MORTALITY OF *TOXOTRYPANA CURVICAUDA* (DIPTERA: TEPHRITIDAE) IN PAPAYAS EXPOSED TO FORCED HOT AIR

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ABSTRACT

Papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, is a quarantined pest of papayas. Papayas with naturally occurring infestations of the papaya fruit fly were exposed to forced hot air at 48°C for 30 to 210 m. Forced hot air at 48°C provided 97% mortality of Papaya fruit fly immature stages in papayas treated for 60 min. Probit 9 mortality predicted that at least 167 min of treatment was needed, but probably would require that the center temperature of the coldest fruit reach 46°C. This is the first quarantine treatment tested against the papaya fruit fly which is a major pest of papayas in Florida.

Key Words: Papaya fruit fly, *Toxotrypana curvicauda*, commodity treatment, forced hot air

RESUMEN

La mosca de la papaya, *Toxotrypana curvicauda* Gerstaecker, es una plaga cuarentenada de la papaya. Papayas naturalmente infestadas con *T. curvicauda* fueron expuestas a aire caliente forzado a 48°C durante 30-210 minutos. El aire caliente forzado a 48°C produjo 97% de mortalidad de los estados inmaduros de las moscas en papayas tratadas durante 60 minutos. La mortalidad probit 9 predijo que al menos se necesitan 167 minutos de tratamiento, pero probablemente se requiera que la temperatura del centro de la fruta más fría alcance los 46°C. Este es el primer tratamiento cuarentenario probado contra esta impotante plaga de la papaya en la Florida.

Papaya (*Carica papaya* L.) is grown throughout the tropical regions of the world (Morton 1987). This plant is a member of the Caricaceae and probably originated in the Neotropics. The plant is grown for its melon shaped fruit which has an orange or red flesh, and is eaten fresh, dried, or is made into juice. The papaya plant and fruit have several pest problems ranging from viruses to insects. Fruit flies will use the papaya as a host, but the latex laden sap probably prevents most species of flies from successfully ovipositing until the fruit is very ripe.

The papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, is a specialist on papayas (Knab & Yothers 1914). Only a few other hosts are known for this species (Baker et al. 1944, Butcher 1952, Castrejon-Ayala 1987, Castrejon-Ayala & Camino-Lavin 1991, Landolt 1994). The papaya fruit fly is found from Mexico south to Brazil, on some Caribbean islands, and in southern Florida. It is one of the larger fruit flies. Females have long ovipositors and eggs are deposited in the central cavity of the papaya fruit (Knab & Yothers 1914). The fruit fly prefers to oviposit in immature green fruit, the early instar larvae feed on the coating and endosperm of developing papaya seeds (Pena et al. 1986). As the larvae mature, they switch to feeding on fruit pulp (Pena et al. 1986). Papaya fruit flies are a major barrier to growing papaya fruits in Florida. A large percentage (up to 30 to 50%) of the papayas in a field is often infested.

There are no postharvest quarantine treatments available for Florida papayas, which are also considered to be hosts of Caribbean fruit fly, *Anastrepha suspensa* (Loew). A postharvest quarantine treatment would greatly expand the export market for Florida papayas. Hot air, hot water, and fumigation with ethylene dibromide (EDB) have been studied in Hawaii as commodity treatments for papayas infested with a number of fruit fly species (Armstrong et al. 1989, Armstrong et al. 1995, Couey & Hayes 1986, Couey et al. 1985). The fumigant, ethylene dibromide, has been banned as a carcinogen (Ruckelshaus 1984), and hot air has been found to damage the fruit less than hot water immersion (Armstrong et al. 1989, 1995, Chan et al. 1981, Jones 1939). This study was conducted to determine if hot air would be feasible as a commodity treatment for papayas infested with immature stages of the papaya fruit fly.

MATERIALS AND METHODS

Initial attempts were unsuccessful to raise papaya fruit flies for the experiment by rearing larvae in commercial papayas from the packinghouse. Not enough larvae were found after commercial fruits were exposed to captive flies in cages to conduct the experiments, probably because the commercial papayas were too ripe. Therefore, wild papayas with naturally occurring infestations were collected on the United States Department of Agriculture—Agricultural Research Service (USDA-ARS) Subtropical Horticulture Research Station in Miami, and from a mixed grove of papayas (cvs. Red Lady and Known-You-1) and guavas in western Dade county in both 1993 and 1994. Papayas were collected from Oct.-Dec. 1993 (Rep. 1-5), and July-Aug. 1994 (Rep. 6-12). There were not enough papayas available to divide them into different weight classes, thus the papayas were sorted into groups of 10 (Reps. 2-6), 11 (Reps. 1 & 8), or 12 (Reps. 7, 9-12) so that each group had equal numbers of similar sized papayas. The groups were then randomly assigned to treatments or control. All fruits were weighed and their diameter was measured. Three control groups were held to estimate the fly population present for each replication. One group of papayas was used for each duration of treatment time.

A forced hot air machine described by Sharp et al. (1994) was used to treat the papayas. Treatments consisted of 30, 60, 90, 120, 150, 180 and 210 min of forced hot air at 48°C. For each replication, one group of papayas was treated separately for each treatment time. Three papayas in each group had 36 gauge type t (copper-constantan) thermocouples placed beneath the surface of the fruit skin. Five of the largest papayas had thermocouples placed at the center of each fruit. Fruit temperatures, air temperature and relative humidity were monitored and recorded by a personal computer. Humidity was measured with a General Eastern humidity meter and sampling head (model M1/SIM-12H, General Eastern Instruments, Woburn MA). The computer was programmed to maintain heat and humidity levels. The humidity was kept below the dew point using the papaya surface temperatures so that the papayas remained dry. Previous research indicated that papayas are very sensitive to surface moisture which may interfere with fruit respiration during heat treatments (Chan et al. 1981, Jones 1939).

After treatment all treated fruit were allowed to cool at ambient air temperatures (≈25°C) and then placed in holding cages. Larvae emerging from fruits were collected and counted for several weeks until the fruits had completely decomposed and all larvae had left the fruit. The experiment was repeated 12 times.

Statistical analysis was performed using probit analysis (SAS Institute 1988) and also by fitting linear and non-linear models using TableCurve 2D (Jandel Scientific 1994).

Results and Discussion

An average of 5.3 ±0.9 larvae emerged per papaya from the 10 to 12 nontreated papayas in each replicate (range of 0.1 to 24.4 larvae per papaya). The estimated treated population totaled an average of 697.3 over the 12 replications (Table 1, mean of 3 controls). The treatment caused 45% mortality in the first 30 min (Fig. 1). In two replications, larvae survived 60 min of treatment and in one replication 18 larvae survived 150 min of treatment (Table 1).

The center temperatures of the heated papayas reached 46°C after about 90 min of treatment (Fig. 2, 557 g papaya). Previous research with heat has shown that other fruit flies are killed when center temperatures of heated commodities reach 46°C (Sharp 1994). There are two possible reasons as to why papaya fruit fly larvae survived 150 min in replicate 4. Either there was an extremely high number of larvae in that particular treatment and/or there was a very large fruit containing the larvae which did not reach the treatment temperature. Due to the limited availability of infested papayas, all sizes were used in the experiment ranging from 37 to 3059g (mean = 543.8g, st. dev. = 412.0). There was one papaya in treatment replicate 4 that weighed 2,605 g. which may have had larvae in it. Papayas were not held individually because of logistical constraints so the individual papaya from which the larvae came could not be determined.

TABLE 1. TOTAL LARVAE RECOVERED FROM PAPAYAS AFTER TREATMENT WITH HOT AIR.

Time	Replicate												
(Min)	1	2	3	4	5	6	7	8	9	10	11	12	Total
30	48	0	2	42	132	11	0	0	6	43	89	10	383
60	0	0	0	9	22	0	0	0	0	0	0	0	31
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	18	0	0	0	0	0	0	0	0	18
180	0	0	0	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0	0	0	0
Control	25	40	1	72	81	80	10	26	166	28	39	45	613
Control	7	22	0	154	59	66	22	30	124	99	5	15	603
Control	0	11	0	293	147	27	29	28	142	37	30	132	876

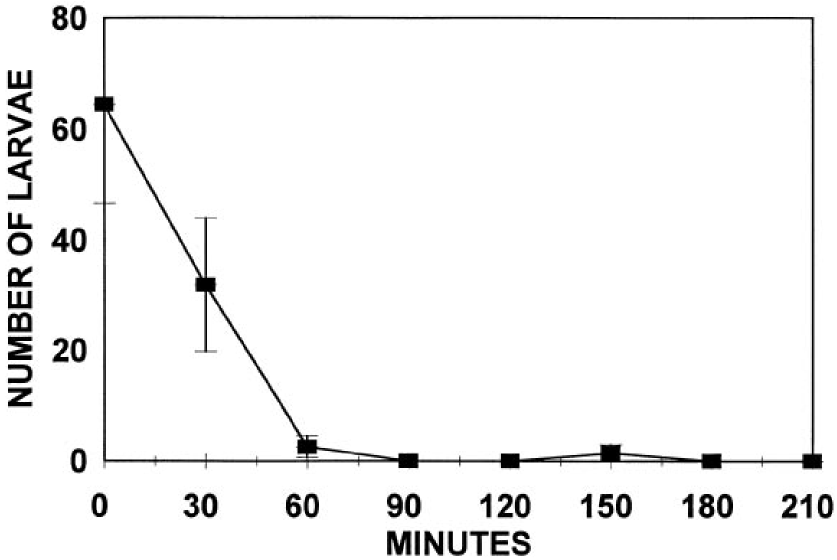

Fig. 1. Mean number of larvae recovered from hot air treated papayas for replications 1-12.

Using different models on the mortality data gives different predictions of probit 9 (99.9968% mortality). Probit (Normal) gave a prediction of 167.5 min, Logit 87.7 min, Gompertz 267.9 min, Gaussian Cumulative 120.6 min, and the best fitting linear equation ($y=a+blnx/x^2$) 123 min. Ignoring the one data point from replicate 4 would give 100% mortality at about 90 min, but the true figure is probably close to 167.5 min. The treatment should probably be extended until the core temperature of the coldest fruit reaches 46°C and remains there for at least 10 min.

Mangan & Ingle (1992, 1994) found that heating mangoes and grapefruit with forced hot air until the core reached 48°C (157 to 200+ min) gave probit 9 mortality of West Indian fruit fly, *Anastrepha obliqua* (Macquart), and Mexican fruit fly, *Anastrepha ludens* (Loew), respectively. Sharp et al. (1991, 1994) found that heating mangos and grapefruit with forced hot air from 101 to 214 min achieved probit 9 mortality of *A. suspensa*. Armstrong et al. (1995) found that heating papayas with forced hot air achieved probit 9 in 210 ± 15 min for Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), melon fly, *Bactrocera curcubitae* (Coquillett), and oriental fruit fly, *Bactrocera dorsalis* (Hendel). This indicates that the papaya fruit fly is similar in its tolerance to heat to the other tephritid species that have been tested.

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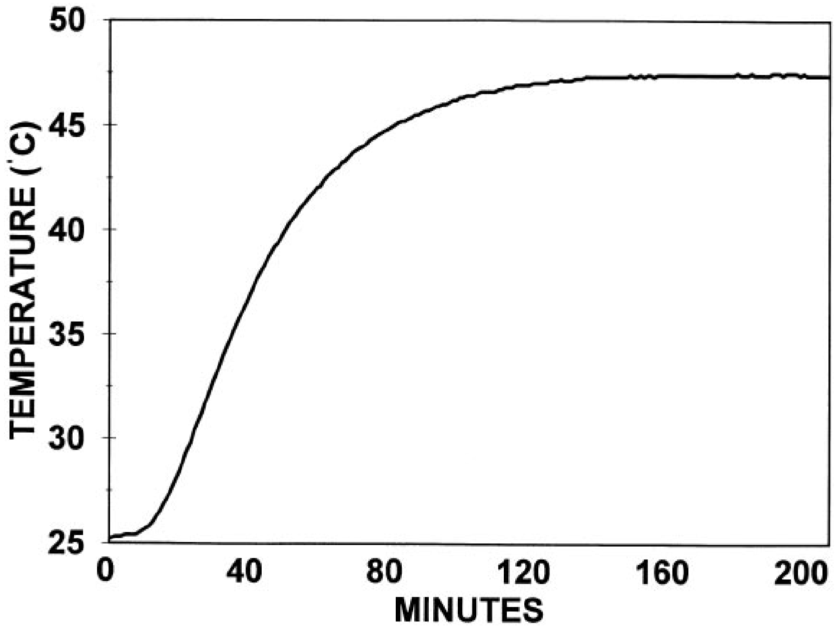

Fig. 2. Core temperature of average sized (557g) hot air treated papaya.

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