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Black Flag of Noni (*Morinda citrifolia*) Caused by a *Phytophthora* species

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A severe foliar blight and fruit rot disease of noni (Indian mulberry, *Morinda citrifolia*) was found on the island of Hawaii in 1999. The disease, named noni black flag, is caused by a pathogen in the genus *Phytophthora*. This is the first report of a *Phytophthora* species causing disease of *M. citrifolia*. The identity of the causative species is under investigation.

Symptoms

Severely diseased plants have characteristic "black flags," which describes the blackened, wilted, withered, or completely necrotic leaves hanging from blackened petioles and stems. In the early stages of infection the leaves, petioles, and stems may have blackened streaks or stripes along the veins. As the disease progresses, entire stems and petioles may collapse after being girdled by black lesions.

Fruit symptoms, common at the stem end, consist of a progressive soft rot with a water-soaked appearance and chocolate-brown or dark brown to black color. Fruit infection often occurs through the pedicel, where the base of the fruit is attached to the stem. Advanced fruit infections may result in dry, shriveled fruit "mummies" that may have a fuzzy or silvery surface.

All nonwoody noni organs and tissues (e.g., leaves, flowers, fruit, petioles, succulent stems, and stipules) are susceptible to lethal infection by the pathogen. In severely diseased plants during extraordinarily wet periods or after many days of continuous rain, virtually all of the seasonal, succulent tissues can die. Dead leaves and stems may hang from trees for weeks or months, until the dead foliage decomposes and new stem and foliage regrowth occurs.

Causal organism

Noni black flag is caused by an unidentified *Phytophthora* species that shares morphological characteristics with known *Phytophthora* species but differs genetically from any of the known species, such as *P. botryosa*. Therefore, the black flag pathogen may be a new and distinct *Phytophthora* species.

Disease cycle—experiments and observations

Pathogen isolation and identification

Colonies of an organism resembling *Phytophthora* were isolated from diseased noni tissues on water agar and identified as a member of the genus *Phytophthora* on the basis of sporangial and vegetative characteristics. The sexual characteristics and DNA profile of the noni organism differ significantly from earlier descriptions by Chee (1969) and other workers, requiring research to clarify and reconcile the differences.

Inoculations

The pathogen isolated from noni was shown to cause black flag. Inoculations conducted by the author confirmed the susceptibility of several noni plant organs (stipules, leaves, fruits, and flowers) to infection by sporangia and zoospores of the pathogen. Upon inoculation, major symptoms associated with the disease were reproduced, including black veins, leaf blight, black flags, and fruit rot. Successful inoculations were conducted on a misting bench and in enclosed, high-humidity chambers.

Rapid infection of stem stipules was common. Stipules showed dark, water-soaked lesions adjacent to the stem 4–7 days after inoculation. Symptoms spread from stipules into and along stems, where thin black streaks developed, and into leaf petioles. Eventually, entire stems and petioles were colonized and turned dark black. Petioles often collapsed within 10 days after inoculation. In some cases the leaf symptoms extended well along leaf veins, turning them and the surrounding leaf tissue black. Older, lower stipules and noni leaves usually were the first to show symptoms. Green fruits and young flowers were inoculated with aqueous suspensions of sporangia and enclosed in plastic bags.

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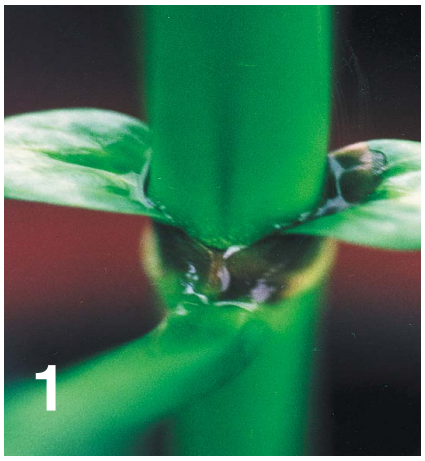
Noni black flag disease—stipule, stem, petiole, and leaf symptoms



Noni plants with black flag disease may express one or more of these leaf and stem symptoms (clockwise order). **1.** Stipules collect water where they join the stem and are readily infected during wet weather. **2.** The pathogen (*Phytophthora* sp.) penetrates the stem, causing black lesions or stripes to form. **3.** Infections progress from the stem cortex and phloem tissues into the leaf petioles and then along leaf veins. **4.** The veins turn black and eventually collapse. **5.** After the veins and petioles are destroyed, the leaves collapse and hang from the plant, withered and brown or black. **6.** Noni plants can recover from the disease during dry weather by sprouting new growth from previously diseased stems that still have fragments of old, diseased leaves attached.

Noni black flag disease—fruit and stem symptoms

Noni black flag causes a severe fruit rot with these typical symptoms (shown in clockwise order). **7.** Green fruits of all ages are susceptible to infection. Fruits may be infected through the flowers, epidermis, or pedicel. **8.** More often, fruit infection occurs through the peduncle, which joins the fruit with the stem and progresses from the base of the fruit to the fruit apex. **9.** Entire fruits and the adjacent stems turn dark brown or black. **10.** Rotten fruits may become desiccated ("mummified") when dry weather follows a black flag epidemic.

Basic biology of *Phytophthora*

The name *Phytophthora* means "plant destroyer." The mycelium of this pseudofungus spreads throughout infected plants, destroying and utilizing plant tissues.

Phytophthora has the ability to infect plants during very wet periods and to survive over dry periods by producing specialized organs and structures.

When infected plant parts are very wet, ~~the pathogen releases swimming *zoospores*~~ from structures called *sporangia*. The zoospores travel over the surface of the plant, locate an infection site, encyst, germinate, and penetrate the plant tissues.

During dry periods, the pathogen survives by producing thick-walled *oospores*, which are relatively resistant to desiccation. To produce them, the pathogen uses its sexual organs called *gametangia*; the male part is called the *antheridium*, and the female part is called the *oogonium*, and oospores result from the union of these organs.

Figures 1, 2, 3, 4, and 7 are from plant inoculation experiments; the symptoms shown resemble those of naturally infected plants.

Within a few days, the fruits showed dark, watersoaked lesions. Inoculated flowers were completely blighted. Abundant visible sporulation of the *Phytophthora* species on the surface of host tissues occurred during incubation of diseased plants in high-humidity, saturated air.

Histopathology

Microscopy of stained tissues of inoculated plants revealed intracellular growth of *Phytophthora* mycelium. Embedded oospores and sporangia of the pathogen formed within symptomatic tissue. The mycelium was consistently observed within the cortex and phloem of stems, petioles, and leaves, where it was associated with a dark necrosis. The pathogen colonized these tissues rapidly, leading to blackened veins that resemble the symptoms of some bacterial plant diseases.

Disease occurrence and distribution

Black flag outbreaks occur during prolonged periods of wet weather. The disease subsides during dry spells. When inoculated plants are moved from frequent mist or high humidity into drier air, disease progression stops and foliar lesions dry out. Apparently, water congestion of tissues enhances infection and disease development. Sporangia and zoospores of the pathogen are probably dispersed between plants or plant organs by splashing or flowing rainwater.

Noni plants can recover from the disease during dry periods by resprouting new growth from previously diseased stems. New foliar growth emerges from the apparently unaffected woody stem tissue just below the withered region of the fleshy stem destroyed by the blight. Apparently, the pathogen is not able efficiently to colonize woody noni stem tissues and rot them, nor has it been observed to kill noni trees or destroy woody tissue.

Confirmed distribution of noni black flag was initially limited to a small coastal area in the Puna district of Hawaii, between Kalapana and McKenzie State Park. The disease was discovered adjacent to state highway 137 near Opihikao in the forest and a nearby noni farm. The natural occurrence of the disease is limited primarily to the shaded, forested, or otherwise sheltered areas along that highway and near Opihikao. Based on surveys conducted by the author, the disease has since spread to newly planted noni farms in areas adjacent to the region originally affected.

Best management practices for control of noni black flag

Control black flag by using integrated cultural and preventive methods such as pruning, sanitation, avoidance, and an appropriate cropping system.

- Learn to recognize black flag disease symptoms, and inspect noni plants regularly during periods of extended rain.
- Promptly prune, remove, and destroy symptomatic foliage and fruits to reduce the pathogen inoculum levels and disease incidence. Diseased stems and branches should be pruned back to a point on the stem or branch several inches below the visible symptoms. Pruning shears or knives should be cleaned in a solution of 1 part household bleach and 9 parts water between cuts.
- Remove fallen or pruned branches, stems, leaves, and fruits; do not allow them to accumulate beneath the noni trees.
- Promote good air circulation within the noni plant canopy to ensure rapid drying of leaves and fruits. This can be accomplished by selecting wider plant spacing and by pruning back verticals to open up the canopy to increase air movement.
- Reduce relative humidity within the noni canopy. Control weeds around the noni plants. Ensure adequate soil drainage. These measures will ensure rapid drying of leaves and fruits after rainfall, reduce water congestion in plant tissues, and minimize the infective potential of the pathogen.
- Avoid introducing diseased noni plants or fruits into high-rainfall areas where the disease has not been reported. Start new noni farms with disease-free plants.
- Maintain good plant nutrition with foliar sprays of fertilizers derived from phosphorous acid, such as Phosgard®.

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Literature cited

Chee, K.H. 1969. *Phytophthora botryosa* Chee. Trans. Br. Mycol. Soc. 52:428.