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POPULATION DYNAMICS OF *PHYLLOCNISTIS CITRELLA* (LEPIDOPTERA: GRACILLARIIDAE) AND ITS PARASITOIDS IN TAFÍ VIEJO, TUCUMÁN, ARGENTINA

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ABSTRACT

Seasonal abundance of the citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), was investigated between Nov 1999 and Apr 2003 in Tafí Viejo (Tucuman province). *Phyllocnistis citrella* populations increased during spring and summer, declined during fall, and disappeared in the winter. Five species of parasitoids, one exotic and four indigenous, attacked citrus leafminer immature stages in commercial and experimental lemon orchards. *Ageniaspis citricola* Logvinovskaya (Hymenoptera: Encyrtidae) was the most abundant parasitoid. *Cirrospilus neotropicus* Diez & Fidalgo (Hymenoptera: Eulophidae) was the most abundant indigenous species, followed by *Galeopsomyia fausta* LaSalle (Hymenoptera: Eulophidae). The other indigenous species were not common and were only occasionally collected from citrus leafminer larvae. Parasitoids and *P. citrella* exhibited similar population fluctuations throughout the entire sampling period. A certain degree of synchrony exists between the most abundant parasitoids (*A. citricola, C. neotropicus*, and *G. fausta*) and the pest. The highest rates of parasitism were observed in the fall. *Ageniaspis citricola* exhibited approximately 29.5% parasitism, whereas all the native species together were only 8.2%. Data showed that a clear dependence existed between percentages of parasitism and citrus leafminer population density for the most frequent parasitoid populations. The results of this study show that *C. neotropicus* has an important role among the native species present in Argentina.

Key Words: pest, performance, parasitism, lemon, citrus leafminer

RESUMEN

La provincia de Tucumán concentra el 90% de la actividad limonera de la Argentina, siendo esta el primer productor e industrializador de limón del mundo. La presencia de *Phyllocnistis citrella* Stainton, pone en riesgo la productividad de este cultivo, atacando a plantas jóvenes y de invernaderos. El objetivo del presente trabajo fue conocer la fluctuación poblacional de *P. citrella* y sus parasitoides, datos de importancia al momento de implementar proyectos de manejo integrado de plagas en cítricos. Se monitorearon cuatro campañas citrícolas entre Nov de 1999 y Jun de 2003; en dos quintas de limones ubicadas en el Depto de Tafí Viejo, Tucumán. *Phyllocnistis citrella* se registró en campo a principios de Noviembre; aumenta su abundancia poblacional en sucesivas generaciones en el verano, época en la que muestra sus picos poblacionales máximos. A comienzos del otoño su abundancia poblacional disminuye y desaparece en invierno. Cinco especies de parasitoides, una exótica (Encytidae) y cuatro nativas (Eulophidae), atacaron los estadíos inmaduros de *P. citrella*. El parasitoide introducido, *Ageniaspis citricola* Logvinovskaya, fue el más abundante con 29,5% de parasitoidismo. *Cirrospilus neotropicus* Diez & Fidalgo fue la especie nativa más abundante y frecuente con 7,8% de parasitoidismo, seguida por *Galeopsomyia fausta* LaSalle. El resto de las especies nativas no fueron muy comunes y sólo ocasionalmente fueron colectadas a partir de *P. citrella.* La especie nativa *C. neotropicus* demostró tener un rol importante, por su frecuencia y abundancia, sobre las poblaciones de la plaga, dando muestras de la importancia de mantener la biodiversidad de la región.

Translation by the authors.

The citrus leafminer, *Phyllocnistis citrella* Stainton, originally from the east and west of Asia, is one of the main pests that affects *Citrus* and related species worldwide (Beattie 1993). *Phyllocnistis citrella* was not reported in the western hemisphere until May 1993 when it was discovered in citrus nurseries in Florida (Heppner 1993a). In Argentina, the citrus leafminer was reported for the first time in late 1995 in citrus plantations in Northern Salta and Northwestern Tucumán (Willink et al. 1996). At present, it is found in all citrus areas of Argentina.

Heavy infestations of *P. citrella* can seriously affect plants from nurseries and those recently planted, although the damage is less significant in mature trees. The presence of this pest makes trees more susceptible to infestation by citrus canker bacterium *Xanthomonas axopodis* pv. *citri* (Sohi & Sandhu 1968). The serpentine mines under the leaf cuticle caused by the larvae of citrus leafminer, provide ample wounding on new growth to greatly amplify citrus canker infection (Gottwald et al. 2002). Larvae carve serpentine mines on the adaxial and abaxial surfaces of newly formed leaves, ingesting the sap and producing a chlorotic leaf patch. This prevents young leaves from expanding, making their margins curl and sometimes even causing the leaves to fall.

At present, *P. citrella* control practices consist of the application of chemical products as well as biological control. Effective chemical control is difficult because the larvae are protected from insecticides by the leaf cuticle (Legaspi et al. 1999). It has been suggested that biological control can become a successful tool for the regulation of populations of this pest (Hoy & Nguyen 1994). Nearly 80 species of parasitoids have been obtained from citrus leafminer worldwide. Of these, approximately 20 species occur in the Neotropical region (Schauff et al. 1998). From *P. citrella* larvae, 39 species of parasitoids from seven families, mainly Chalcidoidea, have been identified (Heppner 1993b) and ten species occur in Thailand (Hoy & Nguyen 1994). Of these, *Ageniaspis citricola* Logvinovskaya is the most significant. LaSalle & Peña (1997), Evans (1999), and Diez & Fidalgo (2004) described three new species of Eulophidae in the Neotropical region. Many of these species are incidental and provide no effective control of the pest. Others, however, play a significant role in the regulation of the population levels, such as species of *Cirrospilus* sp., and *Galeopsomyia fausta* LaSalle (LaSalle & Peña 1997; Urbaneja et al. 1998; Urbaneja et al. 2000).

Five species of parasitoids (Eulophidae) that attack *P. citrella* have been recorded in Argentina: *Cirrospilus neotropicus* Diez & Fidalgo, *Elasmus* sp. (a new species currently being described by the authors), *G. fausta*, *Elachertus* sp., and *Sympiesis* sp. (Frías & Diez 1997; LaSalle & Peña 1997; Schauff et al. 1998; Fernández et al. 1999a; Diez 2001; Diez & Fidalgo 2004). The role of these native parasitoids was studied by Diez et al. (2000), and Diez (2001), who observed that *C. neotropicus* is the most important native parasitoid from *P. citrella* due to its frequency and abundance. Approximately 19% parasitism is due to *C. neotropicus*, whereas the rest of these species are not common and only occasionally collected from citrus leafminer.

Classical biological control, through the introduction of hymenopteran parasitoids, is a method used in different parts of the world for the regulation of the populations of *P. citrella* (Hoy et al. 1995; Argov & Rössler 1996; Smith & Beattie 1996; Hoy & Nguyen 1997; Siscaro et al. 1997; Tsagarakis et al. 1999; Vercher et al. 2000; Nogueira de Sá et al. 2000; Fernández et al. 1999b; Diez et al. 2000; Willink et al. 2002). Two Parasitoids, *A. citricola* and *Citrostichus phyllocnistoides* Narayanan, were introduced in Argentina. The first was reported in Tucumán in 1997 as a case of ecesis in biological control (Fernández et al. 1999b; Diez et al. 2000). However, in 1998 this parasitoid was reintroduced in the citrus plantations of Tucumán with specimens from Peru (Figueroa et al. 1999). It was determined that this parasitoid is widely established in the northwestern region of Argentina, constituting the most important species due to its abundance and the frequency observed on *P. citrella* (Diez et al. 2000; Diez 2001). *Citrostichus phyllocnistoides* was released in the Argentine provinces of Salta, Jujuy, Tucumán and Catamarca in 2001. This species was reared in large numbers and periodically released in citrus plantations throughout the year 2002 (Willink et al. 2002).

The objective of this study was to describe the population dynamics of *P. citrella* and its parasitoids in Tafí Viejo (Tucumán province) and evaluate the importance of the latter for biological control of the pest.

Materials and Methods

The seasonal dynamics of citrus leafminer and its parasitoids were studied between 1999 and 2003 in four sampling periods: Nov 1999 through Apr 2000; Nov 2000 through July 2001; Aug 2001 through Jul 2002; and Aug 2002 through Apr 2003. The study was performed in plots from two fields planted with lemon trees in Tafí Viejo, Tucumán. One of the fields remained free of insecticides (unsprayed, experimental orchard), whereas the other was a commercial orchard and was sprayed regularly. Both fields had approximately 500 lemon trees.

In the commercial orchard (sprayed), routine agronomic practices for the region include frequent use of agrochemicals, insecticides, fungicides, and herbicides. Treatments applied to the sprayed orchard were made to primarily control mites and citrus leafminer. In all years, between Sep and Jan, a copper and oil sprays were made monthly for fungal pathogens and mite control. In 1999 and 2001 only, one application of mineral oil was made in Sep and another in Jan to prevent oviposition of citrus leafminer. To reinforce these applications, a second application of mineral oil was made within the first two weeks of Jan. In 2003 and 2004, abamectin was applied every 15 days between Jan and Mar, for *P. citrella* (Ing. Agr. Fernando Carrera, personal communication).

To determine the density of *P. citrella*, 10 trees were selected randomly from each plot every week, and eight shoots measuring less than 10 cm (9.32 ± 2.6 leaves per shoot) were collected from each tree (Ripolles et al. 1996). Occasionally, fewer shoots were available in the field; in these cases all the shoots present were collected. This is reflected in the results as a decrease in the number of shoots monitored. Each shoot was placed in a polyethylene—terephthalate bag (30 cm × 20 cm), with a sheet of absorbing paper to avoid condensation of humidity. The samples were transported to the laboratory and examined under the microscope to determine the presence of all stages of *P. citrella*. Leaves with larvae and pupae were separated to observe the emergence of adults and parasitoids of *P. citrella*. They were placed in Petri dishes (9 cm diameter) containing plaster of Paris and covered with plastic film; distilled water was added everyday to maintain humidity. The dishes were kept under ambient conditions in the laboratory. All emerging adults of *P. citrella* and parasitoids were identified and counted. These data allowed us to describe the population fluctuation of citrus leafminer and its parasitoids, the percentage of new flush damaged by citrus leafminer (Urbaneja Garcia 2000), the percentage of parasitism (Van Driesch 1983), and species richness of parasitoids in both plots (Odum 1985).

Evaluation of differences between the population density of *P. citrella* and density populations of parasitoids in both plots were made by Student's *t*-test. A χ^2 test was used to evaluate differences between the abundance of the different species of parasitoids. A stepwise multiple regression analysis was performed in order to evaluate the relationship between *P. citrella* density, number of monitored shoots, and different weather variables (daily high and low temperatures and daily precipitation). Weather data were provided by the personnel of the Park Sierras de San Javier. These data were daily collected with a thermograph and rain gauge, installed in the park, within a meteorological square located at 700 m.s.n.m. The number of samples compared was 79. All the statistical analyses were made at significance level $\alpha = 0.05$ (Statistix, Analytical Software, Tallahassee, FL).

Results and Discussion

Population Abundance

Between Nov 1999 and Apr 2003, 64,735 leaves were inspected to determine the presence or absence of *P. citrella.* In total, 45,335 citrus leafminer specimens were recorded, including eggs and larvae at different instars. The highest population levels of *P. citrella* were observed between Jan and Mar, while the lowest incidence occurred in the months of Aug through Dec and Apr through Jul (Fig. 1). The seasonal pattern of *P. citrella* was similar to observations in Florida (Peña et al. 1996) and in southern Texas (Legaspi et al. 1999), where population densities increase from spring to fall and decline during the winter. In general, the reason for the increase in density of *P. citrlla* in spring is the presence of new shoots and the increase in temperature, which is favorable to the pest. In Florida (Peña et al. 1996) and Mexico (Bautista-Martínez et al. 1998), as well as in our working area, the development of some flushes during winter, which were free of *P. cit-*

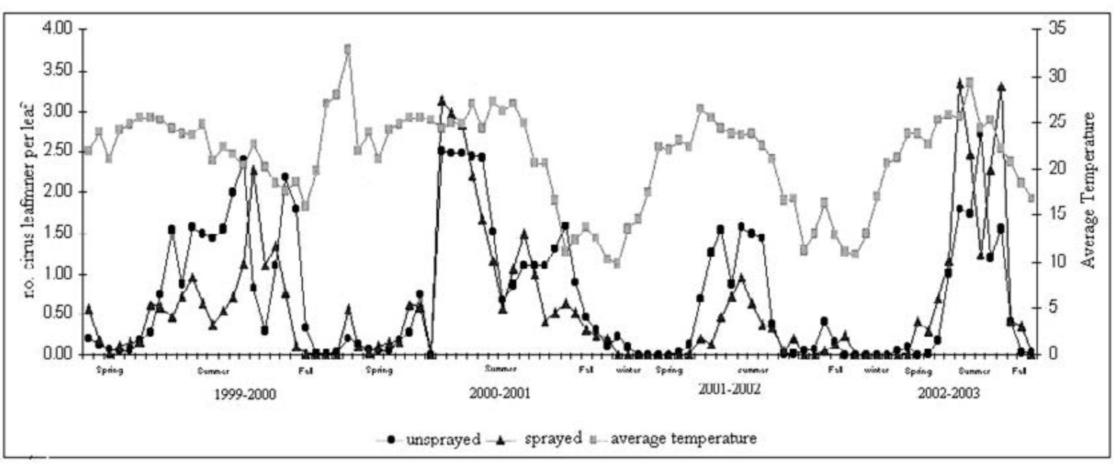

Fig. 1. Average density of *P. citrella* in sprayed and unsprayed lemon orchard in Tafi Viejo, (Tucumán, Argentina) between 1999 and 2003.

rella, were observed. According to Peña et al. (1996), citrus leafminer oviposition declines during the winter due to the low temperatures. Hence, the increase in the population of citrus leafminer in spring could be more related to the increase in temperatures than to the presence of shoots. In this study, the stepwise multiple regression analysis between weather factors, monitored shoots, and *P. citrella* density showed that the weather variables, and not the shoots, consistently affected pest populations ($Y = 1.88 + 2.84$ minimum $T_{(deg\ C)}$ + 0.55 Rainfall - 2.4 maximum $T_{(deg\ C)}$; $R^2 = 0.99$; $F = 4836.7$; $P > 0.001$; $n = 79$). The rise in temperature and rainfall recorded during spring contribute to this population increase.

Throughout all the sampling periods, a decrease in the population abundance of *P. citrella* was observed, which fell an average 34% between 1999 and 2003. Climate variables play an important role among the many factors that could contribute to this situation. In that period a significant decrease in precipitation and a small increase in the average temperature was registered in the study area. This decrease in rainfall could have affected the quantity of shoots, bringing their numbers down, which would be reflected as a decrease in monitored shoots. This situation could partially explain the decrease in the population abundance of citrus leafminer in these years. A similar situation was recorded in southern Texas, where a general decrease in the population levels of citrus leafminer was observed between 1995 and 1998 (Legaspi et al. 2001).

During the first sampling period four population peaks were registered in Jan, Feb, and Mar of 2000, varying between 0.96 and 1.82 citrus leafminer per leaf. In the second period, an important population peak of 2.77 citrus leafminers per leaf was recorded in the first week of Jan. In the third period, two instances of higher population density (0.96 and 1.27 citrus leafminers per leaf) were observed in Jan 2002. In Dec 2002 and Feb 2003 (the last monitored sampling period), two population peaks were recorded, with maximum values of 2.61 and 2.87 citrus leafminers per leaf (Fig. 2). These fluctuating patterns coincide with those shown by the pest both in Florida (Peña et al. 1996) and southern Texas (Legaspi et al. 1999), where populations are most abundant during the summer and early autumn.

In general, there are no differences between the *P. citrella* population fluctuations in either sprayed or unsprayed plots ($t = 1.14$; $P = 0.14$). There were particular instances, however, where the fluctuation curves were inverted (i.e.,whenever the density of *P. citrella* increased in the commercial plot, it decreased in the experimental plot). This could be due to the action of other factors of mortality, such as predators, that could be acting in this plot. In Jan, increases in citrus leafminer population were observed in the experimental plot whereas the population decreased in the commercial plot (Fig. 1). These situations could be partially related to the frequent use of agrochemicals in the commercial plot.

Percentage Leaf Damage

The percentage leaf damage by the immature stages of *P. citrella* was approximately 51% throughout this study. Studies performed in Spain during 1999 (Urbaneja García 2000) reported higher percentage leaf damage (86.7-96.2%) than those observed in this investigation for each monitored sampling period. In Spain, the parasitoid *A. citricola* has not become established. Except for the last sampling period, the percentage of total weekly attacks recorded in the exper-

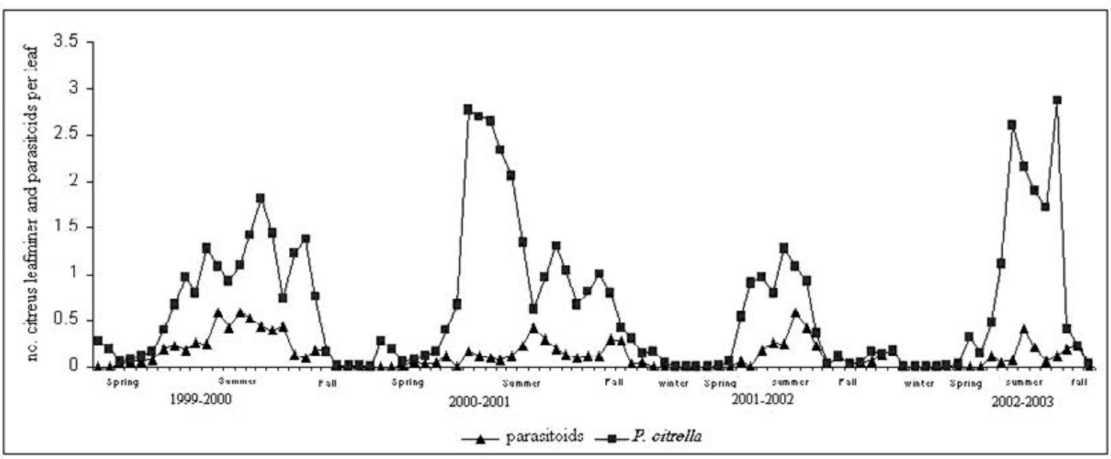

Fig. 2. Average density of *P. citrella* and its parasitoids in Tafi Viejo (Tucumán, Argentina) between 1999 and 2003.

imental plot was generally greater than in the commercial plot. This is undoubtelly related to the frequent use of agrochemicals in the commercial plot. The highest percentage of citrus leafminer attack to the crop was recorded in the unsprayed plot during the summer. Therefore, chemical products used to control the pest in our region should be applied starting in Nov and early Dec, when the temperature and humidity conditions are not yet adequate for development of the pest, and its population density is low in the field. This would thus limit the uncontrolled population growth exhibited by *P. citrella* around mid-Dec, brought about in part by the absence in the field of its parasitoid natural enemies.

Damage caused by *P. citrella* larvae began in late spring (Nov-Dec) amounting to 19.9% of the total. The highest rates were observed in the summer (52%), whereas in the fall damage decreased to 13.4%. No damage occurred in winter. In Spain, reported rates of damage were 30% in the first months when citrus leafminer was observed and 90% during months exhibiting higher population abundance (Urbaneja García 2000).

Parasitoid Complex

The complex of parasitoids recorded on *P. citrella* in the four sampling periods was represented by one introduced exotic species, *A. citricola*, and four native species: *Cirrospilus* (= *Cirrospilus* sp.) *neotropicus*, *G. fausta*, *Elasmus* sp. and *Elachertus* sp., all members of the family Eulophidae. This work confirms previous records obtained for this region (Frías & Diez 1997; Fernández et al. 1999a; Diez 2001). The last species introduced in our region (*C. phyllocnistoides*) has failed to establish and overwinter successfully, since no individual of this species was recovered in the last sampling period.

During this study, five species, one introduced (*A. citricola*) and four native species (*C. neotropicus*, *E. phyllocnistoides*, *G. fausta*, and *Elachertus* sp.), were recorded in the experimental plot, whereas only three species, one introduced (*A. citricola*) and two native species (*C. neotropicus* and *G. fausta*), were observed in the commercial plot. According to Odum (1985), a harsh physical environment, contamination, and other factors tend to reduce the number of rare species and increase the importance or degree of dominance of a few common species (which can better tolerate the pressure or are more adapted to it). This fact, in conjunction with the use of chemical products in the commercial plot, could explain at least in part the differences found in the species richness in both plots. Moreover, the presence of the native species, *C. neotropicus* and *G. fausta*, in the commercial plot would indicate that these species are better able to withstand the pesticides used in lemon plantations in the area. A similar situation was described in Florida regarding the native parasitoid *Pnigalio minio* (Walker) in crops where insecticides were applied (Peña et al. 1996).

Ageniaspis citricola was the most abundant parasitoid in our region, amounting to 62.3% of the parasitoids observed in this study. *Cirrospilus neotropicus* was the most abundant among the native species (29.2%), followed by *G. fausta* (1.3%), *Elasmus* sp. (0.1%), and *Elachertus* sp. (0.05%) ($\chi^2 = 9.48$). However, the structure of the parasitoid complex of *P. citrella* varies according to the region under study. In Spain, *Pnigalio pectinicornis* (Linnaeus) is the dominant species, amounting to 57.1% of the recorded parasitoids (Urbaneja et al. 2000). In Florida, the most important native species was *P. minio* (80%), followed by *Cirrospilus* sp., *Closterocerus* sp., *Zagrammosoma multilineatum* (Ashmead), and *Horismenus* sp. (Peña et al. 1996). In southern Texas, *Z. multilineatum* was the most important species, amounting to 68-74% (Legaspi et al. 1999). In Mexico, two species of *Cirrospilus,* and *G. fausta* were observed as the most representative native species (Bautista-Martínez et al. 1998). In Brazil, *G. fausta* was recorded as the most important native species (53%), followed by *Elasmus* sp., and *Cirrospilus* sp. (Montes et al. 2001). *Cirrospilus neotropicus* exhibited a high frequency in the commercial plot. This could be related to the presence of alternative hosts that are presumed to inhabit nearby *Citrus* plantations and to act as reservoirs for this native species in the area.

Parasitoids exhibited a population fluctuation similar to that of the pest and also a similar behavior throughout the spring to winter period (Fig. 2). Highest abundance of parasitoids coincides with the highest pest density (summer) in all sampling periods ($R^2 = 0.84$). Legaspi et al. (1999) reported the highest abundance of parasitoids in late summer and early fall in southern Texas, corresponding to an increase in host populations.

The population density of different species of parasitoids was the same in both plots ($t = 1.48$; $P = 0.13$). In general, parasitoids were first observed in both plots in Nov and Dec, exhibiting the highest population levels in summer. Population fluctuations recorded in the first, second, and fourth sampling periods were very similar. Similarly, the time of appearance of the parasitoids, except for the population peak corresponding to Jan 2000, was remarkably higher in the commercial plot. In the third sampling period, parasitoids in the commercial plot were first observed a month later than in the experimental plot and exhibited a marked asynchrony, showing a higher density between Nov and Jan. The highest density of parasitoids in the experimental plot was observed between Jan and Apr.

The most abundant populations, *A. citricola*, *C. neotropicus*, and *G. fausta* exhibited similar population fluctuations as *P. citrella* throughout the entire sampling period. Two species, *A. citricola*, *C. neotropicus*, were recorded in all sampling periods, whereas *G. fausta* was present only in the first three sampling periods. No alternative hosts of *A. citricola* have been described. This suggests that the parasitoid exhibits a good synchronization with the pest, spending the winter in diapause on *P. citrella*, with delayed development in the spring. This is probably due to the low relative humidity, a known limiting factor in the rearing of this species. The dry season in Tucumán coincides with the winter and extends a few months into spring.

Populations of *Elasmus* sp. were present sporadically, appearing only in Jan and Apr in the first and third sampling periods, respectively. *Elachertus* sp. was observed on *P. citrella* only during the first sampling period (Mar), and completely disappeared afterwards. Appearance in the field varies for the different species of parasitoids according to the areas and species considered. In Florida, *Cirrospilus* species were found in the field starting in the fall through the spring (Peña et al. 1996). In Brazil, *G. fausta* is found in the field most of the year, *Elasmus* sp. between Jan and Mar, and *Cirrospilus* sp. in Jun and Jul (Montes et al. 2001).

In all but the last sampling periods, the native species *C. neotropicus* was observed in the field before the exotic species *A. citricola*. According to Cornell and Hawkins (1993), parasitoids that successfully colonize invading hosts are usually generalists, can change hosts more easily, and are more successful initially than specialists. This phenomenon could explain why *C. neotropicus* appears before the introduced parasitoid in all sampling periods. *Cirrospilus neotropicus* remains throughout the summer season exhibiting a more or less stable frequency, which is suggestive of its adaptation to its new host, *P. citrella*.

Percentage of Parasitism

The average percentage of parasitism recorded during the entire study was approximately 37.7%. This is lower than those observed by others. Hoy & Nguyen (1997) observed approximately 60% in Florida. Bautista-Martínez et al. (1998) and Legaspi et al. (2001) observed close to 70% in Mexico. Percentages of parasitism recorded in both plots were practically the same (commercial plot 39.9%, experimental plot 35%) ($P = 0.75$; $t = 1.65$). Similar values were found in Spain in plots with different exposure to insecticides (Vercher et al. 1995).

Throughout the study, the highest rates of parasitism were observed in the fall. This might be partially due to a decline in the population of *P. citrella* during the fall season when all populations of parasitoids, specialists or generalists, are already well established (Fig. 3). In addition, populations of parasitoids become synchronous with *P. citrella* populations at this time of year. A similar situation was observed in Veracruz, Mexico, with high percentages of parasitism accompanied by low abundance of collected *P. citrella* (Bautista-Martínez et al. 1998). Analysis of the data showed that a clear dependence existed between percentages of parasitism and citrus leafminer population density for the most frequent parasitoid pop-

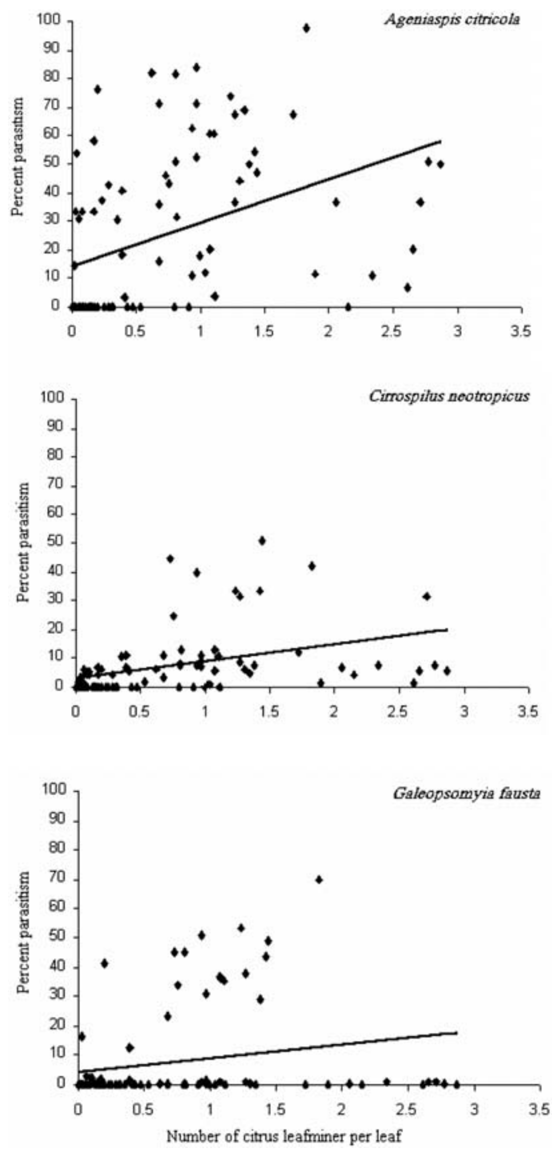

Fig. 3. Relation between percentage parasitism of *Ageniaspis citricola, Cirrospilus neotropicus*, and *Galeopsomyia fausta*, and average density of *Phyllocnistis citrella* in Tafi Viejo (Tucumán, Argentina) between 1999 and 2003.

ulations (*A. citricola*, *C. neotropicus*, and *G. fausta*). This means that the efficiency of the parasitoid increases with population density of the pest (Fig. 3).

Native versus Introduced Parasitoids

Ageniaspis citricola exhibited approximately 29.5% parasitism, whereas all the native species together showed a value of only 8.2%. Data recorded for *A. citricola* in this study were lower than those recorded in other countries. For example, studies conducted in Florida between 1994 and 1995 showed 60 and 80% parasitism for this species (Hoy & Nguyen 1997). The first results on *A. citricola* in Texas showed values of approximately 40% (Legaspi et al. 1999). As for native parasitoids, 5-10% parasitism was observed in Texas (Legaspi et al. 1999). The highest values recorded in Brazil were near 35% (Montes et al. 2001), but peaks of 85.7% were observed in Mexico (Bautista-Martínez et al. 1998).

Cirrospilus neotropicus showed the highest percentage of parasitism (7.8%) among the native parasitoids, followed by *G. fausta* (0.43%), *Elasmus* sp. (0.08%) and *Elachertus* sp. (0.01%). *Elachertus* sp. is an important species in China with 40 to 54% parasitism (Hoy & Nguyen 1997). In Mexico, species in the genus *Cirrospilus* and *G. fausta* exhibit the highest levels (70%) of parasitism (Bautista-Martínez et al. 1998). In Brazil, *G. fausta* caused 53% of parasitism, followed by *Elasmus* sp. with 38%, and *Cirrospilus* sp. with 9% (Montes et al. 2001).

According to LaSalle and Peña (1997), a large complex of native parasitoids are now attacking *P. citrella*, and in many cases are providing control equal to, or greater than, that provided by *A. citricola*. The results of this study show that *C. neotropicus* has an important role among the native species present in our region due to the frequency with which it is observed on the pest. Despite their low number in the region, other native species such as *G. fausta* and *Elasmus* sp. have also been reported to be important control agents of *P. citrella* in other countries.

Data obtained from the four monitoring sampling periods in different times of the year determined that *A. citricola* (introduced species), *C. neotropicus*, and *G. fausta* (native species), among all the species that comprise the parasitoid complex for *P. citrella* in this region. These species have characteristics that suggest they may be good choices for future biological control projects. These species were undoubtedly responsible, in part, for the decrease in the population densities of the pest since their introduction, and to current levels. *Ageniaspis citricola* and *C. neotropicus* are currently going through different processes i.e., the establishment and colonization of *A. citricola*; and the adaptation of *C. neotropicus* to citrus leafminer. More work is needed to better understand the population dynamics of *G. fausta*.

Acknowledgments

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