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Integrated pest management strategies in sweet pepper plastic houses in the Southeast of Spain

Juan Antonio Sánchez[(1)], Antonio Alcázar[(1)], Alfredo Lacasa[(1)], Antonio Llamas[(1)], Pablo Bielza[(2)]

[(1)]*Protección Vegetal, Centro de Investigación y Desarrollo Agroalimentario. Consejería de Agricultura, Agua y Medio Ambiente, C/ Mayor s/n, 30150. La Alberca (Murcia), España.*
[(2)]*Escuela Técnica Superior de Ingenieros Agrónomos. Universidad Politécnica de Cartagena, Paseo Alfonso XIII, s/n, 30203 Cartagena (Murcia).*

Abstract: In the Southeast of Spain, about 10,000 ha of sweet pepper are grown in plastic houses, in the provinces of Almeria, Murcia and Alicante. In the last six years studies to implement Integrated Pest Management have been carried out. The IPM programmes have lead to a high reduction in chemical sprays. The use of *Amblyseius cucumeris, Orius laevigatus* and *Orius albidipennis* has proved to be successful in the control of thrips and TSWV incidence. Most of the other pests are controlled by natural enemies. Knowledge of thrips population dynamics in relation to temperature can be used to its manage. *A.cucumeris* was successful in reducing the increase of thrips populations in the first few months. Strategies for *Orius* releases have been assayed. Tomato Spotted Wilt Virus (TSWV) vectored by *Frankliniella occidentalis* is the main phytopathological problem; however the removal of plants with TSWV sympthoms reduces significantly the disease incidence.

Introduction

The area of pepper crops grown in plastic houses in IPM in the South of Spain has increased remarkably during the last few years. Of 1,930 ha grown in the provinces of Murcia and Alicante, during the 1999 campaign, 2.2% used natural enemies. In the next year a doubling of this area is foreseen. The province of Almeria, the most important producer in Spain, 8,030 ha were grown during the 1999 growing season. Although we do not have the data of the area in Almeria under IPM, a trend similar to the other two regions is likely.

The change in strategies for the control of pests and diseases has taken place for several reasons: the constantly increasing number of chemical treatments required for control, mainly against *Frankliniella occidentalis* (Pergande), the ever decreasing amount of residuals, the demand for organic products and the farmers' willingness to adopt more convenient control methods. According to the data supplied by a few farmers who grew under chemical control during the 1998 and 1999 growing seasons, an average of 27 treatments were made, with an average of 2.5 products for each spray. Thirtythree of these products were meant to control thrips, 18 were against *Bemisia tabaci*, 4 against caterpillars (*Spodoptera exigua* (Hübner) and *Ostrinia nubilalis* (Hübner)), 5 for fungal diseases and 0.5 against *Tetranychus* spp. In the IPM crops during the same growing seasons, an average of 12 sprays were applied, with an average of 1.3 products each. No treatment against thrips was made in any plastic house; the proportion of products used was: 1.3 against *Bemisia tabaci* (Gennadius), 8.5 *Bacillus thuringiensis* against caterpillars, 5.8 for fungal diseases control and 1 for aphids.

As IPM programmes are relatively new, some practices still lack efficacy data under our conditions. The cost of natural enemies represents the greatest expense in IPM programmes. In the region of Murcia it has been estimated to be 79% of the total cost for pest and diseases control; thus, it is profitable to optimize the use of natural enemies by releasing only those species that are well adapted to environmental conditions and demonstrate a good response to the specific pest.

Amblyseius (Neoseiulus) cucumeris (Oudemans) is the most common species used for thrips control in horticultural crops; however, its use in the Mediterranean area is limited by the low relative humidity (Rodriguez, 1991; Vacante & Tropea-Garzia, 1993; Rodriguez & Fidalgo, 1993; Van der Blom *et al.,* 1997). In the case of pepper crops, grown between January and October, the use of this species is limited to the first few months. It is also the most costly control used, representing 30-40% (excluding the release expenses) of the total cost of the natural enemies during the entire growing season.

The Tomato Spotted Wilt Virus is the main phytopathological problem of peppers and its control requires the adoption of several practices, each one contibuting in some ways to the reduction in the disease incidence (Lacasa & Sanchez, 1999). The good control of *F.occidentalis* is one of the key factors to avoid high disease incidence. An understanding of its population dynamics in relation to the temperature can be used to manage the species and to choose the time of natural enemy releases.

This article is the result of several essays and conclusions drawn from experiments carried out in the last six years. It deals with the influence of the temperature on thrips population dynamics, the response of *A.cucumeris* in thrips control, *Orius* release strategies and cultural practices to be used in order to reduce TSWV incidence.

Materials and methods

Influence of the temperature on* F.occidentalis *populations dynamics.

The influence of temperature on *F.occidentalis* population dynamics has been determined through the analysis of data collected from plastic house pepper crops over the last six years.

Most of the data come from IPM plastic houses, where *A. cucumeris*, *Orius laevigatus* (Fieber) and *O. albidipennis* (Reuter) were used to control *F.occidentalis*. Other natural enemies, or compatible products, were used for other pests and fungus diseases. Other plastic houses served as control and no specific treatment was made against thrips, while products with low toxicity for thrips were sprayed to control other pests and diseases. For some growing seasons we dispose of thrips population dynamics data in crops where chemical control for thrips was practiced.

The monitoring of *F.occidentalis* population dynamics was made weekly, by sampling flowers and leaves. The samples were carried in refrigerated containers to the laboratory, where the insects were extracted with funnels Berlese incandescent lamps and the individuals were collected in a solution of 10% alcohol and 1‰ Agral ®. Three samples of ten flowers each and three samples of twenty leaves were taken in the experimental plastic houses, and three samples of twenty flowers each and twenty leaves each were taken from the commercial houses.

The temperature and relative humidity were recorded with either a digital datalogger or a hygrothermograph.

***Response of* A. cucumeris *in controlling* F. occidentalis**

The trial was carried out at the Torreblanca Experimental Station (C.I.D.A.) located in Campo de Cartagena (Murcia) in a 33x11 m plastic house, provided with ventilation in lateral openings 1.2 m wide and 14x10 antitrips mesh. Transplanting took place on Jauary 21, 1999; the variety "Orlando" was used.

The plastic house was divided into two sections by a plastic sheet. On March 18 *A.cucumeris* was released in bags of 500 individuals each, at a rate of 0.5 bag/plant. The assay was considered finished on May 4.

The monitoring of *A.cucumeris* and *F.occidentalis* population dynamics was carried out by taking three samples of 10 flowers each and three samples of 20 leaves each. The extraction was made with Berlese funnels.

Strategies for releasing* Orius *spp

The trial was carried out in the same plastic house as the previous experiment, during the 1999 growing season. It was divided into two sections by a plastic sheet. In section 1 adults of *Orius* spp. were released, while in section 2, nymphs were released. The *O.laevigatus* release took place on April 14 and 27. In both sections *A.cucumeris* were released two weeks before the *O.laevigatus* introduction, in bags of 500 individuals each, at a rate of 0.5 bag/plant. On May 20 a treatment with cipermetrine was made in order to exterminate the *O.laevigatus* and on June 5 the same experiment with *O.albidipennis* was started (Table 1). The *Orius* originated from the insectary of C.I.D.A.'s Crop Protection Department, and had been reared at a temperature of 23°C on *Pelargonium hederifolia* with *Ephestia kueheniella* (Zeller) eggs as a supplementing the diet.

Table 1. Release schedule in Sections 1 and 2.

	Section-1				**Section-2**		
Dates	**n**	**Species**	**Stage**		**n**	**Species**	**Stage**
14-Apr-98	350	*O. laevigatus*	Adults		720	*O. laevigatus*	Nymphs I-II
27-Apr-98	350	*O. laevigatus*	Adults		380	*O. laevigatus*	Nymphs III-V
5-Jun-98	300	*O. albidipennis*	Adults		300	*O. albidipennis*	Nymphs III-V

Effect of the elimination of the plants showing symptoms of Tomato Spotted Wilt Virus (TSWV) on the disease evolution.

The trial to quantify the effect of the elimination of plants showing symptoms of TSWV on the disease evolution was started on July 14, 1997 and was carried out in the same plastic houses used for the experiments described in the above paragraphs. The plastic house was divided into two sections by a plastic sheet. In one section the plants showing symptoms of TSWV were removed weekly, while in the other, the diseased plants were left in the house. The virus incidence at the beginning of the experiment was 2% in both sections.

The monitoring of *F.occidentalis* population dynamics was done as described in the previous experiment.

Results and discussion

Influence of the temperature on* F.occidentalis *population dynamics.

Plastic house pepper crops in the region of Murcia are grown from December or January to September. During this long crop cycle, *F.occidentalis* appears quite early. However, its density remains low in the winter months, and the exponential increase occurs only in mid spring (Figure 1). The time at which the species' population density sees a continuous and rising increase coincides with the period when the average temperature reaches 20°C (Figure 2) and the portion of the day in which the temperature is below 10°C is very short (Figure 3).

In this period the conditions for species development are optimal. In summer there is a decrease in thrips populations caused by high average daily temperatures of between 25-30°C with almost half of the day reaching above average daily 30°C. This is shown in the experiments in which predators were eliminated in mid July, when the average temperature was 25°C. In this case we first observed an increase in the population density, that reached its maximum (10-14 larvae/flower and 6 adults/flower) four weeks after the predators were eliminated. In the subsequent weeks, however, we observed a reduction in the population density, that became stable at around 4 larvae/flower and 1-2 adults/flower. These values are in clear contrast to the data recorded when the predators were eliminated at the beginning of May, when the conditions for species development are optimal. In this case we observed that *F.occidentalis* density increased drastically, reaching its maximum over 50 larvae/flower and 10 adults/flower two weeks after the extermination of predators.

***Response of* A. cucumeris *in the control of* F. occidentalis.**

In the section in which *A.cucumeris* was released, *A.cucumeris* population reached a maximum of 5.4 individuals/flower after 5 weeks (Figure 4) followed by a decrease to 0.5 individuals/flower at the end of the trial. Althoug, *F.occidentalis* was present from the beginning, its population did not increase noticeably until the first week of April (Figure 4). The highest density was reached four weeks later, at the end of the trail (1.5 larvae/flower and 2.6 adults/flower).

F.occidentalis was also observed from the beginning in the section in which *A.cucumeris* was not released. The thrips population increased from the first week of April, but at a higher rate than in the section with *A. cucumeris* (Figure 4). A maximum of 19 larvae/flower and 11 adults/flower was observed at the end of the experiment.

The results of the trial show that releasing *A.cucumeris* effectively reduces the *F.occidentalis* population. Nevertheless, as it has been observed during these years, the response of *A.cucumeris* is not sufficient to control thrips. One of the main reasons is because the density of *A.cucumeris* is very low when thrips development conditions are optimal. Another predator is needed, such as *Orius* spp., which could could work in conjunction with *A.cucumeris* to reduce maximum thrips densities. This is very important for controlling the spread of TSWV.

Orius *strategies release*

In the section where adults of *O. laevigatus* were released, *O.laevigatus* were first observed two weeks later. Their population increased continuously to reach a maximum of 0.3 individuals/flower (Figure 5), then fell to 0.07 individuals/flower. In the section where nymphs were released, no *O.laevigatus* were observed until 2 weeks later than the house in which adults were released. The maximum density reached was 0.07 *Orius*/flower (Figure 5).

In the second phase of the experiment *O. albidipennis* was released. In the section in which adults were used, the first individuals were observed ten days after the release (Figure 5). From that moment on the population increased continuously reaching a maximum of 0.3 *Orius*/flower. When nymphs were used, they were first observed three days after the release. However, the population did not increase until two weeks later, reaching a maximum of 0.2 *Orius*/flower (Figure 5).

In both phases of the experiment the *Orius* population increase was slower when nymphs were released. The fall of *O.laevigatus* after reaching its maximum density in the section where adults were released, was probably due to the decrease in *A.cucumeris* density and the lack of thrips as a main source of prey. The results agreed with what was expected theoretically. In the case of the adults, the oviposition is immediate, while the nymphs have to complete their development and pass the pre-oviposition period. The idea that the use of nymphs could give better results, is based on the supposition that the dispersion after release would be and thus establisment would be better. Neither it is certain that there is no dispersion of the nymphs, nor that they remain in the crops once in the adult stage. Besides, their supposed lack of dispersion is thought to imply a direct control of the thrips, although the low densities used in the releases are supposed to contribute very little to thrips control in the establisment phase, being the potential of the *Orius* linked to the increase of its population in response to the increasing number of thrips.

In our opinion none of the two methods is to be excluded and the choice depends on the aim of the realease. The state of the individuals to be used must also taken into account. In quality controls of *O.laevigatus* made from several natural enemies suppliers during the 1999 growing season, it was observed that the females' average longevity at 25°C was 16 days and the average oviposition was 45 eggs/female, which corresponds to a reduction of 50% and 60% respectively, according to data reported for *O.laevigatus* at this temperature by several authors (Alauzet *et al.*, 1994; Sanchez, 1998).

The timing of *Orius* releases can also have repercussions on the global mechanic of the agroecosystem. On some occasions, *Orius* populations increased after their release, in association with a fall in *A.cucumeris* populations. The *Orius* populations then decreased to a low level until it responded to rising thips density (Figure 1). The interaction between *Orius* and *A.cucumeris* can take place in the absence of thrips (Gillespie & Quiring, 1992). Early *Orius* releases do not guarantee an earlier establisment, nor does having a high *Orius* density prevent the thrips outbreak, which always takes place at a higher or lower level.

It can be therefore said that using *A.cucumeris* in the first phase of the crop can be beneficial to control thrips. Early *Orius* releases can lead to the extermination of the phytoseiid. Since the thrips density is low during the first months due to low temperatures and the initial thrips population increase is slowed by the action of *A.cucumeris*, *Orius* releases can be put off until the average temperature approaches 20°C and the temperature in the crop is >10°C for the majority of the day.

O.laevigatus and *O.albidipennis* are the two most common species of the genus in the Southeast of Spain. *O.albidipennis* is the most common species during the warm season (Lacasa *et al.*, 1996), being better adapted to high temperatures than *O.leavigatus* (Sanchez, 1998). In plastic houses, sweet pepper commercial crops, only *O.laevigatus* is used. It is effective in controlling thrips, and stays at a high density during the period of optinmal conditions for thrips development (Sanchez *et al.*, 1997). Generally at the beginning of the summer a decline in its population can be observed. Although the use of *O.laevigatus* is sufficient to control thrips throughout the season, releases *O.albidipennis*, can be beneficial in places where it does not appear naturally, or a decrease in the *O.laevigatus* population level occurs. The presence of *O.albidipennis* can contribute to the system's stability, with a quicker response to perturbation factors, thanks to its better adaptation to environmental conditions of plastic houses in the summer months. In addition, being a general predator, it can contribute to control aphids, *Spodoptera exigua, Ostrinia nubilalis*, *Tetranychus* spp. and *Bemisia tabaci*.

Effect of the elimination of the plants showing symptoms of Tomato Spotted Wilt Virus (TSWV) on the disease evolution

The removal of the plants with symptoms of TSWV contribute remarkably to reduce the final incidence of the disease. In the section in which the plants with TSWV symptoms were not removed, the disease incidence eight weeks later was 64%, while in the section where the plants with TSWV symptoms were removed it was 20%. In both sections *F.occidentalis* population dynamics were very similar. The loss in production caused by the virus was higher in the section where diseased plants were not removed than in the section in which plants with TSWV symptoms were removed (Sanchez *et al.*, 1999).

In Almeria virus incidence is low. Howerver in both Murcia and Alicante regions, TSWV represents the main phytopathological problem (Garcia *et al.*, 1997). Thus, it is necessary to adopt cultural practices contributing to the reduction of disease incidence.

In a few areas with a peculiar epidemiologic situation there is a high immigration rate of viruliferous thrips, which provoke a fast increase in disease incidence, even when the thrips population density is very low. However, in most of the plastic houses the immigration of viruliferous thrips into the crops is low and the disease spread takes place mainly from the internal foci (Sanchez *et al.*, 1998). As a result it is also useful to employ any technique which contributes to reduce the immigration into the greenhouse, such as putting meshes on the ventilation openings (Lacasa *et al.*, 1994). The elimination of the plants with symptoms of TSWV is especially advisable in the first months of the crops, before *F.occidentalis* outbreak. By eliminating the internal source of infection the proportion of viruliferous individuals in the next generations can be considerably lower.

Acknowledgments

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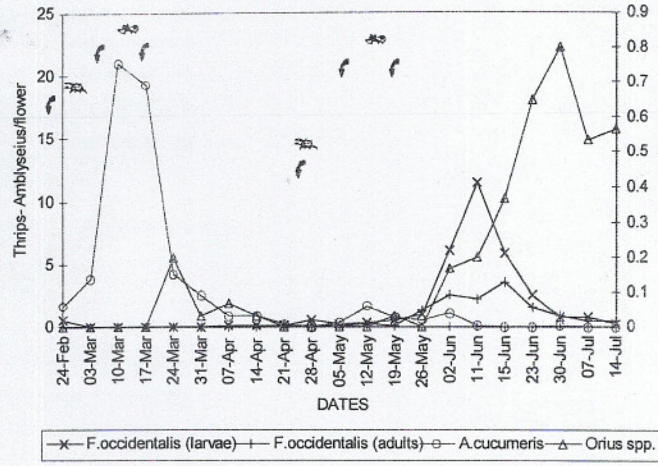

Figure 3

Figure 1. Population dynamics of *F.occidentalis, A.cucumeris* and *Orius* spp. Natural enemies release . *Orius spp.* . *Amblyseius cucumeris* .

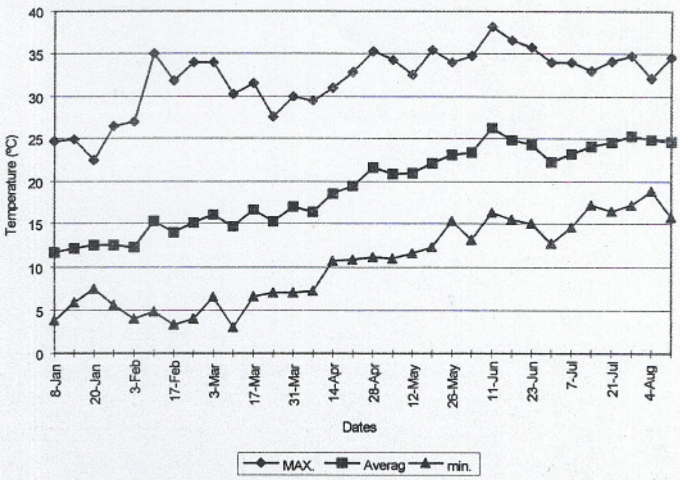

Figure 2. Temperature evolution

Figure 1

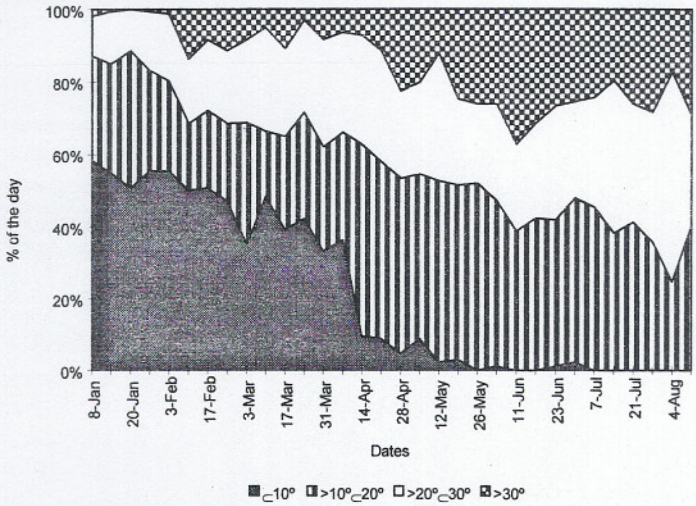

Figure 3. Range of temperature during the day

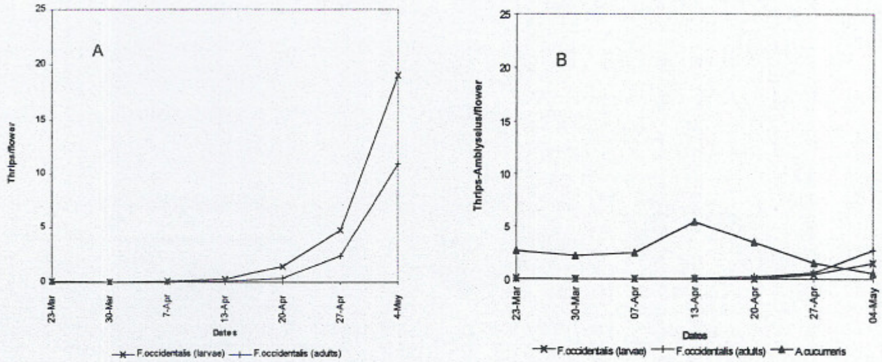

Figure 4. *F.occidentalis* and *Amblyseius cucumeris* Population dynamics. A= Without *A.cucumeris*, B= *A.cucumeris* released

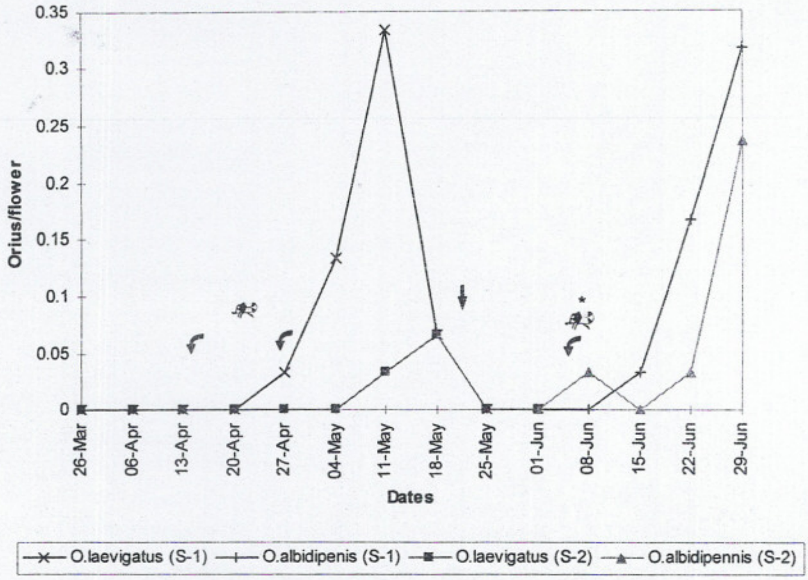

Figure 5. Evolution of *O.laevigatus* y *O.albidipennis*. S-1= nymphs released, S-2= Adults realeased. *Orius laevigatus* and **O.albidipennis* releases. Spray.

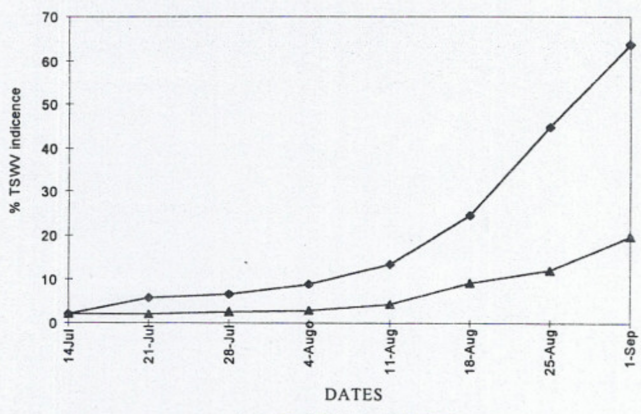

Figure 6. TSWV incidence evolution. Section 1= natural spread, Section-2= plants with symptoms removed.