PEST MANAGEMENT STRATEGIC PLAN FOR BANANA PRODUCTION IN HAWAII

Workshop Summary
March 3, 2003
Pearl City Urban Garden Center
University of Hawaii at Manoa
Honolulu, Hawaii

Editors
Lynne N. Constantinides
John J. McHugh, Jr.

Contact: Cathy Tarutani
e-mail: cathy@hpirs.stjohn.hawaii.edu
(808) 956-2004

TABLE OF CONTENTS

WORKSHOP PARTICIPANTS AND CONTRIBUTORS

Barry Brennan	University of Hawaii at Manoa, Associate Dean & Associate Director Cooperative Extension Service
Luisa Castro	Educational Specialist, University of Hawaii at Manoa
Chian Leng Chia	Tropical Fruit Specialist, Department of Tropical Plant and Soil Sciences, University of Hawaii at Manoa
Scott Chun	Grower; President, Oahu Banana Growers Association
Lynne Constantinides	Crop consultant; Crop Care Hawaii, LLC
Joe DeFrank	Weed Scientist, Department of Tropical Plant and Soil Sciences, University of Hawaii at Manoa
Godwin Esaki	Grower; Kapaa, Kaui
Peter Follett	Research Entomologist, USDA Agricultural Research Service
Bruce Guard	Brewer Environmental Industries
Richard Ha	Grower; President, Hawaii Banana Industry Association
Reggie Hasegawa	United Horticultural Supply
Linda Herbst	Assistant Director, Western Region Pest Management Center, University of California at Davis
James Hollyer	Facilitator; Agriculture Development in the American Pacific Program, University of Hawaii at Manoa
Jonathan Jefts	Grower; Larry Jefts Farms, Oahu
Ron Kauhaahaa	United Horticultural Supply
Michael Kawate	Pesticide Registration Specialist, University of Hawaii at Manoa
Gerald Kinro	Pesticide Specialist, Hawaii Department of Agriculture
Lance Kobashigawa	Pesticide Registration Specialist, Hawaii Department of Agriculture
Winifred Marcos	Grower; Aloun Farms, Inc., Oahu
Mel Matsuda	Grower; Matsuda Fukuyama Farms, Oahu

John McHugh	Hawaii Farm Bureau Federation
Scot Nelson	Plant Pathologist, Department of Plant and Environmental Sciences, University of Hawaii, Komohana Agricultural Complex, Hilo
Ken Ogawa	United Horticultural Supply
Brent Sipes	Plant Pathologist-Nematologist, Department of Plant and Environmental Sciences, University of Hawaii at Manoa
Cathy Tarutani	Department of Plant and Environmental Sciences, University of Hawaii at Manoa
Glenn Teves	Grower; Hoolehua, Molokai
Edward Uyeda	APHIS Plant Pest Quarantine, United States Department of Agriculture, Hilo, Hawaii
Royd Vasconsellos	Grower; Kahuku Farmers, Oahu
Mark Wright	Extension Entomologist, Department of Plant and Environmental Sciences, University of Hawaii at Manoa
Pueo Wright	Grower; organic bananas, Hana, Maui

TOP PRIORITIES FOR HAWAII BANANA PRODUCTION

#1 Banana Production Priority

Sustainable banana production for Hawaii is dependent on the availability of a variety of pest management tools, including multiple chemical control options. The present situation of limited chemical tools for insect and disease control increases the risk of the development of resistance by key invertebrate pests and crop pathogens. The top priority of the Hawaii banana industry is to secure additional registered pesticides for banana production for resistance management which, in turn, would encourage lower overall pesticide use by maintaining the efficacy of labeled pesticides.

Research:

- Develop resistance to Banana Bunchy Top disease.
- Develop strategies for vector control of Banana Bunchy Top disease.
- Develop strategies for control of Banana Rust Thrips.
- Develop control strategies for nematodes; specifically register new chemical products that are safe (to the applicator and environment) and effective.
- Investigate compost production as a control for nematodes.
- Develop economic and action thresholds for key pests.
- Investigate selective grassy weed controls/herbicides for new plantings.
- Investigate resistance management tools.
- Research on lower irradiation dose rates for banana disinfestation.
- Quarantine treatments for bananas.

Regulatory:

- Quarantine, eradication, and regulatory actions for Banana Bunchy Top disease in homeowner gardens.
- Overcome quarantine and regulatory hurdles associated with shipping bananas to California.
- Strengthen State of Hawaii quarantine of incoming plants and planting material so that the possibility of introducing new banana pests is minimized.
- Amend Hawaii Revised Statues to allow for registration of new chemistry pesticides in the state.
- Change Hawaii laws and regulations to allow for import of beneficial insects and insect pathogens (natural enemies) for control of key pests.
- Register pipeline management materials in a timely fashion.
- Allow registration of pesticides under Section 18 (Specific or Crisis Exemption) for resistance management.
- Take a proactive (pre-emptive) approach to registering more pest management tools and options.
- Waiver of licensing fees for new, low-impact (low non-target, mammalian toxicity) chemical and beneficial control organisms.

Education:

- Identification guides for all banana crop pest species.

- Conduct on-farm training to recognize key pests.
- Disseminate information regarding Banana Integrated Pest Management (IPM).
- Homeowner training for recognition of Banana Bunchy Top and what to do if discovered.
- Training in proper field sanitation for reduction of pest pressure.
- Hawaii Visitor Bureau education to keep out infected diseases (e.g. Panama wilt, Banana scab moth)
- Educate regulators regarding pest management challenges in bananas.
- Training sessions on how to grow, manage, and conserve on-farm natural enemy populations.

BACKGROUND

Economic Importance

Hawaii ranks number one nationally in banana production (*Musa* sp.). Planted commercial acreage in Hawaii is 1,660 acres of which 1,490 are harvested acres, representing an annual farm value of $10,640,000. Nearly all banana production is for fresh market. Average yields of fresh market bananas are 9.4 tons per acre. Commercial banana production occurs on all major islands (Hawaii, Maui, Molokai, Oahu, Kauai) with 80% of the production concentrated on the islands of Hawaii and Oahu. Major production regions are: Puna, Hilo and Hamakua districts (Hawaii island), Waimanalo, Kaneohe, Kahuku, Waialua, and Ewa (Oahu), Hana, Haiku, and Wailuku (Maui), and Kilauea, Moloaa, Kapaa, and Koloa on Kauai. Most bananas grown in Hawaii are marketed within the state of Hawaii but the recent lifting of fruit fly quarantine restrictions has generated an increase in export marketing of bananas.

General Cropping Guidelines

Commercial varieties of banana plants do not produce seed and are reproduced and increased vegetatively. Banana "keiki", which are the sword sucker side shoots of a mature banana plant (Photo 1), are cut away from the underground portion (corm) of the mother plant. The "keiki" are planted directly into prepared soil and spaced at 6 – 7 ft. between plants within a row and 8 – 15 ft. between rows (Photo 2). Planting occurs year round. Banana has a very high water requirement. In high rainfall areas [Puna, Hilo, Hamakua (>60 in. annually)] banana is not irrigated. In drier areas (Waialua, Ewa, Kahuku, Koloa) drip irrigation, or sprinkler systems using micro-sprinklers positioned 12 inches above the soil surface, are installed at the time of planting.

Banana is a tropical plant and cannot tolerate any freezing temperatures. In Hawaii, commercial banana production is below 1000 ft. above sea level. The warmer the air temperature the faster the banana plant grows. Banana inflorescences (Photo 3) appear on newly planted bananas at 9 – 12 months after planting. Fruits mature 90 to 120 days after first flowering with banana bunches ready to harvest from 12 to 15 months after initial planting (Photo 4). Subsequent banana crops are produced by "keiki" offshoots from the mother plant (Photo 1). One or two "keiki" are maintained per mother plant to produce subsequent banana crops.

Bananas are grown on a variety of soil types but do best in well drained soils with a pH range of 6.0 – 6.5. Nutrition requirements are high because of the fast growing nature of

the plant. Banana roots are extensive but shallow so frequent fertilization with nitrogen (N) and potassium (K) fertilizers are needed because these nutrients are leachable and move out of the root zone with the heavy irrigation (or high rainfall) requirement of the plant. Damage to the roots is extensive when cultivating for weed control because of the shallow root systems. Weed control is maintained in banana fields by a combination of herbicides and ground cover (crop residue or cover crop or both).

Banana production requires extensive hand labor. Planting, sucker thinning, fertilization, and harvesting tasks are all performed by hand. Pest control also requires hand labor when back pack sprayers are used, a common practice in Hawaii banana fields. Banana bunches (Photo 4) are harvested when the sharp edges of the fruit skin begin to "round" out. Fruit are green at the time of harvest. Banana plants can be 10 to 20 ft. tall and fruit harvest may require that the entire plant be cut down to access the banana bunch. Each banana plant produces only one bunch of fruit. Bunch weight varies from 30 to 150 lb. depending on variety.

Major banana varieties grown in Hawaii are from two distinct types or groups of bananas: Cavendish and Hawaiian Apple Bananas. The Cavendish group represents about 80% of the bananas grown with the dominant cultivars in the group being Williams, Chinese, Valery, Hamakua, and Grand Nain. The remaining 20% are mostly from the Hawaiian Apple Banana group and include the tall Apple and the Dwarf Apple banana. These bananas are smaller and with a more distinctive flavor than their larger Cavendish cousins. The Hawaiian Apple Banana is increasing in popularity as an export banana.

Major Pests of Bananas

The most important insect pests of bananas affecting production in Hawaii are the banana aphid (*Pentalonia nigronervosa*), banana weevil (*Cosmopolites sordidus*), Hawaiian flower thrips (*Thrips hawaiiensis*), and sugarcane bud moth (*Decadarchis flavistriata*). Coconut scale (*Aspidiotus destructor*) is a serious pest affecting export quality of bananas as the presence of one live insect can lead to the rejection of an entire shipment. Banana aphid has major pest status because it is a vector of the banana bunchy top virus.

Three species of nematodes, the rootknot nematode (*Meloidogyne* spp.), reniform nematode (*Rotylenchulus reniformis*), and burrowing nematode (*Radopholus similis*) are economically important pests of banana. These microscopic roundworms attack the root systems of the plant and impair water and nutrient uptake. In extreme cases root systems are so weakened that heavily fruit laden banana plants will topple over in high winds. Symptoms of nematode infection include stunting, narrow and weak pseudostems, chlorosis, plant toppling, root rot and gall formation. Nematode establishment in a field tends to be "patchy" but heavily infested fields have been abandoned.

The most important diseases of banana in Hawaii are banana bunchy top virus, Panama wilt (caused by *Fusarium oxysporum*), and black leaf streak (*Mycosphaerella fijiensis*). Panama wilt can only be managed economically in Hawaii by planting varieties that are resistant to the disease. The crown rot complex is the most serious post-harvest disease problem in bananas. A detailed list of all insect, disease, and nematode pests affecting banana is listed in Table 3.

Weed control in banana is especially critical during the establishment period. The shallow roots of the banana plant make it difficult to compete with weeds for nutrients, moisture, and sunlight. Additionally, weeds can harbor banana mosaic virus which has many alternate weed and cultivated crop hosts. Once the banana plantings have become established there is adequate crop residue and deep shade from the canopy to effectively eliminate weed competition.

Integrated Pest Management

The Hawaii banana industry is very small compared to most crop industries in the United States. The size of the industry makes it difficult to register new products on the crop because of low economic incentive to pesticide manufacturers. Because of this, the Hawaii Banana Industry Association has adopted an integrated pest management (IPM) approach as a means of maintaining the effectiveness of registered pesticides and promotion of environmental stewardship and is a partner with the Environmental Protection Agency in its Pesticide Environmental Stewardship Program. Proper identification of key pests, scouting, monitoring, timely application of effective control measures, and rotation of pesticides with different modes of action are critical to the success of the banana IPM program. Hawaii banana farmers are critically aware of the impact of pesticides on the environment and worker safety. Broad spectrum organophosphate pesticides (e. g. diazinon, with a projected cancellation date in 2007) will eventually no longer be available for use in bananas. Efforts are underway to register target specific, low mammalian toxicity, effective pesticides for banana pest management. With the loss of the broad spectrum pesticides, the use of newer pesticides with a narrow target range make it imperative that IPM practices are followed and maintained in banana production.

OUTLINE OF PLAN

The following is a pest-by-pest analysis of the current pest management practices in banana production in Hawaii. Non-chemical, cultural, and biological control measures are also discussed. A "to do" list for research, regulatory, and education needs is included with each pest analysis. Pests are presented in order of economic importance within each pest section. There is no attempt to prioritize importance between pest groups (e.g., insects vs. nematodes or nematodes vs. pathogens). The plan includes pests currently found in Hawaii but concern was expressed over the introduction of new pests, specifically the banana scab moth (*Nacoleia octasema*) which is a very serious insect pest in other banana growing regions of the world.

INSECTS & MITE PESTS

1. **Banana aphid (*Pentalonia nigronervosa*)**

The banana aphid is a serious problem on banana because it is a vector of banana bunchy top virus (BBTV) (Photo 5), 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 part of the plant. 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. BBTV has not yet been detected on Molokai, in Hana on Maui, or in the Hilo, Puna, and Hamakua production areas of the island of Hawaii. In the banana growing areas where it is firmly established, BBTV has led to the demise of regional commercial production. The problem of BBTV spread and control is complicated by homeowners and gardeners who may not recognize the disease and do not take steps to remove infected plants from their banana plantings. Banana aphid movement is highest during the windy months from February to April. Banana aphid infestations are not as intense in high rainfall areas (>60 inches of rain annually) because free water tends to discourage aphid movement and establishment. Banana aphid is regularly scouted throughout the crop cycle but has an economic threshold of 1 banana aphid per plant when BBTV is present.

Insecticides currently registered:

- Diazinon (Diazinon)
  - Efficacy: fair. Widely used.
  - Limiting factors: registration to expire in 2007, but actual in-field use will expire sooner due to new label restrictions and requirements (e.g., use of closed-cab systems). Banana aphid may develop resistance.
  - Advantages/disadvantages: cost is reasonable, but hazardous to the applicator, aphids hide deep inside the whorl where diazinon cannot contact them.
- Azadirachtin (Azatrol)
  - Efficacy: not known. Seldom used.
  - Disadvantage: Expensive.

- Garlic juice (Envirepel, Nutripel)
  - Efficacy: not known. Seldom used.
- Pyrethrin (Diatect, Prozap, Pyrenone, Pyronyl)
  - Efficacy: not used for aphids.
- Potassium salts of fatty acids (M-Pede)
  - Efficacy: poor. Seldom used.
  - Advantage: Soft on the environment.

Other pest management aids:

- Ant control (ants can move aphids around)
- Horticultural oils (Volck Supreme, Clean Crop Superior)
- Inter-island (and intra-island) quarantine on movement of banana plants
- Natural enemies (ladybugs, lacewings, Syrphid flies, parasitic wasps)
- Neem tree barriers
- Soapy water

Pipeline pest management tools:

- Imidacloprid (Provado, Admire)
  - Efficacy: excellent. May be registered in 2006.
  - Disadvantage: Very expensive.
- Dinotefuran
  - Efficacy: research is needed.
- Flonicamid
  - Efficacy: research is needed.

"To do" list for banana aphid:

Research needs:

- Establish economic thresholds for banana aphid.
- Look for alternatives to diazinon.
- Examine a systems approach to aphid management.
- Investigate pymetrozone (Fulfill) for aphid control.
- Research natural alternatives for aphid control.

Regulatory needs:

- Follow registration pathway for imidacloprid on bananas.
- Change state of Hawaii laws to allow for expedited registration of "new chemistry" pesticides with low non-target impact and low mammalian toxicity especially for disease resistance management.
- Change state of Hawaii laws to allow for importation of pathogenic fungi for aphid control.
- Tighten quarantine to avoid introduction of BBTV to Molokai and parts of Maui and Hawaii island.

Education needs:

- Develop scouting and identification programs.

- Distribute information regarding BBTV quarantine areas.
- Conduct community education programs to destroy BBTV infect plantings.
- Establish a "Hot line" number to report suspected BBTV outside of quarantine areas.

2. **Coconut scale (*Aspidiotus destructor*)**

Found on all islands and in all growing regions, the coconut scale is the most important quarantine pest for export. The coconut scale is an armored scale and is usually found on the under side 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. The presence of 1 live coconut scale (juvenile or adult) can cause rejection of bananas shipped to California. Their piercing and sucking mouthparts extract plant juices, leading to discoloration and yellowing of plant tissue. Peak "season" for coconut scale infestation is from February through April when prevailing windy conditions disperse the scales throughout the plantings.

Insecticides currently registered:

- Buprofezin (Applaud)
  - Efficacy: excellent. New registration.
  - Advantages/disadvantages: target specific, soft on natural enemies, but timing of application is critical to control crawlers.

Other pest management aids:

- Fungicidal oils
- Parasitic wasps (undetermined species)

Pipeline pest management tools:

- Imidacloprid (Provado, Admire)
  - Efficacy: research is needed.
- Developing scouting and thresholds for coconut scale.
- Hot water treatment for the fruit.

"To do" list for coconut scale:
Research needs:

- Investigate the effectiveness of oils and soaps.
- Develop effective post-harvest treatments.
- Research effective biocontrol agents.
- Investigate alternative control measures.
- Develop pesticide resistance management strategies.

Regulatory needs:

- Register bifenthrin impregnated polyethylene sleeves.
- Minimize or break down quarantine barriers with California.

Education needs:

- Identification guide to include juvenile and adult stages, pest biology.

3. **Banana weevil (Banana Root Borer) (*Cosmopolites sordidus*)**

The banana weevil 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. Large numbers of larvae and extensive feeding can result in root destruction, slowed plant growth, reduced fruit production, and, sometimes, toppled plants. Young banana plants are the most at risk because tunneling by the weevil can kill the plants at this stage. The adult weevil feeds and breeds at night. New banana fields planted into former banana orchards are especially susceptible to infestation. An economic threshold of 3 weevils per cut banana corm or pseudostem placed in the field overnight will trigger control action. Banana weevil is found throughout all growing regions.

Insecticides currently registered:

- Carbofuran (Furadan 5%)
  - Efficacy: fair. Applied at time of planting.
  - Limiting factors: only product registered for control of banana weevil.
  - Advantages/disadvantages: long residual activity, but potential groundwater contaminant.

Other pest management aids:

- Field sanitation
- Hot water treatment of corms
- Baiting/trapping by laying freshly cut corm on ground
- Tissue culture to produce clean plants
- Cover banana plant wound with soil after pruning or harvesting
- Plant "keiki" deep to minimize root exposure
- Maintain healthy, vigorous plants

Pipeline pest management tools:
None.

"To do" list for banana root borer:
Research needs:

- Carbofuran resistance monitoring.
- Search for natural enemies.
- Mass trapping.
- Investigate the use of lime to interfere with life cycle.
- Investigate efficacy of neem powder.

Regulatory needs:

- None.

Education needs:

- Spread by exchange of planting material therefore growers should be educated regarding sanitation of planting material.

4. **Sugarcane budmoth caterpillar (*Decardarchis flavistriata*)**

The sugarcane budmoth caterpillar is a localized pest in Hawaii found on the islands of Oahu, Kauai, and Hawaii. This caterpillar feeds on decaying flowers and causes fruit scarring because it feeds on the skin of the fruit. Many growers have adopted the practice of removing all flowers (Photo 6) prior to bagging to reduce sugarcane budmoth damage. Insecticide spray effectiveness is best if applied as soon as the banana bunch emerges. At present, the sugarcane budmoth caterpillar is not considered a serious pest problem in Hawaii, but damage may be controlled using *Bacillus thuringensis* applied to banana bunches prior to bagging.

Insecticides currently registered:

- *Bacillus thuringensis* (M/C Bioinsecticide, Lepinox, Javelin, Xentari, Dipel, Prolong)
  - Efficacy: good. Must be applied early in banana bunch formation.
  - Limiting factors: only product registered for control of sugarcane budmoth.
  - Advantages/disadvantages: soft on environment, target specific, but short residual activity.

Other pest management aids:

- Polyethylene bags
- Some natural enemies

Pipeline pest management tools:
None.

"To do" list for sugarcane budmoth caterpillar:
Research needs:

- Find additional control measures.
- Investigate effectiveness of spinosad.
- Investigate effectiveness of thiamethoxam.

Regulatory needs:

- Change laws to allow for registration of thiamethoxam in Hawaii.
- Register spinosad.
- Address California quarantine restrictions.

Education needs:

- Develop identification, insect biology guide.

5. **Thrips: Anthurium thrips (*Chaetanophothrips orchidii*), Banana rind thrips (*Elixothrips brevisetis*), Banana rust thrips (*Chaetanophothrips 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. The most serious of the thrips pests attacking bananas are banana rust thrips and Hawaiian flower thrips. Pest thrips species are found on all islands and growing regions and infestations become most intense during dry periods or in low rainfall areas.

The nature of the damage caused by anthurium thrips/banana rust thrips 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.

The banana rind thrips feed on leaves, flowers, or stems with the injured tissue taking on a silvery appearance which eventually turns dark brown. On leaves, their 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.

The banded greenhouse thrips causes silver and bronze scars which may result in damage of economic importance. 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 affected.

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. Depending on the extent of feeding, flowers become flecked, spotted, or deformed. Unlike other flower thrips, this species prefers wet and shady areas.

Control of thrips is especially critical during the flowering and fruit development phase of the banana crop cycle. However, control measures need to be employed throughout the growth of banana to minimize thrips damage. Decision to use pesticides for thrips control is based on presence or absence of thrips determined by regular field scouting and monitoring. The presence of thrips on export bananas is cause for quarantine rejection.

Insecticides currently registered:

- Diazinon (Diazinon)
  - Efficacy: fair to good. Widely used.
  - Limiting factors: registration to expire in 2007, but actual in-field use will expire sooner due to new label restrictions and requirements (e.g., use of closed-cab systems). High potential to develop resistance. 28-day PHI limits timing of application to fruit.
  - Advantages/disadvantages: cost is reasonable, moderate residual activity/hazard to applicator, phytotoxic to banana fruit if rate is too high, strong smell.
- Azadirachtin (Azatrol)
  - Efficacy: not known. Seldom used.
  - Advantages/disadvantages: soft on beneficials, but expensive..
- Garlic juice (Envirepel, Nutripel)
  - Efficacy: not known. Seldom used.
- Pyrethrin (Diatect, Prozap, Pyrenone, Pyronyl)
  - Efficacy: poor. Seldom used.
  - Disadvantage: burns the fruit.
- Potassium salts of fatty acids (M-Pede)
  - Efficacy: poor. Seldom used.
  - Advantage: soft on the environment.

Other pest management aids:

- Bagging fruit bunch (Photo 7)
- Horticultural oils
- Soapy water

Pipeline pest management tools:

- Imidacloprid (Provado, Admire)
  - Efficacy: excellent. May be registered in 2004.
  - Disdvantage: very expensive.
- Spinosad (Success)
  - Efficacy: good to excellent. May be registered in 2004.
- Dinotefuran
  - Efficacy: research is needed but known to be very effective against related species.
- Flonicamid
  - Efficacy: research is needed but known to be very effective against related species.
- Bifenthrin impregnated bags
  - Efficacy: research is needed. Import tolerance is established. Used outside U.S.
- Insect pathogens

"To do" list for thrips:
Research needs:

- Investigate thiamethoxam (Actara, Platinum) for thrips control.
- Alternative control measures.
- Study pest thrips biology.
- Investigate insecticide impregnated bags.
- Establish economic thresholds.

Regulatory needs:

- Register bifenthrin impregnated bags.
- Use of an approved disinfesting dip for California export.
- Remove Hawaii quarantine barriers for insect pathogens, beneficial insects (natural enemies), and beneficial fungal organisms.
- Change state of Hawaii laws to allow for expedited registration of "new chemistry" pesticides with low non-target impact and low mammalian toxicity especially for disease resistance management.

Education needs:

- Thrips identification and biology.
- Train growers in monitoring procedures.

6. **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 the fruit surface and reducing marketability. Long-legged ants are found on all islands and prefer wet, high rainfall areas. During the "warm" months of June through October the ant colonies increase in size and can be quite extensive. A single colony in Waimanalo on the island of Oahu has been reported to span underground over 2 miles. Long-legged ants are sugar lovers and are not controlled by the hydramethylnon products (Amdro) which are formulated with a protein bait attractive to other ant species. Control of this pest is critical during fruit production.

Insecticides currently registered:
None.

Other pest management aids:

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

Pipeline pest management tools:
None.

"To do" list for long-headed ant:
Research needs:

- How fruit is scarred by long-legged ant.
- Investigate efficacy of hydramethylon.
- Investigate interactions with other ant species.
- Test baits (carbohydrates vs. proteins)

Regulatory needs:

- Register Maxforce ant baits.
- Develop quarantine protocol for shipment to California.

Education needs:

- Identification, biology, and ecology.

7. **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., BBTV). Big headed ant is also implicated in movement of other honeydew producing insects such as scales and whiteflies and indirectly contributes to quarantine problems for export fruit. Big headed ant is located on all islands and all growing regions but is especially intense in abandoned pineapple fields. Numbers of big headed ants increase during the "dry" season from May through October.

Insecticides currently registered:

- Hydramethylnon (Amdro Pro Fire Ant Bait, Seige Pro Fire Ant Bait)
  - Efficacy: excellent.
  - Advantages/disadvantages: restricted to baiting stations, costly, effective only on certain ant species.

Other pest management aids:
None.

Pipeline pest management tools:
None.

"To do" list for big headed ant:
Research needs:

- Study interaction of bait, ants, scale insects, mealybugs, and aphids.
- Study efficacy of other control measures.
- Develop sampling and monitoring methods for effective control with baits.
- Study interaction between ant species (what happens if one is removed).

Regulatory needs:

- Address quarantine concerns for export.

Education needs:

- Identification, biology, and ecology.

8. **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 prior to bagging appears to greatly reduce larval damage (Photo 8) by removing the preferred oviposition site. The presence of banana moth on harvested fruit will cause rejection for export bananas.

Insecticides currently registered:

- *Bacillus thuringensis* (M/C Bioinsecticide, Lepinox, Javelin, Xentari, Dipel, Prolong)
  - Efficacy: fair. No need to spray if blossoms are removed.

Other pest management aids:

- Polyethylene bags.
- Removal of senescing flowers before bagging bunch.
- Clean up debris on ground if pressure is heavy.

Pipeline pest management tools:
None.

"To do" list for banana moth:
Research needs:
None.

Regulatory needs:
None.

Education needs:

- Field sanitation procedures.
- Identification, biology, and host range.

9. **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 generally a principal threat to banana production in Hawaii but its presence on fruit can be a cause for rejection of export bananas. Spiraling whiteflies are found in all growing regions in Hawaii. Windy conditions spread this pest which can increase in intensity if natural enemy numbers are low. Although mostly a leaf pest it will move to fruit if population pressure is high. If insecticide spray is needed the critical application time is during fruiting.

Insecticides currently registered:

- Buprofezin (Applaud)
  - Efficacy: new registration, limited experience by growers so effectiveness is not known.

Other pest management aids:

- Various natural enemies (predators and parasites)
- Horticultural oils.

Pipeline pest management tools:

- Imidacloprid (Provado, Admire)
- Dinotefuran
- Flonicamid

"To do" list for spiraling whitefly:
Research needs:

- Impact of insecticides on natural enemies.
- Investigate more natural enemies.

Regulatory needs:

- Address California quarantine concerns.

Education needs:

- Identify alternate hosts for spiraling whitefly.
- How to conserve natural enemies.

10. **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. "Cool" temperatures from December

through February can cause significant natural enemy mortality leading to an increase in banana fruit piercing moth. Present on all islands, the banana fruit piercing moth pressure can be intensified if wili-wili (an alternate host for the moth) is used as a windbreak.

Insecticides currently registered:
None.

Other pest management aids:
- Natural enemies
- Naturally occurring polyhedrosis virus
- Remove alternate larval hosts (fruit trees, e.g. guava, wili-wili windbreaks).

Pipeline pest management tools:
None.

"To do" list for banana fruit piercing moth:
Research needs:
- Determine alternate host range.
- Determine type of naturally occurring polyhedrosis virus.

Regulatory needs:
None.

Education needs:
- Identify alternate host.
- How to conserve natural enemies.

11. **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. Damage to leaves intensifies during the dry months from May through November. Incidental Chinese rose beetle found in the bunch will trigger quarantine rejection of export bananas. This can be avoided by daytime harvest of fruit.

Insecticides currently registered:
None.

Other pest management aids:
- Chinese rose beetles are probably killed when insecticides are applied for control of other pests.
- Some natural enemies but effectiveness is very low.
- Daytime harvest of fruit to avoid quarantine restrictions for export.

Pipeline pest management tools:
None.

"To do" list for Chinese rose beetle:
Research needs:
None.

Regulatory needs:
- Quarantine protocol for disinfestation.

Education needs:
- Identification and biology.

12. **Mites (Various species)**

Although frequently found on foliage and fruit, mites are usually minor pests of banana in Hawaii. However, potential damage from these pests can be significant. The piercing and sucking mouthparts of mites damage plant tissue and fruit. Recently, there has been an increase in damage caused by mites. There is only one miticide which is recently registered in the State of Hawaii for mite control on bananas. Mite pests are found on all islands and growing regions and pressure increases during dry periods. If pressure is high then control is especially critical before flowering to avoid damage to fruit.

Insecticides/miticides currently registered:
- Sulfur (Micro Sulf)
  - Efficacy: fair.
  - Advantages/disadvantages: organic, inexpensive, but allergic reaction to sensitive individuals, can burn fruit, and has strong smell.

Other pest management aids:
- Natural enemies
- Preferable alternate hosts (e.g. papaya)
- Adversely affected by rainfall, overhead irrigation.

Pipeline pest management tools:
None.

"To do" list for mite pests:
Research needs:
- Survey of mite pest species.
- Search for predator mites, other mite pest natural enemies.

Regulatory needs:
- Quarantine protocol for disinfestation.

Education needs:

- Identification, biology, ecology, damage.

13. **Banana skipper (*Erionota 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. Because of the effectiveness of biological control of the banana skipper, use of chemical treatments is uncommon. Banana skipper is found throughout all growing regions in Hawaii. Control may be lost if chemical insecticide sprays kill the natural enemies. Localized outbreaks may occur if natural enemy numbers are low during the predator-prey interaction cycle.

Insecticides/miticides currently registered:

- *Bacillus thuringensis* (M/C Bioinsecticide, Lepinox, Javelin, Xentari, Dipel, Prolong)
  - Efficacy: good.
  - Advantages/disadvantages: soft on natural enemies, can be used in conjunction with monitoring (IPM) programs, but short residual activity.

Other pest management aids:

- Biological control by parasites (*Ooencyrtus erionotae*, *Apanteles erionotae*)
- Mechanical control

Pipeline pest management tools:
None.

"To do" list for banana skipper:
Research needs:
None.

Regulatory needs:
None.

Education needs:

- Identification for home gardeners.

NEMATODES

1. **Rootknot (*Meloidogyne* spp.)**
2. **Burrowing (*Radopholus similis*)**
3. **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. 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. Rootknot and burrowing nematodes are the most devastating of the 3 major pest species. Because nematodes live in the soil it is difficult to determine infestation levels until severe damage symptoms are observed. Conditions are favorable for year round development of nematodes. The Brazilian ('apple') group of bananas is generally more tolerant than Cavendish to nematodes. When monitoring methods are employed, economic thresholds for control are low, triggering control measures when 1 to 2 nematodes per plant root are discovered. In nematode infested fields, control is required from pre-plant throughout the cropping cycle.

Nematicides currently registered:

- Dicloropropene (Telone)
  - Efficacy: excellent.
  - Limiting factors: pre-plant fumigant only (need special equipment).
  - Advantages/disadvantages: reasonable cost, but a potential groundwater contaminant, a restricted use pesticide, tricky to apply, and a B2 carcinogen.
- Ethoprop (Mocap)
  - Efficacy: excellent.
  - Advantages/disadvantages: reasonable cost, can be used in established plantings, but an organophosphate pesticide and hard to work with.
- Fenamiphos (Nemacur)
  - Efficacy: excellent.
  - Limiting factors: registration to expire in 2005.
  - Advantages/disadvantages: reasonable cost, but environmentally harsh and hazardous to applicator.
- *Myrothecium verrucaria* (DiTera**)**
  - Efficacy: reported as effective but new product, not fully implemented.
  - Advantages/disadvantages: environmentally friendly, may be registered for organic use, but high level of management required for proper application.

Other pest management aids:

- Fallow and cover crops
- Composting crop residue
- Hot water treatment
- Inoculation of soil with beneficial nematodes
- Propping plants with wires
- Improve drainage.
- Rotation to non-host crops
- Tissue culture plants

Pipeline pest management tools:

- Iodomethane (methyl iodide)

"To do" list for nematodes:
Research needs:

- Investigate cover crops (varieties, duration)
- Prescription for nematode reducing compost production
- Determine beneficial/predator nematode species found in Hawaii
- Resistance management strategies

Regulatory needs:

- Address regulatory hurdles to importation of beneficial/predator nematodes.
- Restrict movement of pest nematodes between islands.

Education needs:

- Training on how to rear and conserve on-farm beneficial/predator nematodes.

PATHOGENS AND DISEASES

1. **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). The most conspicuous symptom of the disease is the "stacked up" bunched or rosette appearance of the upper leaves (Photo 5). Other common symptoms of BBTV include 'Morse code' streaking on leaves (dot and dash patterns on the lower midrib and leaf blade), distorted fruit, erect and narrow leaves, marginal chlorosis and necrosis. The banana aphid, *Pentalonia nigronervosa,* is the sole insect vector of this disease (humans can also mechanically vector the disease). 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 infected bananas. The presence of a single infected plant, at any growth stage, in a field triggers control measures. The roguing, or removal, of BBTV infected bananas is combined with banana aphid control and glyphosate spray of infected banana plants. Aphids feeding on BBTV banana plants must be killed before spraying with glyphosate otherwise they will move to adjacent, uninfected, bananas as their host slowly dies and further spread the disease. In extreme situations quarantines have been imposed throughout the islands to limit the movement of banana planting material. Currently the islands of Molokai and Lanai are free of BBTV as well as the Hana growing region on Maui and the Puna, Hilo, and Hamakua regions on the island of Hawaii.

Pesticides currently registered:

- Glyphosate (Roundup)
  - Efficacy: excellent.
  - Advantages/disadvantages: reasonable cost, safe for applicator, but a concern was expressed that glyphosate can kill beneficial soil organisms.
- Harpin protein (Messenger)
  - Efficacy: unknown.
  - Advantages/disadvantages: safe to use, but may not work.

Other pest management aids:

- Avoidance
- Elimination
- Quarantine
- Aphid management
- Weed control (weed and crop aphid hosts)
- Ant control (keep them from moving aphids around)
- Increase plant vigor.
- Plant spacing
- Banana variety
- Tissue culture for clean planting material

Pipeline pest management tools:

- Genetic engineering for disease resistance and agronomic performance

"To do" list for banana bunchy top virus:
Research needs:

- More insecticide screening trials for aphid control
- Develop on-farm testing kits ("ELISA – like")
- Determine effectiveness of harpin protein

Regulatory needs:

- Register more pesticides.
- Change state of Hawaii laws to allow for registration of "new chemistry" pesticides.
- Strengthen laws to allow eradication enforcement.

Education needs:

- Identification materials for general public/home gardeners.

2. **Crown rot complex (*Botryodiplodia theobromae, Cephalosporium* sp., *Ceratocystis paradoxa, 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%).

Fungicides currently registered:

- Thiabendazole (Decco Salt No. 19)
  - Efficacy: good
  - Advantages/disadvantages: an older fungicide, but Japan will not accept fruit with TBZ residues.
- Azoxystrobin (Abound)
  - Efficacy: unknown. Recently registered.
  - Advantages/disadvantages: reduced risk fungicide, but efficacy unknown.

Other pest management aids:

- Harvest fruit at the correct stage of maturity
- Careful handling in transit to reduce bruising
- Careful storage and temperature control in transit
- Removal of last banana hand and distal flower bud after all hands have opened
- Increase row spacing (to improve air movement in field)
- Destroy infected plant material by burning

Pipeline pest management tools:
None.

"To do" list for crown rot:
Research needs:

- Investigate additional fungicide alternatives for control of crown rot.

Regulatory needs:

- None.

Education needs:

- Identification and management guidelines

3. **Black leaf streak (*Mycosphaerella fijiensis*)**

This fungal disease is very destructive and controlling this disease is one of the most costly production costs faced by banana growers in high-rainfall areas. The disease is found on all islands and all growing regions, but warm, wet and humid conditions favor its development. 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. High pressure from black leaf streak will cause defoliation. The use of preventative control strategies and cultural practices are essential components to the IPM for this disease in Hawaii. Control measures are selected which allow or ensure that at least 10 green leaves are on a banana plant at flowering.

Fungicides currently registered:

- Fenbuconazole (Enable)
  - Efficacy: excellent.
  - Advantages/disadvantages: easy to use, long residual, but cannot be used repeatedly.
- Mancozeb (Dithane, Manzate, Pentathlon, Manex II, Mancozeb, Penncozeb, Mankocide)
  - Efficacy: excellent.
  - Advantages/disadvantages: inexpensive, used for resistance management, but bad smell, good coverage critical, potential human health concerns.
- Maneb (Maneb, Manex, Pentathlon)
  - Efficacy: excellent.
  - Advantages/disadvantages: inexpensive, used for resistance management, easier to use than Mancozeb, but bad smell, good coverage critical, and potential human health concerns.
- Tebuconazole (Elite)
  - Efficacy: excellent.
  - Advantages/disadvantages: easy to use, long residual activity, but cannot be used repeatedly.
- Copper hydroxide (Kocide, Champion, Champ, Bac-Stop, Nu-Cop)
  - Efficacy: poor.
  - Advantages/disadvantages: inexpensive, broad spectrum activity, but extreme eye hazard.
- Harpin protein (Messenger)
  - Efficacy: unknown.
  - Advantages/disadvantages: safe to use, but may not work.

Other pest management aids:

- Horticulture oils
- Site selection and preparation
- Canopy management
- Removal of plant debris
- Moisture management
- Weed control

Pipeline pest management tools:

- Genetic engineering for resistance
- Traditional breeding resistance

"To do" list for black leaf streak:
Research needs:

- Additional control measures, specifically fungicides
- Host plant resistance

Regulatory needs:

- None

Education needs:

- IPM training for growers to manage resistance

4. **Freckle (*Phyllostica 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. Widespread throughout the island growing regions the disease is easily managed when spraying fungicides for black leaf streak. If the disease is present control measures need to be taken before flowering.

Fungicides currently registered:

- Azoxystrobin (Abound)
  - Efficacy: good.
  - Advantages/disadvantages: alternate chemistry for IPM program, slightly systemic, but expensive.
- Fenbuconazole (Enable)
  - Efficacy: excellent. The most effective fungicide.
  - Limiting factors: subject to development of resistance.
  - Advantages/disadvantages: easy to use, long residual, but cannot be used repeatedly.
- Mancozeb (Dithane, Manzate, Pentathlon, Manex II, Mancozeb, Penncozeb, Mankocide)
  - Efficacy: fair.
  - Limiting factors: have to spray often.
  - Advantages/disadvantages: inexpensive, used for resistance management, but bad smell, good coverage critical, and potential human health concerns.
- Maneb (Maneb, Manex, Pentathlon)
  - Efficacy: fair.
  - Limiting factors: have to spray often.
  - Advantages/disadvantages: inexpensive, used for resistance management, easier to use than Mancozeb, but bad smell, good coverage critical, and potential human health concerns.
- Tebuconazole (Elite)
  - Efficacy: good.
  - Limiting factors: subject to development of resistance.

- Advantages/disadvantages: easy to use, long residual activity, but cannot be used repeatedly.

- Copper hydroxide (Kocide, Champion, Champ, Bac-Stop, Nu-Cop)
  - Efficacy: poor.
  - Advantages/disadvantages: inexpensive, broad spectrum activity, but extreme eye hazard.
- Harpin protein (Messenger)
  - Efficacy: unknown.
  - Advantages/disadvantages: safe to use, but may not work.

Other pest management aids:

- Horticulture oils
- Site selection and preparation
- Canopy management
- Removal of plant debris
- Moisture management
- Weed control
- Bagging of fruit

Pipeline pest management tools:
None.

"To do" list for freckle:
Research needs:

- Investigate additional fungicide alternatives

Regulatory needs:
None.

Education needs:

- Identification guidelines

5. **Banana Mosaic Virus**

Banana mosaic virus (BMV), also known as cucumber mosaic virus (CMV), affects banana production around the world. It is found on all islands and growing areas in Hawaii. There are numerous alternate hosts for the disease (on weeds and cultivated plants) so sanitation in and around banana fields is critical for control. 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. BMV infected banana plants must be immediately removed from field. Transmission is by incidental feeding of aphids.

Pesticides currently registered:

- Glyphosate (Roundup)
  - Efficacy: excellent.

- Advantages/disadvantages: reasonable cost, safe for applicator, but a concern was expressed that glyphosate may kill beneficial soil microorganisms.

- Harpin protein (Messenger)
  - Efficacy: unknown.
  - Advantages/disadvantages: safe to use, but may not work.

Other pest management aids:

- Disease free planting material
- Eradication
- Alternate host control
- Aphid control
- Ant control (they move aphids around)
- Growing resistant alternative hosts (e.g. cucumbers with resistance to cucumber mosaic virus)

Pipeline pest management tools:
None.

"To do" list for banana mosaic virus:
Research needs:

- Host plant resistance
- Early detection and monitoring methods

Regulatory needs:
None.

Education needs:

- Identification guide

6. **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 can 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. Disease prevention using IPM techniques should include the selection of resistant cultivars, field sanitation and moisture monitoring practices. Early roguing of symptomatic plants can slow the spread of Panama wilt. Molokai is reported to be free of the disease.

Fungicides currently registered:
None.

Other pest management aids:

- Avoidance (of fields known to have history of Panama wilt)
- Plant disease resistant varieties
- Roguing of diseased plants
- On-farm water management (do not over water, do not drain water from infected to clean field)
- Fumigation
- Debris and crop residue management (field sanitation)
- Control movement of soil from infected field (shoes, equipment)

Pipeline pest management tools:
None.

"To do" list for Panama wilt:
Research needs:

- Resistant varieties
- Systemic fungicides
- Genetic engineering

Regulatory needs:

- Keep race 4 out of Hawaii

Education needs:

- Public education efforts to emphasize hazards associated with moving planting material around, including importation from outside state
- Media video for Hawaii Visitors Bureau/tourism industry

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. 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. The distinction between annual and perennial weeds in Hawaii is not clear cut. For the purposes of this analysis, efficacy ratings are for the general categories of grasses, broadleaves, and sedges (mostly purple nutsedge). Grassy weeds need to be controlled when more than 10 – 20% of ground area is covered or when weeds are more than 6 inches tall. Weed control is especially critical during the establishment period up to 20 months from planting.

Pre-plant herbicides registered (Herbicides used for field preparation prior to planting):

- Glyphosate (Roundup)

- Efficacy: excellent on grasses, good to excellent on sedges, good on broadleaves.
- Limiting factors: some reports of resistance (not yet in Hawaii).
- Advantages/disadvantages: inexpensive, but need to careful of drift, slow rate of kill, and requires minimum of 6 hours of drying time for optimum effectiveness.

- Paraquat dichloride (Gramoxone)
  - Efficacy: good on grasses and broadleaves, fair to good on sedges.
  - Advantages/disadvantages: rapid burndown, inexpensive, good in high rainfall areas, increased effectiveness in low light areas, but hazardous to applicator, no antidote, and a restricted use pesticide.

Pre- and post-emergence herbicides registered (Used prior to or after weeds emerge in new and established plantings):

- Ametryn (Evik)
  - Efficacy: fair to good on grasses and broadleaves, poor on sedges.
  - Limiting factors: potential development of resistance.
  - Advantages/disadvantages: inexpensive, long residual activity, but a potential groundwater contaminant, and long residual activity (potentially too long).
- Diuron (Karmex)
  - Efficacy: good on grasses and broadleaves, poor on sedges.
  - Advantages/disadvantages: inexpensive, persistent, but a potential groundwater contaminant.

Pre- and post-emergence herbicides registered (Used in established plantings only):

- Oxyflurofen (Goal 2XL)
  - Efficacy: good to excellent for grasses and broadleaves, poor on sedges.
  - Advantages/disadvantages: good control of guinea grass seedlings, reasonable cost, but the 2XL formulation can be phytotoxic to the young crop. New formulation may reduce potential phytotoxicity.

Post-emergence herbicides registered (Used to control weeds after they've sprouted):

- Ametryn (Evik)
  - Efficacy: poor on grasses and broadleaves, not used for sedge control.
  - Advantages/disadvantages: inexpensive, but a potential groundwater contaminant, and long residual activity (potentially too long).
- Diuron (Karmex)
  - Efficacy: fair to good on grasses, fair on broadleaves, not used on sedges.
  - Advantages/disadvantages: inexpensive, persistent, but a potential groundwater contaminant.
- Glyphosate (Roundup)
  - Efficacy: good to excellent on grasses and broadleaves, good on sedges.
  - Limiting factors: some reports of resistance (not yet in Hawaii).
  - Advantages/disadvantages: inexpensive, but need to be careful of drift, slow rate of kill, requires minimum of 6 hours of drying time for optimum effectiveness, and will not kill hono hono grass.

- Oxyflurofen (Goal 2XL)
  - Efficacy: good on grasses and broadleaves, poor on sedges.
  - Advantages/disadvantages: good control of guinea grass seedlings, reasonable cost, but 2XL formulation can be phytotoxic to the young crop.
- Paraquat dichloride (Gramoxone)
  - Efficacy: good to excellent on grasses and broadleaves, fair to good on sedges.
  - Advantages/disadvantages: effective on hono hono grass, rapid burndown, inexpensive, good in high rainfall areas, increased effectiveness in low light areas, but hazardous to applicator, no antidote, and a restricted use pesticide.
- Pelargonic acid (Scythe)
  - Efficacy: fair on broadleaves, poor to fair on grasses and sedges.
  - Advantages/disadvantages: rapid burndown, good on small broadleaves, but weak on grasses, have to use high rates, and has an objectionable smell.

Other pest management aids:

- Crop residue as mulch
- Fallow and cover crops
- Plant spacing and density (shade limits weed growth in established plantings)
- Mowing and mechanical control
- Sanitation of equipment, boots, tools to limit movement of seeds and plant parts
- Fire (for burn down)

Pipeline pest management tools:

- Nutsedge rust as biocontrol.

"To do" list for weeds:

Research needs:

- Efficacy of Goal 4F
- Investigate selective grass herbicides (Poast, Fusilade)
- Organic acids for organic farming use
- New cover crops and green mulches
- Selective broadleaf herbicides
- Herbicide screening for nutsedge control (Image, Manage)

Regulatory needs:

- Secure Goal 4F labeling
- Secure Fusilade, Poast labeling

Education needs:

- Importance of sanitation for weed control
- Education on herbicide mode of action to improve efficacy
- Nutsedge control and eradication timing for maximum effectiveness.

LIST OF PHOTOS

All photos by: J. J. McHugh, Jr.

Photo 1. Banana “keiki” growing from base of “mother” plant.

Photo 2. New banana planting.

Photo 3. Banana inflorescence with blossom end protruding from developing “fingers”.

Photo 4. Banana bunch nearing harvest. Bunch is composed of "hands'. Hands are composed of "fingers" or individual bananas.

Photo 5. Banana Bunchy Top Virus disease of newly emerged “keiki”.

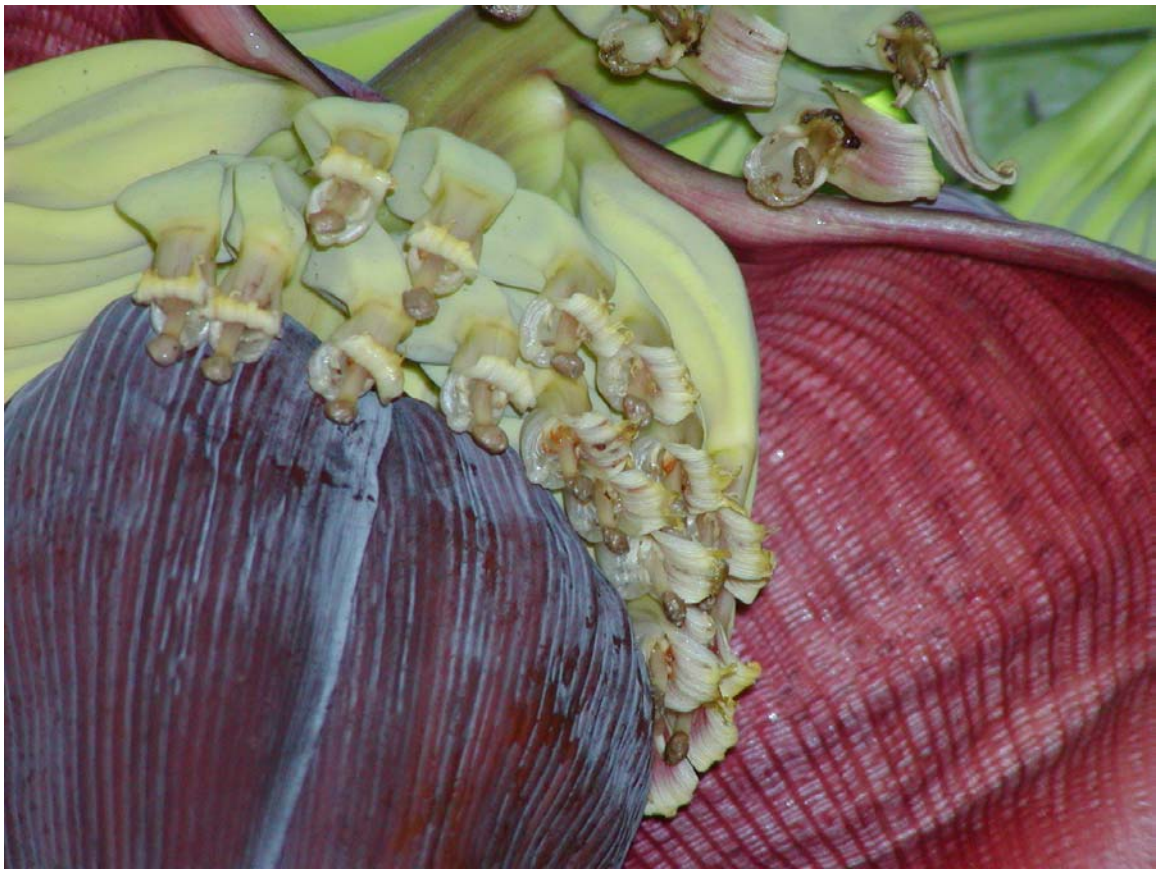

Photo 6. Developing banana bunch with open flower blossoms.

Photo 7. Bagging of banana bunch for control of fruit pests.

Photo 8. Banana bunch with senescing flower blossoms attached to end of fingers.

GLOSSARY OF TERMS

BUNCH	The entire inflorescence which consists of many "hands," each composed of numerous "fingers".
CORM	The basal, underground portion of the pseudostem of the banana plant. Botanically classified as a rhizome. Can be used for planting material.
FINGER	A single banana fruit.
HAND	Banana fingers growing together and forming a distinct portion of the bunch.
INFLORESCENCE	A flower head or entire bunch on a single banana plant.
KEIKI	Sword sucker of the parent or mother plant.
PSEUDOSTEM	The "trunk" of the banana plant.
SUCKER	A young offshoot of the parent or mother plant.
SWORD SUCKER	A narrow leafed sucker of the parent or mother plant. This is the desirable sucker for planting material. Not all suckers are sword suckers.

Table 1. Registered Pesticides for Banana in Hawaii

Active Ingredient	Trade name	Company
	INSECTICIDES	
azadirachtin	Azatrol	PBI/Gordon Corporation
Bacillus thuringensis	M-C Bioinsecticide	Mycogen Corporation
	Lepinox	Ecogen Inc.
	Javelin	Certis, USA, LLC
	Xentari	Valent Agricultural Products
	Dipel	Valent Agricultural Products
buprofezin	Applaud	Nichino America, Inc.
carbofuran	Furadan 5%	FMC Corporation
diazinon	Diazinon	Platte Chemical Company/Prentiss Incorporated
garlic juice	Envirepel	Cal Crop USA
	Nutripel	Cal Crop USA
hydramethylnon	Amdro Pro Fire Ant Bait	BASF Corporation
	Seige Pro Fire Ant Bait	BASF Corporation
metaldehyde	Deadline	Pace International LLC
petroleum oil	Volck Supreme	Valent Agricultural Products
	Clean Crop Superior	UAP Platte Chemical Company
potassium salts of fatty acids	M-pede	Dow AgroSciences, LLC
pyrethrin	Diatect	Diatect International, Inc.
	Pyrenone	AgroEco Environmental Health, Inc.
	Pyronyl	Prentiss Inc.
sulfur	Micro Sulf	Nufarm Americas Incorporated

	NEMATICIDES	
dichloropropene/chloropicrin	Telone	Trical
fenamiphos	Nemacur	Bayer
ethoprop	Mocap	Bayer Crop Science
Myrothecium verrucaria	DiTera	Valent Agricultural Products
	FUNGICIDES	
azoxystrobin	Abound	Syngenta Crop Protection, Inc.
	Quadris	Syngenta Crop Protection, Inc.
copper hydroxide	Kocide	Griffin, LLC
fenbuconazole	Enable	Dow AgroSciences, LLC
fosetyl-Al	Aliette	Bayer Crop Science
harpin protein	Messenger	EDEN Bioscience Corporation
mancozeb	Dithane	Dow AgroSciences, LLC
maneb	Manex	Griffin, LLC
potassium bicarbonate	Kaligreen	Nichimen America Inc.
tebuconazole	Elite	Bayer Crop Science
thiabedazole	Mertect	Syngenta Crop Protection, Inc.
	HERBICIDES	
ametryn	Evik	Syngenta Crop Protection, Inc.
diuron	Diuron	UAP- Platte Chemical Company
glyphosate	Roundup	Monsanto Company
oxyflurofen	Goal	Dow AgroSciences, LLC
paraquat dichloride	Gramoxone	Syngenta Crop Protection, Inc.
pelargonic acid	Scythe	Dow AgroSciences, LLC

Table 2. Unregistered Pesticides Tested on Banana in Hawaii

Insecticides	Insects Tested		
	Banana aphid	Banana rust thrips	Hawaiian flower thrips
imidacloprid	E	E	G
spinosad		E	F
Fungicides	**Diseases Tested**		
Herbicides	**Weeds Tested**		

Efficacy rating symbols: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data but successful on related organisms, - = not applicable and/or used

Table 3. Description of Pests and Pathogens of Banana

Pest/Pathogen	Symptoms
INSECT PESTS	
Anthurium thrips *(Chaetanaphothrips orchidii)* Banana rust thrips *(Chaetanaphothrips signipennis*)	The nature of the damage caused by Anthurium thrips/Banana rust thrips 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.
Banana aphid *(Pentalonia nigronervosa)*	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 part of the plant. Feeding can cause plants to become deformed; the leaves become curled and shriveled, and in some cases galls are formed on the leaves. Young plants may be killed or growth slowed if there is sufficient feeding by this aphid. However, direct damage is generally negligible. The most serious effect of feeding is the transmission of banana bunchy top virus.
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.
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 (the preferred oviposition site) and application of insecticides to banana bunches prior to bagging appears to greatly reduce larval damage. The presence of Banana moth on harvested fruit will cause rejection for export bananas.
Banana rind thrips (*Elixothrips brevisetis*)	Thrips feed on leaves, flowers, or stems with the injured tissue taking on a silvery appearance which eventually turns dark brown. On leaves, their 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 flecked, spotted, and deformed and many buds fail to open. Rind thrips is a polyphagous foliage feeder. On many plant hosts, this thrips causes scaring, cracking and corky growth fruit skins.
Banana skipper *(Erionota thrax)*	Rolled leaves originating from the midrib of plants are a good indicator of banana skipper damage. Because of the effectiveness of biological control of the banana skipper, use of chemical treatments is uncommon. However, localized outbreaks may occur if natural enemy numbers are reduced by chemical insecticide sprays.
Banana weevil *(Cosmopolites sordidus)*	A continuous problem for commercial and home growers. The larvae of this pest bore through the corm, suckers and roots of living and decaying planting material. Large numbers of larvae and extensive feeding can result in root destruction, slowed plant growth, reduced fruit production, and, sometimes, toppled plants. Young banana plants are the most at risk because tunneling by the weevil can kill the plants at this stage.
Big headed ant (*Pheidole megacephala*)	The problem posed by ants is their intimate relationship with the banana aphids. Ant 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., BBTV). The big headed ant is also implicated in movement of other honeydew producing insects such as scales and whiteflies and indirectly contributes to quarantine problems for export fruit.

Chinese rose beetle (*Adoretus sinicus)*	The Chinese rose beetle is a common, minor 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.
Coconut scale (*Aspidiotus destructor*)	The coconut scale is an armored scale and is usually found on the under side 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. The presence of 1 live coconut scale (juvenile or adult) can cause rejection of bananas shipped to California. Their piercing and sucking mouthparts extract plant juices, leading to discoloration and yellowing of plant tissue.
Banded greenhouse thrips *(Hercinothrips femoralis)*	Causes "silver and bronze scars" which may result in damage of economic importance. 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 affected.
Hawaiian flower thrips *(Thrips hawaiiensis)*	Feeds only on flowers. Depending on the extent of feeding, flowers become flecked, spotted, or deformed. Unlike other flower thrips, this species prefers wet and shady areas.
Long-legged ant (*Anoplolepis longipes*)	The long-legged ant has been recently reported as a pest on bananas. In addition to moving aphids around within a planting (thus contributing to the spread of BBTV) the long-legged ant feeds on the surface of the banana fruit causing scarring of the fruit surface and reducing marketability.
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. The spiraling whitefly is not considered a principal threat to banana production in Hawaii but its presence on fruit

	can be a cause for rejection of export bananas.
Sugarcane budmoth caterpillar *(Decadarchis flavistriata)*	This caterpillar feeds on decaying flowers and causes fruit scarring because it feeds on the skin of the fruit. 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.

NEMATODE PESTS

Burrowing (*Radopholus similis*) Reniform *(Rotylenchulus reniformis)* Rootknot *(Meloidogyne* spp.*)*	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. 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. Rootknot and burrowing nematodes are the most devastating of the 3 major pest species. Because nematodes live in the soil it is difficult to determine infestation levels until severe damage symptoms are observed.

OTHER INVERTEBRATE PESTS

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

PATHOGENS	
Banana Bunchy Top Virus (BBTV)	The banana bunchy top virus (BBTV) is a very serious problem for banana growers statewide. The most conspicuous symptom of the disease is the "stacked up" bunched/rosette appearance of the upper leaves. 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. 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.
Black Leaf Streak *(Mycosphaerella fijiensis*)	This disease is found on all islands and all growing regions but warm, wet and humid conditions favor its development. The fungal pathogen penetrates the leaf tissue and creates necrotic lesions, also known as streaks. This streaking effect gives the disease its name. High pressure from black leaf streak will cause defoliation of plantings.
Banana Mosaic Virus (BMV) a.k.a. Cucumber Mosaic	Banana mosaic virus (BMV), also known as cucumber mosaic virus (CMV), affects banana production around the world. It is found on all islands and growing areas in Hawaii. There are numerous alternate hosts for the virus (on weeds and cultivated plants) so sanitation in and around banana fields is critical for control. Common symptoms of BMV are chlorosis of leaves, mosaic symptoms, and heart rot.
Crown Rot Complex (*Botryodiplodia theobromae*, *Cephalosporium* sp., *Ceratocystis paradoxa, Colletotrichum musae, Fusarium roseum, Verticillium theobromae*)	Caused by several fungi. Enters wounded areas on the cut banana hand. Decay can occur rapidly and starts at the stalk end of the finger. Fruit skins exhibit an uneven dark discoloration and infection of the fruit causes brown soft rot. This is an extremely serious post harvest problem in commercial banana production.
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. Widespread throughout the island growing regions, the disease is

	easily managed when spraying fungicides for black leaf streak. If the disease is present, control measures need to be taken before flowering.
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 can 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.

Table 4. Advantages and Disadvantages of Pesticides for Banana

Active Ingredient	Disease/Pest	Advantages/Disadvantages
INSECTICIDES		
azadirachtin	Banana fruit piercing moth Banana moth	● expensive ● soft on beneficials
Bacillus thuringensis	Banana fruit piercing moth Banana moth Banana skipper Sugarcane bud moth	● soft on beneficials ● can be used in conjunction with monitoring IPM) programs ● target specific ● short residual activity
buprofezin	Coconut scale	● target specific ● soft on beneficials ● timing of application critical to control of Coconut Scale crawlers
carbofuran	Banana weevil	● long residual activity ● ground water contaminant
diazinon	Banana aphid Anthurium thrips Banana rust thrips Banana rind thrips Banded greenhouse thrips Hawaiian flower thrips	● cost is reasonable ● moderate residual activity ● hazard to applicator ● phytotoxic to banana fruit if rate is too high ● strong smell
hydramethylnon	Big headed ant Long-legged ant	● restricted to baiting stations ● effective only on certain species of ants ● costly

petroleum oil	Banana aphid Coconut scale Spiraling whitefly Banana rust thrips Banana rind thrips Banded greenhouse thrips Hawaiian flower thrips Mites	● soft on beneficials ● can be phytotoxic ● low effectiveness
potassium salts of fatty acids	Banana aphid Spiraling whitefly Banana rust thrips Banana rind thrips Banded greenhouse thrips Hawaiian flower thrips Mites	● soft on the environment ● low effectiveness on thrips
pyrethrin	Banana fruit piercing moth Banana moth Banana weevil Banana skipper Sugarcane bud moth Anthurium thrips Banana rust thrips Banana rind thrips Banded greenhouse thrips Hawaiian flower thrips	● can be used in organic farming ● low effectivenss ● burns the fruit ● photo unstable ● very short residual activity ● expensive
sulfur	Mites	● organic ● cheap ● allergic reaction to sensitive individuals ● can burn fruit ● strong smell

FUNGICIDES		
azoxystrobin	Black leaf streak	● alternate chemistry for IPM program ● slightly systemic ● expensive ● cannot be used repeatedly
copper hydroxide	Black leaf streak Freckle	● cheap ● broad spectrum ● little to no effectiveness ● extreme eye hazard
fenbuconazole	Black leaf streak Freckle	● easy to use ● long residual ● cannot be used repeatedly
glyphosate	Banana bunchy top virus	● reasonable cost ● safe for applicator ● concern about detrimental effects on soil organisms
mancozeb	Black leaf streak Freckle	● cheap ● use for resistance management ● bad smell ● good coverage critical ● potential human health problems
maneb	Black leaf streak Freckle	● cheap ● use for resistance management ● easier to use than mancozeb ● good coverage critical ● potential human health problems
petroleum oil	Black leaf streak	● soft on beneficials ● can be phytotoxic ● low effectiveness

potassium bicarbonate	Freckle	● soft on beneficials ● high cost ● low effectiveness
tebuconazole	Black leaf streak Freckle	● highly effective ● easy to use ● long residual activity ● cannot be used repeatedly
NEMATICIDES		
carbofuran	Nematodes (burrowing, root-knot, reniform)	● long residual activity ● ground water contaminant
dichloropropene/chloropicrin	Nematodes (burrowing, root-knot, reniform)	● reasonable cost ● potential groundwater contaminant ● restricted use pesticide ● tricky to apply ● B2 carcinogen
ethoprop	Nematodes (burrowing, root-knot, reniform)	● reasonable cost ● can be used in established plantings ● organophosphate pesticide ● hard to work with
fenamiphos	Nematodes (burrowing, root-knot, reniform)	● reasonable cost ● environmentally harsh ● hazardous to applicator
HERBICIDES		
ametryn	Grasses Broadleaf weeds	● inexpensive ● potential groundwater contaminant ● long residual activity

diuron	Grasses Broadleaf weeds	● inexpensive ● persistent ● potential groundwater contaminant
glyphosate	Grasses Broadleaf weeds Sedges	● inexpensive ● drift concerns ● slow rate of kill ● requires minimum of 6 hours to dry for optimum effectiveness ● will not kill honohono grass
oxyfluorfen	Grasses Broadleaf weeds Sedges	● reasonable cost ● good control of guinea grass seedlings ● 2XL formulation can be phytotoxic to young crop
paraquat dichloride	Grasses Broadleaf weeds Sedges	● rapid burn down ● inexpensive ● good in high rainfall areas ● effective on honohono grass ● increased effectiveness in low light areas ● hazardous to applicator ● no antidote ● restricted use pesticide
pelargonic acid	Grasses Broadleaf weeds Sedges	● rapid burn down ● good on small broadleaves ● weak on grasses ● high use rates ● weird smell

Table 5. Efficacy of Pest Management Tools for Control of Insects & Other Invertebrate Pests on Banana in Hawaii

	Pest																
Management Tool:	**BA**	**BFPM**	**BM**	**BW**	**BS**	**BHA**	**CRB**	**CS**	**LLA**	**SW**	**SBM**	**AT**	**BRT**	**BRDT**	**BGT**	**HFT**	**Mites**
Registered Pesticides																	
azadirachtin (Azatrol)	*	P	P	-	*	-	-	*	-	*	*	*	*	*	*	*	-
Bacillus thuringensis (Lepinox, Javelin, Xentari, Dipel)	-	P	F	-	G	-	-	-	-	-	G	-	-	-	-	-	-
buprofezin (Applaud)	-	-	-	-	-	-	-	E	-	*	-	-	-	-	-	-	-
carbofuran (Furadan)	-	-	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-
diazinon (Diazinon)	F	-	-	-	-	-	-	-	-	-	-	F-G	F-G	F-G	F-G	P	*
garlic juice (Envirepel, Nutripel)	*	-	-	-	-	-	-	-	-	-	-	*	*	*	*	*	-
hydramethylnon (Amdro Pro Fire Ant Bait, Seige Pro Fire Ant Bait)	-	-	-	-	-	E	-	-	P	-	-	-	-	-	-	-	-
metaldehyde (Deadline)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
petroleum oil (Volck Supreme, Clean Crop Superior)	P	-	-	-	-	-	-	F	-	F	-	*	P	P	P	P	P
potassium salts of fatty acids (M-pede)	P	-	-	-	-	-	-	*	-	F	-	*	P	P	P	P	P
pyrethrin (Diatect, Pyrenone, Pyronyl)	-	P	P	P	P	-	-	-	-	-	P	P	P	P	P	P	-
sulfur (Micro Sulf)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	F
Pipeline Pest Management Tools																	
bifenthrin-impregnated bags	-	-	-	-	-	-	-	-	-	-	-	?	?	?	?	?	-
dinotefuran	+	-	-	-	-	-	-	+	-	+	-	+	+	+	+	+	-

flonicamid	+	-	-	-	-	-	-	+	-	+	-	+	+	+	+	+	-
imidacloprid (Admire, Provado)	E	-	-	+	-	-	-	+	-	E	-	+	+	+	+	+	-
spinosad (Success)	-	+	+	+	+	-	-	-	-	-	+	+	+	+	+	+	-
Cultural/Non-chemical Controls																	
hot water treatment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
field sanitation	P	?	G	F	*	-	-	-	-	-	-	-	-	-	-	-	-
polyethylene bags	-	-	P	-	-	-	-	-	-	-	P	*	P	*	*	P	-
baiting/trapping	-	-	*	?	-	-	-	-	-	-	-	-	-	-	-	-	-
anthocorid bugs	-	-	-	-	-	-	-	-	-	-	-	*	*	*	*	*	-
Ooencyrtus erionotae	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-
Apanteles erionotae	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-
other predators	P	?	?	?	?	-	-	?	-	?	?	?	?	?	?	?	?
other parasites	P	?	?	?	?	-	-	?	-	?	?	?	?	?	?	?	?

Insect abbreviations (listed alphabetically): AT = anthurium thrips, BA = banana aphid, BFPM = banana fruit piercing moth, BGT = banded greenhouse thrips, BHA = big-headed ant, BM = banana moth, BRT = banana rust thrips, BRDT = banana rind thrips, BS = banana skipper, BW = banana weevil, CRB = Chinese rose beetle, CS = coconut scale, HFT = hawaiian flower thrips, LLA = long-legged ant, SW = spiralling whitefly, SBM = sugarcane bud moth.

Efficacy rating scale: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data, more research needed, - = not applicable or not used, + = no data, but successful on other related organisms, * = not enough experience to rate.

Table 6. Efficacy of Pest Management Tools for Control of Disease & Nematode Pests on Banana in Hawaii.

	Pest							
Management Tool:	**BBTV**	**BLS**	**BMV**	**Freckle**	**PW**	**BN**	**RKN**	**RN**
Registered Materials								
azoxystrobin (Abound, Quadris)	-	G	-	-	-	-	-	-
carbofuran (Furadan 5%)	-	-	-	-	-	P	P	P
copper hydroxide (Kocide)	-	P	-	E	-	-	-	-
dichloropropene/chloropicrin (Telone)	-	-	-	-	-	E	E	E
ethoprop (Mocap)	-	-	-	-	-	E	E	E
fenamiphos (Nemacur)	-	-	-	-	-	E	E	E
fenbuconazole (Enable)	-	E	-	E	-	-	-	-
fosetyl-Al (Aliette)	-	*	-	*	-	-	-	-
glyphosate (Roundup)	E	*	-	-	-	-	-	-
harpin protein (Messenger)	*	*	*	*	*	*	*	*
mancozeb (Dithane)	-	F	-	E	-	-	-	-
maneb (Manex)	-	F	-	E	-	-	-	-
Myrothecium verrucaria (DiTera)	-	-	-	-	-	*	*	*
petroleum oil (Volck Supreme, Clean Crop Superior)	-	P	-	-	-	-	-	-
potassium bicarbonate (Kaligreen)	-	*	-	P	-	-	-	-

tebuconazole (Elite)	-	G	-	E	-	-	-	-
thiabedazole (Mertect)	-	*	-	*	-	-	-	-
Cultural/Non-chemical Controls								
cultivar selection	P	-	-	E	E	E	E	E
de-trashing	-	G	-	P	-	-	-	-
disease forecasting	-	-	-	-	-	-	-	-
disease-free planting material	E	-	E	-	E	E	E	E
fallow & cover crops	-	-	-	-	P	F	F	F
field sanitation	-	-	-	-	P	E	E	E
hot water treatment	-	-	-	-	-	E	E	E
moisture monitoring	-	-	-	-	-	-	-	-
plant spacing	-	G	-	F	-	-	-	-
removal of crop residue	-	-	-	-	-	-	-	-
roguing of infected plants	E	-	E	-	-	-	-	-
site selection & preparation	E	E	E	E	E	E	E	E
windbreaks	P	-	-	-	-	-	-	-

Disease/nematode abbreviations: BBTV = banana bunchy top virus, BLS = black leaf streak, BMV = banana mosaic virus, BN = burrowing nematode, PW = Panama wilt, RKN = root knot nematode, RN = reniform nematode

Rating Scale: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data/more research needed, - = not applicable or not used, * = not enough experience to rate

Table 7. Efficacy of Pest Management Tools for Control of Weed Pests in Banana in Hawaii

	Pest		
Management Tool:	**Grasses**	**Broadleaves**	**Sedges**
Registered Materials			
Pre-plant:			
glyphosate (Roundup)	**E**	**G**	**G-E**
paraquat dichloride (Gramoxone)	**G**	**G**	**F-G**
Pre-emergence:			
ametryn (Evik)	**F-G**	**F-G**	**-**
diuron (Diuron)	**G**	**G**	**-**
oxyfluorfen (Goal)	**G-E**	**G-E**	**P**
Post-emergence:			
ametryn (Evik)	**P**	**P**	**-**
diuron (Diuron)	**F-G**	**F**	**-**
glyphosate (Roundup)	**G-E**	**G-E**	**G**
oxyfluorfen (Goal)	**G**	**G**	**P**
paraquat dichloride (Gramoxone)	**G-E**	**G-E**	**F-G**
pelargonic acid (Scythe)	**P-F**	**F**	**P-F**
Pipeline Pest Management Tools			
Pre-emergence:			
oxyfluorfen (Goal 4FL)	**G-E**	**G-E**	**P**
Post-emergence:			
oxyfluorfen (Goal 4FL)	**P-F**	**P-F**	**P**
Cultural/Non-chemical Controls			
cover crop	**G**	**G**	**G-E**
crop residue	**G**	**G**	**G**
fallow (bareground with shallow cultivation)	**P-F, G (annuals)**	**P-F, G (annuals)**	**P**
plant spacing/density	**G**	**G**	**G-E**

Rating Scale: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), - = not applicable or not used

Table 8. Toxicity of Pest Management Tools to Beneficials of Banana in Hawaii

	Beneficials					
Management Tool:	**Anthocorid Bug**	***Ooencyrtus erionotae***	***Apanteles erionotae***	**Other predators**	**Other parasites**	**Beneficial nematodes**
Registered Materials						
Insecticides:						
azadiractin (Azatrol)	?	?	?	?	?	?
Bacillus thuringensis (M/C Bioinsecticide, Lepinox, Javelin, Xentari, Dipel)	?	?	?	?	?	?
buprofezin (Applaud)	*	*	*	*	*	*
carbofuran (Furadan 5%)	-	-	-	-	-	+
diazinon (Diazinon)	+	+	+	+	+	-
garlic juice (Envirepel, Nutripel)	?	?	?	?	?	?
hydramethylnon (Amdro Pro Fire Ant Bait, Seige Pro Fire Ant Bait)	?	?	?	?	?	?
metaldehyde (Deadline)	-	-	-	-	-	-
petroleum oil (Volck Supreme, Clean Crop Superior)	-	-	-	-	-	-
potassium salts of fatty acids (M-pede)	+	+	+	+	+	-
pyrethrin (Diatect, Pyrenone, Pyronyl)	+	+	+	+	+	-
sulfur (Micro Sulf)	?	?	?	?	?	?
Fungicides/Nematicides:						
azoxystrobin (Abound, Quadris)	?	?	?	?	?	?
copper hydroxide (Kocide)	?	?	?	?	?	?
dichloropropene/chloropicrin (Telone)	-	-	-	-	-	+
ethoprop (Mocap)	?	?	?	?	?	+
fenamiphos (Nemacur)	?	?	?	?	?	+

fenbuconazole (Enable)	?	?	?	?	?	?
fosetyl-Al (Aliette)	?	?	?	?	?	?
harpin protein (Messenger)	?	?	?	?	?	?
mancozeb (Dithane)	?	+	+	?	?	?
maneb (Manex)	?	+	+	?	?	?
Myrothecium verrucaria (DiTera)	-	-	-	-	-	+
potassium bicarbonate (Kaligreen)	?	?	?	?	?	?
tebuconazole (Elite)	?	?	?	?	?	?
thiabedazole (Mertect)	?	?	?	?	?	?
Herbicides:						
ametryn (Evik)	?	?	?	?	?	?
diuron (Diuron)	?	?	?	?	?	?
glyphosate (Roundup)	?	?	?	?	?	?
oxyflurofen (Goal)	?	?	?	?	?	?
paraquat dichloride (Gramoxone)	+	+	+	+	+	-
pelargonic acid (Scythe)	+	+	+	+	+	-
Pipeline Pest Management Tools:						
bifenthrin-impregnated bags (if trapped in bags)	+	+	+	+	+	-
dinotefuran	*	*	*	*	*	*
flonicamid	*	*	*	*	*	*
imidacloprid (Admire, Provado)	-	-	-	-	-	-
oxyflurofen (Goal 4FL)	?	?	?	?	?	?
spinosad (Success)	-	-	-	-	-	-
Cultural/Non-chemical Controls						

anthocorid bugs	?	?	?	?	?	?
Apanteles erionotae	?	?	?	?	?	?
baiting/trapping	?	?	?	?	?	?
beneficial nematodes	?	?	?	?	?	?
cover crop	?	?	?	?	?	?
crop residue	?	?	?	?	?	?
cultivar selection	?	?	?	?	?	?
de-trashing	-	-	-	-	-	-
disease forecasting	?	?	?	?	?	?
disease-free planting material	?	?	?	?	?	-
fallow (bareground with shallow cultivation)	?	?	?	?	?	?
fallow & cover crops	?	?	?	?	?	?
field sanitation	-	-	-	-	-	-
hot water treatment	?	?	?	?	?	?
moisture monitoring	?	?	?	?	?	?
Ooencyrtus erionotae	?	?	?	?	?	?
other predators	?	?	?	?	?	?
other parasites	?	?	?	?	?	?
plant spacing/density	?	?	?	?	?	?
polyethylene bags	?	?	?	?	?	?
removal of crop residue	?	?	?	?	?	?
roguing of infected plants	?	?	?	?	?	?
site selection & preparation	?	?	?	?	?	?
windbreaks	?	?	?	?	?	?

Rating Scale: + = toxic or detrimental; - = not known to be toxic or detrimental; ? = no data, more research needed, * = not enough experience to rate

Table 9. Pest Control Measures by Banana Crop Stage

	Crop Stage					
Pest	**Pre-plant**	**Planting**	**0-9 mos**	**9mos- flower**	**Fruiting**	**Harvest**
Banana aphid						
petroleum oil		√	√	√	√	
potassium salts of fatty acids		√	√	√	√	
diazinon (Diazinon)		√	√	√	√	
field sanitation	√	√	√	√	√	√
barrier of neem trees	√					
ant control	√	√	√	√	√	√
Banana fruit piercing moth						
azadiractin (Neem oil)				√	√	
Bacillus thuringiensis				√	√	
natural virus pathogens (polyhedrosis, granulosis)				√	√	
removal of larval host	√	√	√	√	√	√
windbreak selection (other than wiliwili)	√					
avoid planting of alternative hosts (e.g. guava)	√	√	√	√	√	√
Banana moth						
azadiractin			√	√		
Bacillus thuringiensis			√	√		
polyethylene bags				√	√	
removal of plant debris	√	√	√	√	√	√
deflowering (cutting off banana flower)				√		
Banana weevil						
carbofuran		√				
field sanitation	√	√	√	√	√	√
tissue culturing to produce clean plants	√					
covering exposed tissue with soil after harvesting/pruning						√
deep planting to protect roots from exposure to pest		√				
Banana skipper						
Bacillus thuringiensis			√	√		
Ooencrytus erionotae	√	√	√	√	√	√
Apanteles erionotae	√	√	√	√	√	√

mechanical control (squishing)		√	√	√	√	
Big-headed ant						
hydramethylnon (bait)	√	√	√	√	√	√
Coconut scale						
petroleum oil				√		
increase plant vigor	√	√	√	√	√	
Long-legged ant						
boric acid/**sugar** syrup (bait)	√	√	√	√	√	√
Spiraling whitefly						
petroleum oil			√	√		
potassium salts of fatty acids			√	√		
Sugarcane bud moth						
Bacillus thuringiensis			√	√		
polyethylene bags					√	
Anthurium thrips						
diazinon				√		
pyrethrin				√		
Banana rust thrips						
diazinon				√		
petroleum oil				√		
potassium salts of fatty acids				√		
pyrethrin				√		
Banana rind thrips						
diazinon				√		
petroleum oil				√		
potassium salts of fatty acids				√		
pyrethrin				√		
Banded greenhouse thrips						
diazinon				√		
petroleum oil				√		
potassium salts of fatty acids				√		
pyrethrin				√		
Hawaiian flower thrips						
diazinon				√		
petroleum oil				√		

potassium salts of fatty acids				√		
pyrethrin				√		
Mites						
petroleum oil				√		
potassium salts of fatty acids				√		
sulfur (Micro Sulf)				√		
disruption by irrigation			√			
trap cropping with papaya	√	√	√	√	√	√
Banana Bunchy Top Virus						
glyphosate			√	√	√	
cultivar selection	√					
disease-free planting material	√					
roguing of infected plants			√	√	√	
site selection & preparation	√					
windbreaks	√					
quarantine	√	√	√	√	√	√
aphid management	√	√	√	√	√	√
eliminate plant hosts of aphids	√	√	√	√	√	√
ant control	√	√	√	√	√	√
increase plant vigor	√	√	√	√	√	√
tissue culturing to produce clean plants	√					
Black Leaf Streak						
azoxystrobin			√	√	√	
copper hydroxide			√	√	√	
fenbuconazole			√	√	√	
manganese/zinc/ethylene bisdithiocarbamate ion			√	√	√	
mancozeb			√	√	√	
maneb			√	√	√	
petroleum oil			√	√	√	
tebuconazole			√	√	√	
de-trashing			√	√	√	
plant spacing		√				
site selection & preparation	√	√				
moisture management (weed control)	√	√	√	√	√	√

Banana Mosaic Virus						
disease-free planting material	√					
roguing of infected plants			√	√	√	
site selection & preparation	√					
Freckle						
copper hydroxide			√	√	√	
fenbuconazole			√	√	√	
manganese/zinc/ethylene bisdithiocarbamate ion			√	√	√	
mancozeb			√	√	√	
maneb			√	√	√	
cultivar selection	√					
de-trashing			√	√	√	
plant spacing		√				
site selection & preparation	√					
bagging					√	
Panama Wilt						
cultivar selection	√					
disease-free planting material	√					
fallow & cover crops	√					
field sanitation	√	√	√	√	√	√
site selection & preparation	√					
control movement of water	√	√	√	√	√	√
control movement of soil, planting material & equipment	√	√	√	√	√	√
Nematodes						
carbofuran	√					
clandosan	√					
dichloropropene/chloropicrin	√					
ethoprop	√					
fenamiphos	√					
cultivar selection	√					
disease-free planting material	√					
fallow & cover crops	√					
field sanitation	√	√	√	√	√	√
hot water treatment	√					
site selection & preparation	√					

composting crop residue	√					
innoculation of soil with beneficial nematodes	√					
propping up plants with wire					√	√
improving drainage	√	√	√	√	√	√
crop rotation	√					
tissue culturing to produce clean plants	√					
Weeds						
glyphosate	√		√	√		
paraquat dichloride	√		√	√		
ametryn			√	√		
diuron			√	√		
pelargonic acid			√	√		
oxyflurofen			√	√		
crop residue			√	√	√	√
cover crops	√					
plant spacing & density		√				
fallow	√					
mowing & mechanical control	√	√	√	√	√	√
fire	√	√	√	√	√	√
sanitation (washing seeds off boots, tractor tires, etc)	√	√	√	√	√	√

Table 10. Worker Activity Table for Bananas

	Crop Stage					
Type of Worker Activity	**Pre-plant**	**Planting**	**0- 9mos**	**9 mos- flower**	**Flowering**	**Harvesting**
planting		√				
fertilization	√		√	√	√	
weed control	√		√	√	√	
disease control			√	√	√	
nematode control	√					
insect control		√	√	√	√	√
irrigation	√	√	√	√	√	√
harvesting						√