BioControl **49:** 417–431, 2004.

Suitability of Asian citrus psyllid, *Diaphorina citri*, as prey for ladybeetles

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Received 14 April 2003; accepted in revised form 6 November 2003

Abstract. Given the apparent importance of ladybeetles as biological control agents of the invasive Asian citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae), a series of experiments were undertaken to assess the nutritional suitability of this pest as a prey item. Five species of Coccinellidae were shown to develop successfully on a diet of psyllid nymphs and four species produced viable eggs. Eggs of the flour moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) were used as a reference diet. Larvae of *Curinus coeruleus* Mulsant, *Cycloneda sanguinea* L., *Exochomus childreni* Mulsant, *Harmonia axyridis* Pallas, and *Olla v-nigrum* Mulsant all had survival on a diet of *D. citri* nymphs not different from 100%, although developmental times were extended and adult dry weights were reduced relative to the *Ephestia* egg diet. Species were ranked (highest to lowest) for larval performance on the *D. citri* diet relative to the *Ephestia* egg diet as: *E. childreni*, 0.85; *O. v-nigrum*, 0.82; *C. coeruleus*, 0.80; *H. axyridis*, 0.71; *C. sanguinea*, 0.48. Most females of *C. sanguinea* ceased oviposition on the second day following transferal to the *D. citri* diet, but the fecundity and fertility of females of the other species were not different from those feeding on *Ephestia* eggs. Generation times on the *Ephestia* egg diet at 24 °C (time to egg hatch + larval developmental time + pupation time + adult prereproductive period) were (mean ± SEM): *C. coeruleus*, 56.7 ± 1.32 d; *C. sanguinea*, 28.0 ± 0.88 d; *E. childreni*, 60.8 ± 1.96 d; *H. axyridis*, 32.2 ± 1.47 d; *O. v-nigrum*, 25.8 ± 1.12 d. Adult females of *C. coeruleus*, *H. axyridis* and *O. v-nigrum* consumed the most psyllids in one h, *C. sanguinea* was intermediate, and *E. childreni* consumed the least.

Key words: Coccinellidae, *Curinus coeruleus*, *Cycloneda sanguinea*, development, *Diaphorina citri*, *Ephestia kuehniella*, *Exochomus childreni*, *Harmonia axyridis*, Homoptera, *Olla v-nigrum*, Psyllidae, reproduction

Introduction

The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae), was first reported in Stuart, Florida in 1998 (Halbert et al., 1998) on hedges of Jasmine Orange, *Murraya paniculata* (L.) Jack. The psyllid moved gradually through commercial citrus groves over the next two years, beginning in southern Florida (Halbert et al., 2000), and reaching as far north as Polk County in spring of 2001 (Michaud, 2001). Its current range includes most citrus-producing regions of the state. The psyllid is economically important as the primary vector of citrus greening disease in Asia (Catling, 1970), although this disease is not known to occur in the New World. However, nymphs of *D. citri* inject a toxin as they feed on growing citrus leaves that causes leaf twisting and permanent distortion of the growing terminal, sometimes leading to shoot abscission. Although this damage is unlikely to be a cause for concern on producing trees, it can potentially impact the growth pattern of young trees and necessitate chemical control of psyllids in citrus nurseries and newly planted groves. The development of biological control of *D. citri* in mature groves should ameliorate the economic impact of the psyllid in these more sensitive contexts. Preliminary field observations have implicated ladybeetles as potentially important biological control agents of *D. citri* in Florida (Michaud, 2000a, 2001, 2002a) and a more recent study estimated their collective impact on survival of immatures (Michaud, 2004).

Curinus coeruleus Mulsant (Coleoptera: Coccinellidae) is a species of New World origin, apparently imported from Mexico in 1953 (Gordon, 1985). It is occasionally found in citrus throughout southern Florida, although it is most abundant in the Indian River District along the east coast. *Curinus coeruleus* is known to prey on psyllids and has been employed in a classical biological control program against a psyllid pest of *Leucaena* shrubs in Asia, *Heteropsylla cubana* Crawford (Chazeau et al., 1992). Some basic life-history descriptions are available for this species feeding on *H. cubana* (Jakali and Singh, 1992, 1993).

Cycloneda sanguinea L. (Coleoptera: Coccinellidae) is a New World species indigenous to Florida and was the dominant aphidophagous ladybeetle throughout Florida citrus prior to the arrival of *Harmonia axyridis* Pallas (Muma, 1953; Michaud, 2000b). Gordon (1985) lists 22 aphid species as recorded prey for *C. sanguinea*, and *Aphis spiraecola* Patch and *Toxoptera citricida* (Kirkaldy) can be added to this list (Michaud, 2000b). There are also published reports of *C. sanguinea* consuming crawlers of Florida red scale, *Chrysomphalus aonidum* (L.) (van Brussel and Bhola, 1970), Australian red scale, *Aonidiella aurantii* (Maskell) (de Crouzel et al., 1979), and green scale, *Coccus viridis* (Green) (Sousa and Perez, 1977). Other potential prey items include whitefly nymphs (Link and Costa, 1980), eggs of Lepidoptera (McDaniel and Sterling, 1979) and leafhoppers (Cotte and Cruz, 1989). Both adults and larvae of *C. sanguinea* have been observed feeding on *D. citri* nymphs in Florida citrus (Michaud, 1999, 2002a).

Exochomus childreni childreni Mulsant (Coleoptera: Coccinellidae) is another native ladybeetle and the smallest of the species we examined. Gordon (1985) lists three aphid species as prey for *Exochomus* spp., and a much longer list of scale species. Its distribution is described only from point source collections restricted entirely to the state of Florida. Our collections of this species from citrus include occasional specimens from the Indian River district and southwest Florida, but most are from central Florida. Recent observations in psyllid-infested citrus groves indicate that it preys on *D. citri* nymphs.

Harmonia axyridis (Coleoptera: Coccinellidae) is a species of Asiatic origin that was intentionally introduced to the United States on at least six separate occasions (Gordon, 1985). However, accidental introductions are thought to have led to its establishment in the southern United States (Day et al., 1994), from whence it has spread to dominate coccinellid communities in arboreal habitats throughout continental U.S.A. (Hoebeke and Wheeler, 1996; Lamana and Miller, 1996; Brown and Miller, 1998). It is renowned as an excellent biocontrol agent of aphids and scales, but it is also a formidable intra-guild predator capable of completing development feeding on the larvae of other coccinellid species, including *Coccinella septempunctata* L. (Yasuda, 1999) and *C. sanguinea* (Michaud, 2002b).

Olla v-nigrum Mulsant (Coleoptera: Coccinellidae) is an indigenous species distributed throughout most of the continental United States (Gordon, 1985). Gordon (1985) lists six species of aphids as prey for *O. v-nigrum*, but it is also renowned as a psyllid feeder and, like *C. coeruleus*, has been used in classical biological control programs against *H. cubana* in Asia (Chazeau et al., 1991). Its abundance in Florida citrus has recently undergone a remarkable increase, apparently in response to widespread infestations of *D. citri* (Michaud, 2001).

Although various coccinellids may be attracted to aggregations of potential prey, not all species may be able to utilize particular prey species for successful larval development and/or reproduction (Hodek and Honek, 1996; Michaud, 2000b). Numerical responses of predators to a new prey species hinge on successful larval development and adult reproduction when feeding on the prey. Furthermore, the most suitable prey for coccinellid larval development are not always the most suitable prey for adult reproduction (Michaud, 2000b). Our objective in the present work was to determine the life history consequences of a *D. citri* diet for larvae and adults of these ladybeetle species.

Materials and methods

Source material and stock colonies

Colonies of *D. citri* were maintained on potted trees of jasmine orange, *Murraya paniculata*, in a climate-controlled greenhouse at 24 ± 2 °C with supplementary light provided by 1000W metal halide lights set to 16:8 (L:D) daylength. Jasmine orange is an excellent host plant for the psyllid and suffers less permanent damage from its feeding than do *Citrus* spp. Beetle colonies were established with adults collected from the following localities on the following dates: *C. sanguinea* and *H. axyridis*, Polk County, Oct., 2000; *Olla v-nigrum*, St. Lucie County, March, 2001; *C. coeruleus*, St. Lucie County, August, 2001, *E. childreni*, Polk County, Sept. 2001. Pairs of adult beetles of each species were placed into plastic Petri dishes (5.5 cm × 1 cm) and provided daily with frozen eggs of *Ephestia kuehniella* Zeller, bee pollen, and water encapsulated in polymer beads (Entomos, LLC 4445 SW 35th Terrace, Suite 310, Gainesville, FL). Preliminary work had shown this diet to be highly suitable for the development and reproduction of all species in this study. Once oviposition began, males were removed so that females could continue to oviposit in isolation. Voucher specimens of all species are deposited at the Florida State Arthropod collection at the Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida, U.S.A..

Eggs of *C. sanguinea*, *H. axyridis*, and *O. v-nigrum* were usually laid directly on the surface of the plastic Petri dishes, and sometimes directly on the polymer water beads. Females of *C. coeruleus* and *E. childreni* were provided with small fragments of black carpet in which to embed their egg clusters. Eggs of all species were held in a plexiglass terrarium at 24 ± 1 °C, 60 ± 10% RH under fluorescent lights set to a daylength of 16:8 (L:D). A sample of between 12 and 14 egg clusters from each species was followed to calculate the time required to hatch at this temperature. Larvae for stock colonies were reared in groups of five in plastic Petri dishes (as above) provisioned with *Ephestia* eggs daily, and fresh water beads every 3 days. Larvae pupated in the dishes and emerging adults of each species were placed in 1-liter, wide-mouth, glass Mason jars covered with muslin cloth. The jars had water provided on a cotton wick, and were provisioned daily with *Ephestia* eggs and bee pollen. Mating occurred under these conditions, but for reproduction, females were removed after one or more weeks in the jars and isolated in Petri dishes for oviposition (as above). A series of 20 pairs of newly emerged adults of each species was confined in individual Petri dishes (as above) and fed daily until oviposition occurred to permit calculation of the pre-reproductive period.

Development assays

Development assays were conducted on a laboratory bench under fluourescent lights (L:D = 16:8) at a temperature of 24 ± 1 °C and at 60 ± 10% RH. For each assay, 24 newly eclosed larvae of each species were divided into two groups of 12 replicates, each isolated in a plastic Petri dish (as above). One group served as controls and was fed frozen *Ephestia* eggs daily, the other group received frozen nymphs of *D. citri* daily. Each larva was provided with water encapsulated in polymer beads; these were replaced every 3 days. Data on larval mortality, formation of prepupa, and adult emergence were recorded on a daily basis. Larval developmental time was calculated from hatching (day one) to formation of the prepupa (larva ceases feeding and fastens itself to the dish). Pupation time was calculated from formation of the pre-pupa (since duration of the pre-pupal period is too short to resolve accurately with daily observations) to emergence of the adult. All adults emerging were immediatly placed into 5.0 ml glass vials and dried in an oven at 50 °C for 3 days before being weighed on an analytical balance. An index of larval performance of the *D. citri* diet relative to the standard *Ephestia* egg diet was calculated using the following equation:

$$[(DT_D)/DT_E) + (AW_E/AW_D)]/2$$

where $\mathrm{DT_E}$ = mean developmental time on the *Ephestia* diet
$\mathrm{DT_D}$ = mean developmental time on the *D. citri* diet
$\mathrm{AW_E}$ = mean adult weight on the *Ephestia* diet
$\mathrm{AW_D}$ = mean adult weight on the *D. citri* diet

Reproduction assays

Reproduction assays were carried out under the same environmental conditions as the developmental assays. Emerging adult beetles of each species were confined in pairs in plastic Petri dishes (as above) and provided with *Ephestia* eggs and water beads until the female began to oviposit. The prereproductive period (= pre-oviposition period) was calculated from the day of emergence of the female to the day the first eggs were laid. Upon oviposition, the females were isolated from the males and arbitrarily assigned to one of 2 groups, treatment or control. Females in the treatment group were fed daily with frozen nymphs of *D. citri*, while control females were fed the *Ephestia* egg diet; both groups received water in polymer beads. Frozen nymphs were used because the logistic constraints of producing large numbers of psyllids needed to complete each feeding trial necessitated storing them in a freezer until enough had been accumulated to conduct an experiment. Adult females of *C. sanguinea* and *E. childreni* refused to consume the frozen *D. citri* nymphs; live nymphs had to be provided daily for these species. Eggs were collected daily for each ovipositing female, counted, and placed in the egg incubator at 24 ± 1 °C and 16 h daylength. Incubation period was calculated for egg masses from date of collection to date of hatching. The number of eggs hatching in each cluster was recorded and divided by the number of total eggs to yield an estimate of female fertility. Data were analyzed by one-way ANOVA (SPSS, 1998); fertility data were arcsine transformed before analysis.

Generation times

Mean generation times were estimated for each species at 24 °C on a diet of *Ephestia* eggs by summing the mean time to egg hatch (n = 14), the mean larval developmental time (n = 12), the mean pupation time (n = 12), and the mean pre-reproductive period (n = 20). Life stage duration was compared among species by one-way ANOVA followed by a Least Significant Difference test ($\alpha = 0.05$) for separation of means.

Consumption assays

Consumption assays were carried out on a laboratory bench under 'cool white' fluorescent light at a temperature of 24 °C at 60 ± 10% RH. Adult beetles of each species (2–3 weeks old) were removed from rearing jars, placed into individual Petri dishes (as above) and starved for a period of 24 h with only water beads provided. Beetles (n = 12 females and 12 males) were then introduced individually into plastic Petri dishes (as above) each containing 20 live 3rd and 4th instars of *D. citri*. The number of nymphs consumed by each beetle was tallied at intervals of 20, 40, and 60 minutes without replacement. Consumption of psyllids was compared among species for males and females separately, and between sexes within species, with a one-way ANOVA. This test was followed by a Least Significant Difference test to resolve differences among means ($\alpha = 0.05$) in the species comparisons (SPSS, 1998).

Results

Development assays

Larvae of both *C. coeruleus* and *E. childreni* had 100% survival on both *Ephestia* eggs and *D. citri* nymphs; *C. sanguinea*, 83.3% and 75% survival, respectively; *H. axyridis*, 91.7% and 75%, respectively; and *O. v-nigrum*, 100% and 91.7%, respectively. None of these survival rates were significantly less than 100%, or significantly different between diets, in a Chi-square Goodness-of-fit test ($\alpha = 0.05$).

The five species that developed successfully on a diet of *D. citri* all exhibited significant developmental delays relative to the diet of *Ephestia*

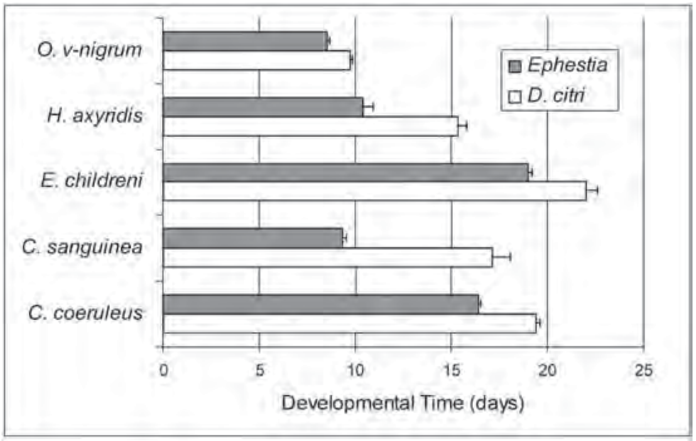

Figure 1. Mean larval developmental times (+ SEM) measured from eclosion to formation of pre-pupa for five coccinellid species (n = 12) reared on either *Ephestia* eggs or *D. citri* nymphs at a constant temperature of 24 ± 2 °C. Differences between diets were significant for all species (one-way ANOVA, $P < 0.01$).

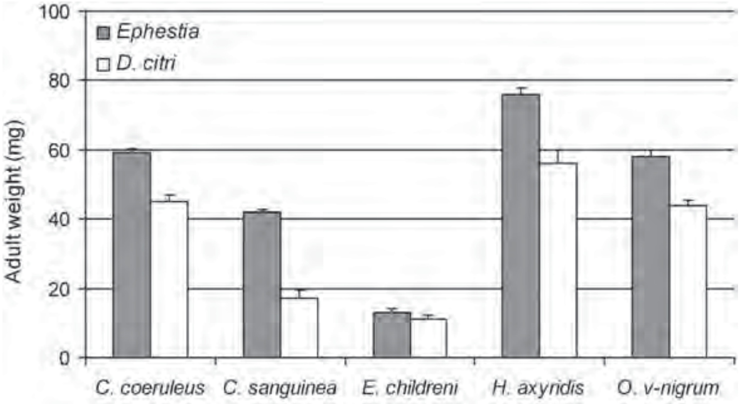

Figure 2. Mean adult dry weights (+ SEM) for five coccinellid species (n = 12) reared on either *Ephestia* eggs or *D. citri* nymphs at a constant temperature of 24 ± 2 °C. Differences between diets were significant for all species (one-way ANOVA, $P < 0.01$).

eggs (Figure 1). The proportional increases in developmental time were: *C. coeruleus*, 18.3%; *C. sanguinea* 83.9%; *E. childreni* 29.5%; *H. axyridis* 47.1%; *O. v-nigrum*, 14.4% (ANOVA, $P < 0.01$ in all cases). Similarly, all five species had reduced adult dry weight on the psyllid diet compared to the *Ephestia* egg diet (Figure 2). The proportional reductions in adult dry weight were: *C. coeruleus*, 23.7%; *C. sanguinea* 59.5%; *E. childreni* 13.1%;

H. axyridis 26.3%; *O. v-nigrum*, 24.1% (ANOVA, $P < 0.01$ in all cases). Indices of larval performance on a diet of *D. citri* nymphs were calculated as: *C. coeruleus* 0.80, *C. sanguinea* 0.48, *E. childreni* 0.85, *H. axyridis* 0.71, *O. v-nigrum* 0.82.

Reproduction assays

Female adults of *C. coeruleus*, *E. childreni*, *H. axyridis*, and *O. v-nigrum* reproduced as well on a diet of *D. citri* nymphs as on *Ephestia* eggs with no significant differences in numbers of eggs laid daily or the percentage of eggs hatching (Table 1). Eleven of 12 *C. sanguinea* females ceased oviposition completely on the second day following transfer to the *D. citri* diet, although they continued to feed on the psyllid nymphs provided.

Generation times

Generation times for the five species reared on *Ephestia* eggs at 24 °C are depicted in Figure 3. All life stages of the two species of the subfamily Chilocorinae, *C. coeruleus* and *E. childreni*, were significantly longer in duration at 24 °C than were similar life stages of the three species of the subfamily Coccinellinae.

Consumption assays

The consumption of psyllids by adult beetles of each species is depicted separately for males and females in Figure 4. Among males, *C. coeruleus* and *H. axyridis* were the most voracious psyllid feeders, followed by *O. v-nigrum* and *C. sanguinea*, with *E. childreni* the least voracious. Females exhibited a similar pattern, except that *O. v-nigrum* females were equally voracious as *C. coeruleus* and *H. axyridis*. The only significant difference between males and females during the first time interval was for *C. coeruleus*, with females consuming more than males ($F = 8.810$; 1,22 df; $P < 0.01$). Females of both *C. coeruleus* and *H. axyridis* had higher cumulative consumption than their male counterparts after the second time period ($F = 7.38$; 1,22 df; $P < 0.05$ and $F = 8.466$; 1,22 df; $P < 0.01$, respectively). After the third time period, cumulative consumption of females was higher than that of males for *C. coeruleus*, *H. axyridis*, and *O. v-nigrum* ($F = 6.477$; 1,22 df; $P < 0.05$; $F = 5.851$; 1,22 df; $P < 0.05$ and; $F = 22.956$; 1,22 df; $P < 0.001$, respectively). Sexual differences in psyllid consumption were not significant for either *C. sanguinea* or *E. childreni* in any time interval.

Table 1. Mean number of eggs laid (± SEM) in seven days and mean percentage eggs hatching (± SEM) for adult coccinellid females (n = 12) fed either frozen *Ephestia* eggs or frozen *D. citri* nymphs

Species / diet	No. eggs laid (± SEM)		F	P	Percent hatching (± SEM)		F	P
	Ephestia	*D. citri*			*Ephestia*	*D. citri*		
C. coeruleus	64.7 ± 8.15	64.5 ± 6.18	0.001	ns	48.4 ± 5.22	50.7 ± 5.05	0.106	ns
C. sanguinea[a]	163.5 ± 20.78	11.6 ± 3.60	66.923	< 0.001	73.1 ± 4.28	59.5 ± 8.84	2.200	ns
E. childreni[a]	35.6 ± 4.40	37.4 ± 4.30	0.084	ns	86.1 ± 4.92	83.3 ± 3.91	0.207	ns
H. axyridis	242.8 ± 14.1	255.8 ± 16.00	0.144	ns	62.1 ± 17.5	64.7 ± 19.5	0.242	ns
O. v-nigrum	224.5 ± 24.12	257.6 ± 11.35	1.542	ns	78.4 ± 2.94	73.5 ± 4.29	0.922	ns

[a] Females of these species would not consume frozen *D. citri* nymphs and were fed fresh, live nymphs.

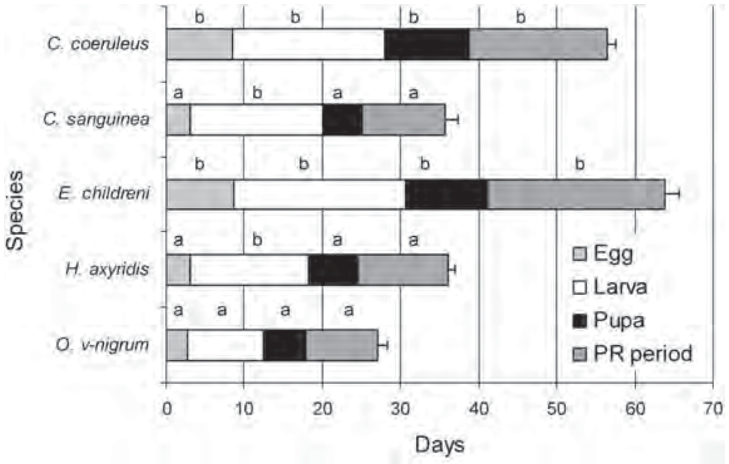

Figure 3. Mean generation times (+ SEM) for five coccinellid species reared at 24 ± 2 °C on a diet of *D. citri* nymphs. Stacked bars represent the mean duration of egg, larval, pupal and female prereproductive (PR period) stages with cumulative standard errors. Life stages bearing the same letter were not significantly different among species (one-way ANOVA, $P > 0.05$).

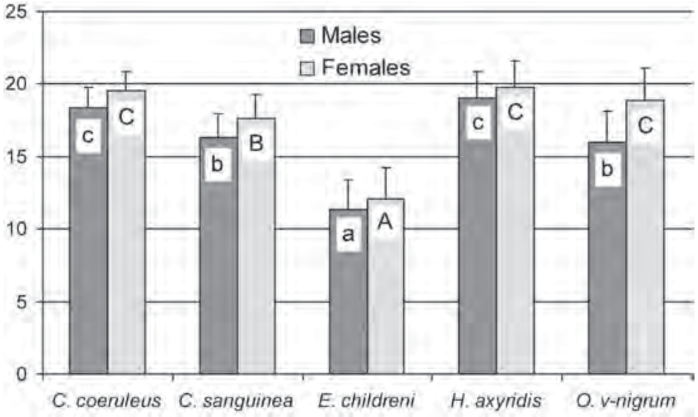

Figure 4. Mean numbers of psyllid nymphs (+ SEM) consumed by adult coccinellids of five species in 60 minutes. Beetles were starved for 24 h and then confined individually with 20 3rd and 4th instar nymphs of *D. citri*. Bars bearing the same letter were not significantly different (one-way ANOVA, $P > 0.05$) among species in cumulative number of psyllids consumed by males (lower case letters) and females (upper case letters) in 60 minutes.

Discussion

These results indicate that immature *D. citri* comprise acceptable and suitable prey for five of the more abundant coccinellid species currently active in Florida citrus. Although larval survival was excellent, increases in larval developmental time and reductions in adult weight relative to the *Ephestia* egg diet suggest that psyllids represent less than optimal food for these beetles. Coccinellid larvae consume only a small fraction of the body of psyllid nymphs; a large proportion is comprised of exoskeleton, primarily the wing bud 'shields', that are not consumed. Therefore, the profitability of psyllid nymphs as prey for coccinellid larvae (in terms of net energy gain) may be lower than the profitability of prey such as aphids or *Ephestia* eggs that are more completely consumed. The observed increases in developmental time and reductions in adult weight on the *D. citri* diet may result from either (1) a lower nutritional value of *D. citri* nymphs relative to *Ephestia* eggs or, (2) a lower net food intake on the *D. citri* diet as a result of consuming a smaller portion of each prey item. It is possible that these developmental costs may be partially offset in the field if larvae consume mixed diets that include other, more nutritious, prey items or proteinaceous food supplements such as pollen.

The results of the consumption assays reveal that adults of *H. axyridis*, *C. coeruleus*, and *O. v-nigrum* are more voracious feeders on *D. citri* than are adults of *C. sanguinea*, and adults of *E. childreni* were the least voracious (Figure 4). Repetition of these experiments with larger numbers of psyllids might resolve further differences in voracity, since in many replicates *H. axyridis*, *C. coeruleus*, and *O. v-nigrum* consumed all the psyllid nymphs provided. However, males and females of both *C. sanguinea* and *E. childreni* appeared to reach satiation after consuming less than 20 nymphs within the same period. Female consumption was significantly higher than male consumption for the three most voracious species during the 60-min period.

The indices of larval performance indicate that *C. coeruleus*, *E. childreni* and *O. v-nigrum* are the most physiologically capable of utilizing *D. citri* for larval development, followed closely by *H. axyridis*, with *C. sanguinea* the least capable. However, the generation time of *O. v-nigrum* is much shorter than that of *C. coeruleus* and *E. childreni*, and its developmental time is extended by a mean of only 1.2 days on the psyllid diet, compared to 5 and 8 days, respectively, for *H. axyridis* and *C. sanguinea*. *Cycloneda sanguinea* was the only species unable to sustain significant egg production on *D. citri*, a factor that likely limits the numerical response of this species to psyllid infestations in the field. These results suggest that *O. v-nigrum* is perhaps the best suited psyllid predator of the five species and are consistent with its tenfold increase in abundance in Florida citrus since the invasion of the psyllid (Michaud, 2001). However, a recent field study found *O. v-nigrum* and *H. axyridis* roughly equal in abundance on *D. citri* infestations in central Florida (Michaud, 2004). The numerical response of *O. v-nigrum* to the advent of *D. citri* parallels that observed in Hawaii in response to the invasion of the Leucaena psyllid, *Heteropsylla cubana* Crawford (Nitrogen Fixing Tree Association, 1990). In contrast, *C. sanguinea* and *H. axyridis* comprised more than 75% of all adult coccinellids in Florida citrus prior to the advent of *D. citri*, a period of abundant *Toxoptera citricida* populations, and were shown to be the only species capable of successful development on this prey (Michaud, 2000a). Thus, relative coccinellid abundance may be strongly influenced by 'bottom-up' processes, i.e., the abundance of particular prey species and their nutritional suitability for coccinellid development and reproduction.

Exochomus childreni is primarily restricted to central and northern regions of Florida (Gordon, 1985) and very little is known of its life history and behavior beyond the fact that it is primarily a scale feeder. Although its comparative performance on *D. citri* nymphs ranked very high in this study, its small size, low voracity, long generation time, and restricted distribution in citrus are all factors that likely limit its potential importance as a biological control agent of *D. citri*. Michaud (2003) found *E. childreni* active in *D. citri* infestations in central Florida citrus groves, but a much lower abundance than *O. v-nigrum* and *H. axyridis*.

A numerical response of *C. coeruleus* populations to Leucaena psyllid was observed in Hawaii in parallel with populations of *O. v-nigrum* (Waterhouse and Norris, 1987) but has not yet been observed in response to *D. citri* populations in Florida. This species is usually quite rare in Florida citrus, except in a region along the east coast from Fort Pierce to Fort Lauderdale where it can be abundant, especially during hot summer months when most species of the subfamily Coccinellinae appear to be inactive or aestivating. For example, on August 8, 2001 we counted 23 adult *C. coeruleus* on psyllid-infested citrus terminals in a Fort Pierce orange grove, compared to only three *C. sanguinea*, three *H. axyridis*, and zero *O. v-nigrum*. The same grove had been dominated by large numbers of *O. v-nigrum* and *H. axyridis* during March of the same year. We obtained successful egg hatch for both *C. coeruleus* and *E. childreni* at constant temperatures of 30 °C and 32 °C (J.P. Michaud, unpublished), temperatures that are lethal for eggs and larvae of *C. sanguinea* and *H. axyridis* (Michaud, 2000b). The low fecundities and long generation times of *C. coeruleus* and *E. childreni*, both species of the subfamily Chilocorinae, may be factors impeding their numerical response to psyllid infestations in the field, but their tolerance of high temperatures may facilitate continued activity during hot summer weather. *Curinus coeruleus* has been used with some degree of success in classical biological control programs against Leucaena psyllid in fully tropical regions such as Hawaii (Nakahara and Funasaki, 1986), India (Jakali and Singh, 1989), Indonesia (Diraviam and Viraktamath, 1991), and the Philippines (Villacarlos and Robin, 1992). Subtropical Florida may, therefore, represent a region of marginal climatic suitability for this species.

Other predators we have successfully reared on an exclusive diet of *D. citri* include a number of spider species, the lacewings *Micromus posticus* (Walker), *Cereaochrysa* spp. and *Chrysoperla rufilabris* Burmeister, and the syrphid fly *Allograpta obliqua* (Say) (Michaud, 2002a). Field studies are planned to elaborate the contributions of these predators, and the introduced parasitoid *Tamarixia radiata* (Waterston), to biological control of *D. citri* in Florida citrus groves.

Acknowledgements

We thank L. Tretyak for technical support and R. Stuart and H. Nigg for reviewing the manuscript. This research was supported by the Florida Agricultural Experiment Station and grants from USDA, APHIS, PPQ and the Florida Citrus Producers Research Advisory Committee and approved for publication as Journal Series No. R-08826.

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