Crop Profile for Bananas in the American Pacific

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General Production Information

Banana production reported for Hawai`i in 2001 was 12,700 metric tons (28 million lb) (Hawai`i Agricultural Statistics Service 2001). In 1998 Guam produced 22 metric tons (49,575 lb) (National Agricultural Statistics Service 1999). Annual banana production (commercial and non-commercial) reported for American Samoa in 1998 was 18,412 metric tons (40.6 million lb) (National Agricultural Statistics Service 2001). Total crop values for those years, were $10.6 million, $54,651 (Guam Department of Agriculture 2002), and $22.9 million for Hawai`i, Guam, and American Samoa (sold and consumed), respectively.

Hawai`i grew bananas on approximately 672 ha (1,660 acres) in 2001 and produced 21,072 kg/ha (18,800 lb/acre) (Hawai`i Agricultural Statistics Service 2001). Guam planted 13.82 ha (34.15 acres) in 1998 (Guam Department of Agriculture 2002), yielding approximately 1,627 kg/ha (1,452 lb/acre). American Samoa grew bananas on approximately 2,741 ha (6,772 acres) in 1999, an estimate based on plant spacing vs. total number of plants, with a yield of 6,725 kg/ha (6,000 lb/acre) (National Agricultural Statistics Service 2001).

Hawai`i produced 46% of the fresh market bananas they consumed in 1997. Production increased from 1998-2000; Hawai`i growers meet 70 to 80% of local demand (Pacific Business News 2001). Commercial export to Guam and Japan resumed in 1999 after several decades of non-shipment (Hawai`i Agricultural Statistics Service 1999). Exports continue to Guam, Japan and the mainland U.S. (Uyeda 2003). Bananas on Guam are sold directly to consumers from roadside stands and small grocers, or through wholesalers to major grocers and the Government of Guam, Department of Education. American Samoans consumed 72% of bananas produced in 1998, selling the rest in roadside stands, markets, and to the Government School Lunch Program; no bananas were exported.

Production costs in Hawai`i, including harvesting and processing for market, were approximately $12,355/ha ($5,000/acre) in 2001. This cost was dependent on production practices and pest control measures on different farms (CTAHR 2001). In 1999, production costs on Guam were estimated to be $20,608/ha ($8,340/acre) (Artero et al. 1999).

Production Regions

Bananas are grown throughout the Hawaiian Islands, Guam, and American Samoa. In 2001, there were 200 commercial banana farms growing bananas within the state of Hawai`i, with 62% on the islands of Hawai`i and O`ahu (Hawai`i Agricultural Statistics Service 2001). On Guam, banana production comes mostly from one large producer in the center of the island and several small villages to the south. There are over 10,000 farms, including approximately 30 commercial growers, throughout the five main islands of American Samoa; most are located on the main island of Tutuila. According to the 1999 Census of Agriculture, a farm was defined as, "any place that raised or produced any agricultural product for sale or consumption", which fit 75% of all households (National Agricultural Statistics Service 2001).

Banana Anatomy

"Banana" is a general term embracing a number of species or hybrids in the genus *Musa*, family Musaceae. In some areas of the world bananas are grown only as ornamental plants or for fiber. Most edible-fruited bananas, usually seedless, belong to the species *M. acuminata*, or are hybrids of *M. acuminata* and *M. balbisiana*. Bananas are perennial herbs with long, rolled leaves that emerge from the center of the plant and unfurl 6-8 days later. The bases of these leaves (petioles) remain tightly fused and form the trunk (pseudostem) of a plant 2-9 m (6-30 ft) in height (Ploetz 1994). The banana is monocarpic, flowering and setting fruit once before it dies. The inflorescence (flower stalk) emerges from the center of the pseudostem, along with the true stem (apical meristem), both of which are surrounded by a protective flag leaf. The flower stalk of most banana varieties is positively geotropic and bends from the vertical until its tip points towards the ground: An exception is the Samoan variety Fe'i (Fa'i Soa'a), whose inflorescence remains vertical. Flower stalks are from 30-90 cm (1-3 ft) long, tapered, and covered in a sheath of overlapping bracts. The flowers are parthenogenic (self-fertile) and occur in groups of 12-20 beneath the bracts. Individual fruits, called fingers, make up the groups (hands), which are arranged in a spiral around the flower stalk, forming a bunch. At fruit set, a healthy banana plant will have 8-12 leaves. Fruits mature in 60 to 100 days after flowers first appear, depending on the season and cultivar. New banana plants arise as suckers from an underground rhizome. As old plants die and new suckers are formed the rhizome expands and is called a mat. Bananas are propagated by suckers, pieces of the rhizome, and by tissue culture (Ploetz 1994).

Cultural Practices

Most of the commercially produced bananas in the American Pacific are the Cavendish-type "Chiquita" banana. In Hawai`i, approximately 54% are Cavendish ('Williams', 'Valery', 'Chinese', 'Grand Nain', 'Bluefields', 'Dwarf Bluefields') with the remaining 46% belonging to the Hawai`i Apple varieties ('Dwarf Hawai`i Apple' and 'Apple') (Hawai`i Agricultural Statistics Service 2002). Commercial growers in American Samoa grow the Cavendish variety, 'Williams', almost exclusively, with the rest of banana production spread between 'Misi Luki', 'Paka', 'Fe'i', etc.

Planting

Bananas originated in the Asian tropics but are now distributed throughout tropical and subtropical regions of the world. Their commercial cultivation is confined to areas where a continuously warm, moist climate prevails. Temperatures in the American Pacific are ideal for banana production, but in some areas moisture levels may be deficient during the dry season and require irrigation. Bananas require a considerable amount of water but are also sensitive to waterlogged situations, so well drained soils are a prerequisite to successful cultivation.

Proper site selection and soil preparation are crucial. Because banana plants are giant herbs with no true stem or trunk, they require protection from wind. Gusts of 97 km/hr (60 mi/hr) can knock plants over and sustained winds of 40-48 km/hr (25-30 mi/hr) can cause excessive leaf tearing. Consequently, selection of a site that is naturally protected from wind, or planting windbreaks composed of bamboo, eucalyptus, tangantangan, etc., is recommended.

Plant spacing varies between island groups. In American Samoa, plants are spaced 3-3.6 m (10-12 ft) apart and between rows, resulting in approximately 865-990 plants/ha (350-400 plants/acre). On Guam, plant spacing varies from 2.4-3.0 m x 3-3.5 m (8-10 ft x 10-12 ft), resulting in 1,000-1,500 mats/ha (400-600 mats/acre). In Hawai`i, bananas are planted with 2.4-4.5 m (8-15 ft) between rows and 1.8-2.1 m (6-7 ft) between plants within a row, yielding about 1853 plants/ha (750 plants/acre) (Nelson, in press).

Plantation Management

A variety of activities, including sucker management, irrigation, fertilization, weed control, crop protection and pre-harvest bunch care are important aspects of banana production. These activities are labor-intensive and workers are in the field daily throughout the year. In American Samoa, few workers wear protective clothing or adhere to restricted entry intervals (REI).

Sucker (mat) Management. This activity is one of the most important management tasks and includes desuckering (removing unwanted suckers) and ratoon selection (suckers left to form the next crop). Desuckering optimizes flowering cycles, bunch development (assimilate partitioning), air circulation, light penetration, and plantation longevity. In the American Pacific, plants may be arranged in rows initially, but this systematic arrangement soon disappears due to random ratoon selection. Many growers in American Samoa maintain their mats (rhizome and attached plants) as follows: one bearing mother plant, a large daughter sucker, and a small granddaughter plant. Plant spacing in American Samoa averages 3 x 3-4 m (10 x 10-12 ft) on center.

Irrigation. Banana plants need at least 25 mm (1.0 in) of water per week for good growth, more under some conditions for optimum development (Robinson 1996). With the dry season lasting up to six months on Guam, irrigation must be provided during most of that time. The system should be designed and in place prior to planting and the design should accommodate various factors affecting production, such as soil type, topography, water quality, water availability, labor and budget. The majority of farms on the island of Hawai`i depend on rainfall for irrigation, while growers on the remaining islands rely on drip irrigation (Farmers Bookshelf 2000, Knowledge Master 2000, Chia 1981). Banana plantations are not irrigated in American Samoa, where annual rainfall is between 3,175 to 7,6200 mm (125-300 in), depending on elevation.

Fertilization**.** The banana is a fast growing plant that quickly yields a heavy crop and requires repeated applications of fertilizer. Fertilizer rates should be based on soil or tissue analysis, but if this information is not available, fertilizer may be applied every 2 or 3 months, especially where heavy rains cause leaching losses (Robinson 1996). Bananas require large quantities of potassium and should be provided with a fertilizer high in potassium such as 10-5-22 (N-P-K) or 10-20-20. On

Guam, soil micronutrients are often lacking and are supplied through manures or foliar sprays containing micronutrients. The first application of fertilizers is made two to three months after planting and should continue through flowering and all ratoons (subsequent crops from the same mat). Commercial growers on American Samoa apply a small can (approximately 225 g (8 oz)) of 10-5-40 or 20-10-20 to the base of each plant from 2-12 times per year. Non-commercial growers seldom use synthetic fertilizers.

Weed control. Weeds inhibit crop production by competing for nutrients and water, increasing humidity in the canopy, and harboring pests and disease. Good weed control practices include pulling by hand or hoeing, mowing, mulching, and using herbicides. Mechanical cultivation is not recommended as it may damage shallow feeder roots. The use of herbicides is an efficient, labor-saving method of controlling weeds in young plantations, before plants have enough foliage to shade out the weeds.

Insect Pests

Banana Aphid (*Pentalonia nigronervosa*)
[American Samoa, Guam, Hawai`i]

This aphid is a serious problem on bananas throughout the world, but not for its debilitating feeding habits. *Pentalonia nigronervosa* is the vector of banana bunchy top disease (see Diseases), the most damaging virus disease of this crop. Adult females reproduce parthenogenically, giving live birth without fertilization. Wingless adults are about 1.5 mm long, vary in color from reddish to dark brown or almost black. Winged forms are produced when the colony becomes crowded or the host plant loses vigor and becomes nutrient poor. Aphid colonies may be found in the crown of the plant, at the base of pseudostems or between outer leaf sheaths. Young suckers are usually the most heavily infested (Speijer 1988). Ants are drawn to the honeydew aphids excrete when feeding and may ward off the aphid's natural predators (Waterhouse and Norris 1987). Ants may also transport aphids between plants. Banana aphids also attack tomato, taro, and some ornamental plants, notably *Heliconia* spp., in addition to banana. The slow spread of banana bunchy top virus on American Samoa and the small number of aphids observed suggest this pest is not a major problem at present (Brooks 1999). This is not the case in Hawai`i. Aphid infestations need to be monitored and controlled when necessary. Diazinon is registered under a 24(c) Special Local Needs label.

Cultural Control: Roguing and burning of diseased plants after first spraying with kerosene or a labeled insecticide. See BBTD in Disease section below.

Biological Control: Numerous predators, parasites, and pathogens attack *P. nigronervosa* (Waterhouse and Norris 1987) and may reduce BBTD transmission by keeping vector populations below levels at which winged forms are produced.

Chemical Control:

- **Diazinon** (Prentox Diazinon AG500). Restricted entry interval (REI), 24 hours. Applied as a directed spray to crown on plants that are not fruiting, at a rate of up to 0.56 kg ai/ha (0.50 lb ai/acre) in 380 L (100 gal) of solution. Applied to approximately 485 ha (1,200 acres) per year in Hawai`i under a 24(c) Special Local Needs label, expiring on 28 September 2005 for Prentox Diazinon.
- **Imidacloprid** (Provado 1.6F, Admire 2F). A possible alternative to diazinon for aphid control; pending registration.
- **Horticultural Oil**. Horticultural oils such as Clean Crop Superior 70 are used in Hawai`i to suffocate aphids and other soft bodied pests. These oils have a low phytotoxicity and minimal impact on humans and the environment.
- **Soap Solution**. 10% liquid detergent in water used by homeowners and others in Hawai`i and American Samoa to kill aphids and other soft-bodied insects.

As part of the banana bunchy top disease control program in American Samoa, infected plants are sprayed before removal with kerosene to hinder movement of aphids to nearby uninfected plants.

Banana Corm Weevil/Banana Root Borer (*Cosmopolites sordidus*)
[American Samoa, Guam, Hawai`i]

This black weevil, 15-20 mm (0.5-0.75 in) long, lays its eggs into holes chewed in the corm and lower pseudostem. The eggs develop into white larvae that riddle the corm with tunnels. These burrows reduce plant vigor and cause premature leaf death, resulting in smaller bunches. They also may render the plants more susceptible to toppling over from wind and to Panama disease. The root borer was first reported on the island of O`ahu in 1981and has since spread to Hawai`i, Kaua`i, Maui and Moloka`i. The adult weevil feeds and breeds at night. Control of this weevil is mainly preventative.

Cultural Control: Rhizomes should be trimmed and pared to remove or open up deep burrows, then placed in a hot water bath at 55° C (131° F) for 15-20 minutes before planting; this treatment is also effective against burrowing nematode (Gowen 1994a). When planting, rhizomes should be completely covered with soil to prevent eggs from being laid on their exposed surface. The weevil is attracted to freshly cut banana pseudostems and may be trapped by baiting the field overnight with cut slices of pseudostem. The weevils are found the next morning and the following two days beneath the stem slices, where they will be actively feeding (Nelson, in press).

Biological Control: There are no known beneficial parasites of the banana root borer within the State of Hawai`i. Field sanitation and hot water treatment of corms are being used to manage this pest (Knowledge Master 2000, Gettman 1984). On Palau in 1948 and 1953, two natural enemies of this weevil, *Dactylosternum hydrophiloides* and *Hololepta* sp., were imported from Malaysia and released. It is not known whether these natural enemies are established or not (Muniappan et al. 1999). Various predatory beetles and ants are believed to suppress *C. sordidus* populations in parts of its range, but their effects have not been evaluated in the American Pacific.

Chemical Control:

- **Carbofuran** (Furadan 5%G). PHI not listed; REI, 48 hours. This chemical is important to banana production in Hawai`i. It is used on many small farms at the time of planting. Growers apply carbofuran to the planting hole and soil surface at time of planting at a rate of 28-34 g (1.0-1.2 oz) per planting hole. The soil surface is retreated with 57 g (2.0 oz) every 4 months.

Banana Skipper (*Erionata thrax*)
[Guam, Hawai`i]

This is a brown skipper with yellow spots on its forewings. It lays batches of eggs on banana leaves. The eggs hatch into larvae that cut a strip of leaf and roll it into a distinctive leaf roll. The larva, covered in a whitish powder, turns into a pupa or cocoon inside the roll. There are two natural parasites of this leaf roller on Guam. One feeds on the larvae and the other attacks the eggs. It is more economical and environmentally safe to let these parasites control the pest than to spray insecticides. Only in severe cases should a grower consider applying insecticide. For smaller plantings, the leaf rolls can simply be squeezed by hand to crush the larvae. Leaves that have been damaged by leaf rollers should not be removed as they are needed for photosynthesis. The banana skipper was first reported on O`ahu in 1973 and had become established on all islands by 1975. Rolled leaves originating from the midrib of plants are good indicators of banana skipper damage. Since 1973, six parasites have been identified and continue to minimize damage caused by this pest. Because of the effectiveness of biological control, chemical treatment is uncommon (Farmers Bookshelf 2000, Knowledge Master 2000).

Chemical Control:

- ***Bacillus thuringiensis*** (ssp. *Kurstaki*, various products; ssp. *Aizawai*, Xentari products). No PHI listed; REI, 4 hours. Applied to control banana skipper at rates of 0.30-0.61 kg ai/ha (0.27-0.54 lb ai/acre) for *Kurstaki* products and 0.058-0.17 kg ai/ha (0.052-0.15 lb ai/acre) for *Aizawai* products. No maximum application rate per year is listed.

Banana Moth (*Opogona sacchari*)
[Hawai`i]

The banana moth, also called *Opogona subcervinella*, 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 bunches prior to bagging appears to greatly reduce larval damage. (Reported from Hawai`i.)

Banana Scab Moth (*Nacoleia octasema*)
[American Samoa]

Banana scab moth is the major insect pest of bananas in American Samoa. The adult moth lays her eggs on the unopened inflorescence (flower stalk) or on the surrounding flag leaf. The larvae hatch after about four days and crawl under the bracts of the flower stalk (Speijer 1988). The larvae feed on the basal hands of the bunch, moving to less mature hands as the bracts begin to fall from the inflorescence. Damage ranges from light scarring of a few bananas in the basal hand, to severe scabbing of the bunch. In the latter case, larvae often eat through the skin and feed on the pulp of the banana (Waterhouse and Norris 1987). In the absence of an export market or local consumer demand for unblemished fruit, only commercial growers in American Samoa attempt to control scab moth damage: The School Lunch Program, commercial growers' major market, demands unblemished fruit. Control is time-consuming since farms must be checked daily for emerging flower stalks and treatments applied immediately. By the time flower stalks have bent to a horizontal position, shortly after emergence, some fruit damage has usually occurred.

Cultural Control: Traditional methods of scab moth control are based on partial or complete removal of the flower bracts, followed by spraying the fruit with water or dusting it with ashes. In 1999, three traditional control methods were compared with two non-EPA registered organophosphate insecticides used locally for scab moth control (SARE Farmer-Rancher Grant FW99-037). Though reduced damage was observed on washed bunches, scabbing was noticeably greater than on bunches treated with insecticides.

Biological Control: At least 10 different parasites have been released in the Pacific Islands in an attempt to control banana scab moth; results are not encouraging (Waterhouse and Norris 1987). Rates of parasitism are generally low but since no scabbing is tolerated on export fruits, chemical sprays must be used. In American Samoa where some scabbing is acceptable, however, natural enemies may become part of an integrated management scheme.

Chemical Control: No chemicals are currently registered for use against banana scab moth in American Samoa. Some growers, however, purchase trichlorfon (Tridex) or pirimiphos-methyl (Actellic) off-island for use against this pest. Growers who obtain these unregistered chemicals usually apply them without appropriate protective clothing or regard for label instructions.

- **Pirimiphos-methyl** (Actellic 2% dust, 20 g ai/kg): This organophosphate insecticide is not specifically labeled for use on bananas (Actellic 1995). Growers on American Samoa apply an unmeasured amount as soon as the inflorescence bends to a horizontal position. The flower bracts are peeled back and the dust is applied with a bulb syringe directly to the developing fruits. Only one application is made. Scabbing is usually limited to damage done before application of the dust.
- **Trichlorfon** (Tridex: 60% a.i.): This is the most effective method of scab moth control to date. Tridex is mixed with water at 20 mL/3.8 L (2 fl oz/3 gal) and is usually sprayed directly on fruits with a hand-held spray bottle. It may also be injected into the emerging inflorescence with a "bell injector" when the inflorescence is still in a vertical position. Two 20 mL (2 x 0.68 fl oz) injections are made, one-third and two-thirds up and on opposite sides of the inflorescence. This one application usually produces scab-free fruit, with little pesticide exposure to the applicator, and is used by many exporting countries to control scab moth damage.

Other Issues: American Samoa Community College (ASCC) Land Grant Entomology division is testing the efficacy of several reduced risk pesticides for scab moth control. All preparations are being injected into the bell of the inflorescence, though the products can also be applied as a spray.

Big-headed Ant (Pheidole megacephala)
[Hawai`i]

Ants are common in banana fields and difficult to control. They form a relationship with banana aphids, feed on the honeydew they secrete, and protect the them from their natural enemies. This results in larger aphid populations and increases the probability of disease spread (e.g. banana bunchy top virus) (Nelson, in press).

Cultural Control: None recommended.

Biological Control: None recommended.

Chemical Control:

- **Hydramethylnon** (AMDRO PRO Fire Ant Bait-BASF Corp./Micro Flo Co.). REI, 12 hours. In fields with actively foraging ants, up to 40 g (1.4 oz) is placed in a bait stations at approximately 15 m x 15 m (50 ft x 50 ft) spacing. For field border treatment, bait stations are placed at about 15 m (50 ft) intervals. Registered in Hawai`i under a 24(c) Special Local Needs label that expires on 3 September 2007.
- **Hydramethylnon** (SEIGE PRO Fire Ant Bait). REI, 12 hours. In fields with actively foraging ants, up to 40 g (1.4 oz) is placed in bait stations at approximately 15 m x 15 m (50 ft x 50 ft) spacing. For field border treatment, bait stations are placed at 15 m (50 ft) intervals. Special Local Needs label expires 3 September 2007.

Chinese Rose Beetle (*Adoretus sinicus*)
[Guam, Hawai`i, Palau]

Chinese rose beetle was introduced to Hawai`i before 1896 and is now a common pest on all major banana-producing islands in the State. The greatest damage is not caused by the larvae, but by the beetle itself. Larvae primarily dwell in the soil and leaf litter surrounding the plants and feed on their roots. The adult beetle is light to dark brown, 10 mm (0.4 in) long, nocturnal, and feeds primarily on tissue between leaf veins. Chinese rose beetles are commonly detected on younger plants. An attempt in Hawai`i to control this pest by the introduction of parasites was unsuccessful. There are no known chemicals to control this beetle (Knowledge Master 2000). Chinese rose beetle is also a pest on many commercial crops and local flora in Guam and difficult to control with insecticides.

Cultural Control: Recommendations from Guam include maintaining a clean, weed-free plantation and buffer zones to minimize damage. On Palau, removal of breeding sites, such as decaying logs and tree stems to reduce populations, is considered important (Muniappan et al. 1999).

Biological Control: Drenching breeding sites with suspensions of entomophagous fungi, such as *Beauveria bassiana* and *Metarhizium anisopliae* are recommended on Guam but not believed to be part of an active management program at present.

Chemical Control: None recommended. Carbaryl is known to control Chinese rose beetle but it is not registered for use in banana.

Coconut Scale (*Aspidiotus destructor*)
[Hawai`i, Palau]

Coconut scale was introduced into Yap on kava plants from the Philippines in 1892. It was first reported on Palau in 1899 and also affects breadfruit, papaya, plumeria, cassava, and banana. The coconut scale is an armored scale and is usually found on the under side of leaves. Scales can also attach themselves to petioles, peduncles and fruits. The piercing, sucking mouthparts of both nymphs and adults extract plant juices, leading to discoloration and yellowing of plant tissue. Heavily infected trees will bear fewer leaves and fruits. Eggs are laid under the covering of the female scale. Eggs hatch into nymphs, called crawlers, which move to a suitable spot and feed. The adult male is winged and flies to locate and mate with nearby females. The total life cycle is about one month. The coconut scale is no longer an important pest of crops in high islands of Micronesia following the introduction of predatory coccinellid beetles, including *Pseudoscymnus anomalus*, *Chilocorus nigritus*, and *Rhizobius satelles* (Muniappan et al. 1999). Coconut scale was first detected on O`ahu in 1968 and is now present on the islands of Kaua`i, Hawai`i, and Maui. *P. anomalus* and *C. nigritus* have also been introduced to Hawai`i (Waterhouse and Norris 1987). The coconut scale is a sporadic problem in Hawai`i. It can be found on the underside of banana leaves, peduncles and fruit. (Knowledge Master 2000). Because some bananas are being exported, growers must be aware that the coconut scale is a quarantine pest. *A. destructor* occurs in American Samoa but is not a pest on banana.

Chemical Control:

- **Buprofezin** (Applaud 70 WP). PHI, 24 hours; REI, 12 hours. Applied as a directed spray to affected plant parts at a rate of 0.35 kg ai/ha (0.31 lb ai/acre). Maximum of 4 applications per cropping cycle.

- **Imidacloprid** (Provado 1.6F, Admire 2F): A possible alternative for coconut scale control; pending registration.

Fruit Piercing Moth (*Eudocima fullonia*)
[Hawai`i]

The fruit-piercing moth is a serious pest in localized areas in Hawai`i. It was first reported on O`ahu in 1985, and by 1986 was present on Kaua`i, Hawai`i, Maui and Moloka`i. 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 tree ripened, home grown bananas. In most commercial areas, natural enemies of the banana fruit piercing moth keep populations below economic threshold levels (Knowledge Master 2000, Mau 1985). *E. fullonia* is present in American Samoa but is not a problem on banana.

Cultural Control: Removal of alternate larval hosts (e.g. guava)..

Biological Control: Natural enemies, naturally occurring polyhedrosis virus.

Chemical Control: None recommended.

Long-legged Ant (Anoplolepis longipes)
[Hawai`i]

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 the fruit surface and reducing marketability. Long-legged ants are found throughout the Hawaiian 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 ants.

Cultural Control: None recommended.

Biological Control: None recommended.

Chemical Control:

- **Borac acid compounds** with Karo syrup.
- **Terro**, a commercial ant control product.

Spiraling Whitefly (*Aleurodicus dispersus*)
[American Samoa, Guam, Hawai`i]

Nymphs and adults are sap-sucking insects and cause mature leaves to appear yellowish-red on upper surfaces. Females lay eggs on the undersurfaces of leaves in a spiral pattern. Nymphs are flat and mobile, becoming fixed after the first instar beneath a white waxy material. Spiraling whiteflies have a broad host range, including coconut, guava, cassava, papaya, ornamental plants and many fruits and vegetables. Similar to aphids and mealybugs, whiteflies excrete honeydew that may attract black sooty mold (Muniappan et al. 1999). Ants that inhabit banana plantings to obtain honeydew tend to protect whiteflies from natural predators. Whiteflies are also known to transmit various plant diseases. Spiraling whitefly was first reported in Hawai`i on the island of O`ahu in 1978. By 1981 it was detected on all major banana-producing islands. 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. However, since the spiraling whitefly has virus vector capabilities it is an on-going concern for many island growers (Knowledge Master 2000). In 1985, a parasitic wasp, *Encarsia haitiensis*, was imported from Guam and released on spiraling whitefly-infested plants around Koror, Palau. The whitefly is still present but the population is considered too low to warrant further control measures (Muniappan et al. 1999). Spiraling whitefly was found in American Samoa in 1981. Several coccinellids and *E. haitiensis* were introduced and have since reduced *A. dispersus* populations to non-economic levels (Waterhouse and Norris 1989, Tauili'ili and Vargo 1993).

Cultural Control: None recommended.

Biological Control: Natural enemies, including the parasitic wasp, *Encarsia haitiensis*.

Chemical Control:

- **Buprofezin** (Applaud 70WP). PHI, 24 hours; REI, 12 hours. Applied as a directed spray to affected plant parts at a rate of 0.35 kg ai/ha (0.31 lb ai/acre) with a maximum of 4 applications per cropping cycle.

Sugarcane Budmoth (*Neodecadarchis flavistriata*)
[Hawai`i]

Sugarcane budmoth is a localized pest in Hawai`i. It feeds on decaying banana flowers and causes fruit scarring. Many growers have adopted the practice of removing all flowers prior to bagging to reduce sugarcane budmoth damage. This insect is reported to cause severe fruit scarring in Hawai`i (Farmers Bookshelf 2000).

Cultural Control: Removal of spent flowers, bagging of fruit.

Biological Control: None recommended.

Chemical Control:

- ***Bacillus thuringiensis*** (ssp. *Kurstaki*, various products; ssp. *Aizawai*, Xentari products). No PHI restriction; REI, 4 hours. These products are applied to the bunch prior to bagging to minimize damage. Dipel 2X is applied to less than 40 ha (100 acres) per year in Hawai`i at a rate of 0.034 kg ai/ha (0.03 lbs ai/acre).

Thrips
[Hawai`i]

Thrips are common insect pests in commercial production. Their piercing-sucking mouthparts damage flowers, fruit, leaves and stems. Several different species feed on bananas. The banana rind thrips, *Elixothrips brevisetis*, occurs on several Pacific islands and was first reported on O`ahu in 1981 and later on the Big Island (the island of Hawai`i) in 1983. It has not been reported on any other islands. Thrips feed on leaves, flowers, or stems, the injured tissue taking on a silvery appearance that eventually turns dark brown. Feeding on leaf tips results in wilting and curling and the undersides of leaves are spotted with small black fecal specks. Flowers become flecked, spotted, and deformed and many buds fail to open. The banana rind thrips is a polyphagous foliage feeder. On many plant hosts, this thrips causes scarring, cracking and corky growth on fruit skins (Muruvanda 1986).

The Hawaiian flower thrips, *Thrips hawaiiensis*, is a widespread species in tropical and temperate climates and is present on all major Hawaiian islands except Lanai. It feeds only on flowers (Takahashi 1936). Depending on the extent of feeding, flowers become flecked, spotted, or deformed. Fruits are damaged through ovipositioning, resulting in a pimpled rather than smooth rind. Unlike other flower thrips, this species prefers wet and shady areas (Sakimura and Krauss 1944).

In 1996, the banana rust thrips, *Chaetanaphothrips signipennis,* was collected in Hilo. The nature of the damage caused by this pest varies: banana rust thrips feed on the pseudostem and fruit. Feeding on leaf sheaths results in dark, v-shaped marks on the outer surfaces of leaf petioles, while fruit damage has a water-soaked appearance. Damaged tissue turns bronzed or rust colored with age. Many young fruits exhibit dark or smoky "curly-cue" feeding tracks on their surfaces. Characteristic oval-shaped reddish "stains" have been observed on mature fruit where fingers touched. Most damage is the result of two larval feeding stages (Knowledge Master 2000, Mau 1998).

The banded greenhouse thrips, *Hercinothrips femoralis,* causes "silver and bronze scars" and may result in damage of economic importance (Zimmerman 1948). The silvering usually occurs with small infestations. With large infestations, or when red spider mite or other factors aggravate thrips damage, the banana fruit turns a peculiar reddish color. This lowers the market value of the fruit even though its edibility is not affected (Bianchi 1946). Thrips are not considered a problem on

banana in American Samoa and of the above-mentioned pests, none is known to occur. *T. hawaiiensis* has been recorded in Samoa, however, so may be present in American Samoa.

Cultural Control: To avoid additional losses and insect damage, the majority of the bananas produced in Hawai`i are covered with polyethylene bags prior to harvest. The bags provide a physical barrier to insect infestations.

Biological Control: An anthocorid bug, *Orius tristicolor,* is a general thrips predator like other species belonging to the genus (Waterhouse and Norris 1989). In Hawai`i, 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.

Chemical Control:

- **Diazinon** (Clean Crop Diazinon 500AG**).** PHI, 28 days; REI, 24 hours. Applied to 400 ha (1,000 acres) per year at a rate of 0.23 kg ai/380 L (0.50 lb ai/100 gal) of water, but with no more than 6 applications per bunch. Clean Crop Diazinon is registered under a 24(c) Special Local Needs label until 4 June 2007. Diazinon is applied directly to fruit bunches.
- **Spinosad** (Success): A possible alternative to diazinon for thrips control; registration pending.
- **Imidacloprid** (Provado 1.6F, Admire 2F): A possible alternative to diazinon for thrips control; registration pending.

Other Issues: Growers in Central America utilize polyethylene bags treated with bifenthrin. Unfortunately, these bags are not registered for use in the State of Hawai`i or other Pacific islands. Preliminary research on the efficacy of these bags in Hawai`i indicated they were effective in controlling insects and lowering damage levels. A tolerance for bifenthrin on imported bananas was recently established (4/30/03). Efforts are being made to register this use in Hawai`i under a 24(c) registration.

Mite Pests (*Tetranychus* spp.)
[Hawai`i]

The piercing and sucking mouthparts of mites usually cause silvery or bronzy patches on lower leaf surfaces but may also affect fruit (Gold et al. 2002). There was a reported increase in mite damage in Hawai`i in 2000. A sulfur product (MicroSulf, EPA Reg. No. 55146-75), was recently (2003) licensed for sale in Hawai`i for use on bananas. However, no efficacy or phytoxicity evaluations have been conducted. Label directions for use indicate applying 10 to 30 lb/acre, as needed. Mite predators are established in Hawai`i and may contribute to mite control although their economic effectiveness is unknown. No other island group in the American Pacific has reported problems with mites on bananas.

Weeds

Weeds are a major agricultural pest in the tropics. Fast growth, broad leaves, and a high competitive ability characterize many tropical weed species. Tall weeds and herbaceous or woody vines can quickly overgrow a neglected plantation, block sunlight and eventually kill plants. Weeds also raise relative humidity in the canopy and encourage fungal diseases, primarily black leaf streak. Some weeds may be alternate hosts for viruses or nematodes. On American Samoa, where annual rainfall is between 3,175-7,620 mm (125-300 in), depending on elevation, weed competition is usually for nutrients, not water. This competition is most critical during the first 4-6 months of a newly established plantation (Paul et al. 1993). Nutrient deficiencies early in banana plant development often retard growth and result in smaller bunches. In the island nation of Tonga, weed control was 7 percent of the farmer's budget and cost about $72 per acre in 1988 (Paul et al. 1993). On the other hand, weeds inhibit soil erosion, especially on steep slopes. Weed control recommendations listed below are based on banana Crop Profiles from Guam, Hawai`i, and American Samoa, and from a booklet by Muniappan et al. (1999) for the Republic of Palau.

Cultural Control: The most common methods of weed control are crop canopy management, hand clearing, and mulching.

Crop canopy. Most weeds thrive in full sun and even partial shading by the plant canopy inhibits their germination and growth. Planting intervals closer than 3 m x 3 m (10 ft x 10 ft), however, are not recommended by the extension service. Not only does it increase competition for nutrients between plants, it raises the humidity under the canopy and can enhance the severity of black leaf streak disease. It also inhibits mist blower application of fungicides against this disease.

Hand clearing. In a survey of commercial growers in American Samoa, all used bush knives (machetes) to clear their fields before and after planting. This method is labor-intensive but only costs the farmer his time. Modern day farmers often have other activities that demand their attention, however, and the use of pre- and post-plant herbicides is increasing. At a minimum, clearing the area around the base of plants (ring-weeding) is necessary in order to identify suckers infected with Banana Bunchy Top Virus (Magee 1967). Weed-eaters are popular but used mainly for cutting lawns. Mechanical cultivation on Guam is only recommended in weed-free zones around the plantation because it may damage shallow feeder roots.

Mulching. Weeds cut during hand clearing are left on the ground as mulch. A thick layer of mulch can inhibit weed germination, moderate soil temperature and evaporation, and decrease erosion. Old leaves and stems are also cut and left on the ground to decompose. In unsprayed orchards with severe black leaf streak disease, affected leaves should be removed and either burned, stacked, or turned topside-down to prevent wind-dispersed ascospores from re-infecting plants.

Biological Control: Numerous natural and introduced insect species are being used on Palau for weed control. A plant-sucking psyllid, *Heteropsylla spinulosa*, was introduced from Australia for control of creeping sensitive weed, *Mimosa diplotricha. Teleonemia scrupulosa*, a tingid bug, is well established on *Lantana camara*. And finally, a host specific eriophyd mite, *Acalitus adoratus*, decreases plant vigor through its leaf feeding habit on Siam weed, *Chromolaena odorata* (Muniappan et al. 1999). Hawai`i uses numerous insect and fungus species in their weed control programs. American Samoa introduced *Liothrips* sp. on several islands in the Territory in the 1990s to control Koster's Curse, *Clidemia hirta*, with mixed results.

Chemical Control: An increasing number of banana growers are using pre- and post-emergence herbicides. In established plantations, extreme caution must be used to keep herbicides from coming in contact with succulent banana plants. Choices in American Samoa are restricted by availability to various formulations of paraquat and glyphosate. There are four pre- and post-emergence herbicides available on Guam for use on bananas: Ametryn, dalpon, diuron and paraquat.

- **Agral LN**: This ionic surfactant, or spreader-sticker, is a wetting agent containing nonylphenyl ethoxylates. In American Samoa, it is commonly mixed with herbicides, insecticides and fungicides at a rate of 9.4 ml/L (1.2 fl oz/gal).
- **Ametryn** (Evik DF): PHI not listed; REI, 12 hours. Evik is applied in Hawai`i as a directed basal spray immediately after fruit set or anytime thereafter. It it is applied to 120 ha (300 ac) per year at a rate of 8.4 kg ai/ha (7.5 lb ai/acre). No more than 25.2 kg ai/ha (22.5 lb ai/acre) is allowed per year. Treatment with ametryn may have to be repeated every 3 to 4 months for control.
- **Diuron** (Karmex DF, etc.): PHI not listed; REI, 12 hours. Diuron is applied for pre-and post-emergence weed control in Hawai`i at a rate of up to 2.7 kg ai/ha (2.4 lb ai/acre) in new plantings and 5.4 kg ai/ha (4.8 lb ai/acre) in established plantings. Diuron is applied to 120 ha (300 acres) per year.
- **Glyphosate** (many products): PHI, 24 hours; REI, 4 hours. Glyphosate is applied to 364 ha (900 acres) per year in Hawai`i for general weed control or for site preparation prior to transplanting crops. It is applied at various rates, not to exceed 10.4 kg ai/ha (9.25 lb ai/acre) per year. In American Samoa, glyphosate is mixed at 74 ml/3.8 L (2.5 fl oz (5 tbsp)/gal) in a backpack sprayer (Crop Protection Reference 1995), usually with an adjuvant (e.g. a spreader-sticker such as Agral). It is recommended weeds be cut to 15 cm (6 in) and spray applied on a dry day after active weed growth resumes.
- **Oxyfluorfen** (Goal 2XL): PHI, 24 hours; REI, 24 hours. Applied as a post-directed application for broadleaf weed control in permanently established bearing and nonbearing banana plantings. Applied at a rate of up to 2.2 kg ai/ha (2.0 lb ai/acre) broadcast as a pre-emergence application. No more than 2.2 kg ai/ha (2.0 lb ai/acre) is allowed per season. Presently registered for use in Hawai`i under a 24(c) Special Local Needs label with an expiration date of 27 January 2007.

- **Paraquat dichloride** (Gramoxone Extra, Gramoxone Max): No PHI listed; REI, 12 hours. Paraquat is applied to 364 ha (900 acres) per year in Hawai`i as a directed spray to control or suppress a broad spectrum of weeds. It is applied at 1.1 kg ai/ha (0.94 lb ai/acre). No maximum per year is listed. Gramoxone is used as a pre-plant herbicide in American Samoa.

Other Issues: The Republic of Palau tested a gall fly, *Procecidochares connexa*, for its effectiveness against Siam weed, *Chromolaena odorata*. They also imported an arctiid moth, *Pareuchaetes pseudoinsulata*, from Guam and reared it in their laboratories for use against the same weed host (Muniappan et al. 1999).

Diseases

Banana Bunchy Top Disease (Nanavirus)
[American Samoa, Guam, Hawai`i]

Banana bunchy top disease (BBTD) is the most serious virus disease of bananas worldwide (Dale 1994) and threatens banana production in the American Pacific. Bananas are a perennial crop and the disease is active year-round. The symptoms are striking. New leaves are short and narrow, often with yellow, tattered margins. They are upright and do not completely emerge from the pseudostem, giving them a bunched appearance. The virus is systemic, moving from an infected plant to all plants in the mat, which no longer produces fruit. BBTD is spread over short distances by the brown banana aphid *Pentalonia nigronervosa*. Long distance spread is by infected planting material including suckers, pieces of the rhizome (mat) and infected tissue culture plants. There are no chemicals to control BBTD, only to eradicate it (Dale 1987). The previous recommendation for BBTD control was labor-intensive and rarely used except on small mats. Symptomatic plants were sprayed with kerosene, chopped up, and burned. The infected mat was dug up, cut in pieces and allowed to dry, then burned. Most growers simply cut down symptomatic plants with a bush knife, leaving the mat to resprout. BBTD was first discovered in American Samoa in the early 1960s (Magee 1967) but the unusually slow spread of the virus has allowed the use of ineffective control methods (Brooks 1999). Since most growers are not trying to maximize production in American Samoa, the sterile mats are of little concern. BBTD was identified on O`ahu in 1989 and since then has been detected in the Kona area of Hawai`i and on Kaua`i. Unlike American Samoa, BBTD has spread rapidly in the Hawaiian Islands and aggressive eradication campaigns were launched in Kona and on Kaua`i in 1999-2000.

Cultural Control: Plant in a clean field; destroy wild banana plants in the area. Windbreaks can stop or slow the flight of incoming, viruliferous aphids, reducing the possibility of new plants becoming infected. Weed control, especially around the base of mats, is an essential element of all management programs, allowing for the early identification of BBTD-infected suckers (Magee 1967). Manual destruction and removal of infected plants and mats and the use of clean, BBTD-free stock is still the most effective method currently in practice. Genetically modified BBTD resistant banana explants are being developed in several laboratories including one at the University of Hawai`i at Manoa. The explants are currently in the trial phase suggesting it will be several years before they are released.

Biological Control: none available.

Chemical Control: Though there are no chemicals to control BBTD, infected plants can be easily and completely destroyed using glyphosate injections. In 1999, the U.S. EPA issued a new pesticide label to the American Pacific, with the assistance of Monsanto. It allows Roundup Ultra to be used as a bananacide for BBTD control.

- **Glyphosate** (Roundup UltraMax, etc.): REI 12 hours. Banana bunches are removed before treatment. A hole is made in the pseudostem of all plants growing from an infected mat. Roundup Ultra is sprayed into the hole on each stem: 1.0 ml (0.034 oz) for stems < 10 cm (4 in) diameter, 2.0 ml (0.068 oz) for stems >10 cm diameter, to a maximum of 1.5 ml (0.051 oz) per mat. Surrounding plants are examined for symptoms of BBTD and injected with glyphosate if symptoms are present. The number of acres treated with glyphosate in Hawai`i is unknown; in American Samoa, its use is infrequent.

- **Diazinon** 50W, Prentox Diazinon AG 500: REI 24 hours. Remove any banana bunches before spraying. In American Samoa, Diazinon 50W is mixed 4.5 g/3.8 L water (2 tbsp/3 gal), plus Agral, a non-ionic surfactant, in a backpack sprayer and applied to plants growing from the virus-infected mat and plants growing within a 2 m (6 ft) radius. In Hawai`i, Prentox Diazinon AG 500 is applied to 485 ha (1,200 acres) per year at a rate of 0.5 kg ai/ha (0.45 lbs ai/acre).

Banana Mosaic Virus (Cucumber Mosaic Virus)
[Hawai`i]

Banana mosaic virus (BMV), also known as cucumber mosaic virus (CMV), affects banana production around the world. However, Hawai`i is the only member of the American Pacific group listing BMV as a problem. Common symptoms of BMV are leaf chlorosis, mosaic symptoms, and heart rot. Proper selection of virus-free planting material is an effective method of preventing BMV contamination of established plantings.

Black Leaf Streak, Black Sigatoka (*Mycosphaerella fijiensis, Pseudocercospora fijiensis*)
[American Samoa, Guam, Hawai`i]

The fungus *Mycosphaerella fijiensis* and its asexual form, *Pseudocercospora fijiensis*, cause black leaf streak disease (BLS), or black Sigatoka (Marin et al. 2003). It is present in all banana-growing countries and is the major cause of reduced yields in most areas. Spores of the fungus are spread by rain splash and wind-blown rain. Warm temperatures, high humidity, and a film of free water on the leaves favors the disease (Fullerton 1994, Paul et al. 1993). Initial symptoms are small purplish streaks on the underside of leaf blades. These streaks enlarge, become visible on the upper leaf surface and coalesce, forming necrotic areas that eventually kill the leaf (McKenzie 1996). Less plant energy is available due to premature leaf loss, causing poor plant growth, reduced yields, and possible early, uneven fruit ripening (Fullerton 1994).

Cultural Control: Cultural methods may be effective during mild infections and include disease forecasting, field sanitation, planting density, drainage, and weeding (Paul et al. 1993).

Disease Forecasting. The use and effectiveness of disease forecasting systems are being explored. Factors such as weather, existing disease level, cultivars, cultural practices, location, soil conditions, and various pest populations are taken into consideration when developing a monitoring system. The objectives of this forecasting system are to gain a better understanding of the relationship between the above-mentioned factors and BLS incidence and severity, and to optimize fungicide applications.

Sanitation, De-trashing. Removal of diseased, spore-producing leaves, or parts of leaves, lowers the number of fungal spores available to cause infection. Leaf removal also increases air circulation in the field, enables wet leaves to dry more quickly, and increases spray penetration and coverage (Nelson 1998). Diseased leaves should be removed from the plantation if possible, or at least stacked, or turned topside-down: Spores are continuously produced from detached leaves for up to 22 weeks (Marin et al. 2003). Leaf removal is only effective during mild infections, however. If BLS is severe, the manual removal of leaves will be as damaging to the plant as removal of leaves by the fungus. In American Samoa, the Land Grant Extension Service recommends removal of leaves that are more than 50 percent diseased.

Planting Density. Placing plants close together decreases airflow and increases relative humidity under the canopy; these conditions favor BLS. Close plant spacing also inhibits application of fungicides by mist blower and increases competition for plant nutrients. If plants are too far apart, weeds may become a problem and land will be underutilized. In American Samoa, average spacing is 3.0 m x 3-4 m (10 ft x 10-12 ft), conforming to recommendations for Tonga and the Windward Islands (Paul et al. 1993, Speijer 1988). Farmers in Guam space plants from 2.5-3.0 m x 3-4 m (8-10 x 10-12 ft) apart resulting in 1,000-1,500 mats/ha (400-600 mats/acre).

Drainage. Poor drainage may lead to flooding and increased relative humidity. It may also inhibit plant growth and plant defense mechanisms. Drains trenched across slopes may be necessary to carry away excess water and reduce soil erosion.

Weed Control. As with high planting densities and poor drainage, weeds increase the relative humidity in a field. Weeds should be destroyed with an herbicide or cut low with a bush knife.

Biological Control: Resistant varieties offer the best hope for a majority of subsistence farmers. BLS-resistant varieties introduced in the past, such as Bluggoe (Fa'i Pata) were said to have some resistance but the most promising introductions are the FHIA hybrids from Honduras (see "Other Issues" below).

Chemical Control: Environmental conditions and site location cause variations in the number of acres treated per year in the Hawaiian Islands. The island of Hawai`i is the primary user of fungicides due to the high level of annual rainfall. All commercial banana growers in American Samoa apply fungicides every two weeks due to

the high levels of precipitation and relative humidity.

- **Azoxystrobin** (Abound): No PHI listed, REI 4 hours. In Hawai`i, Abound is applied at a rate of 0.15 kg ai/ha (0.134 lb ai/acre). No more than 1.2 kg ai/ha (1.07 lb ai/acre) is allowed per year. Abound is a relatively new fungicide available to banana growers, therefore the total area treated is unknown.
- **Fenbuconazole** (Enable 2F): No PHI listed, REI 12 hours. In Hawai`i, Enable is applied when first leaves appear at a rate of 0.10 kg ai/ha (0.09 lb ai/acre). No more than 0.81 kg ai/ha (0.72 lb ai/acre) are allowed per year. Enable is applied to 77 ha (190 acres) per year.
- **Mancozeb** (Dithane F-45, etc.): No PHI listed, REI 24 hours. Mancozeb is applied at a rate of up to 2.7 kg ai/ha (2.4 lb ai/acre). No more than 27 kg ai/ha (24 lb ai/acre) is allowed per year. The island of Hawai`i is the primary user of fungicides due to the high level of annual rainfall. Mancozeb is applied to approximately 283 ha (700 acres) statewide.
- **Maneb** (Maneb 75 DF, etc.): No PHI listed, REI 24 hours. Applied when leaves first appear and repeated as needed. Applied at a rate of up to 2.5 kg ai/ha (2.2 lb ai/acre). No more than 27 kg ai/ha (24 lb ai/acre) is allowed per year.
- **Tebuconazole** (Elite 45 DF): No PHI listed, REI 12 hours. Applied as a foliar spray before disease becomes established. Applied at a rate of up to 1.6 kg ai/ha (1.4 lb ai/acre). No more than 8.1 kg ai/ha (7.2 lb ai/acre) is allowed per harvest cycle.
- **Horticultural Oils**: No PHI listed; REI, after product is dry.

Three chemicals are currently used, in rotation, against BLS in American Samoa: **propiconazole** (Tilt), **tridemorph** (Calixin) and **fusilazole** (Punch). These fungicides have a 24 hour REI. **Benlate** is the only fungicide consistently available and registered for use against BLS but its use is discouraged due to pathogen resistance (Fullerton 1994), which is expected but not confirmed in American Samoa. Tilt is only occasionally available at local outlets and, along with Calixin and Punch, is usually purchased off-island. Farmers spray with a mist blower every two weeks and combine the fungicides with Agral, a sticker-spreader (non-ionic surfactant).

BLS-affected plants in Guam are sprayed with 1.9 L (0.5 gal) **Gavicide 145** (spray oil) mixed with 0.45 kg (1.0 lb) **Dithane M-45** in 380 L water per 0.4 ha (100 gal/acre). For mist blower application, 0.5 L (1.0 pt) Gavicide 145 is mixed with 30-60 ml (1-2 fl oz) **Benlate** in 11.5 L (3.0 gal) water.

Other Issues: The Cavendish subgroup hybrid 'Goldfinger' was introduced to American Samoa in 1998. It has a high level of resistance to BLS but local farmers are slow to accept it, stating that it is soft, tasteless, and mushy when cooked. Though it was recently discovered that people were over-cooking the fruit, they still prefer the taste of the 'Williams' variety to this new hybrid. American Samoa now has several new BLS-resistant hybrids from the Fundacion Hondurena de Investigacion Agricola (FHIA), the same line as 'Goldfinger' (FHIA-01). One hybrid in particular, FHIA-25, looks promising, offering high disease resistance, good flavor and shelf-life, and possible resistance to the burrowing nematode. This hybrid has been taste-tested informally and may be multiplied in tissue culture by American Samoa Community College Land Grant Program. The goal would be to make it available to commercial growers. Introduction of this level of BLS resistance could end most fungicide use in American Samoa.

Crown Rot Complex (*Botryodiplodia theobromae*, *Cephalosporium* sp., *Ceratocystis paradoxa*, *Colletotrichum musae*, *Fusarium roseum*, *Verticillium theobromae*)

[Hawai`i]

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

Cultural Control: Harvest fruit at the correct stage of maturity and handle it gently during harvest and in transit to minimize bruising and reduce the opportunity for crown rot to develop. Maintain storage and temperature control so bananas do not ripen prematurely. Remove last banana hand and distal flower bud after all hands have opened to eliminate the site where crown rot most commonly starts. Increase row spacing in the field to reduce relative humidity. Destroy infected plant material to reduce inoculum levels in the field.

Biological Control: none recommended.

Chemical Control:

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

Freckle (*Phyllosticta musarum*)

[American Samoa, Hawai`i]

Freckle is a fungal disease of bananas that affects fruit quality and appearance. This disease is not a serious concern in Hawai`i except in a few localized areas (Farmers Bookshelf 2000). It has been identified in American Samoa, but is uncommon (Brooks 2002).

Moko Disease (*Ralstonia solanacearum* race 2)

[Guam]

Moko disease is a bacterial vascular wilt of ornamental *Heliconia* spp., as well as banana, and strains of the bacterium can be transported in either (Buddenhagen 1994). It is caused by *Ralstonia solanacearum* race 2, previously known as *Pseudomonas solanacearum* race 2 (Thwaites et al. 2000). Newly emerging leaves on infected plants become yellowish-green and collapse. Older leaves are subsequently affected and also collapse, defoliating and killing the plant. Infested soil, contaminated pruning knives, or insects carrying bacterial ooze to the inflorescence of a healthy plant may spread the disease. Moko disease is a minor problem on Guam at present and has not been reported from other American Pacific islands. Basic sanitation, including removing and destroying infected plants, disinfesting pruning tools, and weed suppression, can help prevent the disease from becoming more serious (Buddenhagen 1994). If the disease does destroy a crop, a minimum two-year clean fallow period may be an effective method of reducing inoculum prior to replanting.

Fusarium Wilt, Panama Disease (*Fusariam oxysporum* f. sp. *cubense*)

[Guam, Hawai`i]

This disease is characterized by bright yellow older leaves that eventually wilt, dry, and hang from the plant like a skirt (Ploetz 1994). One method of identifying the disease is to slice open the plant and note its color. Normal pseudostems have a clean, white interior, but Panama disease produces a characteristic reddish to dark brown discoloration. *F. oxysporum* f. sp. *cubense* is a soil-borne fungus that can either form survival structures or live as a parasite in weed hosts for many years. Panama disease spreads by root-to-root contact, infected rhizomes and suckers, infested soil, running water, tools or machinery (Ploetz 1994). Management of the disease includes resistant varieties, disease-free planting material, and minimizing the movement of infested soil. Panama disease has been identified on Guam and has been a serious problem where observed. The disease exists in Hawai`i but not all races of the pathogen have been identified there. Due to the planting of disease-resistant varieties, the importance of the disease in Hawai`i has decreased (Nelson, in press). Panama wilt has not been reported from other islands in the American Pacific.

Yellow Sigatoka, Sigatoka Disease (*Mycosphaerella musicola*, *Pseudocercospora musae*)

[American Samoa, Guam]

Yellow Sigatoka is similar to black leaf steak disease but is less virulent. It causes yellow streaks (rather than black) that enlarge, turn brown, and become water-soaked with tissue in the center dying and turning gray. Black leaf streak disease will usually replace yellow Sigatoka in an area (Fullerton 1994). Epidemiology and control of yellow Sigatoka is essentially the same as for black leaf streak disease. *M. musicola* has been reported in Guam and American Samoa but is not considered a problem by growers.

Nematodes

Nematodes are small, wormlike members of the animal kingdom ranging from 0.3-4 mm (0.012-0.16 in) in length. Most nematodes are decomposers but some species parasitize plants, others infect animals and humans (Agrios 1988). Plant parasitic nematodes are characterized by their stylet, a spear-like mouth part used to puncture plant cells. Some nematodes feed on cells near the plant's surface, others enter deep into roots and stems to feed. Plants are damaged in several ways. Mechanical damage to the plant surface is usually minor but offers a point of entry to bacteria and fungi. Saliva injected into cells by nematodes prior to feeding causes a local reaction that may kill plant tissue, cause swellings and galls, or distort stems. Root-feeding nematodes inhibit plant uptake of water and nutrients, producing weak, stunted plants and reduced yields. A survey by Grandison (1996) in American Samoa found six species of plant parasitic nematodes. The most important were the burrowing nematode (*Radopholus similis*), lesion nematode (*Pratylenchus coffeae*) and the spiral nematode (*Helicotylenchus multicinctus*). Of eight different nematode genera reported on bananas in Hawai`i, root knot nematode (*Meloidogyne* spp.), reniform nematode (*Rotylenchulus reniformis*), and the burrowing nematode are economically important to commercial production statewide (Sipes 1993).

Toppling Disease, Blackhead Disease (*Radopholus similis*)

[American Samoa, Guam, Hawai`i]

R. similis is the most damaging nematode of bananas worldwide, including the South Pacific (Kirby 1977), and has been reported on Guam, Hawai`i, and American Samoa. It is called the burrowing nematode because it burrows into fleshy banana roots and feeds on the cortex. Initial lesions are dark red but turn black as cortical tissue begins to rot. If *R. similis* enters the rhizome, round, black lesions appear, giving it the name "blackhead disease". The feeding habits of this nematode affect plants in two ways: anchorage and water and nutrient uptake (Gowen and Queneherve 1990). Heavy cortical feeding weakens existing roots and new roots become infected as they grow out of the infected rhizome. Wind, heavy rain, or the weight of a banana bunch can pull the plant from the soil. Under these conditions toppled banana plants can be found throughout an infested plantation. Symptoms of nutrient deficiency due to root damage by *R. similis* include poor plant growth, leaf yellowing, and reduced yields. Since poor soils, drought, nutrient imbalance, or fungal root pathogens may create the same symptoms, identification of the nematode is essential. The life cycle of *R. similis* is about 20-25 days, from egg to egg, at 24-32°C (75-90°F) (Gowen and Queneherve 1990). It is able to complete its life cycle within the root cortex and does not survive long in the soil without banana mats or roots to colonize.

Cultural Control: Cultural controls include fallowing, crop rotation, and exclusion. The first two methods are not apt to be effective in subsistence agriculture, where bananas are grown continuously without replanting.

Fallow. Removing all banana plants, mats, suckers, and alternate hosts from a field for 6-12 months starves the nematodes and is one of the best methods of reducing nematode populations (Gowen 1994a). It is difficult to achieve meaningful reductions, however, due to volunteer plants, weeds or mats and roots left in the soil on which the nematodes can still feed. Fallow fields are unproductive fields and most farmers are not willing to accept short-term losses for possible long-term gains. Due to the possibility of soil erosion, cover crops are being investigated as an alternative to bare fallow and nematicide use. Cover crops may also be used to minimize weeds, soilborne diseases, and nematode populations (Sipes 1993).

Crop Rotation. Planting a crop that is not a host for *R. similis* gives the same results as fallowing and is attainable on American Samoa. At present, for example, some farmers are removing bananas and planting taro. Banana prices are low and taro prices are still comparatively high. Most farmers, however, will leave all or part of the banana mats in the field and just remove the aboveground plants. This will not significantly reduce the nematode population.

Exclusion. Planting nematode-free plants in clean soil is possible on land where bananas have not been grown the previous year. Only planting material known to be free of nematodes should be used. If rhizomes are suspect, they can be trimmed and treated in a hot water bath at 55°C (131°F) for 15-25 minutes. The hot water treatment is difficult to manage, especially on a large scale, due to the size of the planting pieces (Gowen 1994a). Some islands have facilities to produce nematode-free plants in tissue culture. This effort could be coordinated with production of plants for Banana Bunchy Top Virus or black leaf streak disease control projects (see Diseases).

Biological Control: There are no acceptable biocontrol agents available at this time. There are, however, hybrid bananas being developed with fair to good resistance to *R. similis* (see "Other Issues", under black leaf streak disease).

Chemical Control: Soil treatments for nematodes are not cost effective in American Samoa due to low banana prices and lack of an export market. The following nematicides and application rates are for Hawai`i (from Hawai`i Banana Crop Profile, 2003 update)

- **Ethoprop** (Mocap 10%G): PHI not listed, REI 48 hours. Mocap is applied to 160 ha (400 acres) in Hawai`i at a rate of 0.0059 kg ai/80 cm (0.013 lb ai/2.64 ft) radius around each producing stem. No maximum application rate per year is listed. It is used primarily on the island of Hawai`i for post-plant control of root knot, reniform, and burrowing nematodes.
- **Fenamiphos** (Nemacur 3, Nemacur 15%): PHI 15 days, REI 48 hours. Nemacure is applied to 160 ha (400 acres) in Hawai`i at a rate of 5.0 kg ai/ha (4.5 lb ai/acre). Maximum application per year is not to exceed 11.1 kg ai/ha (9.97 lb ai/acre). It is applied for post-plant control of root knot, reniform, and burrowing nematodes, either as a band application with ground equipment, or by low pressure irrigation. For band application, it is placed on each side of the pseudostem at rates dependent on band width. These nematicides are registered in Hawai`i under a 24(c) Special Local Needs label, expiring 4 June 2007.
- **Oxamyl** (Vydate 240 g ai/L (2.0 lb ai/gal)): REI, 48 hours. Vydate is occasionally used in American Samoa. The recommended dosage for soil application 2.2-9 kg ai/ha (2-8 lb ai/acre). It is translocated upward from roots or downward if applied to leaves (Thomson 1998).
- **Aldicarb** (Temik 150 g ai/L (1.25 lb ai/gal)): Used by some growers in American Samoa. It has a REI of 48 h and the recommended dosage is 0.56-11.2 kg ai/ha (0.50-10 lb ai/acre). Aldicarb is translocated upward from roots only (Thomson 1998).

Other Issues: Research continues on cover crops in Hawai`i in anticipation of loss of nematicide registrations (Sipes 1993). See "Other Issues" under black leaf streak disease regarding new nematode resistant banana hybrids.

Lesion Nematode (*Pratylenchus* spp.)

[American Samoa]

Lesion nematodes have a broad host range in the tropics and cause the same symptoms on banana as *R. similis* (Gowan 1994a). Grandison (1996) isolated *P. coffaea* from breadfruit, coconut and guava roots on American Samoa, but damage was only recorded on taro (*Colocasia*) and giant taro (*Alocasia*). *Pratylenchus loosi* has recently been extracted from roots of the banana variety 'Paka', but their effect on yield has not been determined (Brooks, unpublished). This nematode is a new record for American Samoa (Grandison, personal communication).

Cultural Control: Trim corms with a knife and immerse in water maintained at 55°C (131°F) for 20-25 minutes. Clean fallow the infested field (no banana volunteers) for 6-12 months, followed by planting nematode-free suckers or corm bits (Gowen 1994b). See *Radopholus similis*.

Biological Control: none recommended.

Chemical Control: Vydate is occasionally used by commercial growers in American Samoa.

Spiral Nematode (*Helicotylenchus multicinctus*)

[American Samoa]

The spiral nematode is found in most banana growing areas of the world and can cause major damage and yield losses. *H. multicinctus* feeds on the superficial layers of the root cortex, whereas *Radopholus similis* causes deep lesions (McSorley 1994). For this reason, the spiral nematode is often overlooked in the presence of *R. similis*, the more destructive of the two. Like *R. similis*, the spiral nematode can complete its life cycle within the banana root (Gowen and Queneherve 1990). The spiral and burrowing nematodes were reported in American Samoa by Grandison (1996), who observed weakened roots causing poor plant growth, small bunches and toppled plants. Early results from a banana nematode survey in American Samoa report significantly greater numbers of *H. multicinctus* than of *R. similis* in Cavendish-type banana plantations (Brooks, unpublished).

Control methods: See *Radopholus similis*.

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