



REVISION OF MIRID HETEROPTERANS PREYING ON THE *trialeurores vaporariorum* (WESTWOOD), IN PARTICULAR *tupiocoris* *cucurbitaceus* (SPINOLA) OBSERVED IN CENTRAL CHILE

REVISIÓN SOBRE HETERÓPTEROS MÍRIDOS DEPREDAADORES DE *trialeurodes*
vaporariorum (WESTWOOD), EN PARTICULAR *tupiocoris cucurbitaceus* (SPINOLA)
OBSERVADO EN CHILE CENTRAL

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Abstract

Updated information has been revised and is presented on heteropteran (Miridae) predators with potential in biological control of whiteflies, *Macrolophus pygmaeus* Rambur (formerly *M. caliginosus* Wagner), and mostly on *Tupiocoris cucurbitaceus* (Spinola), which has been observed preying on the whitefly *Trialeurodes vaporariorum* (Westwood) (Trialeurodidae) on tobacco plants and greenhouse tomato in the Metropolitan region, central Chile.

Keywords: Biological control, *Macrolophus caliginosus*, *Macrolophus pygmaeus*, greenhouse whitefly.

Resumen

Se presenta una revisión actualizada sobre heterópteros (Miridae) depredadores con potencial para el control biológico de mosquitas blancas, *Macrolophus pygmaeus* Rambur (anteriormente *M. caliginosus* Wagner), y en particular *Tupiocoris cucurbitaceus* (Spinola) sobre la mosquita blanca *Trialeurodes vaporariorum* (Westwood) (Trialeurodidae) en plantas de tabaco y tomate de invernadero en la Región Metropolitana, Chile central.

Palabras clave: Control biológico, *Macrolophus caliginosus*, *Macrolophus pygmaeus*, mosquita blanca del tomate.

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1 Polyphagous vs specialist insect predators in biological pest control

Some characteristics associated with natural enemies are their degree of specificity with their prey, a relatively short development cycle in relation to the pest and a high reproductive capacity, factors that have been considered important for effective biological control agents (Snyder and Ives, 2003).

Polyphagous predators consume pest arthropods that affect crops, but also any other arthropod species present in these environments, so they have not been considered relevant as control agents, compared to the more specific natural enemies used in biological control of pests (Labbé, 2005).

Although specialists generally avoid direct interaction with other natural enemies, they generally consume species that use similar resources and, therefore, are potential competitors (Polis, Myers and Holt, 1989; Polis and Holt, 1992; Rosenheim, Wilhoit and Armer, 1993; Rosenheim, 1998).

Several studies have indicated that generalist predators can work in diverse agroecosystems (Riechert and Bishop, 1990; Settle et al., 1996; Snyder and Ives, 2003) and compensate the deficit of specialists who have a limited range of prey or tend to disappear once the resource runs out.

The programmed release of natural enemies for specific pests can be expensive and complicated, so generalist predators are increasingly appreciated to be used in the long-term crops (Labbé, 2005).

Some generalist polyphagous predators are established in more easily crops than specialists and, therefore, exert permanent control of pest populations (Gillespie and McGregor, N.d.). In addition, since these predators can consume species not related to the pest (Albajes and Alomar, 1999), they occur naturally in many areas, reducing the need to import biological control agents (Khoo, 1992).

2 Zoophytophagous heteropterans

By definition, zoophytophagous predators are omnivorous and can feed on more than one trophic level (Pimm and Lawton, 1978; Eubanks and Styrsky, 2005). Recently, these predators have begun to be studied for their potential in biological control. They can withstand long periods of prey scarcity,

since they can feed on plant tissue as well as arthropods (Naranjo and Gibson, 1996; Wiedenmann, Legaspi and O'Neil, 1996; Brodeur and Boivin, 2006; Ingegno, Pansa and Tavella, 2011). Zoophytophagous predators can use both types of food thanks to biochemical, morphological and physiological adaptations, such as the production of digestive enzymes and detoxification compounds, or by modifications of their mouth parts that allows them to take advantage of both insects and plants (Coll and Guershon, 2002; Snyder and Ives, 2003; Labbé, 2005).

Heteropterans vary greatly in their ability to feed on plants or animals. Their evolution is characterized by a divergence between those predominantly carnivorous and those phytophagous (Cohen, 1996). The feeding of plants in mirids is a new characteristic that is very different from the phytophagy of the ancestral groups. It is generally assumed that heteropterous lineages of phytophagous ancestors emerged with a secondary capacity to feed by predation (Sweet, 1979). Zoophytophagous heteropterans have the ability to exploit both food resources by "trophic switching", which allows them to survive in the absence of prey (Cohen, 1996).

For the zoophytophagous heteropterans, feeding on plants may be occasional or essential to survive and reproduce. For some predators, plants provide important nutrients and water, which in some prey are less abundant (Coll and Ruberson, 1998; Portillo, Alomar and Wäckers, 2012). In such cases, feeding on plants allows maintaining predator populations and improving some characteristics of individual life cycles, such as survival, development time, fecundity and longevity (Cohen and Debolt, 1983). For others, plants are poor food resources that are used only when there is no prey available (Gillespie and McGregor, N.d.). This feeding of plants serves to escape from hunger or to colonize crops before the prey arrives. The feeding of plants is a complement to the food resources of preys, the main source of nutrients. And in another group of heteropterans with extra oral digestion, the plant material simply provides the liquid they need to feed on the prey and is not an important source of nutrients. These predators acquire the proteins, fats and hemolymph necessary from the prey, which they use to complete development (Labbé, 2005). All these feeding strategies can differentiate predators as suitable biological controllers.

The predator *Macrolophus pygmaeus* Rambur can cause some damage to cherry tomato plants. In other crops, other minor damage has been described in the feeding of *Geocoris* large-eyed bugs, even in the presence of prey (Alomar and Albajes, 1996). According to Lalonde et al. (1999), when properly selected predators and tolerant crops are combined, effective pest suppression can be achieved, and in many tomato cultivars *M. pygmaeus* does not harm

the fruit or the plants. In these cases, plant feeding eliminates a minimum amount of plant tissue without causing economic damage. As a result, the use of highly effective zoophytophages in feeding the prey has become common in the world (Labbé, 2005). Some species of mirid predators identified and studied by their high potential as biological control agents in crops are presented in Table 1.

Table 1. Species of predatory mirids identified for biological control of crop pests (Tanada and Holdaway, 1954; Carnero-Hernández et al., 2000; Carvalho and Afonso, 1977; Lucas and Alomar, 2002a; Athanassiou et al., 2003; Agustí and i Ambert, 2009)

Predatory Miridae	Countries
<i>Cyrtopeltis (Engytatus) modestus</i> Distant	Hawaii, USA
<i>M. pygmaeus</i> Rambur	Many in Europe
<i>M. costalis</i> Fieber	Iran
<i>Dicyphus hesperus</i> Knight	Canada, USA
<i>D. hyalinipennis</i> Burmeister	Hungary
<i>D. cerastii</i> Wagner	Portugal
<i>D. errans</i> Wolff	Italy
<i>D. tamaninii</i> Wagner	Spain
<i>Nesidicoris tenuis</i> Reuter	Canary Islands, Philippines, Italy

In a study by Jakobsen, Enkegaard and Brodsgaard (2004), adults of *Orius majusculus* (Reuter) (Hemiptera, Anthocoridae) preyed on *M. caliginosus* in the absence and occasionally also in the presence of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), while neither the nymphs nor the adults of *M. caliginosus* preyed on *O. majusculus*. The nymphs of *O. majusculus* did not consume *M. pygmaeus*. These results suggest that the presence of this mirid will not affect the biological control of *F. occidentalis*.

Some Dicyphinae mirid predators are frequently used in Europe for the control of pests (e.g., whiteflies, aphids and thrips) (Alomar and Albajes, 1996; Riudavets and Castañé, 1998; Tedeschi et al., 1999; Hansen, Brodsgaard and Enkegaard, 2003; Alomar, Riudavets and Castañé, 2006). Due to their potential in biological control, some of them that also feed on plants, such as *Dicyphus tamaninii* Wagner and *M. pygmaeus* are good candidates for crops that tolerate them at low levels of herbivory (Gillespie and McGregor, N.d.). Tedeschi et al. (1999) reported that *M. pygmaeus* feeds on *T. vaporariorum*, *F. occidentalis*, *Aphis gossypii* Glover, *Myzus persicae* (Sulzer), *T.*

tranychus urticae Koch and *Spodoptera exigua* (Hübner). Lykouressis et al. (2008) added *Macrosiphum euphorbiae* Thomas and confirmed *M. persicae* (see also (Margaritopoulos, Tsitsipis and Perdakis, 2003; Sylla et al., 2016). Control strategies that incorporate *Macrolophus* species require seasonal inoculation of commercial crops and environmental management to preserve natural habitats and increase colonization (Alomar, Goula and Albajes, 2002). *D. tamaninii* is an efficient predator of whiteflies at high density in greenhouse tomato (Montserrat, Albajes and Castañé, 2000). *D. hesperus* is a native mirid distributed in North America, which provides good control of *T. vaporariorum* and *T. urticae* in greenhouse tomato (McGregor et al., 1999).

Biological control strategies have traditionally consisted of releases to inoculate foreign natural enemies. However, the periodic and largely unpredictable immigrations of pest populations, which typically occur in early season ventilation of greenhouses, tend to hamper these control strategies. As a result, efforts to control the *T. vaporariorum* whitefly in the greenhouse along the northeastern coast of Spain using *Encarsia formosa* (Gahan) (Hymenop-

tera: Aphelinidae) in spring tomatoes undergo periodic invasions of the whitefly that limit the effectiveness of the parasitoid (Albajes and Alomar, 1999). In this situation, in which insecticides are seldom applied to the crop, native natural enemies, such as the generalist predatory mirids *M. pygmaeus* and *D. tamaninii* also invade the greenhouses (Castañé et al., 1987; Castañé, Alomar and Riudavets, 1997; Castañé et al., 2004). This migration of mirids to greenhouses is common in the Mediterranean region and has been documented in Italy, Greece and France, and also in areas with mild Atlantic climate, such as the Canary Islands and Portugal (Malaua, Drescher and Franco, 1987; Perdakis and Lykouris, 1996, 1997, 2000, 2004a; Tavella et al., 1997; Carvalho and Afonso, 1977). The composition of species varies between regions, although they belong mainly to the genera *Macrolophus*, *Dicyphus* and *Nesidiocoris*.

Due to their polyphagy, the predatory mirids interact in greenhouse tomato with the *T. vaporariorum* whitefly and its parasitoid *E. formosa*. The natural colonization of greenhouses by *M. pygmaeus* and *D. tamaninii*, the two predominant species in the coastal region of Barcelona, Spain, usually leads to the establishment of predator populations in the crop that later feed on the whitefly. No preference was observed for parasitized pupae in greenhouse samples, while laboratory studies revealed a marked tendency to avoid the pupae of the parasitoids. In this area, IPM programs for greenhouse tomatoes and other vegetables should take advantage of the presence of this predatory complex and allow for the immigration and establishment of populations without affecting them with non-selective insecticides (Castañé et al., 2004).

3 Biological control of *T. vaporariorum* with heteropteran mirids predators

Goula and Alomar (1994) described the use of predatory mirids in Integrated Pest Management of whiteflies in tomato in Spain. Among the mentioned Miridae Dicyphinae, from which were described morphological characteristics that help to identify them, are *Macrolophus pygmaeus* (formerly *M. caliginosus* Wagner), *Cyrtopeltis tenuis* Reuter, *C. geniculata* Fieber, *D. tamaninii* and *D. errans* Wolff. In

addition, Chouinard et al. (2006) studied the mirid *Hyaliodes vitripennis* Say and its potential for biological control of mites and aphids in apple trees in eastern North America, including populations of the European red mite *Panonychus ulmi* Koch, the bimaculate mite *T. urticae* and the aphids *Aphis pomi* DeGeer and *A. spiraeicola* Pagenstecher.

4 Biological control of the tomato whitefly in Chile

In Chile, 20,000 ha of tomato, the main vegetable nationwide, are grown per year for fresh and industrial consumption. Of this area, about 1000 ha are grown in greenhouses, especially in regions IV and V (ODEPA, 2008).

One of the main pests of greenhouse tomato is the *T. vaporariorum* whitefly. This polyphagous pest affects more than 250 crops, and has the ability to develop resistance to pesticides, so if a chemical is necessary, it must be selected and applied carefully. This pest reduces the foliar surface and the vigor and growth of the plant, favors the development of saprophytic fungi in the foliage and is a potential vector of viral diseases, which further reduce the quality and yield (Johnson et al., 1992). Producers must evaluate their density continuously to avoid explosive density increases, especially in greenhouses, where the pest develops well due to the absence of natural enemies.

In Quillota, central Chile, *T. vaporariorum* is the main pest of tomato and other crops. In tomato, only the cost of insecticides reaches 49 to 89% of the total cost of pest management (Vargas and Alvear, 1999).

The control of *T. vaporariorum* is affected by its high reproductive potential and the presence of all its stages on the underside of the leaves, which help them avoid contact with insecticides. Today, the insecticide control is based on the use of various contact products, which also affect, however, biological controllers such as *E. formosa*, *Aphidoletes* spp. (Diptera, Cecidomyiidae), Neuroptera and coccinellids. In Quillota, studies have indicated that *T. vaporariorum* in some areas has lost susceptibility to methomyl, probably due to the high selection exerted on the pest by the 12 to 40 applications in the season. In addition, the lower affluence of populations in protected greenhouses has reduced the genetic variability of the pest and accelerated the de-

velopment of resistance to insecticides (Vargas and Alvear, 1999).

In many countries, including Chile, *T. vaporariorum* nymphs are reared in the laboratory and parasitized by *E. formosa*, which is then released for biological control of the pest in the field or in greenhouses. *E. formosa* parasitizes nymphs 3 and 4 of the whitefly, but parasitism is only detected in the stage of blackened pupa (Soto et al., 2001). *Poinsettia* and *Hibiscus* ornamental plants are used to develop *Bemisia tabaci* (Gennadius) and let it to be parasitized by *E. formosa*. This whitefly is not present in Chile, although it is of great global importance for the transmission of plant viruses and for having a very aggressive biotype b (the new species *B. argentifolii* Bellows & Perring according to some authors).

Since 2004 a mirid has been observed in every season in tobacco plants in a garden in Peñaflor, Metropolitan Region, Santiago, Chile. In 2007 this

mirid was also observed in greenhouse tomatoes in the same area, consuming adults and nymphs of *T. vaporariorum*. However, no studies have been done on its impact and biology. As *T. vaporariorum* is a key pest of tomato greenhouse, this predator has been studied to determine its potential as a biological control agent for this and other pests. In Chile, Prado (1991) and Koch, Waterhouse and Cofré (2000) did not present references about this predatory mirid.

5 Identification of a new predatory mirid in Chile

The use of keys by comparison of specimens collected, the predatory mirid in central Chile was identified as the polyphagous species *Tupiocoris cucurbitaceus* (Spinola) (Figure 1) (Barriga Tuñón, n/d).



Figure 1. *Tupiocoris cucurbitaceus* feeding with its stylet inserted in an adult of *Trialeurodes vaporariorum*.

In Figures 2 and 3, respectively, is presented a nymph of *Tupiocoris* and *T. cucurbitaceus* feeding on a larva of the tomato moth, *Tuta absoluta* (Meyrick)

(Lepidoptera: Gellechiidae), a prey mentioned by Biondi et al. (2013) in southern France.



Figure 2. Developed nymph of *Tupiocoris*.



Figure 3. Adult *Tupiocoris cucurbitaceus* preying on a larva of the tomato moth *T. absoluta*.

6 Biology studies of *Tupiocoris cucurbitaceus*

According to Bado, Cerri and Vilella (2005); Del Pino et al. (2009); Lopez, Cagnotti and Andorno (2011); López et al. (2012), *T. cucurbitaceus* feeds frequently on *T. vaporariorum* in pesticide-free greenhouses in Argentina, and can survive, develop and reproduce normally in tobacco or tomato plants. In both crops, this predator had a nymph period of 24.3 ± 1.5 d for females and 23.7 ± 0.6 d for males in the study of Orozco Muñoz, Villalba Velásquez and López (2012) using *B. tabaci*.

For Burla et al. (2014), the high consumption of *T. vaporariorum* eggs by *T. cucurbitaceus* suggests the need for new studies for the inclusion of this predator in biological control programs in greenhouses.

7 Studies on *Macrolophus pygmaeus*

Macrolophus pygmaeus is a very polyphagous predator, which has proved to be effective in the control of many insect pests in greenhouse plants (eggplant, tomato and cucumber) especially whiteflies, aphids and thrips. It is used mainly in the biological control against the whitefly *T. vaporariorum*, especially in tomato. Although crops are often treated with insecticides, biological control is becoming important to control this pest. An IPM program has been developed with mirids for tomato, with the objective of keeping the population densities of the predators high enough to keep *T. vaporariorum* and other pest populations below the economic threshold. Adults of *M. pygmaeus* feed on whitefly and pupal stage nymphs, making it a beneficial insect for the biological control of *T. vaporariorum* (Castañé et al., 2004).

M. caliginosus (= *M. pygmaeus*) appears on the Fitonova (Donoso and Díaz Tobar, 2011) website as being available against the tomato whitefly and tomato moth in Chile, but no details are provided. Carpintero and Carvalho (1993); Morrone and Coscarón (2008); Carpintero and De Biase (2011) presented annotated lists of Miridae in Argentina (see also Ohashi and Urdampilleta (2003); Logarzo, Williams and Carpintero (2005)).

M. pygmaeus is currently sold in Europe for the control of the tomato whitefly in greenhouses (Malezieux et al., 1995; Schelt et al., 1996; Pasini et al.,

1998), and also for the biological control of the tomato moth *T. absoluta* (Sylla et al., 2016) in Mediterranean countries (Albajes and Alomar, 1999; ?; Gue-naoui, Bensaad and Ouezzani, 2011; Urbaneja et al., 2012). Another predatory mirid, *D. tamaninii*, easily colonizes the greenhouses in these countries. Lucas and Alomar (2002b) did not register any intraspecific competition of *D. tamaninii* with *M. pygmaeus*.

M. pygmaeus is atypical among mirids in that females apparently mate only once (Gemeno Marín et al., 2007). Fauvel, Malausa and Kaspar (1987) studied in the laboratory the main biological characteristics of *M. pygmaeus* preying on preimaginal stages of the whitefly in the greenhouse. At 25 °C the incubation of eggs lasted 11.4 d and more than one month at 15 °C. The incubation of eggs was >80% in host plants in good conditions. Feeding on young whitefly nymphs the juvenile development at 25 and 15 °C lasted 19 and 58 d, respectively. Development still occurred at 10 °C but not at 40 °C. The longevity and fecundity of the females fed eggs of *Anagasta kuehniella* Zeller reached 232 d and 409 eggs, respectively.

In a study by Perdakis and Lykouressis (2004b), the adult longevity of *M. pygmaeus* in eggplant and tomato plants was greater at 15 °C, and in eggplant and tomato reached 38.72 and 34.20 d for females, and 92.88 and 62.80 d for males, respectively. Bonato, Couton and Fargues (2006) studied the food preferences of *M. pygmaeus* in *T. vaporariorum* and *B. tabaci*, and Castañé and Zapata (2005) evaluated a meat-based diet for rearing of *M. pygmaeus* for several generations, without any plant material and using cotton rolls for oviposition (see also Iriarte and Castañé (2001)). The performance of the adults of the 7th generation in this diet was evaluated in both whiteflies and *T. urticae*. The predation effectiveness of females and nymphs obtained was similar to that of insects in conventional rearing, so this method is an alternative to conventional and represents an improvement in the production of this predator.

Alomar, Riudavets and Castañé (2006) released 2 and 6 adults of *M. pygmaeus* per plant, initially infested with 10 *B. tabaci* adults. The highest release rate controlled the whitefly populations. A lower release ratio in a second trial did not work, possibly due to excessive plant pruning, which may have affected the establishment of predators. No damaged fruits were observed.

In a study by Mohd Rasdi et al. (2009), adults of

M. pygmaeus were fed with nymphs of *T. vaporariorum*, and were effective to control also other pests in eggplant, tomato and cucumber in greenhouse, especially aphids and thrips.

Some mirids are severe pests, such as *Labops* spp. and *Irbisia* spp. in prairies of *Agropyron* spp. introduced in the western US (Araya and Haws, 1988, 1991). Some have noticed that certain mirids occasionally feed on plants and can insert their stylets in them to obtain sap (Wheeler, 2001). Another example is *Lygus hesperus* (Knight), a key phytophagous pest that affects cotton, which is also an important predator in that crop (Hagler and Naranjo, 2005). In other species, this predatory action is known, as in *Dicyphus errans* Wolff (Quaglia et al., 1993) and *Creontiades pallidus* (Rambur) (Urbaneja et al., 2001), but it has not been considered in IPM.

8 Conclusions

Information is presented on three mirid heteropteran predators of whiteflies, *Macrolophus pygmaeus* Rambur (formerly *M. caliginosus* Wagner), and mostly on *Tupiocoris cucurbitaceus* (Spinola), which was observed preying on *T. vaporariorum* on tobacco plants and greenhouse tomato in Chile in the Metropolitan Region, central Chile. The foliage of the plants where the predator was sampled was carefully observed to rule out any damage to the leaves and especially to the tomato fruits.

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