Effect of Temperature and Fruit Ripeness on the Development of Oriental Fruit fly Larvae (*Dacus dorsalis*) in Avocado[1]

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The development of diversified agriculture is of great interest in Hawaii. About 46% of the total fresh fruit marketed here is locally grown, and we need to increase production of fresh fruit for local consumption as well as export. However, many fruits such as avocado, *Persea americana* Mill., cannot be exported to mainland markets without chemical treatment because of the Oriental fruit fly, *Dacus dorsalis* Hendel, which has been known in Hawaii since 1946. Avocado is one of the staple fruits in the American diet and commands a good market not only in Hawaii but also in the mainland. The development of an avocado industry, however, has been retarded in Hawaii because of plant quarantine restrictions on out-of-state shipment. We ascertained the status of avocado as an Oriental fruit fly host under field conditions. We also determined the effect of cold storage (at 46° and 55°F) and the effect of fruit ripeness on fruit fly development, to provide the avocado industry with additional information on cold storage treatments of avocadoes to minimize the use of chemicals for control of fruit flies.

MATERIALS AND METHODS

Shipments of 23 varieties of mature green avocadoes were received from the Malamaki and Kona Branch Experiment Stations on Hawaii. For induced ovposition tests, Oriental fruit fly pupae were obtained from USDA Fruit Fly Investigations Laboratory in Honolulu. These flies were reared in artificial diet in the laboratory (Tanaka, et al., 1969). The pupae were held in wooden cubical cages (25x25x26 cm) and were provided with yeast hydrolysate, sugar cubes and water. Three days after emergence, the flies were sexed at 46°F and separated into lots of 100 females and 50 males per cage. Thirty such cages each containing a single avocado were used in each test. Each avocado was wrapped in a plastic bag in which a 2.2 cm diameter hole was punched to expose only about 3.4 cm^2 of the fruit. Adult flies were held for at least 10 days before fruit exposure to insure that females were gravid. Fruits were removed from the cages after 24 hours.

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Effect of fruit ripeness on cold storage treatment. Two degrees of ripeness were used—mature green and ¾ ripe fruits. Since avocadoes were usually received mature green, the ¾ ripe fruits were obtained by holding the mature green fruits for 5 to 7 days at 80°F before exposure to flies. After removal from ovipositional cages, fruits were held for 1, 3, or 5 days at 46°F in constant temperature cabinets. Another batch of fruits was held at room temperature (80°F) as a control. After 1-5 days of cold storage, each fruit was transferred to an organdy-covered plastic box containing dust-free grade fine vermiculite and held for 2 weeks at 80°F for pupal recovery.

Effect of holding fruits at 80°F prior to cold treatment. In this test mature green fruits were exposed to flies for 24-hours; held for 1, 2 or 3 days at 80°F; stored for 4, 3, or 2 days, respectively, at 46° or 55°F; and held in plastic boxes for 2 weeks at 80°F. Pupal counts were then made to determine survival.

Results

Field infestation. A very low incidence of field infestation by *D. dorsalis* in avocadoes was observed. In a single shipment of the variety Masutomi containing 33 fruits, 2 were ripe and bruised. From one of these, 3 pupae were recovered and 2 adults emerged while 7 pupae were recovered and 5 adults emerged from the other fruit. It was presumed that the ripeness and bruised condition of the fruit provided an ideal situation for oviposition. However, no field infestation was observed in any of the other varieties from a total of 1391 fruit examined.

Preliminary test. Oviposition by flies on avocadoes was observed. Eggs were either laid on the surface or inside the fruits. During a 24-hour exposure to 100 gravid females, an average of 355 eggs per fruit, 42.84 and 57.1% of which were surface laid and flesh laid, respectively, was observed. There were no shell laid eggs as in pineapple (Macion, et al., 1968). However, very little or no hatch was observed among the surface laid eggs because of dessiccation. Even with the thick skin of the mature green fruit, the female was able to insert her ovipositor and oviposit in the flesh. Larval mortality within the fruit was not determined since it was difficult to locate all of the larvae in the fruit. However, about 5 days after oviposition or before the rind of the fruit hardened we found it necessary to cut open the fruit for larvae to survive. If fruits were not cut open, the flesh became very dry, a condition unfavorable for larval development and survival. When avocadoes were not cut open, death of larvae occurred in the 2nd and 3rd instars.

Comparative tests on fruit ripeness. Some pupae were recovered from mature green and ripe fruits stored at 46° or 55°F, with ripe fruits being favored over mature green ones (Table 1). More pupae developed at 55° than at 46°F, and a decreasing trend of pupal recovery was observed as the length of cold storage was increased from 1 to 5 days. There was no pual recovery from mature green fruits stored at 46°F for 5 days. Most pupae were recovered from control fruits of the variety Ilialu for mature green, and from Rodrigues for ¾ ripe fruits, with averages of 58.0 and 353.7 pupae per fruit, respectively. Masami and Kahaluu varieties followed with 50.0 and 258.7 pupae per fruit. These data suggest a difference in pupal recovery even within varieties in relation to the degree of fruit ripeness.

TABLE 1. *Pupal recoveries from mature green and ¾ ripe avocadoes after storage at different temperatures.*[a,b]

Variety	Storage in days	Recovery from mature green fruits stored at 80°	46°	55°	Recovery from ¾ ripe fruits stored at 80°	46°	55°
Beardslee		12.5 b			52.2 d		
	1		0	2.5 a		11.7 b	36.7 c
	3		0	0		6.5 a	5.2 a
	5		0	0		0	4.0 a
Fujikawa		24.2 b			30.7 c		
	1		5.2 a	9.7 a		17.5 b	21.5 b
	3		0	5.7 a		6.7 a	9.2 a
	5		0	0		0	1.2 a
HAES 7315		7.2 a			66.0 c		
	1		0	11.2 a		27.7 b	44.0 c
	3		0	1.0 a		4.2 a	2.0 a
	5		0	0		0	4.2 a
Hashimoto		21.7 b			50.0 c		
	1		0.7 a	12.2 a		10.2 a	46.5 c
	3		0	3.5 a		2.2 a	6.5 a
	5		0	0		1.5 a	2.0 a
Ilialu		58.0 c			59.2 c		
	1		18.2 b	26.7 b		10.0 a	30.2 c
	3		0	3.7 a		3.5 a	4.2 a
	5		0	0		0	0.5 a
Itzamna		29.5 b			118.2 d		
	1		22.5 b	8.5 a		38.5 b	69.0 c
	3		0	0		27.2 b	23.5 b
	5		0	0		0.5 a	8.7 a
Kahaluu		43.5 b			258.7 d		
	1		7.7 a	8.2 a		145.2 c	246.5 d
	3		0	0		7.7 a	14.5 b
	5		0	9.0 a		0	1.2 a
Masami		50.0 c			124.0 d		
	1		4.2 a	53.7 c		70.2 c	83.2 c
	3		0	6.0 a		17.5 b	16.5 b
	5		0	0		0.5 a	5.5 a
Nishikawa		46.0 c			122.0 d		
	1		29.7 b	84.2 d		58.7 c	41.5 c
	3		1.5 a	19.2 b		3.0 a	16.0 b
	5		0	0		0	0
Rodrigues		38.0 b			353.7 e		
	1		2.0 a	6.0 a		126.2 d	135.0 d
	3		2.7 a	0		24.2 b	43.7 c
	5		0	0		3.0 a	5.5 a
Tsutsumi		16.0 b			158.0 c		
	1		3.5 a	6.2 a		21.5 b	3.0 a
	3		0	6.7 a		8.5 a	4.0 a
	5		0	0		0	2.5 a

[a]Means of 4 fruits per variety, each fruit a replicate.

[b]Means in the same row followed by the same letter are not significantly different from each other (Duncan's multiple range test).

Effect of cold storage treatments after holding fruits at 80°F. Storage at 46° or 55° after holding infested mature green fruits at 80°F for 1-3 days following 24 hours of oviposition significantly reduced, but did not completely eliminate larval development (Table 2). More pupae developed as the length of storage at 80°F was increased from 1-3 days. Holding avocadoes for 3 days at this temperature prior to cold treatment resulted in high pupal recovery due to a large number of larvae that survived the cold treatments. Usually, the presence of larvae was detected through exudates coming from the peduncle of the fruits.

TABLE 2. *Mean number of pupae recovered from avocadoes held at 80°F for 1-3 days before storage at 46° or 55°F.*[a]

		Holding period in days at 80°f before storage at					
	Control	*1*		*2*		*3*	
Variety	*at 80°F*	*46°*	*55°*	*46°*	*55°*	*46°*	*55°*
Ashikawa	54.2 b	14.8 a	11.7 a	8.2 a	10.2 a	--	--
Case	21.8 b	7.0 a	14.2ab	8.7 a	10.4 a	16.5ab	24.5 b
CRC 4-11	28.2 a	1.8 a	21.4 b	0	24.8 b	--	--
Fuerte	109.3 c	2.1 a	3.2 a	6.2 a	3.3 a	16.0 b	17.5 b
HAES 7315	27.4 c	10.7ab	4.6 a	6.7 a	19.2 b	--	--
HAL R5T8	26.7 a	1.4 a	19.7 b	2.4ab	20.2 b	--	--
Hashimoto	47.8 c	10.4 a	27.4 b	23.7 b	26.7 b	--	--
Itzamna	30.5 b	9.7 a	39.2 b	32.2 b	45.5 c	--	--
Masami	120.7 c	33.5ab	23.6 a	48.2 b	58.5 b	--	--
Murashige	224.3 c	4.2ab	5.2 a	8.7ab	9.7ab	--	--
Nishikawa	112.0 d	7.1 a	5.2 a	8.2 a	34.2 b	41.5 b	55.5 c
Rodrigues	254.7 e	20.3ab	66.7 c	8.7 a	93.6 d	39.2 b	109.7 d
Sharwil	69.8 d	3.6 a	9.7 a	20.2 b	7.3 a	59.2 c	29.2 b
Tsutsumi	36.4 a	38.7 c	72.9 b	47.7 b	44.5 b	--	--
Wahiawa	42.2ab	23.7 b	8.2ab	28.5 b	3.5 a	--	--

[a]All values were changed by logarithmic transformation (log x + 1). Any 2 means in the same row followed by the same letters are not significantly different from each other (Duncan's multiple range test at 5% P). Each mean represents 4 replications, 1 fruit/rep.

--No test conducted.

DISCUSSION

D. dorsalis larvae could develop in avocadoes under laboratory conditions, although different varieties differed in their susceptibility or capability of sustaining larvae. The apparent differential susceptibility probably was due to some physiological and biophysical characteristics of the fruit. Macion, et al. (1968), in their work on pineapples, found that the liquid content of the fruits, was determined by translucence readings and fruit specific gravity (which increases directly with ripeness) were the major biophysical factors involved in resistance of pineapple varieties to Oriental fruit flies.

The low degree of field infestation of avocadoes suggests that avocadoes are not a favored host of Oriental fruit flies under field conditions. It appears that fruits such as guavas, mangoes, papayas, and some others are more commonly infested at high Oriental fruit fly population levels. An increase in storage temperature from 46° to 80°F resulted in a corresponding increase in pupal recovery with the lowest (zero) recovery at 46°F. Similar findings were also obtained with pineapples and papayas (Wasti, 1968).

The low storage temperature at 46°F for 5 days could be utilized as commodity treatment for avocadoes being shipped to the mainland since it would kill all fruit fly eggs and some larvae. At 55°F, some eggs hatched and larvae developed to maturity. Messenger and Flitters (1959) found that storage of fruits at 52°F resulted in complete inhibition of egg hatch. In earlier research, the same authors (1954) reported that storage for short periods of 3-4 hours at 40°F and below killed all eggs, larvae and pupae of the 3 species of Hawaiian fruit flies. However, our results show that some larvae that were present prior to cold storage treatment at 46°F survived and developed into pupae. Therefore, other treatments are needed to free the avocadoes from fly infestation. The USDA Plant Quarantine Treatment Manual states that Hawaiian avocadoes must be fumigated at 32mg/liter of methyl bromide for 4 hours at 21.1°C (70°F) or above before shipment to the mainland to eliminate fly infestation. This treatment did not cause any injury in varieties like Kahaluu and Itzamna but produced surface discoloration in variety Fuerte (Akamine, 1963). Further studies at the USDA laboratory in Honolulu showed that a combination of fumigation at 32.6 g/m^3 of methyl bromide for 2.5 hour at 21.1°C and 6 days of post-fumigation storage at 7.2°C (45°F) may be utilized for avocadoes (Seo, et al., 1971).

For some thin skinned varieties of avocadoes a combination of fumigation and cold storage treatments therefore will be necessary to facilitate export of avocadoes to the mainland.

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Summary

Twenty varieties of avocadoes were exposed to female Oriental fruit flies (*Dacus dorsalis* Hendel) for 24 hours. When these avocadoes were stored at 46°F for 5 days no fly pupae were recovered, but at 55°F some pupae developed from larvae that survived the treatment. A decreasing trend of pupal recovery was observed as the length of cold storage was increased from 1-5 days. Survival of flies in avocadoes varied between varieties and even within variety, according to the stage of ripeness of the fruit. Pupal recoveries tended to be higher when the fruit was about ¾ ripe than when they were mature green. Storage at 46°F or 55°F after holding infested mature green avocadoes at 80°F for 1-3 days significantly reduced pupal recovery, although more pupae were recovered as the length of storage at 80°F was increased from 1-3 days.

The use of cold storage treatment at 46°F for 5 days for mature green fruit was sufficient to kill all *D. dorsalis* eggs. In some varieties larvae survived cold treatments of 1 and 3 days. Thus, a combination of cold storage treatment and other conventional control methods is necessary to completely eliminate infestations in some varieties of avocadoes.

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