree, becoming a major source of inoculum to nearby pods, leaves, and stems.
- **Cankers**. Cankers can form under the bark of infected stems and branches. There may be a dark spot on the bark that oozes reddish fluid. The canker can continue to expand until it girdles and kills the branch. Dead and dying leaves are sometimes the first indication of branch dieback. The leaves die because the branch they are on is killed; the pathogen does not directly infect and kill the leaves.

Disease Management

- **Site selection**. A site with relatively low rainfall and good drainage is recommended. High rainfall will increase the spread of *P. palmivora* within the canopy. A well-drained soil will reduce the amount of inoculum in and on the soil.
- **Quarantine**. Avoid transporting soils or plants from areas where the disease occurs into clean areas. Seedlings acquired from outside of Hawai‘i should be exchanged through an intermediate quarantine facility. Contact USDA or the local Extension agency for assistance.
- **Resistance**. Generally, varieties with fruit that have a thicker cuticle are more resistant to black pod rot. Resistant varieties have been identified, but further research is needed to determine if these varieties can withstand the *Phytophthora* species present in Hawai‘i.
- **Removal**. Infected pods should be removed from the area and destroyed. A single infected pod has the potential to release 4 million sporangia.
- **Spacing and pruning**. Trees should be spaced and pruned to allow for increased airflow in and around the orchard. This will reduce the relative humidity and further reduce spread of the disease.
- **Mulch**. Leaf mulch on the ground will reduce the amount of splashing water when it rains. It will also increase the biodiversity of soil microorganisms. However, leaf mulch may result in increased relative humidity in the canopy, which favors infection and disease development.
- **Fungicide**. Although chemical control is an option, it may not be cost effective, depending on the size of the operation and environmental conditions. Below is a list of registered products for cacao pod rot control in the state of Hawai‘i at the time of publication of

Figure 6 (top). Early symptoms of a branch canker caused by *Phytophthora palmivora*. Figure 7 (middle). Branch canker with the bark removed to show the extent of infection. (Note: this is the same branch as in the previous photo. It indicates that internal damage can be more severe than it appears on the surface. Figure 8 (above). Branches killed by cankers. Dead leaves often remain attached after death of the branch. Photos by Fred Brooks.

this paper. Verify with the pesticide label that the product is registered for application to cacao. Follow all label directions and warnings for a safe and proper application of the product.

- GWN-4620 copper fungicide/bactericide
- LPI Chesson fungicide
- AmeriCop 40 DF
- Nu-Cop XLR
- Nu-Cop 3l HB
- Basic copper 50 HB
- Copper hydroxide 10% liquid
- Copper hydroxide 20% DF
- Basic copper 53
- COC WP
- Blue Shield 40 DF
- Cuproquim Nu-Cop 40 DF
- Champ® WG
- Champ® Formula 2 flowable
- Champ® 30 DP
- MasterCop
- Magna-Bon Bahama Klear
- Cuprofix® Ultra 40 Disperss
- Fungi-Phite®
- Fungi-Phite® DF
- Kentan® DF
- Badge® SC
- Badge® x2
- Siscop 60 SC
- DelCup L
- CuH_2O
- Dupont™ Kocide® 3000
- Kocide® 4.5 LF
- Kocide® DF

Acknowledgements

The authors thank Fred Brooks and H.C. Bittenbender for their thoughtful reviews of this manuscript. Dr. Brooks also provided some photographs for this publication.

References

Acebo-Guerrero, Y., A. Hernández-Rodríguez, M. Heydrich-Pérez, M. El Jaziri, and A.N. Hernández-Lauzardo. 2012. Management of black pod rot in Cacao (L.): A review. *Fruits* 67.1: 41-48. Print.

Bittenbender, H.C. Cacao in Hawaii, 2013. 2013. Honolulu: College of Tropical Agriculture and Human Resources.

Bittenbender, H.C. 2011. Cacao *Theobroma cacao* "Food of the Gods." College of Tropical Agriculture and Human Resources. Web. <http://www.ctahr.hawaii.edu/deFrankJ/Streaming%20Media/Windows_Media/hcb_BEVERAGE_CLASS_F2011/text_f2011/pdf_slideshows_f2011/08_Cacao10_252011.pdf>

Crane, J.H., C.F. Balerdi, and G. Joyner. Rev. 2006. Cocoa (chocolate bean) growing in the Florida home landscape. 2005. *EDIS New Publications RSS*. Web. Accessed on 18 Feb. 2015. <http://edis.ifas.ufl.edu/hs307>.

Guest, D. Black pod: Diverse pathogens with a global impact on cocoa yield. 2007. *Phytopathology* 97.12: 1650–653. Print.

International Cocoa Organization. Pests & Diseases. 2013. Web. 18 Feb. 2015. <http://www.icco.org/about-cocoa/pest-a-diseases.html>.

Mrk. The cacao tree. 2002. Xocoatl.org. Web. Accessed on 19 Feb. 2015. <http://www.xocoatl.org/tree.htm>.

Nyadanu, D., R. Akromah, B. Adomako, C. Kwoseh, H. Dzahini-Ob, S.T. Lowor, A.Y. Akrofi, and M.K. Assuah. 2012. Host plant resistance to Phytophthora pod rot in cacao (*Theobroma cacao* L.): The role of epicuticular wax on pod and leaf surfaces. *International Journal of Botany* 8.1: 13–21. Print.

Widmer, T. *Phytophthora palmivora*. n.d. Forest *Phytophthoras* of the World. Web. 18 Feb. 2015. <http://forestphytophthoras.org/species/palmivora-0>.

World Cocoa Foundation. Cocoa Market Statistics. 2014. <http://worldcocoafoundation.org/wp-content/uploads/Cocoa-Market-Update-as-of-4-1-2014.pdf>. Accessed 19 Feb 2015.