Syrphids in Integrated Control of Aphids

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Abstract
This paper focuses on the role of aphidophagous syrphids in different strategies of Integrated Pest Control in greenhouse crops. Southeastern Spain is the world area with the highest production of organic products. Our scientific experience and field experimentation in the use of syrphids for control of pest aphids, show compatibility and effectiveness on the combined use of syrphids with other strategies commonly used in integrated pest control.

Introduction
'Flower flies' is a vernacular name for syrphids (Diptera, Syrphidae), which are known to be frequent visitors of flowers, where they obtain their feeding resource from (i.e. pollen and nectar). This behavior makes that these flies are now regarded as one of the main pollinator groups within insects [1]. In addition, their larvae are predatory, mycophagous, phytophagous or saprophagous (Sommaggio, 1999). The present paper focuses on the species with predatory larvae, which represent over a third of the 6200+ syrphid species known worldwide. The larvae of these species prey on small soft-bodied insects [2], especially aphids (Homoptera, Aphididae), which may cause severe damage mainly in greenhouse crops.

Erasmus, Charles Darwin's grandfather (1731-1802), already recognized the predatory potential of syrphids when stating that "The most ingenious manner of destroying the aphids would be affected by the propagation of its greatest enemy, the larva of the aphidivorous hoverflies". However, and due to its crypsis, low visibility in the field and their nocturnal activity, the use of these larvae in aphid pest control has not been developed until recent times. Episyrphus balteatus (De Geer, 1776), was the first syrphid used commercially in biological control of aphids well inside the 20th century, after its potential as a predatory agent of pest aphids was empirically confirmed [3]. More recently, in 2016, Sphaerophoria rupepellii (Wiedemann, 1820) was released in the market as a new product for control of pest aphids by BioNostrum Pest Control, which, by then, was a ‘spin off’ company at the University of Alicante (Spain).

Why syrphids?
The effectiveness of hoverflies in the control of aphids has been well demonstrated scientifically and relies on the following facts:

a) They act like natural drones, because females lay eggs in situ, among the aphid colonies.

b) Early and dense-dependent oviposition. This allows preventive and curative treatments, as well as avoiding intraspecific competition.

c) Long permanence of the syrphids in crops due to their polyvoltine cycles.

d) Larvae prey on a wide range of aphid species.

e) Larvae are stealthy, reducing the possibility of aphids to escape.
Syrphids in the aphid control in greenhouse crops

Southeastern Spain is the world area with the highest production of organic products. We present here a summary of our scientific and applied experience in the use of syrphids for biological control of pest aphids in Mediterranean greenhouse crops, as well as the results of their combined use with other strategies commonly used in integrated pest control (Figure 1).

The interior of Mediterranean greenhouses has high levels of temperature (+40 °C) and humidity (+85-90%). Only some insect species are adapted to survive in these extreme environmental conditions. We have recorded more than ten species of aphidophagous syrphids inside the greenhouses of this geographic area of Spain [4], but only E. balteatus, Euepeodes corollae (Fabricius, 1794) and S. rueppellii were found not to be sporadic, i.e. they were installed indoors feeding on pest aphids [5]. Of those three, S. rueppellii was found to remain indoors during the entire crop cycle while supporting well the harsh greenhouse conditions [6].

Hoverflies in the control of aphid pest of greenhouse crops

Synergy of the use of syrphids with parasitoids: The control of a pest does not depend exclusively on a single natural enemy, so it is important to know the level of compatibility of syrphids and the parasitoids commonly used for aphid control in greenhouses. Results showed a positive intragremial relationship between syrphids and the parasitoids commonly used for aphid control in Mediterranean greenhouse crops, as well as the provision of pollen and nectar by flowering plants placed inside greenhouses. We studied the effect of supplementary UV radiation under glasshouse conditions was also studied, not affecting on the flight activity of adult syrphids [13], but showing that the use of photo selective meshes: Photo selective meshes are ultraviolet light absorbers that have been shown to be effective for the control of pest aphids by limiting their dispersal ability. We studied the effect of these meshes on the behavior of aphidophagous syrphids in horticultural crops [12]. Experiments showed that the average number of syrphid eggs per plant and the abundance of syrphid larvae was remarkably higher under the photo selective meshes than under the standard coverage. The effect of supplementary UV radiation under glasshouse conditions was also studied, not affecting on the flight activity of adult syrphids [13], but showing that the use of these meshes, and the release of syrphid predators, are compatible strategies to be used in IPM aphid control programs.

Hoverflies in chemical control

Effect of toxicity, attraction or repellency of botanical insecticides in syrphids: With olfactometric techniques, we tested the effect on the behavior (attraction or repellency) of syrphid larvae against the use of VOCs from essential oils. Results showed that some repellents and aphidicide products, attract adults of the predatory syrphid S. rueppellii, which is the main natural enemy of two of the most harmful aphid species in greenhouses of pepper: Myzus persicae (Sulzer; 1776) and Macrosiphum euphorbiae Thomas, 1878 [14].

Conclusion

Investigation on Integrated Pest Management, considered globally as the paradigm for the crop protection in the future,
requires not only the implementation of combined strategies, but integrated strategies [15]. In this summary, we present the results obtained after the integrated use of syrphids with other control strategies (biological, parabiological and chemical) for aphid control. The compatibility or synergy of these combinations have been tested in field or semi-field conditions, taking into account that the analyzed methods are commonly applied in Mediterranean greenhouses, where the greatest quantity of organic products in the world is produced.

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