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HOT WATER AS A QUARANTINE TREATMENT FOR FLORIDA MANGOS INFESTED WITH CARIBBEAN FRUIT FLY[1]

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Abstract. **'Tommy Atkins' and 'Keitt' Florida mangos (Mangifera indica L.) were infested with laboratory-reared Caribbean fruit flies in outdoor cages, whether the fruit was hard immature-green, mature-green, firm-ripe, ripe, or overripe. Fly eggs and early instar larvae infesting both mango cultivars were killed when the fruit was submerged in water at 115°F for 45-65 min. In contrast to control fruit that was dipped for 65 min in 80°F water, hot water-treated (115°F for 65 min) 'Tommy Atkins' mangos exhibited decreased incidence of decay, stem-end rot, and anthracnose when stored at 55°F for 3 or 16 days. Treated fruit did not differ significantly from controls in ripening time at 70°F and produced no off-flavors in informal taste tests.**

The Environmental Protection Agency (EPA) banned the use of ethylene dibromide (EDB) as a fumigant for all fruit intended for consumption in the United States effective September 1, 1984. Subsequently, the EPA proposed a 30 ppb tolerance for EDB residues *per se* in or on mangos effective until September 1, 1985 (1). The tolerance level is expected to be zero for EDB after that date. Therefore, to insure continuous interstate fruit movement among Florida, Texas, Arizona, California, and Hawaii and between the United States and foreign countries, an alternative method must be approved that kills fruit fly infestations in fruits but does not adversely affect fruit quality. A possible alternative procedure is a hot water treatment. Herein is discussed a hot water treatment for controlling Caribbean fruit fly, *Anastrepha suspensa* (Loew), eggs and early instar larval infestations in 'Tommy Atkins' and 'Keitt' Florida mangos without adversely affecting fruit quality. Also presented are observations on the effect of stage of ripeness of both fruit cultivars on oviposition by the fly.

Materials and Methods

Experiment 1. Hot water treatment.—A majority of mature-green and a few color-break mangos ('Tommy Atkins' and 'Keitt') were obtained from a commercial grower in South Miami from July to August, 1984, in cartons (1-layer flats) containing 6-12 fruit. The fruit was infested with eggs of *A. suspensa* by exposing the fruit to ca. 100,000 gravid females in a screened outdoor infestation cage for 72 hr. For evaluation of the effect of hot water on fruit quality, 'Tommy Atkins' mangos were held at 75°F and not infested. After removal from the cage, infested fruit (containing eggs and early instar larvae) was randomized and held at 75°F for 24 hr. Under these conditions, eggs would hatch in ca. 72 hr. Then infested and noninfested fruit were submerged in heated water in 55-gal metal drums. Each of 5 drums was filled with ca. 45.5 gal of tap water and equipped with a Little Giant® Model 3E-12N submersible pump that circulated 400 gal/hr. Each pump was fastened ca. 1 ft from the bottom of the tank to the lower surface of a metal mesh screen that served as a false bottom. The screen was fastened to angle iron that sat on the container bottom. The fruit, contained in fabric dive bags held in place by a brick on the bags, was positioned 4 inches or more below the water surface. Submersible thermometers monitored water temperature and cast iron propane burners heated the water. Water temperatures dropped ca. 1-2°F when fruit was first submerged. Recovery time required for the water temperature to reach the desired reading was ca. 3 min. Following the treatment, treated and nontreated infested fruit were placed in bioassay towers (3). The number of recovered pupae was recorded weekly for 5 weeks or until no more pupae were recovered from the treated and control fruits.

Test 1. Single dip. Based on an unpublished treatment recommendation for Puerto Rican mangos to kill eggs and first and second instar larvae of the Oriental fruit fly, *Dacus dorsalis* Hendel, in Hawaii (4), fruit of size 12 (198 and 252 of 'Keitt' and 'Tommy Atkins') was submerged for 65 min in 115°F water. Other infested fruit (66 and 68 of 'Keitt' and 'Tommy Atkins') served as controls and was not dipped. The test was repeated 3 times with both mango cultivars.

Test 2. Double dip. 'Keitt' mangos (78 of size 10-12) were submerged for 40 min at 107.6°F and transferred within 1 min to water at 120.2°F where the fruit remained for 20 min. Twenty-six fruit (size 10-12) infested but not treated with hot water were used for the control. The test was repeated once.

Test 3. Effect of time. 'Keitt' mangos (size 12) were divided into 7 lots of 36 fruit each. Each of 6 lots was submerged for a different time period (15, 25, 35, 45, 55 or 65 min) into water heated to 115°F. The remaining lot was used as a control (infested, not dipped). The test was repeated twice.

Test 4. Effect of fruit size. 'Keitt' mangos [60 of size 12 (1.05±0.075 lb.) and 60 of size 6 (2.23±0.075 lb.) in 1 test, and 60 of size 12 (1.08 ± 0.066 lb.) and 64 of size 8 (1.96 ±0.088 lb.) in another test] were infested in separate rooms of the cage in a manner previously described. Twenty-five percent of the infested fruit of all sizes was not dipped (control) and the rest was dipped for 65 min in 115°F water.

Test 5. Fruit sensitivity to heated water. Noninfested 'Tommy Atkins' mangos (144 of size 12) were used. A group of 72 fruit was submerged for 65 min in water heated to 115°F, and a group of 72 fruit was submerged for 65 min in water at 80°F. One-half of the fruit of each treatment was stored at 55°F for 3 days and the other half for 16 days; then observations were recorded of firmness, injury, and percent ripe color. The fruit was then held at 70°F for ripening time, decay (anthracnose, caused by *Colletotrichum gloeosporioides* Penz., and stem-end rot, caused by *Diplodia natalensis* P. Evans or *Phomopsis citri* Fawc.), skin injury, percentage ripe skin color (red and yellow), and percentage of acceptable fruits. Soft-ripe fruits were considered acceptable.

Experiment 2. Stage of ripeness.—Ripeness of 'Tommy Atkins' and 'Keitt' mangos was based on the U.S.D.A. inspectors instructions for limes and avocados and is frequently used with mangos (2): Firmness 1, overripe, past use; Firmness 2, ripe, yields to moderate pressure, best for eating; Firmness 3, firm-ripe, yields slightly to moderate

[1]This paper reports the results of research only. Mention of a trade name in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture.

pressure, not quite prime eating; Firmness 4, firm, yields very slightly to moderate pressure; Firmness 5, hard does not yield to moderate pressure. Each fruit was individually weighed on an Ainsworth Model M-3000 balance, scored for firmness, and infested for 30 hr by exposing the fruit to 100,000 gravid female flies in an outdoor cage. Immature-green fruit was put into the oviposition cage within 24 hr after the fruit was picked. Other fruit was held at 75°F, labeled for firmness and then infested. Fruit of each firmness was infested separately to avoid possible oviposition bias by the flies, for example, for a preference for fruit of firmness 2 and not 5. After exposure to flies, each fruit was placed in individual containers filled one-third with vermiculite. The vermiculite was sieved weekly for 6 weeks, and the number of recovered pupae was recorded. Twelve replicate fruit (size 12) of 'Tommy Atkins' and 6 of 'Keitt' (size 8) were used for each firmness test.

Results

Experiment 1. Test 1. Single dip.—No pupae were recovered from 'Tommy Atkins' and 'Keitt' mangos submerged for 65 min in 115°F water (Table 1).

Table 1. Effect of single dip in 115°F water for 65 min on killing eggs and early instar Caribbean fruit fly larvae in 'Tommy Atkins' and 'Keitt' mangos.

	Nontreated control		Treated (115°F for 65 min)	
Cultivar (size)	Fruit (no.)	Pupae (no.)	Fruit (no.)	Pupae (no.)
Tommy Atkins (12)	68	8865	252	0
Keitt (12)	66	4703	198	0

Test 2. Double dip. 'Keitt' mangos submerged for 40 min in 107.6°F water followed within 1 min by submersion for 20 min in 120.2°F water produced no pupae. A total of 1335 pupae was counted from untreated fruit.

Test 3. Effect of time. No pupae were recovered from 'Keitt' mangos submerged in 115°F water for 45 min or longer (Table 2).

Table 2. Effect of time on killing eggs and early instar Caribbean fruit fly larvae in 'Keitt' mangos submerged in 115°F water.

Pupae recovered (no.)						
Control	115°F					
	15	25	35	45	55	65 min
2873	1023	42	3	0	0	0

Test 4. Effect of fruit size. Significantly more pupae were recovered from untreated 'Keitt' mangos size 6 than from size 12; significantly more pupae were recovered from untreated 'Keitt' mangos size 8 than from size 12. No pupae were recovered from treated fruit (Table 3).

Table 3. Effect of 'Keitt' mango size on the number of recovered pupae.

		Nontreated control		Treated (115°F for 65 min)	
	Size	Fruit (no.)	Pupae[z] (no.)	Fruit (no.)	Pupae (no.)
Test 1	12	15	132a	45	0
	6	15	1197b	45	0
Test 2	12	15	912c	45	0
	8	16	2453d	48	0

[z]Mean separation in columns for each test by chi square goodness-of-fit test, 5% level.

Test 5. Fruit sensitivity to heated water. 'Tommy Atkins' mangos heated in water at 115°F for 65 min and stored for 3 or 16 days at 55°F did not differ significantly in ripening time at 70°F from similar fruit treated in unheated water at 80°F (Table 4). Treatment in heated water decreased the incidence of anthracnose and stem-end rot. The benefit of treatment appeared to decrease with increased length of storage. Injury due to heat was not apparent in 66.7% of the fruit treated with heated water, 27.3% showed trace to slight injury, and 2 mangos (6%) showed moderate to severe scald considered unacceptable for marketing. Ripe color developed similarly in all mangos, regardless of treatment, and no off-flavors were detected in informal taste tests. The percentage of acceptable fruits was greatest in those treated in heated water and stored for only 3 days prior to ripening.

Table 4. Quality of 'Tommy Atkins' mangos treated in water at 80 or 115°F for 65 min and stored for 3 or 16 days at 55°F followed by ripening at 70°F.[z]

Water temp (°F)	Storage time (days)	Ripening time (days)	Decay[y] (%)	Injury[x] (%)	Ripe color[w] (%)	Acceptable fruits[v] (%)
80	3	11	64	0	100	36
115	3	11	28	6	100	66
80	16	5	61	0	100	39
115	16	5	47	0	100	53

[z]Each figure represents the average of 3 boxes of mangos, 12 fruits/box.
[y]Percentage of decayed mangos refers to fruit with moderate or severe anthracnose and/or stem-end rot, or a combination of slight anthracnose and slight stem-end rot.
[x]Percentage of injured mangos refers to fruit with moderate or severe skin injury (scald).
[w]Percentage of mangos with at least 75% ripe skin color (red and yellow).
[v]Soft-ripe fruit were considered acceptable if they had no more than slight injury or decay, at least 75% ripe skin color, and no off-flavor.

Experiment 2. Stage of ripeness.—'Tommy Atkins' and 'Keitt' mangos of firmness (ripeness) values from 1-5 were infested in outdoor cages (Table 5). Variation occurred in the number of pupae recovered per fruit regardless of stage of ripeness. For example, the number of pupae recovered from 'Tommy Atkins' immature-green mangos (firmness 5) ranged from 0-13 and for ripe and overripe mangos (firmness 1-2), from 9-570; with immature-green 'Keitt' mangos (firmness 5) the numbers ranged from 4-37 and from 17-113 for

Table 5. Effect of 'Tommy Atkins' and 'Keitt' mango ripeness on the number of recovered pupae.

Ripeness score	No. of fruit	Weight (avg±SE)	Total pupae recovered	Range of pupae/fruit
		'Tommy Atkins'		
5[z]	12	336±11	41 a[w]	0-13
5[y]	12	528±15	30 a	0-18
5[x]	12	496±14	1089 b	2-205
4	12	486±28	727 c	10-306
3-4	12	462±16	922 d	0-330
2-3	12	455±11	469 e	1-108
1-2	12	459±42	3877 f	9-570
		'Keitt'		
5[z]	6	673±70	136 a	4-37
5[y]	6	1096±56	80 b	4-41
3-4	6	584±16	175 c	8-54
2	6	560±33	432 d	17-113
1	6	515±15	119 a	0-77

[z]Immature green.
[y]Mature green.
[x]Color break.
[w]Mean separation in columns and among totals for each variety by chi square goodness-of-fit test, 5% level.

ripe fruit (firmness 2). Percent infested fruit for hard immature-green 'Tommy Atkins' and 'Keitt' mangos was 83 and 100%, respectively.

Discussion

A. suspensa naturally oviposits into 84 cultivars of fruits and oviposits most frequently in rose apple, *Syzgium jambos* (L.) Alst.; cattley guava, *Psidium cattleianum* Sab.; Surinam cherry, *Eugenia uniflora* L.; tropical almond, *Terminalia catappa* L.; common guava, *P. guajava* L.; and loquat, *Eriobotrya japonica* (Thunb.) Lindl. (5). Mangos, although not a preferred host for *A. suspensa* (5, 6), were artificially infested by laboratory-reared females when the fruit was presented in outdoor screened cages. Both 'Tommy Atkins' and 'Keitt' mangos were infested regardless of fruit hardness ranging from immature-green to soft-overripe fruit. Although larger 'Keitt' mangos (size 6-8) were more heavily infested by *A. suspensa* than fruit of size 12, the hot water treatment of 115°F for 65 min apparently was effective in killing early instar larvae in fruit of both sizes. This suggests that the heat penetrated deeply enough to kill eggs and early instar larvae. However, submersion in 115°F water for a time less than 65 min could result in mortality less than 100% and indicate a size effect. The hot water treatment of 115°F for 65 min also reduced the incidence of mango stem-end rot and anthracnose without significantly affecting fruit quality. A single hot water treatment of 115°F for 45 min might prove to be a useful technique to both kill eggs and early instar larvae in fruit and reduce the incidence of mango diseases such as stem-end rot and anthracnose.

Conclusion

Because *A. suspensa* produce viable offspring from mangos in natural conditions (5, 6), a threat exists for potential movement of the fly from Florida to Texas, Arizona, California, and Hawaii. Therefore, the fruit must be treated and certified free of the tephritid to permit interstate fruit movement. The hot water treatment appears promising as a needed alternative treatment to EDB. The recommended hot water treatment to submerge fruit in water heated to 115°F for 65 min for *D. dorsalis* probably can be reduced to 45 min at 115°F for *A. suspensa.*

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JUVENILE INTERSTOCKS FOR TOPWORKING MAMEY SAPOTE (COLOCARPUM SAPOTA (JACQ.) MERN.)[1]

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Abstract. **Topworking mamey sapote trees in the field is extremely difficult once they have flowered and fruited. It would be advantageous to be able to topwork mature seedling trees if they have undesirable characteristics of quality, yield, or pest and disease resistance. If grafted trees are frozen below the graft union, topworking would put bearing groves back into production. Seedling tops prepared for use as interstocks permitted the use of mature scionwood which reverted to a "juvenile-like" condition for topworking mamey sapote. The experiments were successful during the season when grafting generally is not possible.**

The mamey sapote has been grown in Florida since the mid-1800s, but for a long time the fruit was considered a novelty because only a few trees existed in dooryard plantings or fruit collections. These trees were seedlings and they varied in flavor, yield and pest resistance. Grafted trees of 'Cuban No. 1' were introduced in the 1950s and 'Magana' was introduced in 1960. Other cultivars have been selected or introduced in subsequent years (1).

Mamey sapote was a relatively unknown fruit to the local population in South Florida until interest was sparked by the large numbers of Latin immigrants beginning in 1959-60. At that time most of the trees were still seedlings because the tree is difficult to graft. Today hundreds of ungrafted trees exist in dooryard plantings.

In the late 1970s new grafting techniques permitted production of grafted trees of improved cultivars on a limited scale. At this time there were only a few acres of grafted trees in commercial production. Presently there are around 300 acres of grafted trees planted in commercial groves but now all have come into bearing. More orchards are being planted in the southern coastal areas of Florida.

It would be a great advantage to be able to topwork seedling trees or trees of inferior cultivars with scions of superior cultivars. Topworking mature trees in the field is difficult and there is usually a low percentage of graft take. Trees to be topworked are usually cut back to major limbs and the new sprouts are veneer grafted much in the manner of topworking lychee trees (*Litchi chinensis* Sonn.) (2). Previous work by Ogden (3, 5) has shown that juvenile scions collected from seedling terminals can be grafted more readily than scions from mature trees that have flowered

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