

NUMERICAL RESPONSE OF *OLLA V-NIGRUM* (COLEOPTERA: COCCINELLIDAE) TO INFESTATIONS OF ASIAN CITRUS PSYLLID, (HEMIPTERA: PSYLLIDAE) IN FLORIDA

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ABSTRACT

Data are presented on the relative abundance of the coccinellid *Olla v-nigrum* (Mulsant) in Florida citrus, before and after invasion by the Asian citrus psyllid, *Diaphorina citri* Kuwayama. Adults and larvae of *O. v-nigrum* were observed preying on immature psyllids throughout their range in Florida. Immature psyllids were eliminated by predation from many flushed citrus terminals that exhibited damage symptoms; pupae of *O. v-nigrum* and *Harmonia axyridis* Pallas were recovered from adjacent leaves. *Olla v-nigrum*, a relatively rare species before the invasion by *D. citri*, is now a dominant species throughout Florida in citrus groves where the psyllid is present, but remains rare in regions where *D. citri* is absent. The strong numerical response of this native ladybeetle to *D. citri* populations indicates that it is assuming a key role in biological control of the psyllid.

Key Words: abundance, biological control, coccinellids, *Diaphorina citri*, *Harmonia axyridis*, *Olla v-nigrum*

RESUMEN

Se presentan datos sobre la abundancia relativa del coccinélido *Olla v-nigrum* (Mulsant) en cítricos en la Florida, antes y después de la invasión del psílido Asiático, *Diphorina citri* Kuwayama. Adultos y larvas de *Olla v-nigrum* fueron observados alimentándose de las formas inmaduras del psílido a través de la Florida. Se observaron muchos brotes terminales en los cítricos con daños del psílido, pero estos fueron eliminados por depredación; pupas de *O. v-nigrum* y *Harmonia axyridis* Pallas fueron coleccionadas en hojas adyacentes. *Olla v-nigrum*, una especie relativamente escasa antes de la invasión de *D. citri*, ahora es dominante en los cítricos de Florida donde está presente el psílido, pero sigue siendo escasa donde *D. citri* está ausente. La fuerte respuesta numérica de este coccinélido en comparación con las poblaciones de *D. citri* indica que está asumiendo un papel clave en el control biológico del psílido.

The Asian citrus psyllid, *Diaphorina citri* Kuwayama, is the primary vector of citrus greening disease in Asia (Catling 1970) and was first reported in Stuart, Florida in 1998 (Halbert et al. 1998). Originally discovered on hedges of Jasmine Orange, *Murraya paniculata* (L.) Jack, the psyllid spread to infest commercial citrus plantings throughout St. Lucie, and Indian River counties, south to Miami-Dade, and eastward through Okeechobee in 1998. As of March 2001, it can be found throughout southwestern Florida (Lee, Collier, and Hendry Counties) and northward along the central ridge as far as southern Polk County (Alturas and Lake Wales). A relatively recent report on the range of *D. citri* in Florida can be found in Halbert et al. (2000). Efforts have been under way to release and establish two exotic parasitoids, *Tamarixia radiata* (Waterston) and *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agaral) (Hoy & Nguyen 2001) that are reportedly specific for *D. citri* (Tang 1990). This paper reports observations on a native coccinellid species, *Olla v-nigrum* (Mulsant) (= *Olla abdominalis* (Say)), that, together with the Asian multicolored lady-

beetle, *Harmonia axyridis* Pallas, can be found preying on *D. citri* throughout its range in Florida.

The ash-gray ladybeetle, *O. v-nigrum*, is an indigenous coccinellid species inhabiting arboreal habitats throughout most of the United States (Gordon 1985), Mexico (J. P. Michaud, unpublished), and through much of South America including Paraguay (Michel 1992), Argentina (Bado & Rodriguez 1997) and Brazil (Fraga et al. 1986). It occurs in light and dark forms, the dark form predominating in Florida where it can easily be mistaken for the twice-stabbed ladybeetle, *Chilocorus stigma* (Say). The latter is distinguishable from *O. v-nigrum* by its generally smaller size, a recurvature of the edge of the elytra, and the lack of a conspicuous white border along the edge of the pronotum. Although *O. v-nigrum* can be observed feeding on various aphid species (Teddars 1978, Edelson & Estes 1987) the ability of *O. v-nigrum* to develop and reproduce on these aphids has not often been examined. However, it is also renowned as a natural enemy of psyllids (Fraga et al. 1986) and can complete development on species such as *Heteropsylla cubana* Crawford that

are unsuitable food for many other generalist predators (Chazeau et al. 1991).

Although *O. v-nigrum* is attracted to colonies of *Toxoptera citricida* (Kirkaldy) and *Aphis spiraecola* Patch and will feed on them (Michaud & Browning 1999), it is known that these aphid species do not support larval development, despite the fact that viable eggs were produced by adult females fed *T. citricida* (Michaud 2000a). This inability to develop on the primary citrus aphids may partially explain why the species has been relatively rare in citrus until recently. Bado & Rodriguez (1997) reported life history data and prey preference of *O. v-nigrum* feeding on various aphid species including *Schizaphis graminum* (Rondoni), *Hyadaphis* sp., *Metopolophium dirhodum* (Walker), *Uroleucon* sp., *Brevicoryne brassicae* L. and *Myzus* sp. Chazeau et al. (1991) compiled a life table for *O. v-nigrum* feeding on *H. cubana* and concluded this psyllid was a highly suitable prey species. Developmental and behavioral aspects of *O. v-nigrum* feeding on *Psylla* sp. are described by Kato et al. (1999).

Preliminary observations in south Florida in 1999 identified various indigenous predator species attacking *D. citri*, including *O. v-nigrum*, and late instar larvae of this species collected from *D. citri* colonies pupated successfully in the laboratory and yielded viable adults (Michaud 2000b). More recent observations reveal that populations of *O. v-nigrum* have apparently exploded wherever psyllids are present in citrus. This paper reports on the increase in relative abundance of *O. v-nigrum* in apparent response to the availability of *D. citri* as a new food source.

#### MATERIALS AND METHODS

From 1996 to 1998 the commercial citrus-growing regions of Florida were invaded by the brown citrus aphid, *Toxoptera citricida* (Kirkaldy) and, as part of a survey of predators attacking *T. citricida*, a series of observations was made on the relative abundance of coccinellid species in these regions. Flowering and flushing citrus trees are attractive to many coccinellid species. Adult beetles can be found feeding on pollen and nectar of citrus flowers in the spring. Many potential prey species, including aphids and leaf miners, attack newly expanding citrus terminals. Consequently, citrus groves were selected based on the presence of flowering and/or flushing trees and these trees were examined selectively. Relative coccinellid abundance was estimated by visual counts of adult beetles on whole trees. Observation periods ranged from 40 minutes to 2 hours at each site. Voucher specimens were collected and identified by M. Thomas, Florida Department of Agriculture and Consumer Affairs, Department of Plant Industry, Gainesville, FL, 32608. Exact observation dates for each location were as fol-

lows: Dade County (Homestead), 24-II-1997, 7-IV-1998, 13-V-1999; Collier County, 19-V-1997, 15-III-2001; Hendry County, 14-II-1998, 14-V-1998; St. Lucie County, 21-IV-1997, 9-VII-1997, 15-II-1998, 13-V-1998, 14-III-2001; Highlands County, 25-VII-1997, 21-III-1998, 21-III-2001; Polk County, 18-III-1998, 18-V-1998, 27-X-1998, 8-III-2001, 21-III-2001, 27-III-2001.

The data from years 1997 and 1998 reflect coccinellid abundance in Florida during a period when *T. citricida* and *A. spiraecola* were the primary prey available for aphidophagous coccinellids in citrus. Since 1999, population densities of both aphid species have been very low compared to levels observed in previous years, probably due to the numerical responses of predatory species such as *Cycloneda sanguinea* L. and *Harmonia axyridis* Pallas that successfully develop and reproduce on *T. citricida* (Michaud 2000a). Subsequent to the invasion of *D. citri*, I returned to many of the same groves to identify sources of mortality in psyllid colonies. In the course of these observations, data were again collected on the relative abundance of coccinellids by visual counts of adult beetles in the same manner as in previous years. The body of data collected before 1999 now form a historical reference point for the relative abundance of *O. v-nigrum* before invasion by the Asian citrus psyllid. Data on *O. v-nigrum* abundance in the presence and absence of *D. citri*, as a proportion of total coccinellids observed, were compared by means of a '2 × r' contingency table analysis (SAS Institute 1998).

#### RESULTS AND DISCUSSION

The historical data on the abundance of *O. v-nigrum* relative to other coccinellids and those from recent observations are presented in Fig. 1. The data are representative of the four major citrus-producing regions of the state: south Florida (Dade County), southwestern Florida (Collier and Hendry Counties), the Indian River District (St. Lucie County) and the central ridge district (Highlands and Polk Counties). In all regions where psyllids are now present, *O. v-nigrum* has increased significantly as a proportion of total coccinellids (Dade County:  $\chi^2 = 56.468$ , 2df,  $P < 0.001$ ; Collier County:  $\chi^2 = 24.922$ , 1df,  $P < 0.001$ ; Hendry County:  $\chi^2 = 15.923$ , 2df,  $P < 0.001$ ; St. Lucie County:  $\chi^2 = 44.531$ , 4df,  $P < 0.001$ ; Highlands County:  $\chi^2 = 80.415$ , 2df,  $P < 0.001$ ; Polk County:  $\chi^2 = 116.944$ , 5df,  $P < 0.001$ ).

The data represented in Fig. 1 for Spring 2001 in Polk County were collected from a very recent psyllid infestation just south of Lake Wales. Two additional sites further north in Polk County (where *D. citri* is not yet present) were also sampled in spring 2001, one in Lake Alfred on 8-III-2001 and one in Polk City on 27-III-2001 (not shown in Fig. 1 because of graphical constraints).

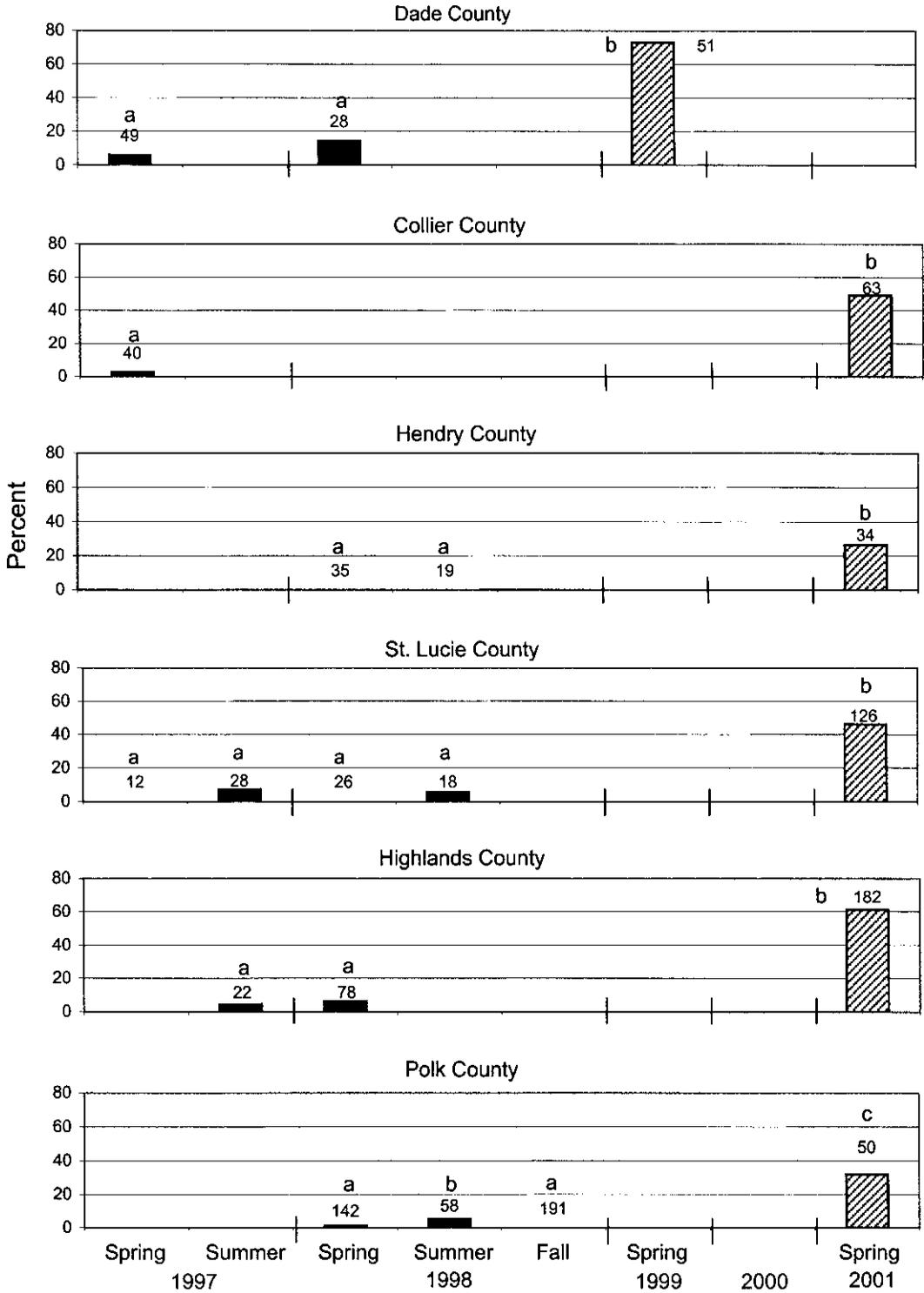


Fig. 1 Relative abundance of *O. v-nigrum* expressed as a percentage of total coccinellid adults observed on flowering and flushing citrus trees at various locations in Florida over a five year period. Solid bars: *D. citri* absent, shaded bars: *D. citri* present. Bars bearing the same letter were not significantly different in contingency table analyses within counties; all significant differences were  $P < 0.001$  in a Chi-square test. Numbers represent sample sizes (n) and spaces associated with letters indicate '0' counts of *O. v-nigrum*; other spaces represent missing data. See text for exact sampling dates.

The total numbers of coccinellids observed at these sites were 131 and 75 respectively, *O. v-nigrum* comprising 3 (2.3%) and 6 (8.0%) individuals, respectively. The proportions of *O. v-nigrum* in samples at these two sites were not significantly different from one another in '2 x 2' contingency table  $\chi^2 = 3.722$ , 1df,  $P = 0.054$ , but both sites had significantly fewer *O. v-nigrum* as a proportion of total coccinellids than did the Lake Wales site ( $\chi^2 = 11.915$ , 1df,  $P < 0.001$  and  $\chi^2 = 33.998$ , 1df,  $P < 0.001$ ). Thus *O. v-nigrum* remains rare in sites where *D. citri* is not yet present, but has increased significantly in abundance at all sites where *D. citri* is present.

During the recent observations in spring 2001, larvae and adults of *O. v-nigrum* were often observed feeding on psyllid nymphs. Pupae collected from hardened leaves adjacent to extinct psyllid colonies gave rise to viable adults in the laboratory. Consumption of the adult stage by coccinellids has not yet been directly observed. Many young citrus terminals exhibited typical damage symptoms (characteristic twisting and distortion of expanding leaves) and retained residues of the waxy nymphal secretions, although no live psyllid nymphs remained. Most nymphs appeared to have been eliminated by predation from terminals with feeding damage and wax residues. Adults and larvae of *C. sanguinea* and *H. axyridis*, as well as larvae of *Ceraeochrysa* sp. and an unidentified syrphid, were other predators observed feeding on nymphs. Although the exotic parasitoid *Tamarixia radiata* is now apparently established in some of these regions (A. Chow<sup>1</sup> personal communication), no mummified or obviously parasitized nymphs were noticed during these observations. However, while adult psyllids were evident, immature stages were quite rare in most of the groves sampled, despite the presence of abundant new growth on some trees.

It is notable that *O. v-nigrum* has been imported to Asia from the new world as a biological control agent of psyllids, particularly for control of *H. cubana*, a pest of nitrogen-fixing trees and shrubs of the genus *Leucaena*. It was imported to Tahiti from tropical America in the 1980s where it gave good control of *H. cubana*, and subsequently to New Caledonia (Chazeau 1987a,b). Control of *H. cubana* by *O. v-nigrum* has not been as effective in New Caledonia as in Tahiti, partially because it is parasitized by *Phalacratophora quadrimaculata* Schmitz (Diptera: Phoridae) (Disney & Chazeau 1990). Another new world coccinellid, *Curinus coeruleus* Mulsant, was later released in New Caledonia to supplement the action of *O. v-nigrum* (Chazeau et al. 1992) and this species was also detected in the present survey, albeit

in low numbers. Subsequently, *O. v-nigrum* was introduced to Reunion Island in 1992 (Vandeschricke et al. 1992) and in Hawaii increases in the populations of both *O. v-nigrum* and *C. coeruleus* were observed in response to invasion by *H. cubana* (Nitrogen Fixing Tree Association 1990). Although these coccinellid predators are considered generalists, they are known to express prey preferences (Dixon 2000) and have the potential to suppress pest populations as effectively as any specialist parasitoid. The ability to use alternative food sources when preferred prey are rare may actually buffer the population dynamics of a generalist species relative to the population of a specialist that inevitably crashes along with the pest population.

The response of *O. v-nigrum* to *D. citri* in Florida vividly illustrates the potential of certain native predators to respond to introduced pests. Although infestations of *D. citri* are still substantial in many groves, populations of indigenous natural enemies are still increasing and should ultimately provide good biological control of the psyllid. The situation is analogous to that of the brown citrus aphid, an invasive pest that was extremely abundant in Florida citrus for the first few years following its introduction. Although isolated outbreaks of *T. citricida* can occur when biological control is disrupted, populations are now relatively low in Florida, due largely to mortality inflicted by generalist predators, and despite the failure of any exotic parasitoid species to establish (Michaud 1999).

It could be argued that the association of abundant *O. v-nigrum* populations with *D. citri* infestations is merely circumstantial evidence and that correlation does not equal causation. However, the evidence is substantial and the trend is consistently significant, both temporally and spatially. Further work is warranted to determine the suitability of a diet of immature psyllids for the development and reproduction of *O. v-nigrum*, as well as *C. sanguinea* and *H. axyridis*. Given the apparent effect of *O. v-nigrum* on psyllid populations, any evaluation of classical biological control programs against *D. citri* must consider mortality contributed by this and other coccinellid species.

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