Relative Tolerance to Vapor Heat Treatment of Eggs and Larvae of *Bactrocera tryoni* (Diptera: Tephritidae) in Mangoes

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ABSTRACT The tolerances of all fruit-infesting stages of the Queensland fruit fly *Bactrocera tryoni* (Froggatt) to vapor heat treahnent were determined to find the most tolerant stage. A series of doses (fruit core temperatures hom 39 to 46°C) of vapor heat treahnent was applied to 'Kensington' mangoes infested with eggs or one of the three larval instal's of B. *tryoni*. Probit analysis of the resulting mortality showed that the stages most tolerant to heat were eggs and third instal's. Quarantine disinfestation protocols should be based on one or both of these stages.

KEY WORDS Insecta, *Bactrocera tryoni*, vapor heat treahnent, disinfestation

MANGOES, *Mangifera indica* L., are potential hosts of Queensland fruit fly, *Bactrocera tryoni* (Froggatt), with the result that postharvest disinfestation is required before export to many markets. Currently, ethylene dibromide fumigation or insecticide treatments are used for this purpose (Swaine et al. 1975, 1984). Because of increasing market reluctance to accept food with chemical residues, alternative means of disinfestation are sought. Vapor heat treatment is an alternative with a proven record of efficacy against several species of fruit flies without damaging the mango fruit host (Merino et al. 1986, Sunagawa et al. 1987). Vapor heat treatment is analogous to high-temperature forced-air disinfestation treatment (Armstrong et al. 1989) except that the humidity of the circulating air is higher and condensation may form on the fruit surface.

We examined the differential mortality response to vapor heat treatment of eggs and the three instal'S of B. *tryoni* infesting mangoes. This information is useful for identifying the most tolerant stage against which further disinfestation research can be aimed and for predicting vapor heat treatment regimes expected to achieve the probit 9 mortality level necessary for quarantine security (Baker 1939).

Materials and Methods

Vapor Heat Treatment System. The vapor heat b'eatment system (Model EHK-lOOOB, Sanshu, Kagoshima, Japan) was an experimental unit with an inside chamber volume of 1.0 m^3 (I55 by 82 by 80 em). Precise proportionally adjusting temperature controllers accurately controlled the air temperature in the chamber. A fan rapidly circulated air between the chamber and the plenum where air heating and humidifying occurred.

The 12 fruit-holding trays, arranged into three columns, could be removed individually during operation with little chamber heat loss. Chamber and fruit core temperatures were monitored with one wet bulb, one dry bulb, and 11 fruit pulp platinum resistance temperature probes (3-mm diameter). The probes were calibrated by potentiometer adjustment while immersed in a precision water bath (Grant Instruments, Cambridge, U.K.). The water bath had a performance rating of ±0.004°C. Relative humidity was calculated from the wet and dry bulb probe readings.

Infestation. Flies were cultured as described by Heather & Corcoran (1985) and used at their peak fecundity (22-48 d old) for infesting fruits. 'Kensington' mangoes were weighed, allocated into a heat-dose category, ripened and punctured three times by a device holding five fine micropins. Puncturing gave more uniform distribution of eggs between and within fruit. Fruits were placed in cages of ~15,000 adult £lies for 15-60 min. Fruits were distributed into cages so that there was no confounding of cage or position effects in a cage with dose.

Fruits were incubated at 25°C for the period required for development of the insects to the stages tested (first instal'S, 72 h; second instal'S, 96 h; third instal'S, 144 h [unpublished data]). Eggs were incubated for 32 h, a period representing ~80% development, because this is the age most tolerant of heat (R. J. Corcoran, personal communication). At the time of treatment, two fruits containing each stage were dissected and sampled to confirm the presence of the required stage.

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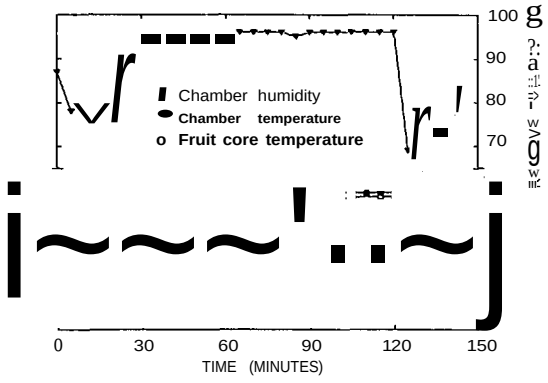

Fig. 1. Humidity and temperature of the chamber air in the vapor heat treatment system and fruit core temperatures during typical operation.

Treating Fruit. Fruits were treated in trays in the vapor heat treatment system. To facilitate removal during operation, fruits were allocated so that one dose occupied one or two trays. Trays could be removed at any time with minimal effect on progress of treatment of the remainder. Load capacity varied from 36 to 79 kg/m^3. For any trial the difference in fruit weights did not exceed 80 g. Mean weights of fruit between trials ranged from 300 to 450 g.

Temperature probes were inselted longitudinally to the middle of the fruit from stem end to minimize heat conductance along the probe. The chamber air temperature was increased from 25 to 47°C in the minimum time possible (19-25 min). This heating profile was chosen because it did not damage 'Kensington' mangoes even at times in excess of those used here (K. K. Jacobi, personal communication).

Fruits were subjected to six doses: these caused fruit core temperatures of 39, 41, 43, 44, 45, and 46°C. We considered a dose to be achieved when all fruit pulp temperature probes reached the required temperature. Probe fruits were selected to be in the middle of the weight range of the fruit. From 14 to 21 fruits were used for each dose. Because of limitations of the capacity of the vapor heat treatment system, not all combinations of dose and stage could be performed at once. Six trials achieved two replicates of each dose-stage combination.

After. treatment, fruits were immediately cooled by immersion in 30 liters of water at ambient temperature ("Ψ25°C) for 30 min and placed into cages on drip trays over sand. Sand was sieved for pupae several times from 12 to 25 d after infestation. After the final sieving the fruit were cut open and inspected for pupae (although the normal behavior for B. *tryoni* is for larvae to leave the fruit before pupation). Pupae were counted and held for adult emergence. The adults were counted.

From 20 to 28% of the fi-uit was handled identically but not vapor heat treated. Pupae recovered from these fruit were held for adult eclosion. Numbers of adults were used to estimate the size of the population in the treated fruits adjusted for natural immature stage mortality.

Data were analysed by probit analysis with a computer program (M. Bengston, personal communication) based on the procedures of Finney (1971). Dose was not log transformed because

Table 1. Summary data of heat dosage-mortality response of immature stages of B. *tryon;* in Kensington mangoes to vapor heat treatment

Sta~e	Core temp, °C	1\:0.treated fruit	1\:0.individuals treated	Surviving adults	~10rtality, %
Eggs	39	19	3,390	1,065	68.58
	41	39	4,983	1,718	65.52
	43	33	5,903	637	89.21
	44	32	5,716	302	94.72
	45	33	.5,887	10	99.83
	46	34	6,074	1	99.98
First instars	39	17	6,374	1,049	83.54
	41	37	7,473	713	90.46
	43	32	8,525	105	98.77
	44	32	8,525	5	99.94
	45	32	8,757	0	100
	46	16	2,294	0	100
Second instal'S	39	17	5,910	374	93.67
	41	34	8,767	791	90.98
	43	35	8,001	181	97.74
	44	37	8,130	22	99.73
	45	36	8,349	2	99.98
	46	19	2,439	0	100
Third instal'S	39	20	3,094	407	86.85
	41	38	3,908	1,026	73.75
	43	36	5,329	622	88.83
	44	37	5,548	148	97.33
	45	36	5,329	20	99.63
	46	37	5,413	0	100

Table 2. Parameters of heat dose-mortality response of immature stages of B. *Iryoni* in 'Kensington' mangoes to vapor heat treatment

Stal{e	n	Slope:t SEM	LTm' (temp, 0c) (95% FLY'
El{l{s	31,953	*0.23 :t 0.09*	42.8 (41.2-45.6)a
Third instars	28,621	*0.31 :t 0.09*	42.0 (38.1-45.3)a,b
First instars	41,948	0.34:!: 0.07	40.2 (39.2-4I.l)h
Second instars	41,944	*0.21 :t* 0.07	39.3 (33.1-40.8)h

" LT"", values followed by the same letter are not si!(nificandy different based on the criterion of failure of the 95% FL to overlap.

this transformation resulted in a lower *:i* value for all probit lines and because graphical analysis showed deviations from linearity in log transformed probit lines. LT 90S were considered to differ significantly if their 95% FL did not overlap.

Results and Discussion

Temperahlre and humidity in the treatment chamber were adequately controlled by the system. After the initial run-up time (19-25 min), temperature remained stable at the set temperature (Fig. 1). Relative humidity reached a plateau more slowly; 22-29 min was required to reach 90% RH. A peak of96% was reached 41-106 min after treatment began.

For all stages heat dose and mortality were positively correlated (Table 1). Eggs were most tolerant of vapor heat treatment followed by third instars, first instars, and second instars (Table 2). Eggs were significantly more tolerant than first instars and second instars, but not significantly more tolerant than third instars. Responses among the instal'S did not differ significantly.

Relative tolerance to heat involves two factors: the absolute tolerance to heat and position of the stage in the fruit. At the temperatures we used, eggs were the absolute most tolerant stage as determined by immersion of different stages in hot water (Heard et al. 1991). Third instal'S were not significantly less tolerant in fruit possibly because they occurred deeper in the flesh where heat exposure was less. Because eggs and third instal'S were the most tolerant stages to the treatment, either of these stages could be used as the target of a disinfestation treatment.

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