Field Infestation of Rambutan Fruits by Internal-Feeding Pests in Hawaii

GRANT T. McQUATE, PETER A. FOLLETT, AND JUDY M. YOSHIMOTO

U.S. Pacific Basin Agricultural Research Center, USDA-ARS, P.O. Box 4459, Hilo, HI 96720

J. Econ. Entomol. 93(3): 846–851 (2000)

ABSTRACT More than 47,000 mature fruits of nine different varieties of rambutan (*Nephelium lappaceum* L.) were harvested from orchards in Hawaii to assess natural levels of infestation by tephritid fruit flies and other internal feeding pests. Additionally, harvested, mature fruits of seven different rambutan varieties were artificially infested with eggs or first-instars of Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), or oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) to assess host suitability. When all varieties were combined over two field seasons of sampling, fruit infestation rates were 0.021% for oriental fruit fly, 0.097% for *Cryptophlebia* spp. (Lepidoptera: Tortricidae), and 0.85% for pyralids (Lepidoptera). Species of *Cryptophlebia* included both *C. illepida* (Butler), the native Hawaiian species, and *C. ombrodelta* (Lower), an introduced species from Australia. *Cryptophlebia* spp. had not previously been known to attack rambutan. The pyralid infestation was mainly attributable to *Cryptoblabes gnidiella* (Milliere), a species also not previously recorded on rambutan in Hawaii. Overall infestation rate for other moths in the families Blastobasidae, Gracillariidae, Tineidae, and Tortricidae was 0.061%. In artificially infested fruits, both species of fruit fly showed moderately high survivorship for all varieties tested. Because rambutan has such low rates of infestation by oriental fruit fly and *Cryptophlebia* spp., the two primary internal-feeding regulatory pests of rambutan in Hawaii, it may be amenable to the alternative treatment efficacy approach to postharvest quarantine treatment.

KEY WORDS *Bactrocera dorsalis, Ceratitis capitata, Cryptophlebia, Cryptoblabes gnidiella, Nephelium lappaceum*

RAMBUTAN (*Nephelium lappaceum* L.), sometimes called the "hairy" lychee, is a tree fruit native to Malaysia and Indonesia and is widely grown in Southeast Asia. It is also common in Australia, South and Central America, the Caribbean, India, Sri Lanka, Florida, and Hawaii (Lim 1992, Zee 1993, Zee et al. 1998). In Hawaii, rambutan currently is a focal crop of a rapidly expanding tropical specialty fruit industry. However, the tropical specialty fruit industry faces serious quarantine problems because commodities grown in Hawaii that are hosts of pest tephritid fruit flies are subject to a Federal quarantine.

Currently, rambutan is a host for both the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Osman Mohd and Chettanachitara 1987, Tindall 1994, USDA 1996) and the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (USDA 1996) (Diptera: Tephritidae) so that rambutan requires disinfestation treatment before export to the continental United States. This study was designed to determine field infestation rates for fruit flies and other internal feeding pests on Hawaii-grown rambutan, and to assess the host suitability of rambutan for *B. dorsalis* and *C. capitata.* These data could then be used in the development of appropriate disinfestation treatments.

This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation by the USDA for its use.

Materials and Methods

Field Census. Nine different varieties of rambutan fruits ('Binjai', 'Gula Batu' [also referred to as 'R-3'], 'R-7', 'R-156 Red', 'R-156 Yellow', 'R-162', 'R-167', 'Rongrien', and 'Seelengkeng') and one unknown variety were collected over the course of two field seasons from orchards in Hakalau, Kainaliu, Kurtistown, and Onomea on the island of Hawaii, and Kilauea on the island of Kauai. Collections for the first field season were made from 16 September 1994 to 22 February 1995. Collections for the second field season were made from 16 August 1995 to 20 March 1996. Harvested fruits were mature with stems attached. After collection, fruits were placed in fruit fly-proof holding containers and transported to the laboratory where each fruit was assigned a number, weighed, and examined for any blemishes. Fruits were then placed individually in perforated 7.6 by 12.7-cm Ziplock bags (LK Plastics, Los Angeles, CA) containing 10 ml of clean sand to serve as an environment for pupation and adult eclosion. Bags were placed on trays in screened cabinets and held at ambient temperature for at least 3 wk to permit development of any internal-feeding pests, before processing the fruits. Processing consisted of removing pupating larvae and pupae from the sand and fruit in each bag and transferring them to small plastic cups (0.25 liter) containing a small amount of sand for pupation, with tissue paper added for any recovered caterpillars. After emergence and the death of any adults, dead larvae were sifted from the sand and transferred to 70% alcohol, and dead pupae and emerged adults were transferred to (dry) vials for subsequent identification.

Artificial Infestation. *Insects.* Mediterranean and oriental fruit flies used for infestation studies were obtained as pupae from a continuous laboratory colony at the USDA-ARS Tropical Fruit, Vegetable and Ornamental Crop Research Laboratory in Honolulu, HI, now part of the U.S. Pacific Basin Agricultural Research Center. Fruit flies used in our tests were kept in an insectary at 24–27°C, 65–70% RH, and a photoperiod of 12:12 (L:D) h. Adults were fed water and a diet consisting of three parts sucrose, one part protein yeast hydrolysate (Enzymatic, United States Biochemical, Cleveland, OH), and 0.5 part torula yeast (Lake States Division, Rhinelander Paper, Rhinelander, WI). Oriental fruit fly adults were at least 8 d old and Mediterranean fruit fly adults were at least 7 d old when eggs were collected.

General Methods. Four varieties of rambutan were used in 1995 ('Binjai', 'R-156 Yellow', 'R-162', and 'R-167'), and three varieties in 1996 ('R-7', 'R-9', and 'Rongrien') for artificial infestation trials. Peaches, which were mature but firm, were obtained from a local grocery store and used in 1995 as a control fruit. Papayas were used in 1996 as a control fruit and were collected at a mature green or color break stage from a local packing house and held in containers that excluded fruit flies until they were fully ripe. In 1995, rambutan and peaches were artificially infested with (1) 20 Mediterranean fruit fly eggs, (2) 20 oriental fruit fly eggs, (3) 20 Mediterranean fruit fly first instars (<2 h old), and (4) 20 oriental fruit fly first instars. For each of these treatments, 24 fruits of each rambutan variety and 24 peaches were artificially infested. In 1996, 28 fruits of each rambutan variety and 28 papayas were used for each of the same egg and first-instar infestations. Before artificial infestation, fruits were all soaked for 2 min in a 5% bleach solution to reduce surface pathogens, allowed to air dry, and then weighed.

Egg Infestation. Eggs were handled with a fine-tip paint brush and placed onto pieces of moist, presoaked blotter paper in petri dishes. Eggs were precounted in sets of 20 eggs on blotter paper, which facilitated transfer from blotter paper to fruit. For rambutan, a small flap of skin (pericarp) was sliced open and eggs were inserted on top of the flesh (aril) toward the back edge of the flap. The flap was then closed and fruits were placed in a plastic cup (7 cm diameter by 7 cm high) with 10 ml of clean sand and covered with a screened lid. For peaches and papayas, eggs were inserted into a 3.0- to 6.0-mm deep incision in the flesh. Fruits were then placed on hardware cloth stands over 100 ml clean sand in 1-liter plastic buckets with screened plastic lids. Four days after the Mediterranean fruit fly eggs were inserted, subsamples of five fruits of each variety of rambutan and five of the peach/papaya controls were opened to determine percentage egg hatch. Egg hatch was similarly determined for fruits artificially infested with oriental fruit fly eggs.

First-Instar Infestation. Eggs were placed on moist, presoaked blotter paper and held in petri dishes sealed in Ziplock bags and placed in an environmental chamber. Oriental fruit fly eggs were held at 26°C for 32 h. Mediterranean fruit fly eggs were held at 24°C for 48 h. Before egg hatch, a small piece of rambutan fruit (1995, variety 'R-167'; 1996, variety 'Rongrien') was added to the blotter paper to provide a food source for larvae from egg hatch until the time of their insertion into the rambutan fruits. First instars were precounted in sets of 20 on separate pieces of blotter paper in petri dishes before placement in fruits as described for egg infestation. All fruits artificially infested by eggs or first instars were placed in an environmental chamber held at 26°C and 70% RH and held for at least 3 wk before assessment of survivorship.

Statistical Analysis. Data on percent adult survival after artificial infestation were arcsine transformed and then subjected to analysis of variance (ANOVA) with mean separations conducted using the Waller–Duncan *K*-ratio *t*-test (SAS Institute 1990).

Results

Field Census. A total of 47,188 rambutan fruits was collected over the two field seasons to assess levels of infestation of internal pests. Average fruit weights (±SEM) by variety are presented in Table 1. When all varieties were combined over both field seasons, fruit infestation rates were 0.021% for *B. dorsalis,* 0.097% for *Cryptophlebia* spp. (Lepidoptera: Tortricidae), and 0.85% for pyralids (Lepidoptera). Infestation rates by cultivar for *B. dorsalis, Cryptophlebia* spp., and pyralids are presented in Table 1. Mediterranean fruit fly was not recovered from any of the fruit collections. Species of *Cryptophlebia* included both *C. illepida* (Butler), the native Hawaiian species, and *C. ombrodelta* (Lower), an introduced species from Australia. Twenty-one fruits overall (0.044%) (Table 1) were infested by *Cryptophlebia* spp. However, in addition to that observed infestation, 26 bags were found to have a hole in the bag (and were dropped from our analysis, overall) as would be produced by *Cryptophlebia* spp. larvae chewing through the bag. Although no *Cryptophlebia* spp. were found in these bags, the propensity of these species to chew through plastic bags, combined with a concern not to under-represent infestation levels by these species, commends us to list these additional bags as having *Cryptophlebia* spp. infestation (Gula Batu [4]; R-156 Red [2]; R-156 Yellow [3]; R-162 [1]; R-167 [2]; Rongrien [3]; Unknown [11]). This would give a total of 47 fruits infested by *Cryptophlebia* spp. out of 48,214 fruits, or an infestation rate of 0.097%. A subset of 34 pyralids, which included observed morphological variation as well as specimens recovered from each of the rambutan varieties, from

Table 1. Summary of infestation of rambutan varieties by *Bactrocera dorsalis*, *Cryptophlebia* spp., and by pyralid species

Variety	No. fruit collected			Weight, gm	*Bactrocera dorsalis*[a]				*Cryptophlebia* spp.[b]				Pyralidae[c]			
	Season 1	Season 2	Total	Mean ± SEM	No. infested fruit	% fruit infested	No. larvae	Mean no. larvae per infested fruit	No. infested fruit	% fruit infested	No. larvae	Mean no. larvae per infested fruit	No. infested fruit	% fruit infested	No. larvae	Mean no. larvae per infested fruit
Binjai	425	6,000	6,425	38.69 ± 0.10	0	0.0	0	0.0	0	0.0	0	0.0	7	0.109	10	1.43
Gula Batu (R-3)	45	1,797	1,842	35.34 ± 0.13	0	0.0	0	0.0	0	0.0	0	0.0	73	3.963	129	1.77
R-7		2,000	2,000	36.10 ± 0.13	0	0.0	0	0.0	0	0.0	0	0.0	6	0.300	6	1.00
R-156 Red		5,998	5,998	42.94 ± 0.15	7	0.117	24	3.43	1	0.017	1	1.00	8	0.133	8	1.00
R-156 Yellow		3,997	3,997	27.73 ± 0.10	0	0.0	0	0.0	0	0.0	0	0.0	41	1.026	55	1.34
R-162	3,064		3,064	40.02 ± 0.13	0	0.0	0	0.0	3	0.098	3	1.00	13	0.424	14	1.08
R-167	9,997		9,997	38.26 ± 0.08	2	0.020	8	4.00	2	0.020	2	1.00	25	0.250	26	1.04
Rongrien		4,997	4,997	35.36 ± 0.09	0	0.0	0	0.0	2	0.040	2	1.00	88	1.761	104	1.18
Seelengkeng	4,983		4,983	39.20 ± 0.11	0	0.0	0	0.0	9	0.181	9	1.00	52	1.044	59	1.13
Unknown	1,394	2,491	3,885	33.75 ± 0.14	1	0.026	1	1.0	4	0.103	7	1.75	90	2.317	143	1.59
Overall	19,908	27,280	47,188		10	0.021	33	3.30	21	0.044	24	1.14	403	0.854	554	1.37

[a] Totals for *Bactrocera dorsalis* include two fruits (1–'R-167' and 1-unknown variety) infested by *Biosteres longicaudata*, a tephritid fruit fly parasite. Only one parasite was found in each of these fruits.
[b] Overall infestation rate by *Cryptophlebia* spp. would be 0.097% (47 fruits infested out of 48,214 fruits) if one includes the 26 bags found to have a hole in the bag. See text for discussion.
[c] Most, if not all of the pyralids are *Cryptoblabes gnidiella* (Milliere).

each of the sites, and from both years, were all identified as *Cryptoblabes gnidiella* (Milliere). Therefore, most, if not all, of the pyralids collected are assumed to have been this species, which had not previously been collected on rambutan in Hawaii. In our study, 37.2% of pyralid-infested fruits had been noted to have mealybugs and/or scale present compared with only 13.9% mealybug and/or scale infested fruits overall. This association with Homoptera infestation was highly significant ($\chi^2 = 183$, df = 1, $P < 0.005$). Several other moths also emerged from rambutan in our census, including tineids (0.023% infestation, including *Chloropleca* sp.), the tortricid *Amorbia emigratella* Busck (0.015% infestation), blastobasids (0.013% infestation), and gracillariids (0.011% infestation). Except as noted, these moths were not identified beyond the family level. A small percentage of fruits collected were infested by insects that did not develop sufficiently to permit identification or were unidentifiable because of poor condition.

Most rambutan infested by internal feeding insects had no external signs of infestation. For example, over all varieties, three of 10 fruits infested by *B. dorsalis*, 18 of 21 fruits infested by *Cryptophlebia* spp., and >67.0% of the fruits infested by pyralids had no readily apparent external signs of infestation. From a quarantine standpoint, this suggests that culling fruits based on signs of infestation, a common practice in the industry, cannot reliably remove all infested fruits.

Artificial Infestation. *Egg Infestation.* For both Mediterranean fruit fly and oriental fruit fly, observed egg hatch was not significantly different in rambutan and control fruits. Percentage survival to adult stage of eggs of Mediterranean fruit fly and oriental fruit fly artificially infested in rambutan and control fruits in both 1995 and 1996 are presented in Fig. 1 A and B, respectively. For Mediterranean fruit fly egg-infested fruits, there were significant differences in infestation among rambutan varieties tested in 1995 ($F = 3.05$; df = 4, 115; $P = 0.0199$) but not among varieties tested in 1996 ($F = 1.24$; df = 3, 108; $P = 0.2977$). Percentage survival to adults among rambutan varieties tested in 1995 ranged from 31.5% (±3.3% [±SEM]; R-167) to 45.2% (±4.3%; R-162) compared with 31.2% (±4.5%) in peach. Percentage survival to adults in 1996 averaged 53.2% (±4.3%) among rambutan varieties and 40.9% (±6.5%) in papaya.

For oriental fruit fly egg-infested fruits, there were significant differences in infestation between rambutan varieties and the control, but not among varieties, tested in 1995 ($F = 13.32$; df = 4, 115; $P < 0.0001$) and significant differences among varieties tested in 1996 ($F = 9.25$; df = 3, 108; $P < 0.0001$). In 1995, percentage survival to adults among rambutan varieties averaged 65.9% (±3.2%) compared with 37.5% (±3.9%) in peach. Percentage survival to adults among rambutan varieties tested in 1996 ranged from 51.4% (±3.0%; R-9) to 65.2% (±2.1%; R-7) compared with 42.1% (±4.5%) in papaya.

First-Instar Infestation. For fruits infested with first instar Mediterranean fruit flies (Fig. 2A), there were

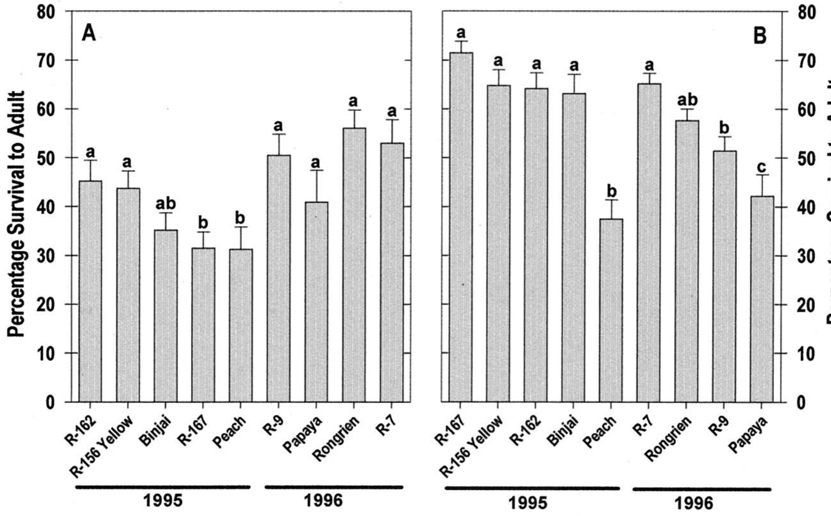

Fig. 1. Percentage survival (mean ± SEM) to adult stage of tephritid fruit fly eggs artificially infested in different varieties of rambutan fruits, relative to control fruits (1995, peach; 1996, papaya). Letters at the top of the bars refer to results of ANOVAs performed by year. Percentage survival was not significantly different where adjacent columns have the same letter. (A) Mediterranean fruit fly egg infestation. (B) Oriental fruit fly egg infestation.

significant differences in infestation among varieties tested in 1995 ($F = 6.62$; df = 4, 115; $P < 0.0001$) and also among varieties tested in 1996 ($F = 6.12$; df = 3, 108; $P = 0.0007$). Percentage survival to adults among rambutan varieties tested in 1995 ranged from 47.1% (±4.7%; R-167) to 64.2% (±3.7%; R-162) compared with 37.1% (±4.7%) in peach. Percentage survival to adults among rambutan varieties tested in 1996 ranged from 40.9% (±3.3%; R-7) to 61.4% (±2.9%; R-9) compared with 57.5% (±5.0%) in papaya.

For fruits infested with first-instar oriental fruit flies (Fig. 2B), there were significant differences in infestation between rambutan varieties and the control, but not among varieties, tested in 1995 ($F = 16.15$; df = 4, 115; $P < 0.0001$) and no significant differences among varieties tested in 1996 ($F = 1.20$; df = 3, 108; $P = 0.3119$). Percentage survival to adults in 1995 averaged 64.1% (±2.8%) among rambutan varieties tested and 32.3% (±4.2%) in peach. Percentage survival to adults in 1996 averaged 45.1% (±3.2%) among rambutan varieties tested and 48.8% (±4.1%) in papaya.

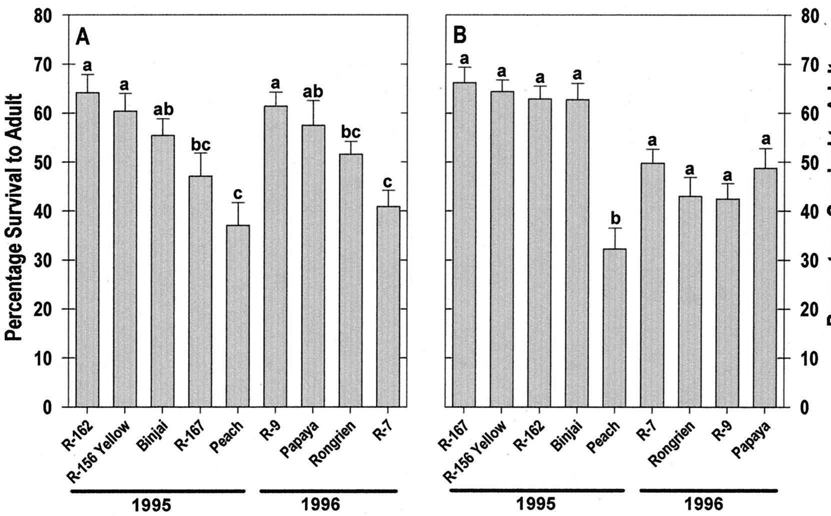

Fig. 2. Percentage survival (mean ± SEM) to adult stage of tephritid fruit fly first instars artificially infested in different varieties of rambutan fruits, relative to control fruits (1995, peach; 1996, papaya). Letters at the top of the bars refer to results of ANOVAs performed by year. Percentage survival was not significantly different where adjacent columns have the same letter. (A) Mediterranean fruit fly first-instar infestation. (B) Oriental fruit fly first-instar infestation.

Discussion

The low infestation rates in the field make it difficult to draw conclusions about the relative infestability of different rambutan varieties by various insect pests. Therefore, infestation results are discussed in terms of all varieties combined. Field infestation rate of rambutan by oriental fruit fly in this study was low (0.021%). This finding agrees with assessments of *B. dorsalis* on rambutan fruits in Southeast Asia (Osman Mohd and Chettanachitara 1987, Tindall 1994). The spinterns on the fruit are thought to interfere with *B. dorsalis* oviposition (Osman Mohd and Chettanachitara 1987). Our data showing low tephritid fruit fly infestation in the field but moderately high survival of Mediterranean fruit fly and oriental fruit fly on artificially infested rambutan fruits in the laboratory support this hypothesis. However, other properties of the pericarp, such as thickness, may also be important.

Cryptophlebia illepida (Butler) and *C. ombrodelta* (Lower) were found attacking rambutan for the first time. *Cryptophlebia* spp. are internal feeders and therefore pose a quarantine threat similar to fruit flies. *Cryptophlebia* spp. are federally regulated pests previously known to attack two other sapindaceous fruits, lychee (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.). Eggs are laid singly on the fruit surface and newborn larvae bore through the skin and feed at the skin/pulp interface. Typically, only one larva is found feeding in a fruit. Export of lychee fruits from Hawaii requires a hot water immersion or irradiation treatment for fruit fly disinfestation, and requires that fruits be free of *Cryptophlebia* spp. (Anonymous 1997). *Cryptophlebia* spp. are not currently regulated pests on rambutan. Rambutan exported from Hawaii, however, must undergo an irradiation treatment with a minimum absorbed dose of 250 Gy for disinfestation of tephritid fruit flies (Anonymous 1997). This treatment can also disinfest rambutan fruits of any *Cryptophlebia* spp. (P.A.F., unpublished data).

Cryptoblabes gnidiella also was not previously recorded from rambutan in Hawaii. The infestation rate by *C. gnidiella* (up to 0.85%, overall) was higher than both *B. dorsalis* and *Cryptophlebia* spp. This pyralid was first recorded in Hawaii on Oahu in 1905 and was initially identified as *Cryptoblabes aliena* Swezey (Zimmerman 1958), although it was subsequently determined to be synonymous with *Cryptoblabes gnidiella* (Milliere) (Zimmerman 1972). *C. gnidiella* was first described from France but is now widely distributed throughout the warmer parts of the world and has been reported from Eurasia, Africa, Malaysia, and Bermuda (Zimmerman 1972). It is a pest of grapes, citrus, loquat, pomegranates, and avocado in Israel (Avidov and Gothilf 1960, Ascher et al. 1983, Yehuda et al. 1991–1992). *C. gnidiella* often infests fruits as a secondary pest, feeding on honeydew and refuse produced by Homoptera, but it can also be a primary pest (Wysoki et al. 1993). It is capable of developing on mealybug refuse alone, and on some fruits (e.g., grapefruit) larval survival is dependent on the presence of mealybugs or their refuse. However, on other fruits (e.g., grapes) there is no difference in development of larvae on mealybug-infested versus noninfested fruits (Avidov and Gothilf 1960). The significant association of *C. gnidiella* and Homoptera in this study suggests *C. gnidiella* may be primarily a secondary pest. Further research is needed to assess the pest status of this species on rambutan.

In addition to *Cryptophlebia* spp. and *Cryptoblabes gnidiella,* several other moths were recorded infesting rambutan at very low levels. A number of lepidopterous pest species have been recorded in other areas where rambutan is cultivated. The primary fruit borer in Southeast Asia is the gracillariid, *Conopomorpha cramerella* (Snellen). *Conopomorpha cramerella* oviposits on young fruits, which often show no external symptoms of infestation because the larvae feed beneath the fruit skin (Osman Mohd and Chettanachitara 1987, Tindall 1994, Yaacob and Subhadrabandhu 1995). The gracillariid found in our collections was not identified to species, but *C. cramerella* is not reported to occur in Hawaii. Additional lepidopterous pests of rambutan fruits in Southeast Asia include *Deudorix epijarbas cinnabarus* Fruh. (Lycaenidae), *Dichocrocis puntiferalis* Guen. (Pyraustidae), *Dichomeris indiserta* Meyr. (Gelechiidae), *Eublemma versicolora* Walk. (Noctuidae), and *Tirathala rufivena* Walk. (Pyralidae) (Ahmad and Ho 1980, Osman Mohd and Chettanachitara 1987). None of these species have been recorded in Hawaii, although two other species of *Dichomeris* [*D. acuminata* (Staudinger) (alfalfa leaftier) and *D. aenigmatica* (Clarke)] and one other species of *Eublemma* [*E. accedens* (Felder & Rogenhofer)] have been recorded.

The methodology employed in this study was designed to detect insect species that penetrate and subsequently feed inside rambutan fruits. Although some surface pests, such as mealybugs, were noted we did not attempt to summarize infestation by surface-feeding pests. Rambutan can be attacked by five other surface-feeding regulatory pests: red wax scale, *Ceroplastes rubens* Maskell; green scale, *Coccus viridis* (Green); gray pineapple mealybug, *Dysmicoccus neobrevipes* Beardsley; yellow flower thrips, *Frankliniella schultzei* (Trybom); and pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (USDA 1996). Infestation rates of mealybugs and other surface pests need further attention because they may contribute to infestation by *Cryptoblabes gnidiella* and are, themselves, also regulatory pests whose presence potentially could interrupt fruit shipments.

The quarantine treatments currently available (irradiation) or proposed (high-temperature-forced-air) for rambutan from Hawaii were developed by treating hundreds of thousands of insects to meet the probit 9 efficacy standard. The probit 9 standard (99.9968% treatment efficacy or a maximum of 32 survivors in a million treated individuals) was initially recommended with fruit flies and heavily infested fruit in mind (Baker 1939), and has been the guiding principle in quarantine research. However, this standard may be too stringent for quarantine pests in commodities that are poor, or rarely infested hosts (Landolt et al. 1984, Vail et al. 1993). The "alternative treatment efficacy" approach measures risk as the probability of a mating pair, gravid female, or parthenogenic individual surviving in a shipment (Liquido et al. 1997). This approach may be more appropriate than probit 9 level quarantine treatment for commodities with low infestation rates. Because rambutan is a poor host for its main regulatory pests, *B. dorsalis* and *Cryptophlebia* spp., it may be amenable to the alternative treatment efficacy approach to development of postharvest quarantine treatments.

Acknowledgments

We thank N. J. Liquido for his role in initiating this study and the cooperating farmers for allowing us to harvest rambutan fruits. We thank G. Asmus, C. Brinkman, R. Ijima (USDA-ARS, Kapaa, HI), P. Barr, Z. Gabbard, R. Gibbons, E. Matias, R. Morton, J. Ross, S. Souza, C. Sylva (USDA-ARS, Hilo, HI), P. Bianchi, T. Burke, D. DeMello, Jr., N. Dollar, H. Llantero, M. L. Marshall, S. Marshall, G. Ross, and A. Uehara (UH-Hilo, HI) for assistance in picking and/or processing fruit samples. We thank P. Barr for assistance in data management. We thank J. W. Brown (USDA-Systematic Entomology Laboratory, Washington, DC) for assistance in identification of *Cryptophlebia* spp. and S. Miller (Bishop Museum, Honolulu, HI), B. Kumashiro (Hawaii State Department of Agriculture, Honolulu, HI), and D. Adamski (USDA-Systematic Entomology Laboratory, Washington, DC) for assistance in identification of microlepidoptera. We thank V. P. Jones, R. A. Franqui, S. A. Allan, and one anonymous reviewer for constructive comments on earlier drafts of the manuscript.

References Cited

Ahmad, Y., and T. H. Ho. 1980. List of economic pests, host plants, parasites and predators in West Malaysia (1920–1978). Bulletin 153. Ministry of Agriculture, Kuala Lumpur, Malaysia.

Anonymous. 1997. Papaya, carambola, and litchi from Hawaii. Fed. Reg. 62: 36967–36973.

Ascher, K.R.S., M. Eliyahu, E. Gurevitz, and S. Renneh. 1983. Rearing the honeydew moth, *Cryptoblabes gnidiella*, and the effect of diflubenzuron on its eggs. Phytoparasitica 11: 195–198.

Avidov, Z., and S. Gothilf. 1960. Observations on the honeydew moth (*Cryptoblabes gnidiella* Milliere) in Israel. Ktavim 10: 3–4.

Baker, A. C. 1939. The basis for treatment of products where fruit flies are involved as a condition for entry into the United States. USDA Circ. 551.

Landolt, P. J., D. L. Chambers, and V. Chew. 1984. Alternative to the use of probit 9 mortality as a criterion for quarantine treatments of fruit fly (Diptera: Tephritidae)-infested fruit. J. Econ. Entomol. 77: 285–287.

Lim, T. K. 1992. Rambutan industry in the Northern Territory—current status, research and development emphasis. Acta Hortic. 321: 62–70.

Liquido, N. J, R. L. Griffin, and K. W. Vick, eds. 1997. Quarantine security for commodities: Current approaches and potential strategies. Proceedings of joint workshops of the Agricultural Research Service and the Animal Plant Health Inspection Service, 5–9 June and 31 July–4 August 1995. USDA-ARS 1996–04.

Osman Mohd, S. B., and C. Chettanachitara. 1987. Postharvest insects and other pests of rambutan, pp. 57–60. *In* P. F. Lam and S. Kosiyachinda [eds.], Rambutan: fruit development, postharvest physiology and marketing in ASEAN. ASEAN Food Handling Bureau, Kuala Lumpur, Malaysia.

SAS Institute. 1990 SAS user's guide, version 6.10. SAS Institute, Cary, NC.

Tindall, H. D. 1994. Rambutan cultivation. FAO Plant Production and Protection Paper 121. Food and Agriculture Organization (FAO) of the United Nations, Rome.

USDA. 1996. Movement of rambutan fruit, *Nephelium lappaceum*, from Hawaii into other regions of the United States. Qualitative, pathway-initiated pest risk assessment. *In* Pest Risk Assessments—Hawaiian Fruits, vol. 1. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Biological Assessment and Taxonomic Support, Riverdale, MD.

Vail, P. V., J. S. Tebbet, B. E. Mackey, and C. E. Curtis. 1993. Quarantine treatment: A biological approach to decision-making for selected hosts of codling moth (Lepidoptera: Tortricidae). J. Econ. Entomol. 86: 70–75.

Wysoki, M., S. B. Yehuda, and D. Rosen. 1993. Reproductive behavior of the honeydew moth, *Cryptoblabes gnidiella.* Invertebr. Reprod. Dev. 24: 217–224.

Yaacob, O., and S. Subhadrabandhu. 1995. The production of economic fruits in Southeast Asia. Oxford University Press, New York.

Yehuda, S. B., M. Wysoki, and D. Rosen. 1991–1992. Phenology of the honeydew moth, *Cryptoblabes gnidiella* (Milliere) (Lepidoptera: Pyralidae), on avocado in Israel. Israel J. Entomol. 25–26: 149–160.

Zee, F. T. 1993. Rambutan and pili nuts: potential crops for Hawaii, pp. 461–465. *In* J. Janick and J. E. Simon [eds.], New crops. Wiley, New York.

Zee, F. T., H. T. Chan, Jr., and C.-R. Yen. 1998. Lychee, longan, rambutan, and pulasan, pp. 290–335. *In* P. E. Shaw, H. T. Chan, Jr., and S. Nagy [eds.], Tropical and subtropical fruits. Agscience, Auburndale, FL.

Zimmerman, E. C. 1958. Insects of Hawaii, vol. 8. Lepidoptera: Pyraloidea. University of Hawaii Press, Honolulu.

Zimmerman, E. C. 1972. On *Cryptoblabes gnidiella* and *aliena* (Lepidoptera: Pyralidae: Phycitinae). Pac. Insects 14: 433.

Received for publication 12 October 1999; accepted 17 March 2000.