Distribution and Parasitism of *Sophonia rufofascia* (Homoptera: Cicadellidae) Eggs in Hawaii

Andrei V. Alyokhin,[1,2] Pingjun Yang,[1,3] and Russell H. Messing[4]

ABSTRACT The leafhopper *Sophonia rufofascia* (Kuoh & Kuoh) is a recent invasive pest attacking a wide variety of plant species in Hawaii. We surveyed the distribution and parasitism of its eggs in a number of natural and agricultural habitats on the islands of Kauai, Oahu, and Hawaii. Egg density was fairly low, with egg distribution affected both by plant species and plant habitat. Approximately 40% of *S. rufofascia* eggs, averaged over all plants and sites, were parasitized by *Chaetomymar* sp. nr. *bagichi* Narayanan, Subba Rao, & Kaur; *Schizophragma bicolor* (Dozier); and *Polynema* sp. Haliday (Hymenoptera: Mymaridae). Percentage parasitism varied widely among different plant species and habitats. *C.* sp. nr. *bagichi* was the most abundant and widely distributed species, but the parasitoid guild varied depending on plant and on habitat. The implications of these results on decisions regarding classical biological control of twospotted leafhopper in Hawaii are discussed.

KEY WORDS *Sophonia rufofascia*, parasitoid, biological control

The leafhopper *Sophonia rufofascia* (Kuoh & Kuoh) was first described from southern China (Kuoh and Kuoh 1983). Since its discovery on Oahu in 1987 (Heu and Kumashiro 1989), this insect has spread to all major Hawaiian islands, where it is currently widely distributed from sea level to 1,460 m (Fukada 1996). A recent host-range survey conducted in Hawaii indicated that *S. rufofascia* is extremely polyphagous, attacking over 300 species of host plants in 83 families (Fukada 1996). Among the host plants, 68% are economically important fruit, vegetable, and ornamental crops, and 22% are endemic to the Hawaiian islands (including 14 rare and endangered species). Leafhopper feeding produces interveinal chlorosis, which can eventually result in necrosis of affected leaves (Jones et al. 2000). Furthermore, leafhopper oviposition into leaf mid-veins can damage vascular bundles of some hosts, causing the death of distal tissue (Culliney 1998, Jones et al. 2000).

On several host plants, damage caused by the leafhopper through feeding and oviposition results in severe necrosis and dieback (Jones et al. 1998). The most noticeable plant that might be killed by the leafhopper in Hawaii is the false staghorn fern or "uluhe," *Dicranopteris linearis* (Burm.) Underwood. This fern is an important ground cover of agricultural watersheds and hillside forests. Leafhopper confinement in field cages on uluhe fronds resulted in the necrosis of 85% of frond surface compared with only 12% necrosis of the surface of control fronds (Jones et al. 2000). Therefore, it has been suggested that recently observed uluhe death over fairly extensive areas in Hawaii might be attributed to leafhopper damage (Jones et al. 2000). Large dead patches of this plant often leave the ground bare and subject to erosion and invasion by exotic weeds. On some islands (e.g., Oahu and Kauai), the erosion is so severe that it affects agricultural irrigation systems that rely on watershed streams.

Besides damaging valuable endemic vegetation, the twospotted leafhopper also feeds on many economically important plants (Fukada 1996). The most critically damaged crop appears to be guava, *Psidium guajava* L. Feeding and oviposition by the leafhopper causes "guava yellowing," which can reduce yields by 23% compared with pesticide-protected trees (Jones et al. 1998).

The twospotted leafhopper has recently established in Los Angeles and San Diego counties, California, (Garrison 1996). Potentially, it could spread throughout the coastal areas of southern California as well as other areas of the southern United States mainland, where many economically important fruit, vegetable, and ornamental crops provide suitable hosts for leafhopper development.

Recent field surveys conducted by Yang et al. (2000) and Johnson et al. (2000) in Hawaii Volcanoes National Park on the island of Hawaii indicate that the eggs of twospotted leafhoppers are attacked by two species of adventive parasitoids, *Chaetomymar* sp. nr. *bagichi* Narayanan, Subba Rao, and Kaur and *Schizophragma bicolor* (Dozier) (Hymenoptera: Mymaridae) as well as three to five species of endemic Hawaiian parasitoids in the genus *Polynema* Haliday (Hymenoptera: Mymaridae). However, little is cur-

[1] Department of Entomology, University of Hawaii, 3050 Maile Way, Honolulu, HI 96822.
[2] Current address: Department of Biological Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469.
[3] Current address: Hawaii State Department of Health, 4398-B Pua Loke Street, Lihue, HI 96766.
[4] Kauai Agricultural Research Center, 7370 Kuamoo Road, University of Hawaii, Kapaa, HI 96746.

Table 1. Abundance and parasitism of *S. rufofascia* eggs in different plant species within the surveyed areas.

Site	Island	Plant	No. leaves collected	No. eggs per 1 m^2 of leaf area		% parasitism		Correlations[a]	
				Mean	SE	Mean	SE	ρ	P
Lihue-Koloa FR	Kauai	Guava	556	5.43	2.19	52.08	11.97	0.14	0.6838
		Uluhe	426	36.37	11.08	7.33	3.71	−0.51	0.4338
Kauai Ag Station	Kauai	Grapefruit	554	2.93	1.10	75.00	25.00	0.39	0.3217
		Kukui	356	2.65	0.99	48.50	20.67	−0.99	0.2254
Kilauea Agronomics	Kauai	Guava	957	42.59	11.41	57.74	7.53	−0.34	0.6228
Waimanalo Ag Station	Oahu	Guava	416	23.58	8.94	36.61	8.55	0.16	0.2189
Kuaokala GMA	Oahu	A'a'lii	4513	39.65	11.03	79.84	5.93	0.65	0.1881
		Kukui	311	5.77	2.44	78.75	9.60	−0.28	0.5528
Maunawili Trail	Oahu	Guava	672	42.84	14.51	50.31	10.20	−0.92	0.0724
		Tree fern	2685	515.27	136.76	69.04	9.56	−0.80	0.5441
		Kukui	399	8.86	3.80	55.45	13.89	0.19	0.5441
		Ohia	2334	157.80	42.55	25.55	6.29	0.19	0.3965
		Ti	164	14.00	4.50	29.73	10.12	0.66	0.1481
		Uluhe	1110	123.50	33.07	9.28	2.84	−0.50	0.1562
Wailuku River SP	Hawaii	Guava	794	25.19	7.44	55.96	13.95	−0.41	0.4685
		Tree fern	877	75.10	42.01	59.34	21.78	0.35	0.6
Boiling Pots Lookout	Hawaii	Kukui	391	50.71	11.15	58.22	10.23	0.67	0.208
Kapapala Ranch	Hawaii	Guava	1125	6.90	2.23	19.11	4.56	0.37	0.686
Puhimau Crater Area	Hawaii	A'a'lii	3751	117.22	35.30	25.34	8.50	−0.30	0.8729
		Faya tree	4155	117.31	19.90	16.54	2.39	−0.55	0.8717
		Ohia	2095	35.10	15.85	9.37	7.27	0.30	0.0687
Devastation Trailhead	Hawaii	Tree fern	1868	5.09	3.30	0	0	N/A	N/A
		Uluhe	280	0	0	N/A	N/A	N/A	N/A
ANOVA									
F				15.2		3.98			
df				22, 131		21, 93			
P				<0.0001		<0.0001			

[a] Spearman rank correlations between leafhopper egg density and percentage egg parasitism.

rently known about the impact of extant parasitoids on leafhopper populations in Hawaii.

Johnson et al. (2000) reported that percentage parasitism of leafhopper eggs was fairly low, but their survey was limited to only four plant species growing within Hawaii Volcanoes National Park. Even in such a limited setting, they detected significant variation in parasitism among sites and plant species. Moreover, it is possible that the observed uluhe recovery within some dead patches (Peter Follett, USDA-ARS, personal communication) is associated with suppression of leafhopper populations by these parasitoids. In the current study, we conducted a more extensive survey across three Hawaiian islands in an attempt to identify extant parasitoid species attacking *S. rufofascia* in Hawaii and quantify their impact on the target host.

Materials and Methods

Plant Species Surveyed. Foliage from a total of nine plant species was monitored for the presence of twospotted leafhopper eggs. Plant species were selected according to their abundance in respective habitats, ecological or economic importance, and their status as *S. rufofascia* hosts. They included four endemic Hawaiian species; two adventive species of Polynesian introduction, which have cultural and economic significance for Native Hawaiians; two economically important fruit trees; and two invasive weeds. Table 1 shows sampling sites for each of the plant species surveyed. Ohia-lehua, *Metrosideros polymorpha* Gaud.; Hawaiian tree fern, *Cibotium chamissoi*

Kaulf.; uluhe fern, *Dicranopteris linearis* (Burm.) Underwood; and a'ali'i, *Dodonaea eriocarpa* Jacq. are endemic to Hawaii and play an important role in native ecosystems. Kukui, *Aleurites moluccana* (L.) Willdenow and ti, *Cordyline fruticosa* (L.) A. Cher.) were introduced to the islands by early Polynesian settlers and are widely used in native Hawaiian cultural practices. Grapefruit, *Citrus paradisi* Macf., and common guava, *Psidium guajava* L., are economically important fruit trees for Hawaiian agriculture. However, guava also may become an important weed within disturbed habitats, such as pastureland. Faya tree, *Myrica faya* Aiton, is an exotic weed that causes significant damage to native ecosystems.

Survey Sites. Surveys were conducted at 11 sites on the islands of Kauai, Oahu, and Hawaii. Types of natural plant communities were determined using descriptions and vegetation maps developed by Ripperton and Hosaka (1942), Mueller-Dombois and Fosberg (1974), and Sohmer and Gustafson (1987). Accordingly, surveyed habitats were classified as dry (annual precipitation <1,200 mm), mesic (annual precipitation 1,200–2,500 mm), or wet (annual precipitation >2,500 mm) as well as closed (canopy cover >60%) or open (canopy cover 25–60%). On Kauai, samples were collected in a mesic open forest with mixed understory at the Lihue-Koloa Forest Reserve (Kawaihau District), an experimental unsprayed grapefruit orchard, and several kukui trees on the grounds of the Kauai Agricultural Research Center (Kawaihau District), and a 194-ha unsprayed commercial guava orchard (Kilauea Agronomics, Hanalei

District). On Oahu, samples were collected from an experimental unsprayed guava orchard on the grounds of Waimanalo Agricultural Research Center (Koolaupoko District), a dry open forest in the Kuaokala Game Management Area (Waianae District), and a tropical rainforest along Maunawili Trail on a windward side of Koolau mountain range (Koolaupoko District). On Hawaii, samples were collected from wet closed forest with shrub understory at Wailuku River State Park (South Hilo District), several ornamental kukui trees near Boiling Pots lookout (South Hilo District), dry open guava shrubland bordering open pastures at Kapapala Ranch (Kau District), mesic closed forest with shrub understory near Puhimau Crater in Hawaii Volcano National Park, and mesic closed forest with tree fern understory at the head of Devastation Trail in Hawaii Volcano National Park.

Sampling Procedures. Leaves were sampled at random from each of the target plant species within each site at approximately monthly intervals from November 1999 to May 2000. The total number of leaves collected from each species at each site is shown in Table 1. The leaves were sampled at a height of 0.05-2 m above the ground. No attempt was made to distinguish between sun versus shade leaves, nor among leaves at different stages of maturity. Leaves were brought to the laboratory and checked for the presence of oviposition scars using backlighting as described by Yang et al. (2000). The total area of collected leaf material was estimated by measuring 35 leaves of each species with a leaf area meter (LiCor-3100, Lincoln, NE) and then multiplying the mean area of measured leaves by the total number of leaves in a sample. The number of oviposition scars per square meter of leaf surface was recorded. Infested leaves were placed in 4.5-liter self-sealing plastic bags and incubated for 1 mo at 24 ± 2°C and natural lighting. Earlier observations (P.Y., unpublished data) revealed that 1-month incubation under these conditions results in the emergence of all viable leafhoppers and their parasitoids. All other insects occurring incidentally on the leaf surface were removed before incubation. Insect emergence was checked daily, and all emerging leafhopper nymphs and parasitoids were removed and stored in 75% alcohol. Parasitoids were originally identified by John Huber (Agriculture and Agri-Food Canada). *Chaetomymar* sp. nr. *bagichi* is currently being described as a new species by Huber. Voucher specimens of leafhoppers and parasitoids are stored in the Canadian National Collection of Insects, Ottawa, Canada, and in the Entomology Museum, University of Hawaii at Manoa.

At the beginning of the fourth week, leaves were removed from the bags, and the number of holes left by emerging leafhoppers and their parasitoids were counted. Emerging leafhopper nymphs leave a characteristic breach in the scar tissue (Culliney 1998), whereas emerging parasitoids leave a small round aperture (Johnson et al. 2000). Therefore, these two types of emergence holes are easy to distinguish. However, it is impossible to distinguish emergence holes left by different parasitoid species. All scars that remained intact were cut open under a dissecting microscope (Culliney 1998) and checked for the presence of developing leafhoppers and parasitoids.

Statistical Analysis. Overall percentage parasitism was calculated according to the formula:

$$PP = \frac{(P_l + P_f + P_e) \times 100\%}{L_l + L_f + L_e + P_l + P_f + P_e},$$

where PP is the overall percentage parasitism; P_l is the number of parasitoids emerging in the laboratory; P_f is the number of holes left by parasitoids emerging in the field before leaf collection; P_e is the number of dissected parasitoid immatures; L_l is the number of leafhoppers emerging in the laboratory; L_f is the number of holes left by leafhoppers emerging in the field before leaf collection; and L_e is the number of dissected leafhopper immatures.

Before the analysis, data normality was checked using the Wilks-Shapiro test ($P = 0.01$) (PROC UNIVARIATE, SAS Institute 1999). When necessary, the data were transformed using rank transformations (Conover and Iman 1981) or arcsine transformations (Zar 1999). Means and standard errors were calculated from the nontransformed data only. Because not all plants occurred within each site, a two-way factorial analysis of variance (ANOVA) was not appropriate, and egg density among different plants and habitats was analyzed by a one-way ANOVA, using plant-site combinations as a main effect (PROC GLM, SAS Institute 1999). ANOVA was followed by orthogonal multiple contrasts that were designed a priori (Zar 1999) to test the differences between various habitat types (Table 2). Plant effects also were tested separately by pooling the data for each plant species across all habitats where that species occurred and then performing an additional one-way ANOVA (PROC GLM, SAS Institute 1999). Analysis of percentage parasitism was very similar to the analysis of egg density, except we used a one-way analysis of covariance (ANCOVA) (PROC GLM, SAS Institute 1999) instead of the one-way ANOVA. Number of eggs per square meter of leaf surface area was used as a covariate. This allowed us to test whether plant species and habitat affected parasitoids directly, or parasitoid abundance simply followed the abundance of their hosts. Spearman correlation coefficients (PROC CORR, SAS Institute 1999) were calculated to detect possible relationships between leafhopper egg density and percentage parasitism within each plant-site combination. Chi-square goodness-of-fit tests (PROC FREQ, SAS Institute 1999) were used to test the null hypotheses that the sex ratio of emerging parasitoids was not different from 1:1.

Results

Egg Distribution. The mean density of leafhopper eggs per square meter of leaf surface area varied significantly among samples collected from different plants within different habitats (Table 1). Overall,

Table 2. Orthogonal contrasts of *S. rufofascia* egg abundance and parasitism in different types of natural and agricultural habitat.

Contrasted groups		Mean egg density per 1 m² (SE)		F	P	Mean % eggs parasitized (SE)		F	P
Group 1	Group 2	Group 1	Group 2			Group 1	Group 2		
Natural habitats	Agricultural habitats	74.91 (14.48)	24.52 (5.09)	9.51	0.0026	38.13 (3.37)	54.67 (6.32)	6.38	0.0133
Open natural habitats	Closed natural habitats	18.82 (4.18)	97.96 (19.77)	36.86	<.0001	45.73 (6.89)	35.20 (3.8))	2.75	0.1007
Dry open natural habitats	Mesic open natural habitats	17.44 (5.25)	20.90 (7.12)	0.22	0.6406	56.15 (8.46)	27.22 (9.46)	7.24	0.0084
Guava shrubland	Dry open forest	6.90 (2.23)	22.71 (7.42)	2.45	0.1206	19.11 (4.56)	78.36 (6.14)	17.06	<.0001
Mesic closed natural habitats	Wet closed natural habitats	56.52 (12.92)	122.29 (30.00)	13.30	0.0004	14.50 (3.43)	43.75 (4.65)	18.9	<.0001
Mesic forest with shrubs	Mesic forest with ferns	88.27 (16.10)	2.55 (1.77)	89.26	<.0001	16.21 (3.61)	0.00 (0.00)	N/A	N/A
Wet closed forest with shrubs	Tropical rainforest	45.16 (17.89)	143.71 (37.36)	2.87	0.0929	57.58 (11.32)	39.91 (4.94)	2.24	0.1379
Ornamental trees	Fruit trees	26.68 (9.00)	23.00 (6.14)	0.09	0.7594	53.80 (10.42)	55.30 (8.16)	0.48	0.4923
Grapefruit orchard	Guava orchards	2.93 (1.10)	33.95 (7.68)	22.69	<.0001	75.00 (25.00)	48.14 (6.31)	3.88	0.0519

leafhoppers appeared to have a preference for wetter, closed habitats rather than drier, open ones (Table 2). Wild plants had a higher leafhopper infestation than cultivated plants. More eggs were found in the foliage from closed natural habitats than from open natural habitats. There was no difference in egg density between dry and mesic open natural habitats, but wet closed habitats harbored more eggs than mesic closed habitats. The type of mesic closed habitat also appeared to be an important factor, with shrubs harboring more leafhopper eggs than ferns (Table 2).

When averaged across different habitats, plant species also had a highly significant effect on leaf infestation (Table 3). Tree ferns had by far the greatest density of leafhopper eggs, followed by faya tree and the endemic Hawaiian plants ohia and a'ali'i. The lowest density of eggs was on cultivated grapefruit.

Percentage Parasitism. Our samples yielded the following parasitoid species: *Chaetomymar* sp. nr. *bagichi* Narayanan, Subba Rao, and Kaur, *Schizophragma bicolor* (Dozier), and *Polynema* sp. Haliday (Hymenoptera: Mymaridae). These are the same parasitoids recovered by Yang et al. (2000) and Johnson et al. (2000). *C.* sp. nr. *bagichi* was by far the most abundant and widely distributed species in our survey (Table 4). *Polynema* sp. parasitized only eggs deposited into a'ali'i

leaves, whereas *S. bicolor* attacked eggs in both a'ali'i and faya tree leaves. The sex ratio was highly female-biased for *C.* sp. nr. *bagichi* ($\chi^2 = 702.15$, df = 1, $P < 0.0001$) but did not differ from 1:1 for *Polynema* sp. ($\chi^2 = 0.11$, df = 1, $P = 0.7418$) (Table 4). All *S. bicolor* were females.

There was significant variation in overall percentage parasitism among samples collected from different plants within different habitats (Table 1). At the same time, we did not detect any correlation between the density and percentage parasitism of leafhopper eggs within any of the plant-habitat combinations (Table 1). Overall, eggs were more heavily parasitized within agricultural habitats than within natural habitats (Table 2). Among natural habitats, parasitism was higher within dry open habitats than mesic open habitats, with guava shrubland less affected by parasitoids than dry open forest. Also, a higher percenage of eggs was parasitised within wet closed habitats than in mesic closed habitats. Plant species also had a substantial influence on percentage parasitism (Table 3). There was a marginally significant difference in the percentage parasitism of leafhopper eggs on cultivated grapefruit and guava (Table 2). However, because grapefruit foliage contained few eggs, it is difficult to say how meaningful that difference was.

Table 3. Plant species effect on the abundance of *S. rufofascia* eggs and egg parasitoids.

Plant	No. eggs per 1 m² of leaf area		% parasitism	
	Mean	SE	Mean	SE
A'a'lii	74.91	20.22	51.00	10.55
Tree fern	227.83	82.22	54.30	10.92
Ti	14.00	4.50	29.73	10.12
Grapefruit	2.93	1.10	75.00	25.00
Guava	24.45	4.28	45.24	4.45
Kukui	17.00	4.96	59.92	6.88
Faya tree	117.31	19.90	16.54	2.39
Ohia	96.45	28.47	17.46	5.19
Uluhe	56.42	17.34	8.44	2.20
ANOVA				
F	6.01		5.36	
df	8, 123		8, 106	
P	<0.0001		<0.0001	

Discussion

Our results confirm earlier observations (Fukada 1996) that *S. rufofascia* is a highly ubiquitous and polyphagous species, infesting a wide variety of plant species in a wide variety of geographic areas. However, overall egg density per unit of leaf area was fairly low. Therefore, even though leafhopper oviposition may kill the distal leaf tissue of some hosts (Culliney 1998, Jones et al. 2000), it is unlikely that oviposition alone can cause significant damage to affected plants.

The distribution of leafhopper eggs in our survey was very uneven. Because plant occurrence was itself habitat-dependent, it was hard to distinguish between the effects of plant and habitat characteristics on leafhopper distribution. Also, it was not feasible to sample all potential host plant species within all of the sur-

Table 4. Parasitoid emergence from foliage samples collected from different plant species within the surveyed areas.

Site	Island	Plant	Chaetomymar sp. nr. bagichi		Polynema sp.		S. bicolor	
			♂	♀	♂	♀	♂	♀
Lihue-Koloa FR	Kauai	Guava	0	9	0	0	0	0
		Uluhe	0	2	0	0	0	0
Kauai Ag Station	Kauai	Grapefruit	0	3	0	0	0	0
		Kukui	0	5	0	0	0	0
Kilauea Agronomics	Kauai	Guava	1	62	0	0	0	0
Waimanalo Ag Station	Oahu	Guava	0	17	0	0	0	0
Kuaokala GMA	Oahu	A'a'lii	0	0	18	22	0	1
		Kukui	1	10	0	0	0	0
Maunawili Trail	Oahu	Guava	0	555	0	0	0	0
		Tree fern	0	23	0	0	0	0
		Kukui	0	39	0	0	0	0
		Ohia	1	27	0	0	0	0
		Ti	0	49	0	0	0	0
		Uluhe	0	30	0	0	0	0
Wailuku River SP	Hawaii	Guava	2	38	0	0	0	0
		Tree fern	0	11	0	0	0	0
Boiling Pots Lookout	Hawaii	Kukui	1	198	0	0	0	0
Kapapala Ranch	Hawaii	Guava	1	4	0	0	0	0
Puhimau Crater Area	Hawaii	A'a'lii	0	0	1	0	0	9
		Faya tree	0	1	0	0	0	21
		Ohia	0	0	0	0	0	0
Devastation Trailhead	Hawaii	Tree fern	0	0	0	0	0	0
		Uluhe	0	0	0	0	0	0
Total			7	1,083	19	22	0	31

veyed areas. Nevertheless, it is worth noting that we observed as high as 100-fold differences in relative infestation of the same plant species within different habitats and as high as 30-fold differences in relative infestation of different plant species within the same habitat (Table 1). Therefore, it appears that both plant species and habitat environment played an important role in determining the abundance of *S. rufofascia* eggs.

Parasitoids attacked a significant proportion of leafhopper eggs collected during our survey. When averaged across all plant species and habitats, >40% of the eggs were found to be parasitized by one of the mymarid species known to attack this pest. The exact composition of the parasitoid complex was strongly affected by the plant species containing leafhopper eggs. Only samples collected from a'ali'i and faya tree yielded *S. bicolor* and *Polynema* sp., whereas samples collected from other plants yielded exclusively *C.* sp. nr. *bagichi.* Interestingly, the latter parasitoid was completely absent in samples collected by Yang et al. (2000) in Hawaii Volcano National Park in 1995, whereas Johnson et al. (2000) reared all three species from the leaves of a'ali'i, faya tree, and ohia collected in the same area in 1997 and 1998. Also, P.Y. (unpublished data) observed between three and four species of mymarid parasitoids emerging from samples collected at Kilauea Agronomics and along Maunawili Trail in 1995.

Chaetomymar sp. nr. *bagichi* is a new, adventive species in Hawaii that probably arrived from Asia together with *S. rufofascia* (Johnson et al. 2000). The geographic range of this parasitoid is rapidly expanding over the areas already invaded by its host (Johnson et al. 2000). Therefore, the general scarcity of *S. bicolor* and *Polynema* sp. in our study (in contrast to earlier

surveys) could possibly be explained by their competitive displacement by *C.* sp. nr. *bagichi.* This phenomenon has been observed in a number of other parasitoid-host and predator-prey systems (Pemberton and Willard 1918, Turnbull and Chant 1961, Ehler and Hall 1982, Elliott et al. 1996). At the same time, a'ali'i and faya trees appear to somehow facilitate parasitism by *S. bicolor* and *Polynema* sp. A'ali'i foliage often contains eggs laid by the native leafhoppers *Nesophrosine maritima* Kirkaldy and *N. nuenue* Kirkaldy (Zimmerman 1948), which are parasitized by *Polynema* sp. (P.Y., unpublished data). Thus, this endemic parasitoid might be specifically adapted to efficient host utilization on this plant. It is unknown why *C.* sp. nr. *bagichi* was absent from *S. rufofascia* eggs laid into faya tree leaves.

The majority of *C.* sp. nr. *bagichi* and all *S. bicolor* reared in our survey were females. Female-biased sex ratio is not unusual among mymarids. In many species, males are either completely absent or found only occasionally (Clausen 1940). *S. bicolor* males are known to exist in Hawaii, but are rare (P.Y., unpublished data).

The existence of a parasitoid complex attacking *S. rufofascia* eggs in Hawaii is an important consideration when planning new introductions to control this pest. The fairly high rates of egg parasitism detected in the present survey might be sufficient to keep leafhopper populations below economically damaging levels. Assessing leafhopper damage was beyond the scope of our investigation, but we did not observe any large-scale plant die-backs that were feared several years ago. Furthermore, the most severe signs of "leafhopper yellows" were observed on faya tree. This species is an aggressive weed in native ecosystems, and its presence in Hawaii is undesirable in any case. Also,

competition between previously established and newly introduced species might result in host range expansion (Pianka 1981, Feder et al. 1995). Because there are many rare leafhopper species endemic to Hawaii (Zimmerman 1948), such an expansion by parasitoids is highly undesirable.

Acknowledgments

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