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Taro Leaf Blight in Hawai'i

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Taro (*Colocasia esculenta* (L.) Schott) grows in Hawai'i and throughout the tropical Pacific as an edible aroid of historical and contemporary significance (Figure 1). Farmers cultivate *kalo* (Hawaiian for taro) in wet lowland (Figure 2) or dryland (Figure 3) taro patches for its starchy, nutritious corms. The heart-shaped leaves are edible and can also serve as food wrappings. Historically, taro crops provided nutritious food that helped early Polynesians to successfully colonize the Hawaiian Islands.

Figure 1. A taro (*Colocasia esculenta*) patch in Hawai'i.

"Taro" refers to plants in one of four genera within the family Araceae: *Colocasia*, *Xanthosoma*, *Alocasia*, and *Cyrtosperma*. These aroids vary in use and extent of cultivation among Pacific Island societies. In Hawai'i, the genus most commonly grown and consumed is *Colocasia*, and "taro" or "dasheen" commonly refers to *C. esculenta*. Globally, taro is the fourteenth most consumed vegetable, with 12 million tonnes (~13 million US tons) produced from about 2 million hectares (~5 million acres) and yielding on average 6.5 tonnes/ha (2.8 US tons/acre) (FAOSTAT 2010 estimates; Ramanatha et al. 2010).

In 2009, approximately 1814 tonnes (2,000 US tons) of *C. esculenta* were harvested in Hawai'i from 100 farms on 180 ha (445 acres). More than 80% of Hawai'i's present-day taro production occurs on the island of Kaua'i. The farm value of Hawai'i's taro crop in 2009 exceeded $2.4 million (United States Department of Agriculture 2011). Processors use mature corms of Hawaiian cultivars to make poi by steaming and macerating the taro. Cultivars processed into poi commercially are predominantly 'Lehua' types, and to a lesser extent 'Moi' and 'Api'i.' However, many Hawaiian cultivars are processed into poi for subsistence use or steamed and eaten as pieces. The Chinese taro cultivar (Bunlong taro) is prepared as deep-fried "chips" or as taro "baskets" in restaurants, as dim sum, as hash patties or as steamed taro "cakes." Other modern Hawaiian taro products include taro batters, taro breads or rolls, and taro pancakes, in which poi is added to wheat flour. Cooks bake, boil,

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Figure 2. Taro cultivation in a wet, lowland setting (*lo‘i*) in Hawai‘i. The *lo‘i* can be filled with water or drained by the farmer.

Figure 3. A dryland taro field in Hawai‘i. Plants are grown here in deep soil and irrigated by rainfall.

or steam taro leaves as food wrappings in *laulau, a* Hawaiian delicacy prepared with steamed pork enclosed in layers of taro leaves and wrapped in ti leaves.

Taro leaf blight, caused by *Phytophthora colocasiae* Racib., is historically the most important and damaging disease of taro worldwide and is responsible for major taro yield losses globally. This disease was responsible for the widespread taro crop failure in the Samoan archipelago in the 1990s. Taro crops in American Samoa were devastated by an epidemic of taro leaf blight from 1993-1994 (Trujillo et al. 1997). Taro production fell from 357,000 kg (786,000 lb) per year before the epidemic to less than 5,000 kg (11,000 lb) by the end of 1995 (Brooks 2008). Similarly, in 1993 the value of exported taro for Western Samoa (now Samoa) was US$3.5 million, about 58% of Samoa's agricultural exports. By 1994 the value of exported taro was less than US$60,000.

The severity of the Samoan epidemic was partly due to widespread planting of a single susceptible taro cultivar throughout the archipelago. During such epidemics, leaves on taro cultivars that normally live for 30-40 days are destroyed in 10 days or less. As leaves die, photosynthesis is reduced and corm yields diminish. Highly susceptible cultivars appear to melt in the field, the leaves getting smaller and smaller, on shorter and shorter leaf stalks. Unfortunately, there is little to be done to prevent a severe epidemic of taro leaf blight if pathogen inoculum is present and environmental conditions are favorable for infection and disease development. In this article we discuss the causal pathogen, symptoms of the disease, and management options for taro leaf blight in Hawai‘i.

Hosts of *P. colocasiae*

Phytophthora colocasiae infects taro and dasheen (*C. esculenta*, *Colocasia esculenta* var. *globulifera*), and some cultivars of ape or tamu (*Alocasia macrorrhiza*). The most susceptible hosts are among cultivars of *C. esculenta*.

Biology and morphology of *P. colocasiae*

Organisms in the genus *Phytophthora* are no longer classified as fungi, but rather as pseudo-fungi in the Stramenopiles. *Phytophthora colocasiae* is heterothallic, requiring two opposite mating types (designated A1 and A2) to form oospores, the sexual stage. Only the A1 mating type occurs in Hawai‘i and in most other taro-growing areas. Oospores have thick walls and are well suited for long-term survival in the absence of their taro hosts. This characteristic suggests that migration

Figure 4. Sporangia and mycelia of *Phytophthora colocasiae* (magnified).

Figure 5. A sporangium of *Phytophthora colocasiae* releasing zoospores, which swim in free water to infect taro leaves (magnified).

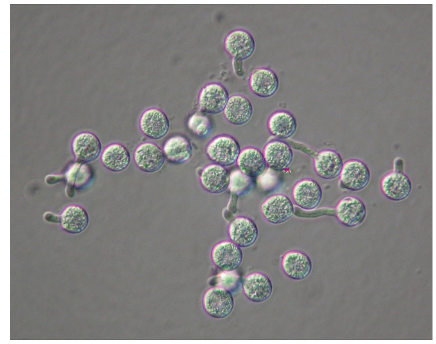

Figure 6. Germinating zoospores of *Phytophthora colocasiae* (magnified).

and sexual recombination may play important roles in the population dynamics of the pathogen. Chlamydospores are thick-walled asexual spores that sometimes grow in laboratory cultures. Like oospores, they may also be involved in the natural survival of the pathogen in soil between crops. This pathogen produces another type of asexual spore, called a sporangium (Figure 4). Sporangia (plural of sporangium) are oval in shape, hyaline (colorless), and semi-papillate (the tip of the spore is not pointed). They have a short stalk or pedicel attached to the base of the sporangium and are deciduous (spores fall from the mycelium). Sporangia can germinate directly and infect host tissue via germ tubes. If there is a brief chilling period in the weather and moisture on the leaf, however, they can also germinate indirectly, releasing swimming, infective spores (zoospores) (Figure 5). After a short period, the zoospores lose their swimming tails and encyst. The encysted spores then germinate (Figure 6), and their germ tubes penetrate the taro tissue. *Phytophthora colocasiae* grows well between 20-25°C (68-77°F) and most rapidly from 27-30°C (80-86°F). Minimum and maximum temperatures for growth are 10°C (50°F) and 35°C (95°F), respectively.

Disease distribution

The first report of taro leaf blight was from Java in 1900 (Raciborksi 1900). *Phytophthora colocasiae* now infects taro throughout the Pacific, Asia, East Asia, Africa, the Caribbean, and the Americas. Taro leaf blight disease occurs in all taro-growing areas of Hawai‘i.

Yield loss

Taro leaf blight can reduce taro corm yield by 50% or more for highly susceptible taro cultivars. Leaf yield losses of up to 95% have occurred for susceptible varieties in Hawai‘i. Epidemics can completely destroy susceptible cultivars in the field. Poi quality can be reduced, as reduced photosynthesis results in decreased production of gums and starches.

Disease symptoms

Phytophthora colocasiae primarily infects leaves, but petioles and corms are also susceptible (Brooks 2008).

Leaves

Early leaf infections often occur where rainfall or dew droplets tend to accumulate, at the margins and tips of leaves. The first symptoms appear on the upper surface of leaves as small, brown to olive-green flecks, or as spots surrounded by faint, diffuse halos (light green or yellow tissue around lesions) (Figure 7). The circular spots enlarge rapidly, forming zonate, brown to purplish-brown lesions (Figure 8). The zones in the leaf spots result from differential radial growth of the pathogen within leaf tissues during periods of fluctuating temperaure and relative humidity. This radial expansion of leaf spots during moist weather occurs rapidly on leaves of susceptible cultivars, rotting large sections of leaves in a few days. On the undersides of leaves, spots appear water soaked, or dry and tan or gray (Figure 9). As the spots expand in diameter they combine, causing a blight that can destroy the leaf in seven days or less (Figure 10, Figure 11). Conspicuous droplets of amber, bright orange, or reddish-brown plant exudate often ooze from lesions (Figure 12). A narrow but distinct yellow halo may surround lesions, a symptom that may appear during dry weather or on particular taro cultivars. During dry weather the rate of lesion expansion slows and lesions may change color, turning tan to brown with dark brown margins (Figure 13). During dry weather or on some resistant taro cultivars, the centers of lesions become papery, break apart, and fall away and give a "shot-hole" appearance. This symptom may also appear on susceptible cultivars when wet weather is followed by dry conditions (Figure 14). A prominent sign of *P. colocasiae* infections is a powdery white ring containing masses of pathogen sporangia. These rings form near the advancing edges of lesions during wet or humid weather (Figure 15). Dead taro leaves may hang like necrotic flags from erect petioles.

Petioles (leaf stalks)

Lesions are gray to brownish-black, vary in length, and can occur anywhere on the petiole (Figure 16). As the pathogen destroys the tissue, petioles turn soft and may break if unable to support the weight of the leaves (Figure 17). Petiole lesions expand rapidly and may produce a reddish-orange exudate. These lesions and exudates may sometimes be confused with injury caused by the taro planthopper (*Tarophagus proserpina* [Kirkaldy] *Hemiptera: Delphacidae*) (Figure 18).

Corms

Infection can occur on any part of the corm and develop rapidly after harvest. Infected corm tissues are brown and firm. They commonly occur in very susceptible cultivars, particularly during or after wet, warm conditions. In the early stages of corm rot, the symptoms are subtle. Diseased tissue has a light tan color and is rubber-like and soft. Later an expanding, brown, discolored area with a diffuse, indistinct border develops. In the advanced stages of rot, decayed corm tissues turn brown to purplish. These corm rots typically start from the stem end.

Disease cycle

Sporangia of the pathogen develop on infected leaves and petioles and are readily distributed by splashing water and wind-blown rain. Although taro leaves have a waxy surface, the minute droplets of water that accumulate on leaves provide sufficient

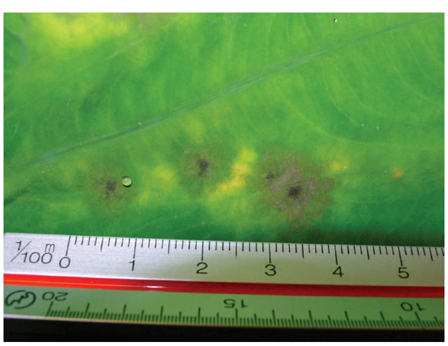

Figure 7. The first symptoms appear on the upper surface of leaves as small, brown to olive-green flecks, or as spots surrounded by faint, diffuse halos (light green or yellow tissue around lesions).

Figure 8. The circular spots enlarge rapidly, forming zonate, brown to purplish-brown lesions.

Figure 9. On the undersides of taro leaves, spots appear water-soaked or dry and tan or gray.

water for spore germination. Released zoospores or sporangia germinate rapidly and penetrate host tissues, causing infections. In taro paddy culture, spores can move with the water throughout a field and into adjacent paddies. The pathogen can live for a time as mycelium in dead and dying plant tissues and in infected corms. During dry periods it can survive in the soil matrix as encysted zoospores, or possibly as chlamydospores (Gollifer et al. 1980; Quitugua and Trujillo 1998). The mycelium of *P. colocasiae* is usually short lived in soils, remaining viable for less than five days. However, encysted zoospores of this pathogen can survive for several months in the absence of a living host plant. Oospores and chlamydospores may act as survival structures in infected plant tissues or in soils, but they are not commonly found in the field.

Disease epidemiology

The warm, wet climate of the tropics allows taro to grow throughout the year, ensuring a continuous supply of susceptible host plants for the pathogen. Conducive air temperatures and periods of sustained leaf wetness promote taro leaf blight epidemics by favoring pathogen dispersal, infection, and disease development (Thankappan 1985; Trujillo 1965). Epidemics can develop when nighttime air temperatures reach 17-20°C (63-68°F), as cool temperatures stimulate the release of infective zoospores. So instead of direct germination by a single sporangium causing a single infection, the released zoospores can cause multiple infections, greatly increasing the epidemic potential and crop damage. Due to the near-vertical position of taro leaves and their thick, waxy, hydrophobic leaf cuticles, sporangia and zoospores tend to either wash off leaves and into soils, or splash onto other leaves or petioles. In wetland (flooded) taro production, the movement of paddy water carries these sporangia and zoospores among plants and between fields. Because growers propagate taro vegetatively by transplanting *huli* and *keiki*, they often unknowingly transport *P. colocasiae* among fields and over long distances by moving infected planting material.

Integrated pest management

Taro leaf blight epidemics can progress quickly and with great severity. The highly infectious nature of the disease may exclude the use of a single cultural or physical management practice. The use of pesticides on taro is costly and can pose environmental hazards on Pacific islands. Therefore, taro growers may

Figure 10. As the spots expand in diameter they combine, causing a blight that can destroy the leaf in seven days or less.

Figure 11. Taro leaf destroyed by blight.

Figure 12. Conspicuous droplets of amber, bright orange or reddish-brown plant exudate often ooze from lesions.

Figure 13. During dry weather the rate of lesion expansion slows and lesions may change color, turning tan to brown with dark brown margins.

need several complementary practices to reduce the incidence and severity of taro leaf blight to acceptable levels. Some of these practices are listed below and vary in their effectiveness.

Site selection and preparation

Avoid geographic regions or fields with a history of severe taro leaf blight, especially if planting a susceptible taro cultivar. Also, an environment that is highly conducive for taro leaf blight development can overcome the disease resistance or tolerance of some cultivars. Although blight-resistant plants can recover if the weather improves, the quality of the corms or poi will be adversely affected. Therefore, if the selected site has a history of severe taro leaf blight, using resistant cultivars may be helpful but is not a guarantee against crop loss. Soils may be drenched with approved products such as MetaStar™ or Ridomil® as a pre-plant treatment. This can provide initial protection against taro leaf blight for 4-6 weeks. The soils at dryland sites should be well drained and fertile. In some locations (e.g., Ho‘olehua, Moloka‘i), calcium and magnesium levels may be low, so growers should add these elements before planting. Soil tests will indicate elements at low levels as well as physical properties of soils that require management. Planting in areas

Figure 14. The papery symptom may also appear on susceptible cultivars when wet weather is followed by dry conditions.

of low rainfall away from traditional windward locations would be unfavorable for taro leaf blight epidemics and would favor taro plant production. For example, blight-susceptible taro cultivars have been grown successfully under drip irrigation on Maui at the Kula Ag Park and Kula Ag Station. This would apply to taro production in leeward sites. This recommendation was made to taro farmers in the Dominican Republic and similar site locations, which resulted in the full economic recovery of their taro industries (John Cho, *personal communication*).

Windbreaks

Windbreaks near a taro field may cause poor air circulation and a higher relative humidity. This keeps taro leaves wet for a longer period of time, allowing taro leaf blight to spread and become more severe (Figure 19). Fields in open areas have better

Figure 15. A prominent sign of *P. colocasiae* infections is a powdery white ring containing masses of pathogen sporangia. These rings form near the advancing edges of lesions during wet or humid weather.

Figure 16. Lesions are gray to brownish-black, vary in length, and can occur anywhere on the petiole.

air circulation and lower relative humidity, allowing taro leaves to dry more rapidly and reduce infection. However, strong winds occurring in unprotected fields can damage taro leaves and weaken plants. In the Samoan archipelago, farmers will pull up their taro and throw it away after a hurricane. They say damage from the strong winds ruins the flavor of the corms. Taro leaf blight also tends to be more severe in the shade of trees growing within taro fields due to prolonged wetness of the taro leaves and higher relative humidity.

Planting materials and variety selection

First, blight-susceptible taro can be successfully grown in many areas as long as the weather is not favorable for infection and leaf blight development. Also, taro cultivars should be chosen that will grow vigorously at the selected site. For example, ‘Pololu’ produces a firm corm, even when grown in swampy water. ‘Pa‘akai’ grows well in brackish *lo‘i*. ‘Mana,’ and ‘Lauloa’ are relatively drought tolerant. ‘Moi’ can be held in the field for months after maturity, as can ‘Piko,’ but to a lesser extent. Choose and prepare planting materials carefully to ensure they are free of taro leaf blight symptoms. Taro plant architecture and leaf orientation may also have a role in susceptibility to infection and the spread of leaf blight. Some cultivars with a more upright, less horizontal leaf growth, such as ‘Mana’ cultivars, may be less prone to infection than ‘Piko,’ with its leaves growing in a more horizontal position. Some cultivars, like ‘Piko,’ are also more open in the center, whereas the cultivar ‘Lauloa ke‘oke‘o’ has leaves that grow clustered together. Whichever cultivar is selected, optimum plant nutrition can maximize its resistance to taro leaf blight.

Resistant cultivars

Resistant cultivars offer the best sustainable management strategy against taro leaf blight. Unfortunately, none of the Hawaiian taro varieties listed in Bulletin 84 (Whitney et al. 1939) has agronomic resistance to the disease. And, as the choice of taro cultivars by farmers is driven by their personal tastes (poi flavor, color, stickiness, acidity) and market considerations (milling and poi production), some resistant cultivars may not be useful to all Hawaiian growers. John Cho, a Plant Pathologist at the University of Hawai‘i, developed taro hybrids on Maui—‘99-6’ (‘Lehua Hoohua’) and hybrid ‘2002-57’—that have gained wide adoption by Kaua‘i taro growers and in some cases displaced the Kaua‘i industry standard, ‘Maui Lehua.’ These hybrids yield well and have excellent taste and poi quality characteristics.

Eduardo Trujillo, a Plant Pathologist at the University of Hawai‘i, collected disease-resistant dryland taro varieties from the Republic of Palau in the 1990s. He numbered them ‘P1,’ ‘P2’ . . . ‘P20,’ and tested them in Hawai‘i for resistance to taro leaf blight. Blight-resistant cultivars such as ‘P10,’ ‘P16’ (‘Meltalt’), and ‘P20’ (‘Dirratengadik’) performed well in Hawai‘i field trials (Greenough et al. 1996; Trujillo et al. 1997). In Samoa and American Samoa, ‘P10’ was by far the most popular variety, but problems with corm rot developed. ‘Antiguo,’ renamed ‘Rota’ in American Samoa, was used as the susceptible cultivar in the Hawai‘i trials. The average leaf damage per cultivar was 8% for ‘P16’ and ‘P20’ and 28% for ‘Antiguo’ (Greenough et al. 1996, Trujillo et al. 1997). Three blight-resistant taro hybrids obtained from crossing Palauan and Hawaiian taros (‘Pa‘akala,’ ‘Paukaea,’ and ‘Pa‘alehua’) and were patented by Trujillo in 2002 (Trujillo 2002), but due to cultural considerations the University of Hawai‘i at Mānoa relinquished the rights to these patents.

Figure 17. As the pathogen destroys the tissue, petioles turn soft and may break if unable to support the weight of the leaves.

Breeding for disease resistance

Cultivars with resistance to taro leaf blight are usually developed through breeding programs. The resistant Palauan taro varieties imported from Hawai‘i allowed growers in American Samoa, and later in Samoa, to recover from the severe losses caused by taro leaf blight. However, desirable characteristics and qualities are often lost during breeding. Thus, breeding for taro leaf blight resistance should focus on maintaining or improving desirable qualities, such as larger corms, shorter time to plant maturity, and improved taste and texture. A taro breeding program in Bubia, Papua New Guinea, discovered several promising taro lines. Other researchers have identified or developed resistant taro in a number of locations globally. The Secretariat of the Pacific Communities’ (SPC) Regional Germplasm Centre in Suva, Fiji, coordinates the distribution of blight-resistant taro to all non-commercial sources. These taros are donated by breeding programs located in more than 20 countries in the Pacific and Asia. This program provides an opportunity to introduce genetic diversity into Hawai‘i’s taro production.

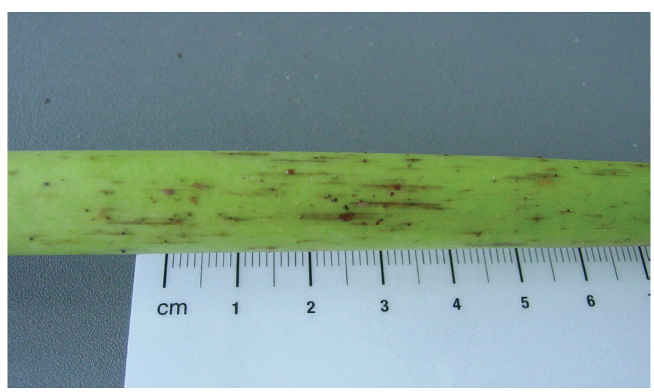

Figure 18. Taro leaf blight lesions and exudates may be confused with injury caused by the taro planthopper (*Tarophagus proserpina* [Kirkaldy] *Hemiptera: Delphacidae*) (above).

The key to breeding taro varieties for Hawai‘i is to wind up with a purple taro having Hawaiian taste and texture characteristics. In Hawai‘i, a taro breeding program was started by John Cho, UH College of Tropical Agriculture and Human Resources (CTAHR) in 1998. Dr. Cho's goals were to improve commercial taro for pest resistance, including taro leaf blight, and increase its genetic diversity (Cho 2003). Because Hawaiian taro cultivars have a low genetic diversity, introduced taro from Micronesia, Palau, Indonesia, Papua New Guinea, Thailand, and Nepal were used in his program to incorporate different sources of blight resistance. Several new F1 hybrids and backcrossed F1 hybrids were produced and are being evaluated. Some recommended cultivars from Dr. Cho's program include ‘99-6,’ ‘99-7,’ and ‘99-9,’ which are half ‘Maui Lehua,’ a quarter Thai, and a quarter Samoan. Dr. Cho also donated some of his cultivars to the Regional Germplasm Centre. A continuing breeding program at CTAHR has the specific goal of improving current cultivars to produce a commercial taro variety for Hawai‘i with a strong resistance to taro leaf blight (S. Miyasaka, *personal communication*).

Isozyme analysis and DNA markers have identified significant genetic differences in isolates of *P. colocasiae* within and among countries that may affect the pathogenicity of the isolates (Lebot et al. 2003). A taro cultivar resistant to leaf blight in one country is likely to be exposed to genetically different isolates of *P. colocasiae* when grown in a different country (Lebot et al. 2003). Because geographically variable genotypes of *P. colocasiae* might recombine somatically (i.e., fuse together and mix their DNA), or evolve rapidly (e.g., by mutation), a sustainable breeding strategy for taro is needed. One strategy, based on recurrent selection, uses a wide genetic base of taro composed of carefully selected parents from diverse geographic origins. This repeated selection would encourage multigenic resistance (having more than one resistance gene) in taro progenies (Lebot et al. 2004). Taro from breeding programs should be tested against *P. colocasiae* isolates already present locally before introducing new breeding lines. However, it might also be wise to breed for leaf blight resistance to local strains of *P. colocasiae* in each country where the pathogen is present.

Plant spacing

Spacing between plants should match the carrying capacity (soil and nutrition, water availability) of the field and not exceed it. Wider spacing between plants may not reduce the severity of taro leaf blight during optimum environmental conditions for disease. Planting taro at higher densities within fields, although favoring the development of blight, produces higher corm yields per hectare. For example, a narrow within-row spacing (0.5 m or 2 ft) can increase the total weight and number of harvested corms, though the individual corms will be smaller in size. From 7,000 to 11,000 plants per acre (about 2,800 to 4,400 plants per ha) are acceptable for dryland taro cultivation at some

Figure 19. Integrated agroforestry practices for taro cultivation have been used for centuries in the Pacific region. Such systems include intercropping of taro with sweet potato, cassava, papaya, banana, sugarcane, breadfruit, yam, and other plant species. Windbreaks, such as a row of banana plants, when adjacent to a taro crop can allow leaf blight epidemics to develop more severely on taro due to more prolonged periods of taro leaf wetness and higher relative humidities in the taro leaf canopy.

Figure 20. Integrated agroforestry practices for taro cultivation have been used for centuries in the Pacific region. Such systems include intercropping of taro with sweet potato, cassava, papaya, banana, sugarcane, breadfruit, yam, and other plant species.

locations in Hawai‘i. However, higher planting densities can have associated problems such as more southern blight disease, caused by the fungal plant pathogen *Sclerotium rolfsii*, a major limiting factor for taro production.

Irrigation

Use furrow or drip irrigation for dryland taro cultivation. Avoid overhead irrigation, as splashing water can spread the infective spores of *Phytophthora* among leaves of the same plant and from plant to plant. Wet leaves also favor germination and infection by the *P. colocasiae* spores. However, sometimes overhead irrigation can suppress parasitic insects such as aphids and planthoppers.

Plant nutrition and fertilizers

Healthy plants having adequate plant nutrition can maximize their genetic potential. For example, such plants can replace lost and damaged leaves more quickly. Field tests conducted by the University of Hawai‘i at Mānoa, however, indicated that increased nitrogen fertilization increases the severity of taro leaf blight. Plants lacking sufficient calcium in leaves may have weaker cells walls and therefore succumb more rapidly to infection by *P. colocasiae* and disease development. In many other cropping systems, foliar and/or soil-drench applications of phosphorous acid fertilizers such as Phosguard® effectively manage epidemics caused by species of *Phytophthora*. For recommended levels of nutrients, go to the following publication: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-4.pdf.

Cropping system diversity

Growing a taro crop consisting of a single cultivar (i.e. genotype) or similar genotypes can lead to crop failure. The severity of the taro leaf blight epidemic in the Samoan archipelago was enhanced by the extensive planting of a single variety, taro ‘Niue.’ Intercropping taro with other types of plants, rather than growing taro as a sole crop, reduces the probability of severe epidemics of taro leaf blight and probably other diseases such as corm rots and root knot. Integrated agroforestry practices for taro cultivation have been used for centuries in the Pacific region (Figure 20). Such systems include intercropping of taro with sweet potato, cassava, papaya, banana, sugarcane, breadfruit, yam, and other plant species. Alternatively, planting different taro cultivars in a field might reduce the probability of severe crop loss. On Moloka‘i, one author of this publication plants over 25 different taro cultivars in a given field, including a combination of Hawaiian varieties and Hawai‘i-Palau taro hybrids such as ‘99-4,’ ‘99-33,’ ‘2000-44,’ and ‘2000-104,’ hybrids that emerged from John Cho’s breeding program. The first two hybrids have a similar genetic background with ‘99-6,’ while the latter two have different genetic backgrounds. The basic idea is that diversity in a plant population creates a more stable agroecosystem and places less pressure on a plant pathogen population to overcome the disease resistance.

Sanitation

Routinely removing infected leaves from fields will reduce the amount of pathogen inoculum (i.e., spores), but it is tedious and has substantial labor costs. It consists of removing from the field and destroying parts of leaves with blight symptoms, or whole leaves with blight covering more than

50% of the leaf. When environmental conditions favor taro leaf blight development (i.e., during prolonged rainy periods), however, sanitation may have little effect on disease development. Because only a few infected leaves in a field are enough to start a severe epidemic, the practice of sanitation may not be worth the effort. Removing leaves from taro plants has the same detrimental effect on their growth as the leaf blight disease, so leaf removal quickly becomes unproductive. Seasonal weather changes affect the addition of new taro leaves. In general, a leaf can be removed once every 2-3 weeks during summer and about once every 3-4 weeks during winter without seriously affecting plant growth and corm yield. Since taro leaf blight can destroy the leaf of a susceptible variety in 7 days, the rate of disease progress can exceed the rate of plant growth, making sanitation unproductive. This method of sanitation has been shown to be ineffective in the Samoan archipelago. Therefore, farmers are advised not to rely solely on sanitation for management of taro leaf blight. Combining sanitation with other management practices such as site selection, planting density, intercropping, and planting a resistant taro cultivar or cultivars can reduce the severity of taro leaf blight.

Biological controls

Foliar application of biological control agents has some potential to protect taro plants from infection, but more research and product development are needed. Significant reductions in the number of infected leaves and disease severity were observed in taro plants sprayed with the fungus *Trichoderma* (Palomar et al. 2001). However, similar research has not been conducted in Hawai‘i, and no biological control products are currently registered for use in Hawai‘i on taro.

Postharvest treatments (physical, chemical)

Taro should either be processed promptly or consumed and is better left unharvested than stored. Most taro corms are consumed or processed promptly after harvest. Therefore, corm rots caused by *P. colocasiae* or other pathogens are not usually significant post-harvest problems. However, when corms are stored in warm and/or wet conditions, or for prolonged periods, severe rot can occur. Corms should be refrigerated during storage to slow the development of rot.

Pesticides

Chemical management of taro leaf blight is labor intensive and expensive, and it may not prevent an epidemic. An integrated approach that combines cultural, biological, and chemical methods is best. Protectant sprays containing copper, manganese, or zinc have been effective against taro leaf blight, but heavy rains make repeated applications necessary and can lead to soil contamination. Pesticide products with the active ingredient metalaxyl (e.g., Ridomil®) can suppress the pathogen, but in Hawai‘i they are labeled only for pre-plant application. For most Pacific islands, routine use of pesticides is neither economically feasible nor environmentally suitable. In Samoa, control of taro leaf blight was achieved by sprays of Ridomil,® Manzate,® and phosphorous acid products. Please refer to Table 1 for a list of pesticide products registered in Hawai‘i for management of *Phytophthora*.

Table 1. Pesticides registered in Hawai'i for management of *Phytophthora* on taro.[1]

Product name Active ingredient (%) Formulation Rate Use

Product name	Active Ingredient (%)	Formulation	Rate	Use
Fosphite® Fungicide[2]	Mono- and di-potassium salts of phosphorous acid (53.00)	Emulsifiable concentrate	1-3 qts. per 100 gal. water/acre (5-7 L per 1,000 L of water/ha)	**Disease Prevention**: Apply lower rate at 2- to 4-week intervals after plants become established. **Disease Control**: Apply higher rate at 2- to 3-week intervals until control is reached. Do not apply more than 6 times per crop cycle or year.
Acrobat® 50WP[2]	Dimethomorph (50.00%)	Wettable powder	6.4 oz per acre	For suppression only. Apply as a tank mix with another fungicide active against leaf blight. Do not make more than 2 sequential applications. Do not make more than 5 applications per season or exceed 32 oz. per acre per season. Do not apply within 7 or 30 days of harvest for leaves and corms, respectively.
MetaStar™ 2E AG	Metalaxyl: N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester (23.00%)	Emulsifiable concentrate	4 to 8 pts. per acre at planting	Apply as a broadcast soil application in enough water or liquid fertilizer to provide uniform coverage and to incorporate it in the top 2 inches of soil. For banded applications, a 7-inch band is recommended. **Surface Application**: Apply at planting in sufficient water or liquid fertilizer to provide uniform coverage.
Forum®[2]	Dimethomorph (43.5%)	Emulsifiable concentrate	6.0 oz. per acre	If Forum has been applied as the only pesticide for *Phytophthora*, the next application must be a product with a mode of action different from Forum. Do not make more than 5 applications of Forum per season. Do not exceed 30 oz per acre per growing season. Do not use less than 20 gallons of water per acre for ground applications. Do not apply within 7 or 30 days of harvest for the greens and corms, respectively.
Reason® 500 SC[2]	Fenamidone: (5S)-3,5-dihydro-5-methyl-2-(methylthio)-5-phenyl-3-(phenylamino)-4H-imidazol-4-one (44.4%)	Soluble concentrate	5.5 – 8.2 fl oz/A; 0.178 – 0.267 lb. ai/A	For optimum results, begin applications as soon as crop and/or environmental conditions become favorable for disease development. Applications should be made at 5- to 10-day intervals depending upon disease conditions.
Ridomil Gold® SL	Mefenoxam (45.3%)	Emulisifiable concentrate	1-2 pts. per acre	For *Phytophthora* root rot management, apply as a pre-plant via broadcast or 7-inch band (apply in water or liquid fertilizer and incorporate in the top 2 inches of soil) or apply as soil spray at planting in water or liquid fertilizer.

[1]Not all products are labeled for use in Hawai'i for foliar applications on taro.

[2]Products labeled for use in Hawai'i for foliar spray treatments against *Phytophthora*.

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