

Crop Profile for Bananas in Hawaii

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General Production Information

- Hawaii is the only significant commercial producer of bananas in the U.S. (National Agricultural Statistics Service, 2002).
- Planted commercial acreage in Hawaii was 1,710 acres in 2000 and 1,660 acres in 2001. Harvested acreage was 1,460 acres in 2000 and 1,490 acres in 2001 (Hawaii Agricultural Statistics Service, 2001).
- Banana production in Hawaii totaled 14,500 tons in 2000 and 14,000 tons in 2001 (Hawaii Agricultural Statistics Service, 2001).
- Total value of the Hawaii banana industry was \$10,440,000 in 2000 and \$10,640,000 in 2001 (Hawaii Agricultural Statistics Service, 2001).
- Average production costs are approximately \$5,000 per acre (including harvesting and processing for market) and are dependent on production practices and pest control measures (CTAHR, 2001)
- Nearly 100% of harvest bananas are for fresh market use (Hawaii Agricultural Statistics Service, 2001).

Production Regions



Bananas are grown commercially throughout the state of Hawaii. In 2001, the island of Hawaii had 730 harvested acres. Major growing areas on Hawaii island are Puna, Hilo, and the Hamakua coast. The island of Oahu had 645 harvested acres mostly in Kaneohe, Waimanalo, Kahuku, and Waialua with increasing production in Ewa. Major growing areas on Kauai include Kapaa, Koloa, Kilauea, and Moloaa. On Maui, production is concentrated in Hana, Haiku, and Wailuku. A total of 200 commercial banana farms were in production in Hawaii during 2001 with 62% located on the islands of Hawaii and Oahu (Hawaii Agricultural Statistics Service, 2001).

Table 1. Average rainfall in commercial banana producing areas in Hawaii (NOAA, 2003).		
Island	Region	Ave. Annual Rainfall (in.)

Hawaii	Puna	140.0
	Hilo	126.3
	Hamakua	150.0
Maui	Hana	80.0
	Haiku	65.0
	Wailuku	28.0
Oahu	Waimanalo	42.8
	Kaneohe	80.0
	Kahuku	45.0
	Waialua	29.9
	Ewa	28.0
Kauai	Koloa	60.0
	Kapaa	80.0
	Kilauea, Moloaa	50.0

Cultural Practices

Banana production systems are perennial. The plant is an herb with leaf sheaths that form above the ground in trunk-like pseudostems. Flower development is initiated from the underground true stem portion of the plant 9 – 12 months after planting. The inflorescence grows up through the center of the pseudostem. Fruits mature in 90 – 120 days after flowers first appear, depending on season and cultivar. The plant has 8 – 12 leaves up to 9 feet long and 2 feet wide (Knowledge Master, 2003).

Bananas are propagated exclusively by vegetative means through suckers, corms, or tissue culture. "Seed" pieces are planted at a spacing of 8–15 ft. between rows and 6-7 ft. between plants within a row. Approximately 750 plants per acre (including tractor rows) can be planted in a 2-line system with this spacing (Nelson, in press). Multiple suckers can be produced from 1 banana plant but are maintained at

1 or 2 fruit producing plants for commercial production. Approximately 80% of the banana cultivars grown in Hawaii are from the Cavendish group: Williams, Valery, Chinese, Hamakua, and Grand Nain. The remaining 20% are mostly from the Hawaiian Apple Banana group (Tall Apple and Dwarf Apple) with approximately 1% belonging to the Bluefield group (Bluefield and Dwarf Bluefield).

Bananas are best grown in well-drained soils with pH of 6.0 – 6.5. Because of the fast growing nature of the plant, irrigation and nutrition requirements are high. Windward locations with high rainfall (> 60 in/year) do not use supplemental irrigation (Table 1). Drier locations use drip irrigation to supply a minimum of 1 inch of water per week. Potassium is especially critical to optimum fruit yield and must be applied every 2 to 3 months for sustainable commercial production. The roots of the banana plant are very extensive but shallow and movement of leachable nutrients (N and K) occurs rapidly in high rainfall areas. Mechanical cultivation for weed control can be detrimental to the shallow banana root system. Weed competition from nutrients and moisture are maintained by a combination of ground cover and timely herbicide sprays (Farmers Bookshelf, 2003).

Banana production requires a high amount of hand labor. Field activities which are performed by hand include planting, sucker thinning, harvest, weeding, and insect and disease control when applied by back pack sprayers.

Insect Pests

Anthurium thrips, *Chaetanaphothrips orchidii*

Banana rind thrips, *Elixothrips brevisetis*

Banana rust thrips, *Chaetanaphothrips signipennis*

Banded greenhouse thrips, *Hercinothrips femoralis*

Hawaiian flower thrips, *Thrips hawaiiensis*

Thrips are common insect pests in commercial banana production. Their piercing (rasping)-sucking mouthparts damage flowers, fruit, leaves and stems. Several different species feed on bananas.

Anthurium thrips have been reported as a synonymous species of Banana rust thrips (Morton, 1987). The banana rust thrips was first collected in Hilo in 1996. The nature of the damage caused by this pest varies: banana rust thrips feed on the pseudostem and fruit. Thrips feeding on leaf sheaths results in dark, v-shaped marks on the outer surfaces of leaf petioles. Fruit damage is characterized by a water-soaked appearance. Damaged tissue turns bronzed or rust colored with age. Many young fruits exhibit dark or smoky serpentine feeding tracks on their surfaces. Characteristic oval shaped reddish "stains" have been observed on mature fruit where fingers touched. The majority of the damage detected is the result of larval feeding (Knowledge Master; Mau, 1998).

The banana rind thrips feeds on leaves, flowers, or stems with the injured tissue taking on a silvery appearance which eventually turns dark brown. Feeding on leaf tips results in wilting and curling. The undersides of leaves are spotted with small black fecal specks. Flowers become flecked, spotted, and deformed and many buds fail to open (Knowledge Master).

The banded greenhouse thrips causes silver and bronze scars which may result in damage of economic importance (Zimmerman, 1948). The silvering usually occurs with small infestations. When large infestations occur, or when thrips damage is aggravated by the red spider mite and other factors, the banana fruit turns a peculiar reddish color which lowers the market value of the fruit even though the edibility of the fruit is not effected (Bianchi, 1946).

The Hawaiian flower thrips is a widespread species in tropical and temperate climates and is present on all of the major Hawaiian Islands except Lanai. It feeds only on flowers (Takahashi 1936). Depending on the extent of feeding, flowers become flecked, spotted, or deformed. Unlike other flower thrips, this species prefers wet and shady areas (Sakimura and Krauss, 1944).

Control

Chemical Control:

- **Diazinon** (Clean Crop Diazinon 500 AG) – PHI = 28 days, REI = 24 hr. Applied as a low pressure, directed spray to bunches, crowns and leaf sheaths, at a rate of 0.5 lb ai/acre. No more than 6 applications per bunch. (Registered under 24(c) Special Local Needs label, expires on 4 June 2007.)

Alternative Chemical Control:

- **Spinosad** (Success) is a possible alternative to diazinon for thrips control, pending registration for banana.
- **Imidacloprid** (Provado 1.6F, Admire 2F) is a possible alternative to diazinon for thrips control, pending registration.
- **Bifenthrin** impregnated bags for fruit. A tolerance for imported banana was recently established (4/30/2003) and efforts are being made to secure a 24(c) registration for use in banana in Hawaii.

Non-chemical Control:

An anthocorid bug, *Orius tristicolor*, is a generalist thrips predator like other species belonging to the Orius genus (Waterhouse and Norris, 1989). In Hawaii, there are two additional species of anthocorid bugs, *Orius persequens* and *Orius insidiosus*. The economic value of these bugs as thrips biocontrol agents is unknown.

To avoid additional losses and insect damage, the majority of the bananas produced in Hawaii are covered with a polyethylene bag prior to harvest. The bags provide a physical barrier to insect infestations.

Banana Aphid

Pentalonia nigronervosa

The banana aphid is a serious problem on banana because it is a vector of Banana Bunchy Top Virus (BBTV), the most damaging virus disease of bananas in Hawaii. Aphid colonies may be found in the crown of the plant, at the base of the pseudostems, or between outer leaf sheaths. Young suckers are typically the most heavily infested (Knowledge Master). Feeding causes plants to become deformed; the leaves become curled and shriveled and in extreme infestations galls can form on leaves. Direct damage from feeding is generally negligible.

Control

Chemical Control:

- **Diazinon** (Prentox Diazinon AG500) – REI = 24 hr. Applied as a directed spray to crowns on plants that are not fruiting. Applied at a rate of up to 0.5 lb ai/acre in 100 gallons of solution. Applied to approximately 1,200 acres per year. (Registered under a 24 (c) Special Local Needs label, expires on 28 September 2005.)
- **Horticultural Oil:** Horticultural oils such as Volck Supreme and Clean Crop Superior are used to suffocate aphids and other soft bodied pests. These oils are low in toxicity to plants and have little impact on the environment and humans.
- **Soapy water:** May be used to kill aphids that dwell in leaf pockets and the pseudostem of plantings. Many homeowners utilize this non-toxic method to reduce aphid populations.

Alternative Chemical Controls:

- **Imidacloprid** (Provado 1.6F, Admire 2F) is a possible alternative to diazinon for aphid control, pending registration.

Non-chemical Control:

- Numerous generalist predators and parasites are established in the Hawaiian Islands (Knowledge Master). None will control banana aphid adequately enough to prevent the transmission of BBTV.

Banana Moth
Opogona sacchari (Bojer)
(also called *Opogona subcervinella* (Walker))

The banana moth lays its eggs on senescing flowers, decaying leaves, pseudostems or fruit. The larvae feed on detritus and decaying plant material though they are often found feeding on healthy tissue at the interface with decaying plant parts. The removal of flowers and application of insecticides to banana bunches at the time of fruit bagging greatly reduces larval damage.

Control

Chemical Control:

- **Bacillus thuringiensis** (subspecies Kurstaki, various products; subspecies Aizawai, Xentari products) - PHI = 0 days, REI = 4 hr. Applied to fruit bunches prior to bagging at rate of 0.03 lb ai/acre.

Alternative Chemical Control:

- None.

Non-chemical Control:

- Polyethylene bags can serve as physical barrier to banana moth.
- Remove flower tips from banana to eliminate oviposition site.

Banana Fruit Piercing Moth
Othreis fullonia

The fruit-piercing moth is a serious pest in localized areas. Unlike most moth and butterfly pests, the caterpillar stage does not severely damage plant foliage. Instead, the adult moth punctures and feeds on ripening fruit and creates opportunities for fungal and bacterial infections. High moth populations may result in premature ripening and fruit drop. The fruit piercing moth will continue to be a pest of home grown bananas which are tree ripened. In most commercial areas, natural enemies of the banana fruit piercing moth keep populations below economic threshold levels (Knowledge Master; Mau, 1985).

Control

Chemical Control:

- None.

Alternative Chemical Control:

- None.

Non-chemical Control:

- Natural enemies.
- Naturally occurring polyhedrosis virus.
- Removal of alternate larval hosts (e. g. guava)

Banana Skipper

Pelopidas thrax (Erionata thrax)

Rolled leaves originating from the midrib of plants are a good indicator of banana skipper damage. Since 1973, six parasites have been identified and continue to minimize damage caused by this pest (HDOA). Because of the effectiveness of biological control of the banana skipper, use of chemical treatments is uncommon (Knowledge Master).

Control

Chemical Control:

- **Bacillus thuringiensis** (subspecies Kurstaki, various products; subspecies Aizawai, Xentari products) - PHI = 0 days, REI = 4 hr. Applied to control banana skipper at rates of 0.27 – 0.54 lb ai/acre for Kurstaki products; 0.052 – 0.15 lb ai/acre for Aizawai products. No maximum application rate per year listed.

Non-chemical Control:

- Mostly under control by two species of parasitic wasps, *Ooencyrtus erionotae* and *Apanteles erionotae* (HDOA).

Banana Root Borer

Banana Weevil, *Cosmopolites sordidus*

The banana root borer is a continuing problem for commercial and home growers. The larvae of this pest bore through the corm, suckers and roots of living and decaying planting material. Planting infested rhizomes increases the damage caused by this insect (Nelson, in press). Large numbers of larvae and extensive feeding can result in root destruction, slowed plant growth, reduced fruit production, and, sometimes, toppled plants. The tunneling can kill young plants (Nelson, in press). The adult weevil feeds and breeds at night.

Control

Chemical Control:

- **Carbofuran** (Furadan 5%G) - PHI = none listed, REI = 48 hr. Applied at time of planting to the planting hole and soil surface at rate of 25 to 30 g/planting hole. Soil surface is retreated with 50 g at 4 months after planting and again at 4-month intervals after establishment.

Non-chemical Control:

- There are no known beneficial parasites of the banana root borer within the state.
- Field sanitation and hot water treatments of corms are being used to manage this pest (Knowledge Master; Gettman, 1984). Peeling the rhizomes free of lesions and immersing in a hot water bath at 54°C for 10 minutes is practical and effective in controlling this pest (Nelson, in press). At planting, rhizomes or corms should be completely covered with soil to prevent eggs from being laid on their exposed surface.
- This insect is attracted to freshly cut banana pseudostems and can therefore be trapped by baiting the field over night with sliced pseudostems. Root borers can be found the next morning or within 48 hours by overturning the stems where they will be actively feeding (Nelson, in press).

Big-headed Ant

Pheidole megacephala

Ants are very common in banana fields and virtually impossible to control. The problem posed by ants is their intimate relationship with the banana aphids. Ants feed on the honeydew secreted by the banana aphids and protect the aphids from their natural enemies. This results in larger aphid populations and increases the probability of disease spread by the aphids (e.g., banana bunchy top virus) (Nelson, in press).

Control

Chemical Control:

- **Hydramethylnon** (AMDRO PRO Fire Ant Bait-BASF Corp./Micro Flo Co.) - REI = 12 hr. Applied in bait stations for control of big-headed ant (*Pheidole megacephala*). In fields with actively foraging ants, up to 1.4 oz placed in bait station at approximately 50 ft. x 50 ft. spacing. For field border treatment, bait stations placed in borders of the field at approximately 50 ft. intervals. (Registered for use in Hawaii under a 24(c) Special Local Needs label, expires 3 September 2007.)
- **Hydramethylnon** (SEIGE PRO Fire Ant Bait) - REI = 12 hr. Applied in bait stations for control of big-headed ant (*Pheidole megacephala*). In fields with actively foraging ants, up to 1.4 oz placed in bait station at approximately 50 ft. x 50 ft. spacing. For field border treatment, bait stations placed in borders of the field at approximately 50 ft. intervals. (Registered for use in Hawaii under a 24(c) Special Local Needs label, expires 3 September 2007.)

Alternative Chemical Control:

- None.

Non-chemical Control:

- None.

Chinese Rose Beetle

Adoretus sinicus

The Chinese rose beetle is a common pest on all major banana-producing islands in Hawaii. All the damage is caused by the feeding of the adult beetle. The beetle is nocturnal and feeds primarily on leaf and inter-veinal tissue and is commonly found attacking younger plants.

Control

Chemical Control:

- No known chemical controls to alleviate this problem (Knowledge Master).

Alternative Chemical Control:

- None.

Non-chemical Control:

- Attempts to control this pest by the introduction of parasites have not been successful (Knowledge Master).

Coconut Scale

Aspidiotus destructor

The coconut scale is an armored scale and is usually found on the underside of leaves but can also attach themselves to petioles, peduncles and fruits. When attached to fruits, they become a significant quarantine problem for banana exports (Nelson, in press). Their piercing and sucking mouthparts extract plant juices, leading to discoloration and yellowing of plant tissue.

Control

Chemical Control:

- **Buprofezin** (Applaud 70WP) – PHI = 1 day, REI = 12 hr. Applied as a directed spray to affected plant parts. Applied at a rate of 0.31 lb. ai/acre. Maximum of 4 applications per cropping cycle.

Alternative Chemical Control:

- **Imidacloprid** (Provado 1.6F, Admire 2F) is a possible alternative for coconut scale control.

Non-chemical Control:

- Introduction of natural enemies will be considered if warranted (Knowledge Master).

Long-legged Ant

Anoplolepis longipes

Ants are very common in banana fields and virtually impossible to control. The long-legged ant has been recently reported as pest on bananas. In addition to moving aphids around within a planting (thus contributing to the spread of BBTv) the long-legged ant inadvertently damages the surface of the banana fruit by releasing a toxic chemical when threatened, causing dry necrotic lesions on surface of the fruit and reducing marketability. Long-legged ants are found on all islands and prefer wet, high rainfall areas. These ants are sugar lovers and are not controlled by the same bait products used for big-headed ant control.

Control

Chemical Control:

- None.

Alternative Chemical Control:

- Boric acid compounds with Karo syrup.
- Terro (commercial ant control product).

Spiraling Whitefly *Aleurodicus disperses*

Whiteflies are sap-sucking insects that damage and discolor plant leaves and tissue. Similar to aphids and mealybugs, whiteflies excrete honeydew that may lead to black sooty mold. Ants feed on this honeydew and protect the whiteflies from natural predators. In 1979, the spiraling whitefly was considered a serious economic pest. Since then, five natural enemies have been introduced from the Caribbean to control this pest. By July 1981, the spiraling whitefly was considered under control and is not considered a principal threat to banana production in Hawaii.

Control

Chemical Control:

- **Buprofezin** (Applaud 70WP) – PHI = 1 day, REI = 12 hr. Applied as a directed spray to affected plant parts. Applied at a rate of 0.31 lb. ai/acre. Maximum of 4 applications per cropping cycle.

Alternative Chemical Control:

- **Imidacloprid** (Provado 1.6F, Admire 2F) is a possible alternative for spiraling whitefly control; pending registration.

Non-chemical Control:

- Introduced parasites and predators contribute to lowering of spiraling whitefly pressure in banana fields (Knowledge Master).

Sugarcane Budmoth Caterpillar

Decadarchis flavistriata

The sugarcane budmoth caterpillar is a localized pest in Hawaii. This caterpillar feeds on decaying flowers and causes fruit scarring. Many growers have adopted the practice of removing all flowers prior to bagging to reduce sugarcane budmoth damage. At present, the sugarcane budmoth caterpillar is not considered a serious pest problem in Hawaii, but damage may be controlled using *Bacillus thuringiensis* applied to bunches prior to bagging (Nelson, in press).

Control

Chemical Control:

- ***Bacillus thuringiensis*** (subspecies Kurstaki, various products; subspecies Aizawai, Xentari products) - PHI = 0 days, REI = 4 hr. Applied to fruit bunches prior to bagging at rate of 0.03 lb ai/acre.

Alternative Chemical Control:

- None.

Non-chemical Control:

- Polyethylene bags can serve as physical barrier to sugarcane budmoth.

Mite Pests

Although frequently found on foliage and fruit, mites are usually minor pests of banana in Hawaii. However, potential damage from these pests is significant. The piercing and sucking mouthparts of mites damage plant tissue and fruit. Recently, there has been an increase in damage caused by mites (Nelson, in press)..

Control

Chemical Control:

- A sulfur product, MicroSulf (EPA Reg. No. 55146-75) was recently (2003) licensed for sale in Hawaii for use on bananas. However, no efficacy or phytotoxicity evaluations have been

conducted. Label directions for use indicate applying 10 to 30 lb/acre as needed.

Alternative Chemical Control:

- None.

Non-chemical Control:

- Mite predators are established statewide and can contribute to pest mite control in banana orchards although the economic control effectiveness of mite predators is unknown (Knowledge Master).

Weeds

Weed control is needed in new plantings to ensure rapid growth and establishment of plant material. Grassy weeds in particular have been reported to reduce yields (Chia and Nishimoto, 1986). Weed management is an important component in banana production. Since banana plants are surface feeders, heavy weed infestations rob them of nutrients. Weeds not only compete with the crop for food, water, nutrients and sunlight, they also provide shelter for insects and host diseases. Weeds can be managed through cultural and chemical means.

Control

Chemical Control:

- **Ametryn** (Evik DF) - PHI = none , REI = 12 hr. Applied as a directed basal spray immediately after setting banana or anytime thereafter. Applied at rate of up to 7.5 lb ai/acre. No more than 22.5 lb ai/acre allowed per year. Applied to approximately 300 acres per year.
- **Diuron** (Karmex DF, Direx DF) - PHI = none, REI = 12 hr. Applied for pre- and post-emergence weed control at a rate of up to 2.4 lb ai/acre in new plantings and 4.8 lb ai/acre in established plantings. No more than 9 lb ai/acre allowed per year.
- **Glyphosate** (Roundup UltraMax, etc.) - PHI = 1 day, REI = 4 hr. Applied for general weed control or for site preparation prior to transplanting crops. Applied at various rates. No more than 9.25 lb ai/acre allowed per year. Applied to approximately 900 acres per year.
- **Oxyfluorfen** (Goal 2XL) - PHI = 1 day, REI = 24 hr. Applied as a post-directed application for broadleaf weed control in permanently established bearing and nonbearing banana plantings. Applied at rate of up to 2 lb ai/broadcast acre as a pre-emergence application. No more than 2 lb ai/acre allowed per season. Presently registered for use in Hawaii under a 24(c) Special Local Needs label with expiration date of 27 January 2007.

- **Paraquat Dichloride** (Gramoxone Extra) - PHI = none, REI = 12 hr. Applied as a directed spray to control or suppress a broad spectrum of emerged weeds. Applied at rate of up to 0.94 lb ai/acre. No maximum listed per year. Applied to approximately 900 acres per year.

Non-chemical Control:

- Adjusting banana plant spacing to produce a dense canopy can reduce weed problems by blocking out needed sunlight.

Diseases

Banana Bunchy Top Virus

The banana bunchy top virus (BBTV) is a very serious problem for banana growers statewide. This virus has caused the demise of some farms and has forced many others to replace their existing banana variety with a less susceptible variety ('apple' rather than Cavendish) (Nelson, in press). The most conspicuous symptom of the disease is the "stacked up" up bunched/rosette appearance of the upper leaves (Nelson, in press). Other common symptoms of BBTV include 'morse code' streaking on leaves (dot/dash patterns on the lower midrib and leaf blade), distorted fruit, erect and narrow leaves, marginal chlorosis/necrosis. The banana aphid, *Pentalonia nigronervosa*, is the sole vector of this disease. Adoption of recommended banana aphid management practices is strongly urged. Eradication of BBTV is difficult and the likelihood of finding a cure is slim. Prevention is the key to management of this disease. Planting infected material and failing to destroy diseased plants contributes to the spread and transmission of BBTV. The Hawaii Department of Agriculture continues to educate growers and strives to control the spread of this serious disease by roguing infecting bananas (Ferreira, 1989; Matayoshi, 1993; Ferreira, et al., 1997).

Control

Chemical Control:

- **Glyphosate** (Roundup UltraMax, etc.) – PHI = harvesting of fruit from treated mats is not allowed, REI = 4 hr. Applied to destroy banana plants infected with the Banana Bunchy Top Virus as well as non-infected banana plants to establish disease free buffers around plantations. Applied by injecting up to 0.0013 lb ai/2-3 inches of pseudostem diameter. No more than 0.020 lb ai/mat (or unit) allowed.

Non-chemical Control:

Growers are encouraged to implement a number of cultural practices to slow or prevent the spread of this disease.

- **Avoidance:** Includes the use of disease-free planting materials; avoid planting the most susceptible varieties in areas where bunchy top is prevalent; establish new farms in isolation; destroy wild banana plants in surrounding areas; surround farm with windbreaks to impede aphid movement; become familiar with the symptoms of the disease and scout field regularly for disease incursion (Nelson, in press).
- **Elimination:** Rogue infected plants by first spraying a diseased plant with an aphid insecticide to kill infective aphids before they can fly to another plant and then injecting the plant with an herbicide such as Roundup. One single infected sucker can threaten the entire plantation. Therefore, the entire mat should be removed (Nelson, in press).
- **Aphid control:** Commercial farmers control aphids using periodic sprays of approved insecticides (see chemical controls above).
- **Quarantine:** Areas of Hawaii where bunchy top disease does not occur are protected by inter-island quarantine measures which prohibit the shipping of bananas from areas with the disease (Nelson, in press).
- **Transgenic Resistance:** Research is ongoing in this area.

Banana Mosaic Virus

Banana mosaic virus (BMV), also known as cucumber mosaic virus (CMV), affects banana production around the world. Common symptoms of BMV are chlorosis of leaves, mosaic symptoms, and heart rot. Proper selection of virus free planting material is an effective method of preventing BMV contamination.

Black Leaf Streak

Mycosphaerella fijiensis

This fungal disease is very destructive and is one of the greatest costs faced by banana growers in high-rainfall areas (Nelson, in press). It favors warm, wet and humid environments. There are two fungal spores associated with this disease: conidia (asexual) and ascospores (sexual). These spores are transported by wind currents to new plant hosts. The fungal pathogens penetrate the leaf tissue and create necrotic lesions, also known as streaks. This streaking effect gives the disease its name. The use of disease-free varieties, weather monitoring programs and preventative control strategies are encouraged (Nelson, 1994).

Control

Chemical Control:

Environmental conditions and site location cause variations in the number of acres treated per year. The island of Hawaii is the primary user of fungicides due to the high level of rainfall annually.

- **Azoxystrobin** (Abound) – PHI = 0 days, REI = 4 hr. Applied prior to disease development at a rate of up to 0.135 lb ai/acre. No more than 1.08 lb ai/acre allowed per year. Abound is a relatively new fungicide available to banana growers.
- **Fenbuconazole** (Enable 2F) – PHI = none listed, REI = 12 hr. Applied when first leaves appear at rate of up to 0.09 lb ai/acre. No more than 0.72 lb ai/acre allowed per year. Applied to approximately 190 acres per year.
- **Mancozeb** (Dithane F-45, etc.) – PHI = 0 days, REI = 24 hr. Applied when leaves first appear at rate of up to 2.4 lb ai/acre. No more than 24 lb ai/acre allowed per year. Applied to approximately 700 acres per year.
- **Tebuconazole** (Elite 45 DF) – PHI = 0 days, REI = 12 hr. Applied as foliar spray before disease becomes established on bagged bananas. Applied at rate of up to 1.44 lb ai/acre. No more than 7.20 lb ai/acre allowed per harvest cycle.
- **Maneb** (Maneb 75 DF, etc.) – PHI = 0 days, REI = 24 hr. Applied when leaves first appear and repeated as needed. Applied at rate of up to 2.25 lb ai/acre. No more than 24 lb ai/acre allowed per year.
- **Horticultural Oils** – PHI = 0 days, REI = until dry.
- **Effective spray application:** Practices that will improve spray coverage include: calibrating spray equipment on a regular basis, minimizing drift, use of a mist blower instead of backpack sprayer and use of 31 in diameter fan nozzles vs. 28 in nozzles for mist blowers (Nelson, in press).

Non-chemical Control:

- **Site selection and preparation:** Better drained soils result in less relative humidity and drier leaves, thereby reducing disease incidence and severity. *M. fijiensis* is dependent upon high relative humidity and abundant free moisture. In addition, plant spacing and density can be managed to decrease relative humidity and duration of leaf wetness, and thereby increase spray penetration and coverage (Nelson, 1998).
- **Canopy management:** Practice canopy management through pruning to increase sunlight and airflow in the canopy. This will reduce periods of dew on the grass and weeds and banana leaf wetness duration (Nelson, in press).
- **De-trashing:** Severely diseased leaves or parts of leaves should be removed when disease exceeds 50% for that leaf. This practice reduces the concentration of airborne spores in the canopy, thereby reducing new infections and disease development. De-trashing also increases airflow and reduces humidity, enabling wet leaves to dry more quickly and increasing spray penetration/coverage. De-trashing increases the efficiency of fungicide applications by removing the most troublesome material (heavily diseased leaves) from the spraying area. De-trashing also increases the penetration of sunlight into the canopy, creating stronger plants (Nelson, 1998).
- **Removal of plant debris:** If diseased plant material can be removed from the area, disease levels will diminish. However, this is difficult to achieve, practically. At least try to turn diseased leaves face down on the ground when they are detached or when the plant is harvested, as most

pathogen spores are produced on the upper leaf surfaces (Nelson, in press).

- **Moisture management:** Minimizing relative humidity can greatly reduce disease levels in the field. Good soil drainage and weed control help to reduce relative humidity. In addition, more roads throughout a banana field can increase aeration and decrease leaf wetness duration (Nelson, in press).

Crown Rot Complex

Botryodiplodia theobromae, *Cephalosporium* sp., *Ceratocystisparadoxa*, *Colletotrichum musae*,
Fusarium roseum, *Verticillium theobromae*

Crown rot is a serious post-harvest disease problem of bananas. Several fungal pathogens are involved in this process. Infection occurs after the hands are cut from the main banana bunch and the disease organisms enter through the wounded tissue. Symptoms first appear on the stalk end of the banana fruit fingers. Uneven dark discoloration spreads rapidly to fruit skin and pulp, which is reduced to a brown soft rot. Because of the variety of causal organisms rotting can also occur at the fruit tip and is also associated with fruit spots and blemishes. The disease complex is promoted by high humidity (>85%) (Feakin, 1972).

Control

Chemical Control:

- **Thiabendazole** (Decco Salt No. 19) – Applied as a dip treatment (200 ppm ai) after harvest. (Abound) – A supplemental label for Abound was recently approved (2003) for use in Hawaii that allows for a postharvest dip treatment (200-400 ppm ai).

Non-chemical Control:

- **Harvest fruit at the correct stage of maturity:** Fruit harvested too young are more susceptible to crown rot.
- **Careful handling:** Gentle handling in transit minimizes bruising and reduces the opportunity for crown rot to develop.
- **Careful storage and temperature control:** In transit temperature control must be maintained so that bananas do not ripen prematurely and create conditions favorable for crown rot.
- **Removal of last banana hand and distal flower bud after all hands have opened:** This practice eliminates sites where crown rot is most likely to start.
- **Increase row spacing in field:** Reduces relative humidity in field so that conditions are less favorable for disease development.
- **Destroy infected plant material by burning:** Reduces inoculum level in the field.

Freckle

Phyllosticta musarum

Freckle is a fungal disease of bananas that affects fruit quality and appearance. This disease is not a serious concern, except in a few localized areas (Farmers Bookshelf). It is easily controlled with fungicides registered for control of black leaf streak.

Panama Wilt

Fusarium oxysporum

This is one of the most devastating diseases for bananas worldwide. Symptoms include internal stem necrosis (reddish-brown), root and rhizome rot, yellow leaves, plant wilting and plant death. Plants may die during flowering or during periods of moisture stress. The pathogen may survive almost indefinitely in soils and infects plants through the root system. The fungus then penetrates into the vascular system of the pseudostem, causing necrosis and blocking transport of water. Although the disease exists in Hawaii, not all races of the pathogen are known to exist in Hawaii. Due to the planting of disease-resistant varieties, the importance of this disease in Hawaii has decreased (Nelson, in press). Disease prevention should include the selection of resistant cultivars, field sanitation and moisture monitoring practices.

Control

Chemical Control:

- None effective for controlling this disease (Nelson, in press).

Non-chemical Control:

- **Avoidance:** Susceptible varieties (e.g., ‘Gros Michel’, many cooking bananas) should not be planted in a field with a history of Panama wilt. Use of clean, disease-free planting material, such as plants derived from tissue culture should be encouraged. Planting down slope of a field with a history of this disease should be avoided. Water runoff from diseased areas into non-diseased areas should be avoided to minimize disease spread. Disinfesting pruning tools may help to reduce spread of contaminated soil or plant debris from one plant to another (Nelson, in press).
- **Disease-resistant varieties:** Plantings of the Cavendish and dwarf Brazilian varieties which are resistant to the Hawaii race(s) of the pathogen are encouraged. These varieties are already commonly grown in Hawaii (Nelson, in press).

Nematodes

Rootknot, *Meloidogyne spp.*
Burrowing, *Radopholus similis*
Reniform, *Rotylenchulus reniformis*

Of the eight different nematode genera reported on bananas in Hawaii, three (rootknot, burrowing, and reniform) are economically important to commercial production statewide. Nematodes are a major concern for growers especially on the island of Hawaii. These roundworms attack the root system of plants and impair water and nutrient uptake. Fields not properly managed for nematodes can result in lower yields and higher crop losses (Sipes, 1993). Sometimes, heavily infested fields must be abandoned. Common symptoms of severe nematode infection include stunting, poor plant growth, narrow and weak stems, foliar chlorosis, root rotting and galling, and plant toppling (Nelson, in press).

Control

Chemical Control:

- **Ethoprop** (Mocap 10% G) – PHI = none listed, REI = 48 hr. Applied at rate of up to 0.013 lb ai/2.64 ft radius around each producing stem. No maximum application rate per year listed. Used primarily on the island of Hawaii for post-plant control of root knot, reniform and burrowing nematodes. Applied to approximately 400 acres per year.
- **Fenamiphos** (Nemacur 3) – PHI = 15 days, REI = 48 hr. Applied as either a band application with ground equipment or by low pressure irrigation. For band application, administered on each side of the banana pseudostem at various rates depending on band width. Maximum application allowed per year dependent on band width. For application by irrigation, applied at a rate of up to 4.5 lb ai/acre. Maximum application allowed per year is 9.97 lb ai/acre. (Registered for use in Hawaii under a 24(c) Special Local Needs label, expires 4 June 2007.)
- **Fenamiphos** (Nemacur 15%) – PHI = 15 days, REI = 48 hr. Applied as a band on each side of the banana pseudostem to control root knot and burrowing nematodes. Applied at various rates depending on band width. Maximum application allowed per year dependent on band width. Applied to approximately 400 acres per year. (Registered for use in Hawaii under a 24(c) Special Local Needs label, expires 4 June 2007.)

Non-chemical Control:

- **Fallow and Cover Crops:** Nematode populations can be reduced by fallowing fields for six to eight months using a non-host or bare ground fallow. The longer the fallow period the greater reduction in nematode populations. Due to the possibility of soil erosion, cover crops are being investigated as an alternative to bare fallows and use of nematicides. Cover crops may also be used to minimize weeds, soil borne diseases and nematode populations. Additional research continues with cover crops in anticipation of loss of nematicide registrations (Sipes, 1993).
- **Crop Residue:** The removal and destruction of old banana plantings and living material will stop nematode reproduction and begin reducing nematode population densities (Sipes, 1993).

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