Chapter 7

Whiteflies Management

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1. Introduction

"Whiteflies" is the common name of an insect group (Hemiptera: Aleyrodidae) which has around 1556 described species (Martin & Mound, 2007), although only about thirty species have been mentioned in Spain which are included in the table 1 (Martin *et al*., 2000). The origin of this group of insects is very varied, as its current spread. But, in general, these are organisms from hot climates: more than 724 species have been described in tropical areas, and only 420 species in warm areas (Bink-Moenen & Mound, 1990).

In general, there are two types of damage caused by whiteflies: direct and indirect. The first is caused by the insects feeding on the plant, adults as well as nymphal stages (immature), causing the sap-sucking that leads to weakening and reduction of plant yield, and also inducing very different physiological disorders on plants. The indirect damages are referred to as all the problems derived from the production of honeydew by the insect immatures, and especially, the capacity of the adults of some species to transmit very different vegetal viruses, that can lead to the continuity of the crop being put at risk in a specific area.

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Table 1. Whitefly species present in Spain

Subfamily *Aleurodicinae*	
Aleurodicus dispersus Russell, 1965	
Lecanoideus floccissimus Martin et al., 1997	
Paraleyrodes minei Iaccarino, 1990	
Subfamily *Aleyrodinae*	
Acaudaleyrodes rachipora (Singh, 1931)	*Aleurolobus olivinus* (Silvestri, 1911)
Aleurothrixus floccosus (Maskell, 1895)	*Aleurotrachelus atratus* Hempel, 1922
Aleurotrachelus rhamnicola (Goux,1940)	*Aleurotuba jelinekii* (Frauenfeld, 1867)
Aleurotulus nephrolepidis (Quaintance, 1900)	*Aleuroviggianus* adrianae Iaccarino, 1982
Aleuroviggianus polymorphus Bink-Moenen, 1992	*Aleyrodes elevatus* Silvestri, 1934
Aleyrodes proletella (Linnaeus, 1758)	*Aleyrodes singularis* Danzig, 1964
Asterobemisia carpini (Koch, 1857)	*Asterobemisia paveli* (Zahradnik, 1961)
Bemisia afer (Priesner & Hosny, 1934) sens lat.	*Bemisia medinae* Gómez-Menor, 1954
Bemisia tabaci (Gennadius, 1889)	*Bemisia spiraeoides* Mound & Halsey, 1978
Dialeurodes citri (Ashmed, 1885)	*Dialeurodes setiger* (Goux, 1939)
Parabemisia myricae (Kuwana, 1927)	*Pealius quercus* (Signoret, 1868)
Simplaleurodes hemisphaerica Goux, 1945	*Siphoninus phillyreae* (Haliday, 1835)
Tetralicia ericae Harrison, 1917	*Tetralicia iberiaca* Bink-Moenen, 1989
Trialeurodes ericae Bink-Moenen, 1976	*Trialeurodes ricini* (Misra, 1924)
Trialeurodes vaporariorum (Westwood, 1856)	

2. Pest-species of horticultural crops in spain

Although all the whitefly species are phytophagous, that is to say, they feed on vegetables, only a few of them can be considered as significant pests of agricultural crops, taking into account that there are more than one thousand five hundred species described.

In the scope of this book, that it to say, horticultural plants grown under greenhouse, we can mention two species of whiteflies that have represented and nowadays represent a serious problem in vegetables, especially in crops under greenhouse: *Bemisia tabaci* (Gennadius, 1889) and *Trialeurodes vaporariorum* (Westwood, 1856).

It is worth mentioning also the economic importance of *Aleurothrixus floccosus* (Maskell), *Paraleyrodes minei* Iaccarino, *Dialeurodes citri* (Ashmead) and *Parabemisia myricae* (Kuwana) in citrus trees (Soto *et al*., 2001), and of *Aleurodicus dispersus* Russell and *Aleurodicus floccissimus* (Mar-

tin *et al*.) in ornamentals and sub-tropical crops from the Canary Islands (Hernández-Suárez *et al*., 1997). Other species that has increased its incidence in outdoors horticultural crops in the last few years, like Cruciferae, is *Aleyrodes proletella* (L.), the cabbage whitefly (Castañe *et al*., 2008).

T. vaporariorum, known with the common name of greenhouse whitefly, has been the species of whitefly that caused major problems, since being considered as a greenhouse pest in the seventies (Llorens & Garrido, 1992) until the eighties and nineties. At that time, a very effective control of its populations was achieved, and furthermore, its importance in crops under greenhouse was substituted for *B. tabaci*, known as the cotton or tobacco whitefly; largely due to the great capacity to generate populations resistant to phytosanitaries by *B. tabaci* and the absence of an effective method to control it, as well as its great importance as a vector of very severe plant viruses. In the nineties, the presence of 3 different biotypes of *B. tabaci* (biotypes called B, Q and S), was detected in Spain, each of them with its biological peculiarities and, therefore, with its economic importance on the crops (Guirao *et al*., 1997; Banks *et al*., 1999; Moya *et al*., 2001; Beitia *et al*., 2001; Baraja *et al*., 2002).

Currently, both species are considered as harmful for horticultural crops in our whole country, although we can say that there is a predominance of *T. vaporariorum* in warmer geographical areas (as in Catalonia), in contrast with a predominance of *B. tabaci* in hotter areas (such as Andalusia and Canary Islands). Both species are effective vectors of vegetal viruses in different horticultural plants (table 2) (Amari *et al.*, 2008; Berdiales *et al*., 1999; Célix *et al*., 1996; Font *et al*., 2003,2004; García-Andrés *et al*., 2006; Jordá, 2004; Lozano *et al*., 2004, 2009; Monci *et al*., 2002; Navas-Castillo *et al*., 1997, 1999, 2000; Sanchez-Campos *et al*., 1999; Segundo *et al*., 2004).

Table 2. Vegetal virus transmitted by the two species of whitefly in horticultural crops in Spain

Vegetables Viruses	Initials	Vector
Beet pseudo-yellows virus	BPYV	Tv
Cucumber vein yellowing virus	CVYV	Bt
Cucurbit yellow stunting disorder virus	CYSDV	Bt
Sweet potato chlorotic stunt virus	SPCSV	Bt
Tomato chlorosis virus	ToCV	Bt y Tv
Tomato infectious chlorosis virus	TICV	Tv
Bean yellow disorder virus	BnYDV	Bt
Tomato yellow leaf curl virus, Tomato yellow leaf curl Sardinia virus, Tomato yellow leaf curl Málaga virus, Tomato yellow leaf curl Axarquía virus	TYLCV	Bt
	TYLCVSarV	
	TYLCMalV	
	TYLCAxV	
Tomato torrado virus	ToTV	Bt y Tv
Sweet potato leaf curl virus, Sweet potato leaf curl Spain virus, Sweet potato leaf curl Canary virus, Sweet potato leaf curl Lanzarote virus	SPLCV	Bt
	SPLCESV	
	SPLCCaV	
	SPLCLaV	

Bt: *Bemisia tabaci*.
Tv: *Trialeurodes vaporariorum*.

3. General characteristics of whiteflies

B. tabaci as well as *T. vaporariorum* are polyphagous species, they develop on several crops and also on spontaneous herbaceous plants, which facilitates the maintenance of their populations throughout the year. Both sexes are present, with haploid adult males and diploid females; reproduction is carried out by arrhenotokous parthenogenesis, so that fertilized eggs give rise to females and unfertilized eggs give rise to males.

The biological cycle of both species is similar and it can be summarized as follows:

Initially **the egg** is whitish and then turns caramel (*B. tabaci*) or blackish (*T. vaporariorum*) with the embryonic development. It has an oval, reniform or elongated shape and is usually held on to the vegetal support (generally on to the underside of the leaves) by a pedicel of variable size.

When eggs hatch, a **nymphal instar**, which is mobile, appears first. It moves on the leave (mainly on the underside) until it fixes itself to the plant, through its mouth stylet, and remains there until the adult emerges. After this nymphal instar, there are three more that are identified by the "molting" of the old cuticle and the subsequent increase of size. All the nymphal instars are very similar amongst themselves, the differences between them are their size, their appearance, and in some cases, the different wax secretions, as well as the presence of silks or setae. The first nymphal instars have a flat and translucent aspect, then they turn more opaque and develop the wax secretions and the typical setae of each species. At the end of the 4th nymphal instar, the nymph stops feeding and the typical compound eyes of the imago begin to be appreciated clearly (by transparency), then, also the wings can be seen, and ultimately, the transformation into an adult is produced within the "pupal casing". This process, when any cuticle molting is produced, is improperly referred to as "pupa" (the insect state that is found on the leaf) by some authors.

It is relatively easy to carry out an identification of both species, from the adult stage as well as from the fourth nymphal instar:

At first sight, the adults of both species are very similar, but *B tabaci* has a slightly yellower colour and a smaller size. Both species have roof shaped wings on the back, leaving head and thorax in the open; but *B. tabaci* has "small roof" shaped wings forming an angle of 45 degrees with respect to the leaf surface, while *T. vaporariorum* has triangle shaped wings (Photos 1 and 2).

Photo 1. *T. vaporariorum* eggs

Photo 2. *B. tabaci* eggs

Another very noticeable difference is referred to its eyes. The whitefly adults have compound eyes formed by two groups of “omattidia” (visual units or simple eyes). In the case of *B. tabaci*, both groups of omattidia are joined, while in *T. vaporariorum* they are totally separate (in an upper and a lower groups) (Figure 1) and (Photo 3).

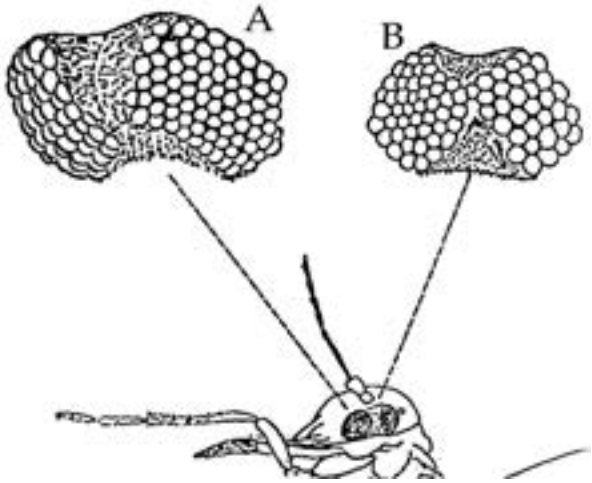

Figure 1. Differences between the ommatidia groups in *B. tabaci* (right) and *T. vaporariorum* (left)

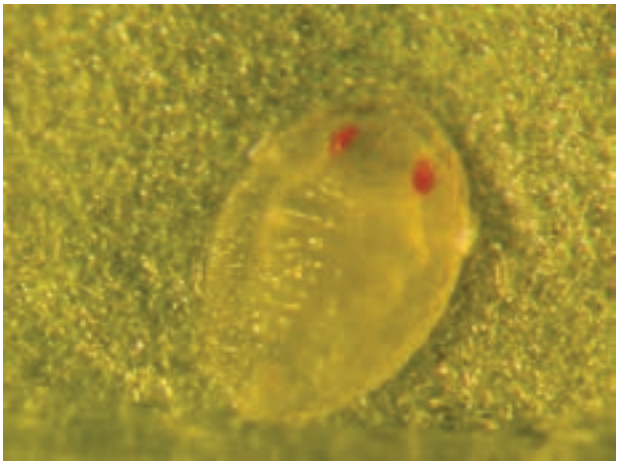

Photo 3. Fourth instar nymph of *B. tabaci*

From the 4th nymphal instar, it is also relatively easy to distinguish both species. In *B. tabaci* the back surface is convex and the outline is irregular. However, *T. vaporariorum* has a totally flat back surface and high respect to the vegetal substrate, and also it is surrounded by long transparent silks in its whole perimeter (Photo 4 and 5).

As it has been mentioned before, eggs from both species can be also distinguished, when just laid, they are yellowish white but the eggs of *T. vaporariorum* turn blackish when mature, while the eggs of *B. tabaci* turn caramel colour (Photo 6 and 7).

Photo 4. Fourth instar nymph of *T. vaporariorum*

Photo 5. *B. tabaci* adult

Photo 6. *T. vaporariorum* adult

Photo 7. Joined ommatidia groups in *B. tabaci*

4. Natural enemies of both species

As with many other phytophagous organisms, these two species of whiteflies in Spain have a great number of natural enemies (or beneficials) which are developed at the expense of them; amongst them we can find parasitoids, predators and also entomopathogens. These natural enemies can be autochthonous species of the Mediterranean Basin or exotic species introduced and adapted to our geographical area, which carry out their control activity of whitefly populations as usual.

Only some of these natural enemies have been considered as effective agents of biological control and are commercialized by specialised companies and distributed to be used in greenhouses, at the right moment and in the appropriate way. The trouble is that not all the species of beneficials are capable of inducing a significant mortality in the whitefly populations, which means they are not capable of controlling these pests under the economic threshold of damage to crop, and sometimes, they can even go unnoticed.

The species of natural enemies to which we will give more attention in this publication are those available commercially; however, and since the presence of other beneficials associated with populations of these two species of whiteflies is often observed, we have deemed convenient to mention these non-commercial natural enemies for general knowledge.

4.1. Parasitoids

The parasitoids of whiteflies belong to the order Hymenoptera (that is to say, they are “tiny wasps”) which are included within the superfamilies Chalcidoidea (families *Aphelinidae, Eulophidae, Pteromalidae, Encyrtidae and Signiphoridae*) and Platygastroidea (family *Platygastridae*) (Polaszek, 1997). Particularly, within the family *Aphelinidae* there are a great number of parasitoids of *B. tabaci* and *T. vaporariorum*, being the genera *Encarsia* Föster and *Eretmocerus Howard,* those which have a higher number of species related with both whiteflies.

In table 3 we can find all the parasitoid species mentioned in Spain regarding the two species of whitefly *B. tabaci* and *T. vaporariorum* (Hernández-Suárez, 1999; Castañé *et al*., 2009; Natural History Museum, 2009).

The parasitoids are organisms that, in general, present a great specificity, that is to say, they have a reduced range of host species on which they can develop, and in some occasions, they are limited to only one species.

Table 3. Main species of parasitoids mentioned in Spain on *B. tabaci* and *T. vaporariorum*

	White fly guest	
Species of Parasitoide	***Bemisia tabaci***	***Trialeurodes vaporariorum***
Aphelinidae		
Encarsia acaudaleyrodis Hayat	+	+
Encarsia azimi Hayat	+	+
Encarsia formosa Gahan	+	+
Encarsia hispida De Santis	+	+
Encarsia inaron (E. partenopea)	+	+
Encarsia lutea (Masi)	+	+
Encarsia melanostoma Polaszek & Hernández	+	+
Encarsia mineoi Viggiani	+	+
Encarsia noahi Polaszek & Hernández	+	+
Encarsia pergandiella Howard	+	+
Encarsia sophia (Girault & Dodd)	+	+
Encarsia protransvena Viggiani	+	
Encarsia tricolor Förster	+	+
Eretmocerus mundus Mercet	+	
Eretmocerus eremicus Zolnerowich & Rose	+	+
Platygastridae		
Amitus fuscipennis MacGown & Nebeker		+

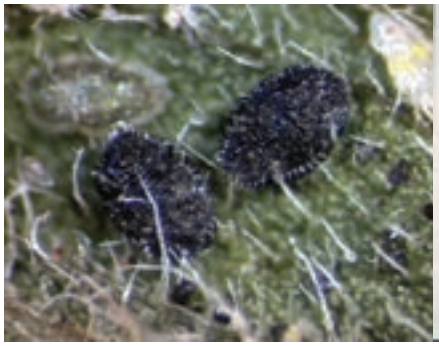

Photo 8. *Encarsia formosa*, pupa

Photo 9. *E. formosa,* adult

Photo 10. *Encarsia hispida,* pupa

Photo 11. *E. hispida,* adult

Photo 12. *Encarsia lutea,* pupa

Photo 13. *E. lutea,* adult

Photo 14. *Encarsia noabi,* pupa

Photo 15. *E. noabi,* adult

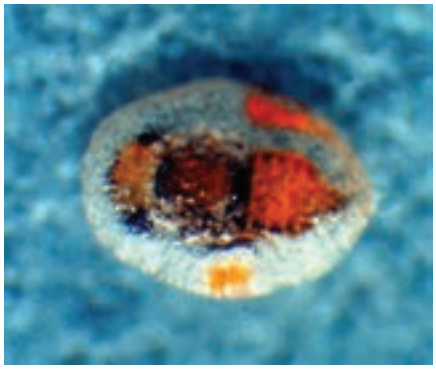

Photo 16. *Encarsia pergandiella,* pupa

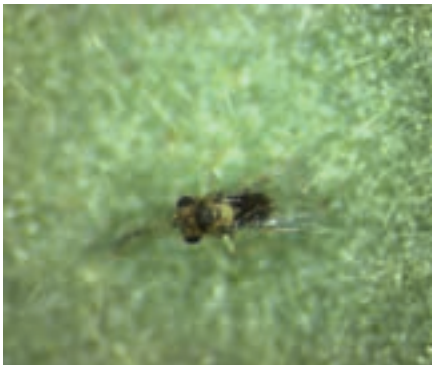

Photo 17. *E. pergandiella,* adult

Photo 18. *Encarsia sophia*, pupa

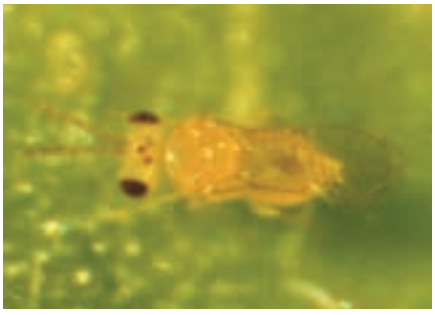

Photo 19. *E. sophia*, adult

Photo 20. *Encarsia tricolor*, pupa

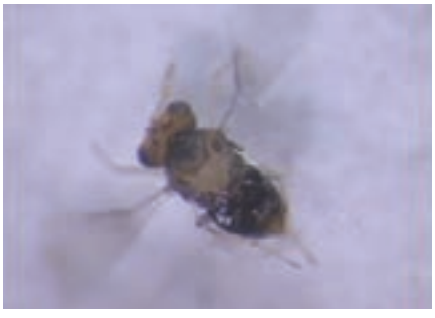

Photo 21. *E. tricolor*, adult

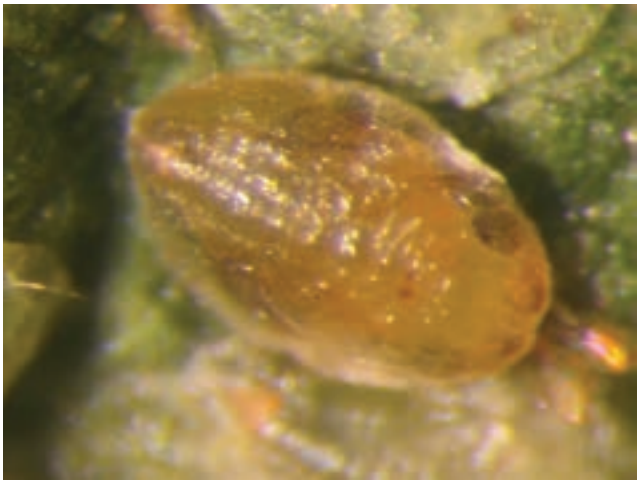

Photo 22. *E. eremicus*, pupa

Photo 23. *Eretmocerus eremicus*, adult

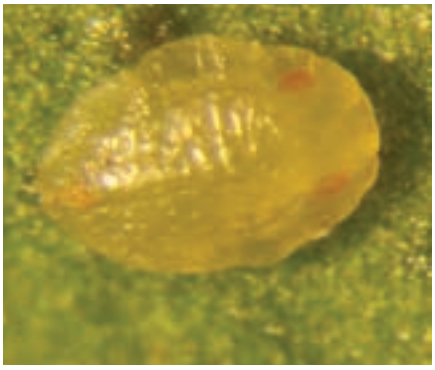

Photo 24. *Eretmocerus mundus*, pupa

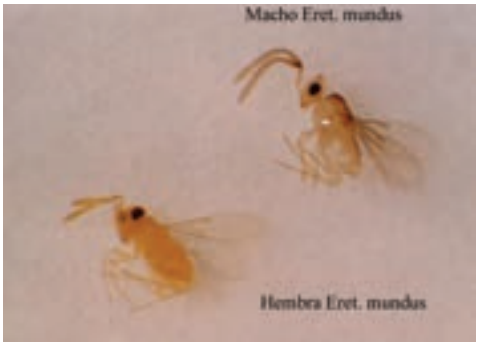

Photo 25. *E. mundus*, adult

4.2. Predators

Amongst the predators of whiteflies we can find different groups of insects, such as anthocorids and mirids (Hemiptera), coccinelids (Coleoptera), chrysopids (Neuroptera) and drosophilids, syrphids and muscids (Diptera), as well as *Phytoseiidae* and *Stigmaeidae* mites (Acarina).

Predators are organisms that show a great polyphagy habitually, that is to say, they have a broad spectrum of prey species, on which they can feed the adults as well as the immature stages.

Within the predator neuropterans of whiteflies, *B. tabaci* and *T. vaporariorum,* two species stand out in Spain: *Chrysoperla carnea* (Stephens) and *Conwentzia psociformis* (Curt.).

Within the dipterans, the main predatory species of aleyrodids are found within the *Drosophilidae* (*Acletoxenus formosus* (Loew)) and *Muscidae* (*Coenosia attenuata* Stein) families, although the action of other generalist dipterans that occasionally feed on these whiteflies, such as cecidomyiids and syrphids, is also mentioned.

Among the coleopterans, particularly in the *Coccinellidae* family, we can find some predatory species that have achieved the greatest successes in biological control (De Bach & Rosen, 1991). The *Coccinellidae* family is the most important in relation to the biological control of aleyrodids; on the two species of whitefly, *Clitostethus arcuatus* Rossi (Bt and Tv), *Delphastus catalinae* (Horn) (Bt and Tv), and other predatory coccinelids of scale pests such as *Cryptolaemus montrouzieri* (Mulsant) (Bt) and *Coccinella undecimpunctata* L. (Bt) which have been mentioned in Spain.

Although the Hemiptera order is composed mainly of phytophagous insects, the hemipterans include several families with predatory species, highlighting in particular *B. tabaci* and *T. vaporariorum*: the mirids *Macrolophus caliginosus* (Wagner), *Nesidiocoris tenuis* (Reuter), *Dicyphus tamaninii* Wagner and *D. errans* (Wolf). Also significant is the action of other hemipterans such as *Nabis pseudoferus ibericus* Remane (Nabidae) and *Orius* laevigatus (Fiebre) and *O. majusculus* (Reuter) (Anthocoridae).

Finally, the use of the predatory mite *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae), of Mediterranean origin, should be highlighted in the biological control of *B. tabaci* in pepper and cucumber crops (Belda y Calvo, 2006).

Photo 26. *Acletoxenus formosus*, adult

Photo 27. *Amblyseius swirskii*, adults and eggs

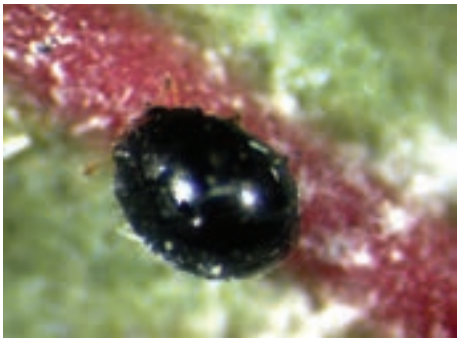

Photo 28. *Delphastus catalinae*, adult

Photo 29. *Cryptolaemus montrouzieri*, adult

Photo 30. *Macrolophus caliginosus*, adult

Photo 31. *Nesidiocoris tenuis*, adult

4.3. Entomopathogens

Entomopathogens are organisms that cause diseases on insects, being the causal agent of very different viruses, bacteria, fungi, protozoa and nematodes. The entomopathogens have the problem that they do not look for their hosts actively, as parasitoids or predators do, therefore, their use in biological control is directed and limited to a mass production and application as a "biopesticide". Furthermore, their main limitation is their dependence on high humidity. On the other hand, however, they have the advantage of being compatible with the use of chemical treatments and they are very easy to manage (Fransen, 1990).

Among the entomopathogens that are capable of attacking whiteflies we can highlight the entomopathogenic fungi *Aschersonia aleyrodis* Webber, *Paecilomyces fumosoroseus* (Wize) Brown & Smith, *Beauveria bassiana* (Balsamo) y *Lecanicillium* (=*Verticillium*) *lecanii* (Zimm.) Viégas and *L. muscarium* (Petch.). These fungi germinate in the insect's cuticle, pierce it and then colonise the inside host (Fransen, 1990).

Also the nematodes *Steinernema feltiae* (Filipjev) (Nematoda: Steinernematidae) and *Heterorhabditis bacteriphora* Poinar have been assessed as possible biological control agents of *B. tabaci* (Cabello and Ruiz-Platt, 2007).

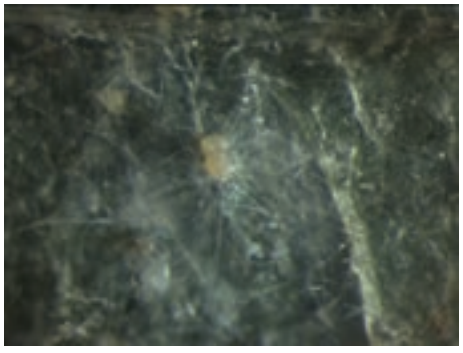

Photo 32. *Paecilomyces fumosoroseus*, on on whitefly eggs

Photo 33. *Lecanicillium lecanii*, on *T. vaporariorum* nymph

5. Biological control of whiteflies through natural enemies

As it has been mentioned before, to carry out the biological control of the two species of whitefly, through natural enemies, and considering the characteristics of the horticultural crops of greenhouses, which are temporary and favour the disappearance of the auxiliary organisms of the different pests, we must turn to the introduction of such beneficials from the mass breeding and commercialisation of them by companies devoted to it.

To reference the auxiliaries that are being used now in Spain against *B. tabaci* and *T. vaporariorum*, there is nothing better than turning to the information provided by the Spanish Ministry of Environment and Rural and Marine Affairs (MARM, 2009), as well as the Vademecum of Phytosanitary Products (De Liñán, 2009). In accordance with these two sources, nowadays, the natural enemies commercialized against the two species of whitefly are:

5.1. Amblyseius swirskii Athias-Henriot,1962

Phytoseiid mite, effective predator of eggs and young nymphs of whiteflies. Also it is known for its high activity on thrips larvae, *Frankliniella occidentales* (Pergande).

The geographical origin of this mite is the Eastern Mediterranean Sea (Greece, Israel, Turkey, …) which permits it to survive and act in high temperatures such as those reached inside greenhouses (it reduces its effectiveness from 40 ºC). It is effective in several horticultural crops, but it has been shown that it does not have any effect on tomato crops.

Adults are white-orangey, with a pear shaped body. Eggs are usually laid on the underside of leaves, close to nervations, as well as on flowers. Initially eggs are oval and white, and then turn caramel colour when hatching is approaching. It displays one larval stage and two nymphal stages (protonymph and deutonymph), which are differentiated by the number of legs (6 the larvae and 8 the nymphs).

Adults as well as nymphs are very mobile and they are capable of eating a great number of preys (from 15 to 20 whitefly eggs or larvae per day), which makes it an effective predator; in addition to its capacity to

feed on pollen and nectar, which permits its establishment in the greenhouse in the absence of preys, once that flowering has begun, it becomes an effective biological control agent of whiteflies.

It must be also highlighted, as it has been mentioned before, that it is capable of establishing itself in crops even though humidity and temperature conditions are not favourable for other auxiliary species, which permits also that once it is established in the greenhouse, it is not necessary to introduce it again.

Method of use

It can be used as a preventive measure (in the absence of pests) and as a curative measure.

The introduction (with pollen) of 25-30 individuals/ m^2 is recommended as a **preventive** measure. If the minimum presence of whiteflies has already been detected, the introduction must be repeated 1 or 2 times leaving a 15-day interval.

The **curative** release requires the introduction of 50-100 individuals/m^2, releasing the highest dose in the areas of higher presence of the pest. And if it is necessary, this action must be repeated 15 days later.

The organisms provided by the different producing companies must be used within 24 hours after their receipt, and in any case, they must be kept at a temperature of 10-15 ºC until they are used.

At the moment, it is commercialized by two companies, Certis and Koppert. The first one sells it under the name of AMBSURE, in sprinkler packs of 1.000, 50.000 or 100.000 units (adults and nymphs). Koppert commercialises it in sachets with 250 individuals mixed with bran and in boxes of 100 and 500 sachets (SWIRSKII Mite Plus), and also in bottles of 500cc which contain 50.000 individuals (SWIRSKII Mite). Técnicas de Control Biológico (TCB) commercialises it with the trademark TCB-Swirskii. It sells it in cardboard containers of 25.000 individuals and sachets of 250 individuals in boxes of 500 sachets. MIP System Agro (BIOMIP); commercialises it with the trademarks SWIRSKII MIP 25 (cardboard containers with 25.000 units) and SWIRSKII MIP S in sachets.

5.2. Encarsia formosa (Gahan, 1924)

This is an aphelinid hymenopteran whose adults have an approximate size of 1 mm and they have a yellow abdomen and blackish thorax. Its populations are composed exclusively of females (98 % approximately) because the males of this species are very rare (they are brown-blackish and have a morphology similar to females).

E. formosa has a neartic origin (Polaszek *et al*., 1992), although it is currently spread worldwide, because it has been introduced in several countries as a biological control agent of *T. vaporariorum*.

It is a solitary endoparasitoid (it lays the eggs inside the whitefly nymphs) although superparasitism (more than one egg in the same nymph) can be observed when a population is abundant (Agekyan, 1982). Although it is known that it acts on *B. tabaci*, it is used mainly in the control of *T. vaporariorum*: when both species of whitefly are present, it shows a clear preference for the second one; it parasitizes all the nymphal stages of this whitefly, although it prefers the third and fourth instars, emerging only when the host reaches the fourth. *E. formosa* is capable of distinguishing between the pupae of *T. vaporariorum* parasitized and non-parasitized, avoiding oviposition in the first ones (van Lenteren *et al*., 1976).

There is a clear difference in the parasitism generated on *B. tabaci* and *T. vaporariorum*: in the first one, the development of the parasitoid turns the puparium caramel colour, while in the second case it turns black.

Its thermal range of effective action stands between 18 and 30 ºC approximately; it can hardly fly under 18 ºC and above the highest temperature an adult's longevity is reduced considerably. A female is capable of parasitizing between 80 and 100 specimens of whitefly in the course of its life.

Method of use

As it has been mentioned before, this species is highly recommended for the control of *T. vaporariorum*. This insect is distributed in puparial stage, inside the whitefly puparium, which are stuck to cardboard cards, each of them with 60-100 pupae/card according to each producing companyIt must be used with preventive introductions at the rate of 50 pupae/100 m^2, but when there is a low population of whiteflies, it must be introduced to the order of 1-3 pupae /m^2.

The companies that commercialise it in Spain are: Agrobío (ENCARSIA Formosa), Certis (ENSURE (f)) and Koppert (EN Strip). This last company also commercialises a mixing of *E. formosa* and *Eretmocerus eremicus*, with the trademark ENERMIX, and other mixing of *E. formosa* and *Eretmocerus mundus* with the trademark BETRIMIX.

After receiving them, the organisms can be kept between 1 and 2 days at a temperature of 8-10 ºC.

5.3. *Eretmocerus eremicus* Rose & Zolnerowich, 1997

It is an hymenopteran from the Aphelinidae family, parasitoid of different species of aleyrodids, but it is used in the biological control of *B. tabaci*. Also it was known (and commercialized) with the name of *Eretmocerus californicus*.

Adults are tiny wasps similar to those of *E. mundus*, endoparasitoids of aleyrodid nymphs, whose egg is laid under the nymph, between the nymph's body and the foliar area, and the first larval instar penetrates inside. The parasitized whitefly nymphs follow their development until the parasitoid completes its own development, and at that moment, the whitefly dies. Females prefer parasitizing the 2nd nymphal instar of whitefly. Also the predatory activity of adult females, which feed on whitefly nymphs that can entail a significant mortality in their populations, around 40 % of the general mortality due to the parasitoid, should be highlighted. Adults live an average of 8-10 days, at an average temperature of 25 ºC.

Method of use

This insect is spread as pupae, inside the whitefly puparia, which are placed stuck to cards, or within *blisters* or other containers. Usually, there is an amount of 50 to 250 pupae/distribution unit.

The recommended usage dose contains from 10-12 parasitized nymphs/m^2, carrying out 3 releases with a 2-week interval. It is advisable to carry out the release at a not very high room temperature, that is to say, early in the morning or at dusk. The release must be done soon after receiving them, but if that is not possible, the insects should be kept at a temperature between 8-10 ºC.

The companies that commercialise this auxiliary are: Biobest (ERETMOCERUS-SYSTEM), Certis (ERETSURE (e)) and Koppert (ERCAL).

Also, Koppert commercialises a mixing of *E. eremicus* and *E. mundus*, with the name of BEMIMIX.

5.4. *Eretmocerus mundus* (Mercet, 1931)

Like the previous species, this is an Aphelinidae hymenopteran, a parasitoid of several species of whiteflies, among them *B. tabaci*. As it is a species of Mediterranean origin, it is clearly adapted to the conditions of our horticultural crops in greenhouses.

It is a primary parasitoid and also an ecto-endo parasitoid, because as *E. eremicus* does, females lay the eggs outside of the whitefly nymph's body and the first larval instar of the parasitoid is introduced in the whitefly nymph's body.

Adults have an approximate general size of 1 mm. Females are lemon-yellow, except for the end of the ovipositor, and males are smaller and darker.

Eggs are oval and transparent when just laid, but turn brown later. After eggs hatch, three larval stages follow, the first one is transparent and pear shaped, similar to eggs; the second is oval and the third is almost transparent and shaped round. The prepupa is lightly yellow, and the pupa which is located inside the whitefly puparium with the ventral surface directed to the dorsal surface of the host, is dark yellow, turning brown as it is developed.

E. mundus distinguishes the host larvae that have been parasitized, only laying eggs in non-parasitized larvae. Although it parasitizes all the larval stages of *B. tabaci* it prefers the second and third instars (Urbaneja y Stansly, 2004).

Also, it can carry out a predatory action because it feeds on parasitoids through the wound in the vasiform orifice of the aleyrodid with its ovipositor (Geling ,1983).

The larva parasitized by *E. mundus* turns gold-yellow and has displaced mycetomas and more globose exuviae than the larva without being parasitized. Before the adult emerges, the dark eyes and the wing rudiments can be picked out through its transparency. When it is going to

emerge from the puparium, the adult parasitoid makes a round hole in the cover of the puparium with its jaws, this aspect allowing the distinguishing of the nymph that has been parasitized, because in this last case, the exit of the whitefly adult from the puparium causes an inverted-T shaped opening.

Under the climatic conditions of southeast Spain and the Canary Islands, the activity of this parasitoid has been observed throughout the year. In general terms, the development from egg to adult, at 25 ºC, usually lasts between 18-20 days. The females usually live between 9-11 days and with an average lay of 30-50 eggs over the course of their lives.

Females are very long-lived during winter, and they are capable of remaining active during this season, which favours their spread on any vegetal host (Gerling, 1983).

Method of use

As it is effective against *B. tabaci*, it must be introduced in the crop after the presence of this whitefly has been identified. It has been shown that it can act with temperatures lower than 20 ºC and also higher than 30 ºC, although it is less effective.

It is distributed just like *E. eremicus*, in puparia of parasitized whitefly. A **preventive dose** of 1-2 puparia/m^2 can be used, compared with a normal **dose** of 2-3 puparia/m^2, and **curative dose** of 3-9 puparia/m^2. The releases must be carried out with mild temperatures, that is to say, early in the morning or at dusk, scattering the puparia contained in the containers between the leaves. The first nymphs of the parasitized whitefly may be observed two weeks later.

If they are not used directly after receipt, the insects can be stored for 1-2 days, in the dark and at a temperature of 8-10 ºC.

The insect is presented in different formats, according to the company that commercialises it, but two ways of sending it can be distinguished: separate parasitoid pupae, in containers or *blisters* with sawdust or other similar material; pupae stuck to cardboard cards.

The companies that commercialise it in Spain now are: BEMIPAR, Koppert; MUNDUS_SYSTEM, Biobest; ERMUNcontrol, Agrobío; MUNDUSCOLOR, Biocolor; MunduPAK3000, Bioplanet; ERETSURE (m), Certis and MUNDUS-BG, BGreen Biological System, TCB-MUNDUS, Técnicas de Control Biológico and MUNDUS MIP, Mip System Agro (BIOMIP).

5.5. *Macrolophus caliginosus* Wagner, 1951

It is an heteropteran from the Miridae family, predator of *B. tabaci* and also of *T. vaporariorum*. It is very voracious and capable of attacking whitefly in all its development stages, although it prefers eggs and nymphs. It looks for its prey actively and when it finds it, it sticks its stylet in and fully sucks out its insides.

Adults are between 3mm and 3.5mm long, are light green and have a thin appearance, red eyes, long and green antennae with a black base, and long legs which allow them move easily. Furthermore, this predator has the advantage that it can feed on other pest organisms in horticultural crops such as aphids, red spider mites, butterfly's eggs and caterpillars, miner larvae and thrips. Therefore, it can help to control these pests with high populations in the crop.

Adults live on plant sprouts, and lay the eggs on the leaves, preferably on the nerves and peduncle tissues. After eggs hatch, 5 nymphal instars follow before the adult's appearance. The female's longevity is 40 days, with a lay that ranges between the 100 and 250 eggs; depending on the environmental climatic conditions.

An adult of this mirid can eat more than 30 whitefly eggs per day. And it must be taken into account that under special conditions, of high population of mirids and low presence of prey, this insect can cause damages to crops, because it is also a vegetal feeder.

Method of use

It has been used for the control of both species of whitefly. In the particular case of tomato crops, the results obtained from *M. caliginosus* have been very positive. This predator is able to control the two species of whitefly that appear in tomatoes and even contribute to the control of other pests. However, it has a disadvantage, in that it has a very slow

population development, and therefore, it must be introduced as soon as possible. In general, it is released some weeks around the whitefly foci so that *M. caliginosus* benefits from the presence of whitefly for its development and helps the parasitic wasps to control the first foci.

The insect is commercialized as adults and nymphs, in containers with vermiculite or other similar inert material. After the receipt of the insects, these can be kept for 1-2 days (if they are not used immediately), at a temperature between 10-12 ºC.

A normal usage dose consists of 0.5 individuals/m^2 and a curative dose, of 5 individuals/m^2. And always with 2 introductions, leaving a 2-week interval in between.

At present, the possibility of releasing this predator in the nursery is being considered, with the purpose of this being established when transplanting. Also the use of reservoir plants, the called “banker plants”, is subject to study, these plants permit their presence inside the greenhouse, feeding on other hosts, before the whitefly population appears (Urbaneja *et al*., 2002).

The commercialising companies of this insect in Spain are: Certis, MACSURE (c); Biocolor, CALIGICOLOR; Agrobío, MACROcontrol, and Koppert, MIRICAL and MIRICAL-N.

5.6. *Nesidiocoris tenuis* (Reuter, 1885)

It is also a heteropteran from the family Miridae, and comes from the Mediterranean Basin.

It is a predator of eggs and nymphs of the two species of whitefly, and also feeds on red spider mites, moth’s eggs, thrips, and even aphids and miner larvae.

Adults are 6 mm long, green and thin with long legs and antennae. They are placed mainly on stems and leaves. Eggs are translucent and females lay them on stems and leaves; in general, at 25 ºC, hatching occurs 6-8 days later, and then the insect goes through 5 nymphal instars. It is yellowish-green and placed mainly on the underside of the leaves, until adults emerge.

Adults and nymphs are active predators that look for their prey, to which they attach their mouth, sucking out the content of their bodies, so that they only leave the prey’s tegument on the plant.

They can consume between 40-50 eggs and 20-25 nymphs of whitefly, daily. Adults can also feed on plants, in the absence of prey; in fact, under some circumstances it is difficult to determine if it is an auxiliary or a pest for the crop (Sánchez et. al, 2009).

Method of use

This insect must be introduced early in the crop, because its population development is a little slow, especially under low temperatures.

In general, the recommended dose is 0.5-1.5 individuals/m^2, in weekly releases, up to the level of 2 individuals/m^2 if it is necessary.

After the receipt of these insects, they can be kept 1-2 days at 8-10 ºC.

In tomato crops, if there is a high population of bedbugs, and especially with a low prey/predator relation, damages can be produced in the plant apexes.

The following companies commercialise it in Spain: Agrobío, NESIDIOcontrol; Certis, NESISURE (t), Koppert, NESIBUG, Técnicas de Control Biológico, TCB-NESIDIOCORIS and Mip System Agro (Biomip), NESIDIOCORIS MIP.

5.7. *Beauveria bassiana* Bassi, 1835

B. bassiana is a parasitic fungus, whose conidia constitute the infectious unit. It has two stages on insects: one saprophytic and the other pathogenic. The pathogenesis stage is developed when the fungus comes into contact with the live tissue of the insect and humidity reaches 85 % within the microclimate.

The infectious process that leads to the insect's death goes through three stages: 1) germination of conidia and penetration of the hyphae in the insect's body, 2) invasion of the internal tissues of the insect, and 3) sporulation and the start of a new fungus cycle.

Usually, colonies grow slowly and are white although they can turn yellowish or pinkish in the course of time.

This fungus has a wide field of action; not only whiteflies, but also scale insects, aphids, thrips and other insects.

Method of use

This fungus is presented in three formats to be used against whiteflies: as a concentrated suspension of spores, as an oily dispersion of spores and as a spore concentrate in the form of a wettable powder.

Each of these formats is commercialized by a different company. The first one by Futrureco, with the name of BOTANIGARD SC. A different concentration of use is recommended depending on the crop to which it is going to be applied. It is recommended to apply with normal spraying, beginning the treatment when infestation has just started. The parasitized individuals die after 4-6 days. It is not advisable to mix it with fungicides. It must not be stored at temperatures higher than 30 ºC. At room temperature, in a cool and dry place, it can be kept for 2 years.

The second preparation is commercialized by Agrichem, with the name of NATURALES L. Independently from the crop, it is recommended to apply between 0.75 and 1 l/ha of preparation; as the application on leaf spraying at the beginning of the infestation and, if it is necessary, to repeat the treatment every 7 days. The parasitized individuals die after 7 days. This product must not be mixed with fungicides. And it must be stored at a temperature lower than 25 ºC and for a period lower than one year.

Finally, we can find the product commercialized by C.Q. Massó, with the name of BASSI WP. For this compound it is recommended a different dose depending on the crop to be treated, and it is also advisable to apply the product in normal spraying and at the beginning of the infestation. The parasitized individuals die after 4 and 6 days. It must not be mixed with fungicides and must not be stored at temperatures higher than 30 ºC. In a cool and dry place, at room temperature, the product can be kept for 2 years.

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