Tephritid Fruit Fly Populations in a Dragonfruit Orchard in Hawaii: Border Plant Use and Infestation Rate

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Abstract. Dragonfruit, *Hylocereus undatus,* has been grown commercially in Southeast Asia, Australia, South America, Israel, and the United States. In Hawaii, commercial fruit production has recently begun, based on newly introduced varieties. Dragonfruit originating from Vietnam but intercepted in Japan has been found to be infested by oriental fruit fly, *Bactrocera dorsalis*, and melon fly, *B. cucurbitae*. Because both of these tephritid fruit fly species are present in Hawaii, there is risk of infestation by these species in Hawaii, and fruit export requires postharvest quarantine treatment for disinfestation. For dragonfruit production in Hawaii intended both for local sales and for export, there is a need to better understand the risk of infestation and to develop approaches to minimize chances of infestation. In support of the development of dragonfruit as a commercial crop in Hawaii, a dragonfruit orchard on the east side of the island of Hawaii was monitored over the 2007–2008 fruiting seasons in order to document the levels and spatial distribution of tephritid fruit fly field populations and the level of infestation, and to develop approaches for suppression of infestation. Low population levels (< 0.25 flies/trap/day) of both tephritid fruit fly species were present both seasons, with population detection most successful in traps placed in roosting host plants along the orchard border rather than within the orchard. Based on random fruit collections near the end of the production seasons, infestation rate in mature fruits increased from 4.1% and 6.1% (2007) to 28.0% and 8.0% (2008) for oriental fruit fly and melon fly, respectively. Approach to field suppression in this crop, which lacks host foliage, is discussed.

Key words: *Bactrocera dorsalis, Bactrocera cucurbitae, Hylocereus undatus*

Introduction

Hylocereus undatus (Haworth) Britton & Rose (Cactaceae), the night-blooming cereus, was apparently first introduced to Hawaii from Mexico about 1830. The variety introduced rarely, if ever, bore fruits, but fruits could form if flowers were hand-pollinated (Staples and Herbst 2005, Neal 1965). *Hylocereus undatus* fruits, called dragonfruit, have been cultivated in Vietnam for over 100 years and is also grown commercially in other Southeast Asian countries (e.g., Malaysia), Australia, South America (e.g., Columbia, Nicaragua), Israel, and the United States (Merten 2003). In Hawaii, commercial dragonfruit production has recently begun (Figure 1), based on newly introduced varieties. The varieties grown in the eastern portion of the island of Hawaii were introduced from Thailand and given the local names 'Sweetest One' and 'Pink Star'. Dragonfruit originating in Vietnam has been found, through import inspection in Japan, to be infested by both oriental fruit fly, *Bactrocera dorsalis* (Hendel), and melon fly, *B. cucurbitae* (Coquillett) (Diptera: Tephritidae), with subsequent laboratory forced infestation trials confirming the infestability by both fruit fly species (Iwaizumi et al. 1995). Because both fruit fly species are present in Hawaii, there is risk of infestation and fruit export requires postharvest quarantine disinfestation treatment (Wall

Figure 1. Dragonfruit (*Hylocereus undatus*) orchard in Kapoho, Hawaii. Surrounding second-growth ohia (*Metrosideros polymorpha*) forest can be seen at the right, behind the dragonfruit orchard.

and Khan 2008, Follett and Sanxter 2000). For dragonfruit production in Hawaii intended for local sales and export there is a need to better understand the risk of infestation and to develop approaches to minimize chances of infestation. Dragonfruit production, however, provides a challenge to the use of protein bait sprays as a tephritid fruit fly population suppression technique because dragonfruit plants lack leaves and bait sprays are typically applied to foliage of host plants (oriental fruit fly) or on leaves of plants on which these fruit fly species roost (oriental fruit fly and melon fly) (McQuate and Vargas 2007). Because dragonfruit is a relatively new crop for Hawaii there are few orchards where it is commercially produced. Additionally, those few orchards are split between the very different climates of the eastern (wetter) and western (drier) portions of the island of Hawaii. In support of the development of dragonfruit as a commercial crop in Hawaii, a dragonfruit orchard on the east side of the island of Hawaii was monitored over the 2007–2008 fruiting seasons in order to document tephritid fruit fly field population levels and spatial distribution, the levels of fruit infestation, and to develop approaches for suppression of infestation.

Materials and Methods

Site. The research was conducted on a 2-ha farm in Kapoho, Hawaii, cleared within a secondary-growth ohia (*Metrosideros polymorpha* Gaud.) forest. The center of the dragonfruit orchard is at about UTM Easting 00300886, Northing 2155535 m Zone 05 Q, and the farm elevation is 184 m at that point. The average annual rainfall of a National Weather Service rainfall station about 300 m distant from the farm (Kapoho Landing; National Weather Service ID: KAWH1; 88 m elevation) is 263.8 cm (averaged over the years 1963–2000). A weather station at the middle of the dragonfruit orchard recorded a similar

annual total for the period 1 Sept. 2008 to 31 Aug. 2009 (282.7 cm). The annual rainfall at the farm would be expected to average a bit higher than at Kapoho Landing because the dragonfruit farm is at a higher elevation. Two cultivars of dragonfruit ('Sweetest One' and 'Pink Star') were cultivated on over 500 posts, with multiple plants established on each post. The grower imported both varieties to Hawaii from Thailand and coined the variety names. Approximately 80% of the plants were 'Sweetest One'. The remaining plants ('Pink Star') were planted in rows that were interspersed between rows planted to 'Sweetest One'.

Figure 2. Protein-baited trap hung in castor bean (*Ricinus communis*) plants established along the dragonfruit orchard border. Also shown is the uluhe fern (*Dicranopteris linearis*; upper right corner) that dominates the second-growth ohia (*Metrosideros polymorpha*) forest understory surrounding the orchard.

Tephritid fruit fly population assessment. Tephritid fruit fly populations were monitored using yellow-bottom Multilure traps (Better World Manufacturing, Fresno, CA) baited with commercial torula yeast pellets (four parts torula yeast [Lake States Type B] and five parts dry borax decahydrate by weight, pressed into 5-g tablets, ERA International Ltd., Freeport, NY), dissolved at a rate of three tablets per 300 ml water in each trap. Traps were deployed after the beginning of the fruiting season in 2007 (17 Sep.) but were deployed before first fruit ripening in 2008 (16 Jul.). Traps were serviced weekly until after the last major harvest of the growing season (10 Dec. 2007; 12 Nov. 2008), with fresh bait provided every two weeks. In year 1 (2007), a total of nine protein-baited traps was established. Three were hung on wire fencing that supported dragonfruit branches and six were placed in the orchard border (three in large potted ornamental plants [*Bauhinia* sp., *Cassia* sp., and *Michelia alba*), one in a neem tree (*Azadirachta indica* A. Juss.), one in understory vegetation of *Acacia* sp. trees and one in understory vegetation of an ohia stand. Before the 2008 fruiting season, plants known to be roosting hosts of melon fly and oriental fruit fly (McQuate 2010, McQuate and Vargas 2007) were established along the orchard border to increase the potential tephritid fruit fly roosting sites where bait sprays could be applied. Twelve clusters of two plants each of castor bean, *Ricinus communis* L. (Fig. 2), and six clusters of three plants each of cassava, *Manihot esculenta* L., were established along the border encircling the dragonfruit orchard. A protein-baited trap was hung in the interior of each plant cluster (Fig. 2) as described in McQuate (2010) and McQuate and Vargas (2007). Protein-baited traps were also placed in three bordering potted pak lan plants, *Michelia* x *alba* A. P. de Candolle, and at three sites in association with bordering uluhe fern, *Dicranopteris linearis* (N. L. Burm.) Underw. (Fig. 2), which dominates the understory of the surrounding ohia forest. Overall, a total of 30 protein-baited traps was monitored weekly in 2008, 24 in the orchard border and six associated with dragonfruit plants in the orchard (Fig. 3).

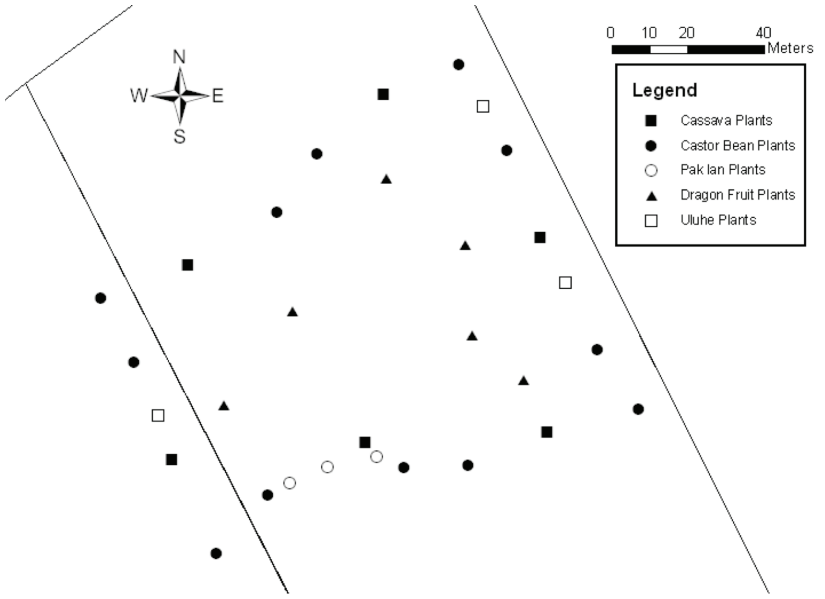

Figure 3. Locations of trap sites for the 2008 dragonfruit production season, including traps established in border plant clusters and traps within the dragonfruit orchard.

Fruit infestation rate. During the 2007 production year, five ripe dragonfruits thought to potentially be infested by tephritid fruit flies were collected on 10 October. Additionally, an additional 49 ripe fruits were randomly collected on 14 November, near the end of the fruiting season. During the 2008 production year, 50 ripe fruits were randomly collected on 12 November, again near the end of the fruiting season. All collected fruits were examined for external defects, weighed and placed individually in separate 4-liter screened-top plastic containers which had a layer of sand on the bottom to serve as substrate for pupariation. Fruits were held for at least two weeks at which time fruits and sand were processed for recovery of any tephritid pupariating larvae and pupae. Recovered pupariating larvae and pupae were then held in small screened cups with sand on the bottom and emerged adults identified by sex and species. Unemerged pupae were identified to species in 2007, but not in 2008. Total numbers of recovered pupae are presented in the summary table (see below), but results (e.g., number of individuals of a given species per kg fruit) and discussion focus on totals identified to species.

Statistical analyses. Trap catch was expressed as number of flies per trap per day. Significance of difference in catch between in-orchard traps and border traps, between catch in different roosting hosts, and in proportion of total trap catch in border vs in-orchard traps for each production year was assessed using a Wilcoxon signed-rank test (Sokal and Rohlf 1969) with statistical significance determined through tabled critical values (Rohlf and Sokal 1969).

Results

Tephritid fruit fly population assessment. Oriental fruit fly trap catch averaged (± SEM) 0.036 ± 0.012 (in-orchard) and 0.18 ± 0.046 (in border) flies/trap/day and melon fly

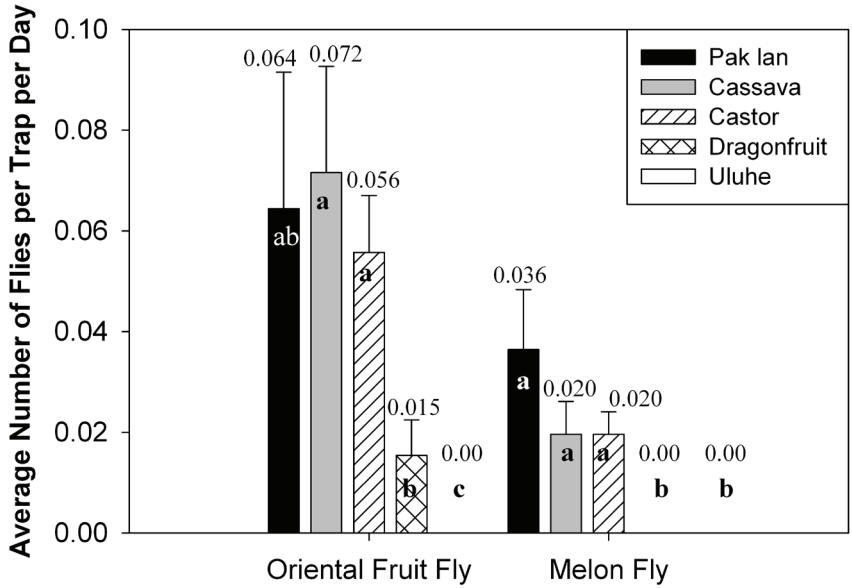

Figure 4. Average oriental fruit fly and melon fly catch (flies/trap/day) in traps placed in roosting host plant species established along the orchard border in the 2008 production season. For a given fruit fly species, columns with the same letter are not significantly different at the $\alpha = 0.05$ level.

trap catch averaged 0.097 ± 0.028 (in-orchard) and 0.20 ± 0.034 (in border) flies/trap/day over the course of the 2007 production season. For both oriental fruit fly (Ts = 0; n = 11) and melon fly (Ts = 2; n = 11), trap catch was significantly higher ($\alpha < 0.01$) in border traps than in traps in the orchard. There was no significant difference between species in the proportion of the flies caught in border traps versus in-orchard traps (Ts = 13.5; n = 10; $\alpha > 0.05$).

Oriental fruit fly trap catch averaged 0.015 ± 0.0071 (in-orchard) and 0.054 ± 0.0096 (in border) flies/trap/day and melon fly trap catch averaged 0.0 ± 0.0 (in-orchard) and 0.019 ± 0.0042 (in border) flies/trap/day over the course of the 2008 production season. Because number of traps used in 2007 and 2008 differed considerably, it was not possible to compare fly populations between the two production years. In 2008, there was, again, significantly higher catch of both oriental fruit fly (Ts = 12; n = 14; $\alpha = 0.0043$) and melon fly (Ts = 0; n = 13; $\alpha < 0.005$) in traps placed in border areas relative to traps placed within the dragonfruit orchard. No melon flies were caught in the in-orchard traps and there was a significantly higher proportion of flies caught in border versus in-orchard traps for melon fly relative to oriental fruit fly (Ts = 0; n = 7; $\alpha < 0.02$).

Average catch (flies per trap per day) of oriental fruit fly and melon fly among the different border plant sites in 2008 is presented in Figure 4. Neither fruit fly species was ever caught in the traps placed in uluhe fern, and no melon flies were ever caught in traps placed within the dragonfruit orchard. Among border plants, there was no significant difference in catch, for either oriental fruit fly or melon fly, in traps placed in castor bean, cassava, or pak lan. For oriental fruit fly, catch in traps placed in either castor bean or cassava (but not traps placed in pak lan) was significantly greater than catch within the dragonfruit orchard

or in the surrounding uluhe fern. The same was true for melon fly except that catch in pak lan was, also, significantly greater than catch within the dragonfruit orchard or in the surrounding uluhe fern.

Fruit infestation rate. Fruits were found to be infested by both oriental fruit fly and melon fly in both production years. No parasitoids were recovered from any of the infested fruits in either year. A summary of infestation rates of fruits is presented in Table 1. Locations of uninfested and infested fruits, together with numbers of oriental fruit fly and melon fly individuals recovered from each infested fruit, is presented in Figures 5A (2007) and 5B (2008). Infested fruits were on the eastern side of the orchard in 2007, but were distributed throughout the orchard in 2008. In 2007, two of the five nonrandomly selected fruits were found to be heavily infested by melon fly (averaging 272.0 fruit fly individuals per kg fruit), with no infestation by oriental fruit fly. In the 2007 random collection of 49 fruits, three fruits (6.1%) were infested by melon fly (averaging 13.8 individuals per kg fruit) with two of these (4.1%) also infested by oriental fruit fly (averaging 2.3 individuals per kg fruit). In the 2008 random collection of 50 fruits, a total of 15 fruits was infested (30.0%). Fourteen of these (28.0%) were infested by oriental fruit fly (averaging 16.3 individuals per kg fruit) and 4 (8.0%) were infested by melon fly (averaging 13.1 individuals per kg fruit). Three of those four fruits were also infested by oriental fruit fly.

Discussion

Dragonfruit grown in Hawaii is clearly subject to field infestation by both oriental fruit fly and melon fly, necessitating field control measures to minimize infestations and post-harvest quarantine treatment of fruits to be exported from Hawaii. In both seasons, population detection was better for both fly species in traps placed in plants that bordered the dragonfruit orchard rather than in association with randomly selected dragonfruit plants within the orchard. Detection in traps associated with dragonfruit plants, though, may be improved if traps would be primarily associated with dragonfruit plants located on the outer borders of the orchard. Addition of known roosting host plants along the borders of the orchard provided trap sites that improved fly catch relative to traps placed in the uluhe fern understory that surrounded the dragonfruit orchard or traps associated with dragonfruit plants. The added roosting host plants could be used as sites for bait spray application, which could help in population suppression. Ongoing research will look at the application of protein bait sprays to these established roosting plants, as well as the possibility of establishing in-orchard bait stations (e.g., Piñero et al. 2009), as sites for application of toxicant-containing protein baits.

Acknowledgments

I thank Glenn Asmus for technical assistance in the establishment of roosting plants along borders of the dragonfruit orchard, field trapping, fruit collections, and processing of fruits for assessment of infestation by tephritid fruit flies; Charmaine Sylva for technical assistance in the establishment of roosting plants along borders, fruit collections, and the preparation of site maps; and Dragonfruit Farms for supporting this research. I also thank Wee L. Yee, Nicanor J. Liquido, and two anonymous reviewers for constructive comments on earlier drafts of the manuscript.

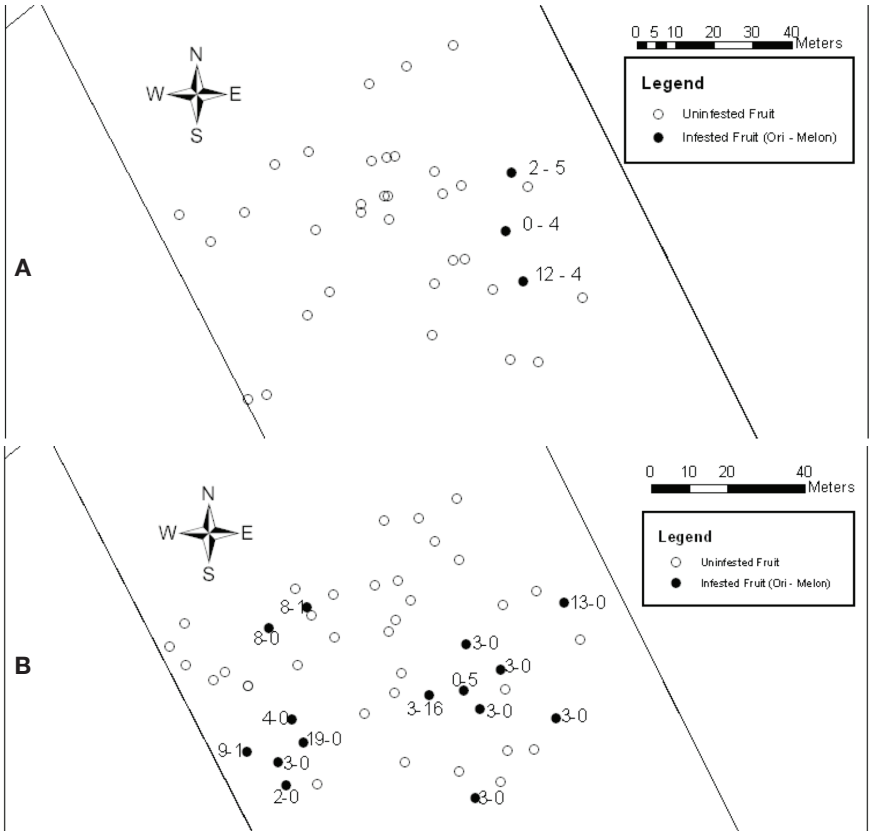

Figure 5. In-orchard location of uninfested and infested dragonfruits collected near the end of the production season. Also given are the numbers of tephritid fruit fly individuals (presented as "number of oriental fruit flies" – "number of melon flies") recovered from each infested fruit. A. 2007 production year; B. 2008 production year.

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Table 1. Summary of infestation by tephritid fruit flies in dragonfruit collections from 2007 to 2008.

Collection date	No. of fruits	Total fruit weight (kg)	Total no. tephritid pupae	No. fruits infested by *B. dorsalis*	Total no. *B. dorsalis* pupae	No. *B. dorsalis* per kg infested fruit	No. Fruits infested by *B. cucurbitae*	Total no. *B. cucurbitae* pupae	No. *B. cucurbitae* per kg infested fruit	Total no. unidentified pupae
10/10/07	5	0.9	120	0	0	0	2	120	272.0	0
11/14/07	49	13.0	30	2	14	2.3	3	13	13.8	3
11/12/08	50	15.5	167	14	84	16.3	4	23	13.1	60

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