FRUIT FLIES AND MANGO SEED WEEVIL IN RELATION TO QUARANTINE

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I am surprised so many came to this meeting, because the commercial value of mangos is not very large. In fact, I have always considered it to be nil as far as Hawaii is concerned. Looking at the group here, I will bet that the total value of your efforts, salaries, etc. for these three days added together is greater than the annual value of commercial production of mangos in Hawaii. In the Hawaii Department of Agriculture's statistics for 1991, mangos were included under the tropical specialty fruit sales, with a farm value of $46,600. The farm price was 73 cents a pound. There were 40 farms totaling 65 acres with 2,750 trees of which 810 were bearing. So, you see, we have a long way to go.

There are a number of factors that have limited the commercial expansion of this crop. Other speakers in the conference will cover cultivars, propagation, physiology, commercial production, economics, trade, marketing, and so forth. In the time allotted to me I will attempt to provide information on one of the limiting factors responsible for plant quarantine regulations.

Hawaii's mangos are hosts for plant pathogens, insects, mites, and other pests that are not present on the U.S. mainland. Tom Davenport mentioned that the mango seed weevil is not present in the Americas; neither are fruit flies, except every once in while they get into California and Florida and create havoc.

Plant quarantine regulations deter the accidental introduction and dissemination of mango pests into Hawaii. Tom Davenport also mentioned a number of insect pests from various parts of the world that were discussed at an international conference a few months ago. We have enough difficult problems and do not need any more. The plant quarantine regulations deter the possibility of these pests entering into Hawaii and also the dissemination of mango pests to the mainland. I wholeheartedly support Hawaii's state quarantine regulations and the U.S. Department of Agriculture's federal regulations. The quarantine regulations should be maintained and followed to prevent the movement of these serious pests to the mainland.

I shall briefly discuss the mango insect pests in Hawaii. Special emphasis will be given to tephritid fruit flies and the mango weevil, *Cryptorhynchus mangiferae* (Fabricius). We have 13 insect and mite pests that attack mangos in Hawaii. Some of these and their commodity treatments will be discussed by other speakers. The mango shoot caterpillar is a noctuid moth that is a minor problem. There are a number of scales (Homoptera). The mango soft scale, *Protopulvinaria mangiferae* (Green), the green scale, *Coccus viridus* (Green), the red wax scale, *Ceroplastes rubens* Maskell, and the Cockerell scale (white scale), *Pseudaulacaspis cockererelli* (Cooley), all attack growing mangos. The green scale has a quarantine regulation against it because it is not present on the mainland. We also have the red banded thrips (Thysanoptera), *Selenothrips rubrocinctus* (Giard), attacking the foliage. Two species of mites (Acari), the mango bud mite, *Eriophyes mangiferae* (Sayed), and the mango spider mite, *Oligonychus mangiferus* (Rahman & Sapra), occasionally cause problems and are difficult to control for the lack of a properly registered pesticide.

In the Diptera (true flies) we have a mango blossom midge, *Dasineura mangiferae* Felt, that is quite prevalent at this time of year in the blooms you see on the trees. In addition to the blossom midge, there are two tephritid species of fruit flies that attack ripe mangos.

Fruit Flies

There are four species of tephritid fruit flies (Diptera, family Tephritidae) in Hawaii. Two species, the Oriental fruit fly, *Bactrocera dorsalis* (Hendel), and the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), are pests of mango. The egg, larva, and adult stages of development of these fruit flies are greatly influenced by air temperature. Pupal development is greatly influenced by soil temperature.

Eggs. Eggs are deposited by the female beneath the skin of the host fruit and develop within two to three days.

Larvae. The eggs hatch and the larvae begin to tunnel out the fruit. Larvae are negatively phototrophic and tend to put their heads down into the pulp of the fruit and their small spiracles near the surface to obtain air and survive. Larva development takes place in about six to ten days depending on the temperature. The larvae molt twice. There are three stages in the development. From the egg comes the first instar, then the larva molts twice, producing the second and the third instars. The third instar develops into the pupa.

Pupae. The pupa is a stage in which the larva changes from a maggot to an adult insect. Pupae are found in the soil, usually in the top 2 in. They can be found in the top 2-6 in. of the soil. It takes nine to 10 days for the pupal development to take place and adults to emerge.

Adults. Adults of newly emerged flies must find a source of protein and carbohydrate for maturation of the ovaries and the testes. This preovipositional period may take one to two weeks for wild flies. The length of time for the preovipositional period depends upon the species of fruit fly and the ambient temperature.

Under natural conditions the flies will obtain this source of protein and carbohydrate from plant exudations, animal excrement, fruit fly regurgitant, honey dew, bacteria, yeasts, and fruit juices. Adult fruit flies in nature may live from two to six weeks or longer, again depending upon the temperature, humidity, and activity.

We have a number of things that we can do to reduce populations of fruit flies in mango orchards.

Preharvest control. *Biological control* is the use of fruit fly parasites, predators, and pathogens. A number of these beneficial organisms have been purposely introduced into Hawaii to reduce the populations of fruit flies.

Sanitation. Removing unusable fruit in the orchard is important. All infested fruit should be destroyed. The fruit can be buried, cooked, and fed to poultry or swine. Cultivating the soil beneath the trees to expose larva and pupa to ants, poultry, lizards, and song birds is also a worthwhile idea.

Fruit picking or stripping. Picking all the fruit from a tree has been used primarily in eradication programs. This was used a great deal in California. They picked all the fruit from the tree to remove any ovipositional sites that would be available for the continued development of the fruit fly population.

Wild host destruction. Elimination of noneconomic or noncultivated hosts that fruit fly populations need to survive is effective, especially in eradication programs. Fruit of these wild hosts provide a source for survival when the cultivated hosts are absent or not fruiting.

Paper bagging of fruit. Bagging of fruit to prevent fruit fly ovipostion has been used by many backyard growers and small farmers in Hawaii. The bag is removed 24-48 hours prior to harvest to allow the natural color of the fruit to develop. I do not recommend it for commercial farmers. Small holes must be made in the paper bag in order for transpiration to take place. Plastic bags are not used.

Chemical control. Bait sprays are the most common method of fruit fly control. The bait spray is mixture of a protein hydrolysate and the insecticide malathion applied to the mango foliage as a spray. Large droplet size is more important than a fine spray or complete coverage. Male and female fruit flies are attracted to the protein, feed on it, and the toxicant kills them before they are sexually mature or deposit their full complement of eggs.

We are gradually losing many of the insecticides, miticides, and fungicides, used as tools in the past. What is going to happen when we lose the presently registered compounds? We have nothing in the developmental stage for fruit fly control in the field. You can recall that when Rachael Carson published her book, "Silent Spring," we lost DDT, and others have followed.

Postharvest treatments. Commodity treatments are needed in order to be able to transport mangos and other host fruits from areas infested with fruit flies through quarantine barriers into areas that are free of the pests. The commodity treatments have been developed by researchers in the U.S. Department of Agriculture Fruit Fly Laboratory. Dr. Armstrong is going to speak after me and will discuss some of the later developments in commodity treatments. Some of the commodity treatments mentioned here are effective for fruit fly control but have not been approved for fruit flies in mangos.

Fumigants. These are chemicals which produce a gas or vapor that is toxic to insects, bacteria, or rodents. Methyl bromide (MB) and ethylene dibromide (EDB) have been used in the past. As many of you know, the use of EDB was canceled in 1984. The use of MB is presently on the ropes and we will likely lose it as an effective fumigant. Research on new fumigants is scarce.

Lethal temperatures. The use of heat and cold to kill insects is an old remedy. It is based upon the thermal tolerance of the insect and the commodity. Mortality is a function of temperature and time. We have a number of treatments that are concerned with lethal temperatures.

Vapor-heat treatment. Heated air which is saturated with water vapor is used to raise and hold the commodity to a specific temperature for a prescribed period of time. This has been effective for papayas and has also been tried and is utilized in other countries for fruit flies in mangos.

Heat and cold treatments. Hot and cold baths have been used with papayas which were immersed in hot water (120°F, 49°C) for 20 minutes for disease control and then held at 46-48°F (5-6°C) for 10 days cold storage (the time it takes for a ship the reach the U.S. mainland).

Two-stage hot-water treatment. A modified hot-water and cold-storage treatment to kill fruit fly eggs is promising. Papaya fruits are submerged in 105-109°F (41-43°C) water for 30 minutes and then transferred to a bath at 118-122°F (48-50°C) for 20 minutes. The fruit are then hydrocooled and placed in cold storage at 50°F (10°C)

Hot-water treatment. Mangos held in a hot water bath at 114.6 – 116.8°F (45.9-47.1°C) for 67.5 minutes will kill fly eggs and larvae. Mangos had to be mature green and fully developed to withstand the treatment. Immature mangos did not ripen and shriveled up after treatment.

High-temperature forced-air treatment. Hot air is circulated with fans over papayas for about 7 hours until the final (fourth) stage and air temperature of 120°F (49°C) is reached or fruit center temperatures reach 117°F (47.2°C) but do not exceed 118°F (47.8°C). You will be hearing more about this treatment for mangos from Dr. Armstrong.

Cold treatment. USDA regulations require a cold treatment, to kill eggs and larvae of the medfly, for 10 days at 32°F (0°C) or below; 11 days at 32.9°F (0.5°C) or below; 12 days at 33.9°F (1.11°C) or below; 14 days at 35°F (1.66°C) or below, or 16 days at 36°F (2.22°C) or below. Notice that as the temperature increases slightly the length of time for exposure of the commodity to that temperature is lengthened. Quick freezing is also an effective disinfestation treatment for fruits that can be used after freezing.

Gamma irradiation. Irradiation will kill all stages of the fruit flies. The dosages that kill fruit flies range in the neighborhood of 150-500 Gray (GY) (15-50 Krad) and will also injure some commodities. There are still questions about consumer acceptance of irradiated food. Irradiation is used to sterilize the fruit flies released in eradication programs. Dr. Moy is going to speak on irradiation later this morning and he will give you the latest information. In my opinion, irradiation has great chances of being approved as a quarantine treatment for fruit fly disinfestation of mangos and other tropical fruits.

Shrink-wrap plastic. This is the enclosing of individual fruits with a semipermeable plastic shrink-wrap film. The shrink-wrap film has extended the shelf life of papayas, has retarded ripening, (depending upon the atmosphere within the fruit), and has reduced water loss. Jang (1990) reported that shrink wrap reduced Med fly egg hatch by 80 percent after 72 hours and 120 hours. Shrink wrap is a new idea that is being investigated as a possibile quarantine treatment.

Insect growth regulators (IGR). These are chemicals that interfere with the action of insect hormones controlling molting, maturity, and other growth functions from the pupae to the adult stage. Saul and Mau et al. (1985, 1987) tested methoprene applied as a dip to papayas and peaches. It allowed larvae to pupate but prevented adult insects from emerging. Another problem we have in plant quarantine is that you cannot have anything survive. Just because the larvae pupated and no adults emerged, that particular method of treatment would not be accepted. IGRs are experimental compounds.

Methods for fruit fly disinfestation of mangos and other tropical fruits and vegetables have been developed by researchers in the USDA Tropical Fruit and Vegetable Research Laboratory. Their research program continues to be the lead agency in Hawaii for future development of commodity treatments.

Mango Weevil

Mango weevil *Cryptorhynchus mangiferae* (Fab.) (Coleoptera, family Curculionidae) was first reported in Hawaii in 1905 (Pope 1929). We also have a scolytid beetle, the mango bark beetle, *Hypoglossum pyrrhostictum* (Butler), and the scarabaeid mango flower beetle, *Protaetia fusca* (Herbst). The latter two may become serious problems.

The mango weevil is more difficult to kill than fruit flies. Immature and adult stages of the weevil are found in a protected position within the seed in the center of the fruit and not near the surface. Less than 1 percent of the mangos examined have shown beetle damage to the flesh. Damage is confined almost entirely to destruction of the seed, which is of prime importance to propagators of rootstock.

Weevil life cycle information in Hawaii was developed by Balock and Kozuma (1964). Adult beetles are about 1/3 in. long, and they may live for a long time (437 days in the laboratory). Warren Yee tells me he read a paper describing how a weevil was starved but lived for several months without food or water. Adult mango weevils have elbowed antennae and a very short beak, unlike the sweet potato weevil. They have a habit of feigning dead. They are active at night, feign death and hide in crevices in the bark of the tree during the day. The pre-ovipositional period is variable.

Eggs. Eggs are fastened singly on the surface of the skin of young mangos with a brownish exudate which completely covers the egg. The female also uses her short beak to make a crescent-shaped cut in the skin of the mango near the egg. Exudate from the cut flows out and solidifies; this also covers and protects the egg. Eggs hatch within five to seven days, depending on the temperature. A female may deposit as many as 15 eggs per day, and in the laboratory we have seen as many as 300 eggs within a three-month period.

Larvae. The larvae are legless grubs with a light brown head that bore directly into the fruit by cutting a hole in the chorion (egg shell) where its surface was in contact with the fruit. Larvae quickly penetrate the flesh and bore into the seed. As the fruit matures the tunnel is obliterated. The exact number of instars in not known but is believed to be from five to seven. Larval development takes from 15 to 22 days. As many as six larvae have been observed in a seed.

Pupae. Pupal development occurs within the seed and takes from seven to 10 days, depending on the temperature. When first formed, the pupae are white, and they then change to a reddish color near completion of development. Within seven to 10 hours after the reddish color change occurs, the pupa changes to an adult weevil. Egg to adult development may take as long as six to seven weeks.

Adults. Adults remain in the seed for a long time, perhaps months. Under natural conditions, the infested fruit falls to the ground, the flesh disintegrates, the seed becomes wet with rain, disease organisms soften the seed, and the adults chew their way out. Rodents may feed on the seed. Ants may enter the seed and devour the pupae, larvae, or adults. Pope (1929) reported that adults appear in May in Hawaii and begin laying their eggs on the very small mangos.

Preharvest control. *Sanitation.* Since there are no known alternate hosts for this weevil, the biggest source of infestation is dropped fruit and mango seeds lying on the ground. Field sanitation, regular removal and destruction of fruit and/or seed, is recommended, but it is not a sure cure. Even undersized fruits remaining on trees after the harvest season should be destroyed.

Chemicals. Sprays applied to the boles of the trees to contact adults hiding in the crevices of the bark have not been very successful in Hawaii. An effective chemical spray for mango seed weevil has not been found.

Commodity Treatments. No quarantine treatments for mango weevil have been approved by the USDA, to my knowledge.

Fumigants. EDB was used experimentally, but its use was canceled in 1984. Methyl bromide at 3 lb/1,000 ft^3 for 8 hr at 70°F (21°C) killed all stages of the weevil but damaged the fruit. Research for new fumigants is not receiving the attention it should. Alternative methods of commodity treatments for the mango weevil are needed if the mango industry is to expand in Hawaii.

Lethal temperatures. Hot water immersion treatments for mangos in Mexico and the Caribbean Basin have been effective. Both vapor heat and forced air are under consideration as quarantine measures for the mango weevil. Subfreezing temperatures were investigated by McBride and Mason (1934) many years ago.

Gamma irradiation holds promise as an effective commodity treatment for the mango weevil. Seo et al (1974) found adults were more resistant to gamma irradiation than were eggs, larvae, and pupae. Researchers have reported larvae development is inhibited and pupation prevented at 20,000 rads. Pupae failed to develop into adults with dosages of 10,000 rads or higher. No adult mortality occurred at 80,000 rads. Researchers in South Africa report that mango fruit is very sensitive and phytotoxicity occurred to mangos at 100 krad or higher.

Microwave (dielectric heating). Studies utilizing microwaves to control mango weevil were initiated by Seo et al. (1970). Mangos were irradiated continuously for 25-60 sec or irradiated in four to 10 increments of 10-15 sec each. The interval between increments was 3-4 sec. The fruit undergoing treatment was rotated 360°. Results indicated that continuous treatment with microwaves of stationary fruit for 45 sec or longer cooked the rind and pulp of 90 percent of the fruits. Rotating the fruit in 10-15 sec intervals cooked the pulp, but only in small areas next to the seed. The internal seed temperatures varied from 123 to 165°F (50.56-73.89°C). Mortality of adult weevils ranged from 50 to 99 percent. Further work is needed to secure approval of this method as a quarantine treatment.

Radiographic (x-ray). Radiographic detection (Hansen 1981) has been used to detect insects in plant tissue. Preliminary tests utilizing an x-ray machine to determine if mango weevils could be detected in the seed was done by a group of us including Cathy Cavaletto and Leng Chia. This technology is used to inspect luggage in the airports. Fruit were examined with a Hewlett-Packard 43804 Faxitron x-ray system. Tube voltages of 40-50 KV for 2.5-5 minutes exposure, depending upon fruit size, were used. Fruit size varied from 180 to 850 g. Kodak Industrex Instant 600 photographic paper produced the final images by which the fruits were judged to be infested or clean. We were able to see larvae within the seeds. Fruits were then cut open and the seeds examined for weevils. Of 163 fruits examined, 31.3 percent were infested. The researchers had an 89 percent accuracy in determining the presence or absence of the weevil. With the improvements in baggage inspection x-ray machines and computerized methods for examination, further work is justified in the development of this as a possible quarantine treatment.

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