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A biological pest control story

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Abstract: The use of biological pest control and IPM has quickly spread in pepper greenhouses in Campo de Cartagena (Spain) in the last ten years. IPM is currently applied in 90% (1,600 ha) of the greenhouse surface. The development of biological pest control in Campo de Cartagena is especially relevant for the whole Mediterranean area because it was possible despite of the high risk of pest outbreaks and the high incidence of insect-borne diseases (*Frankliniella occidentalis*-Tomato spotted wilt virus, TSWV). The first trials to investigate the potential of native *Orius* spp. for controlling *F. occidentalis* in Campo de Cartagena were carried out in 1994 in experimental greenhouses at the IMIDA research station. In the following years, the use of natural enemies was optimised and the economic viability of the program was tested. Further assays were carried out to study the epidemiology of TSWV and to establish cultural practices to reduce the incidence of this virus. The adoption of IPM strategies greatly reduced the use of pesticides. The incidence of TSWV experienced a great reduction in the years following the establishment of biological pest control: the incidence of the virus in IPM greenhouses in 2002 and 2003 was 1.2% and 0.87%, respectively.

Key words: biological pest control, IPM, pepper, *Frankliniella occidentalis, Orius* spp., *Eretmocerus mundus, Neoseiulus californicus,* TSWV.

Introduction

The successful development of biological pest control programs in greenhouse peppers in Campo de Cartagena has no precedent in the Mediterranean area. There are several aspects that make the development of biological control in this area especially interesting: (1) Biological pest control was established in spite of the high risk of pest outbreaks and the high incidence of insect-borne diseases (*Frankliniella occidentalis* (Pergande)-Tomato Spotted Wilt Virus, TSWV); (2) The adoption of new biocontrol strategies spread very quickly; in fewer than ten years almost the entire surface of protected pepper crops (about 1,600 ha) switched from chemical to pest control using natural enemies; (3) Some of the natural enemies (e.g. *Neoseiulus* (*Amblyseius*) *californicus* (McGregor) and *Eretmocerus mundus* Mercet) used to control key vegetable crop pests throughout the world were first collected for mass rearing and assayed for pest control on a large scale in this area.

Campo de Cartagena is a flat area located along the coastal strip of the Murcia and Alicante regions. In this area, peppers grown under plastic greenhouses coexist with other vegetable crops (artichokes, lettuce, broccoli and celery), cucurbits (melon and watermelon) and citrus (lemon and orange). The highly heterogeneous landscape and the relatively open structures of the plastic greenhouses facilitate a high degree of interaction with other crops. Open fields and wild plants serve as pest and disease reservoirs during pepper crop-free periods and vice versa. However, the surrounding environment is also a great source of natural enemies that immigrate and establish in crops when the use of pesticides is reduced.
Many stories could be told about the change in pest control strategies in pepper greenhouses

in Campo de Cartagena. Here we are telling the story of a research group involved in establishing the scientific bases of biological pest control for greenhouses grown peppers.

Evolution of Biological Pest Control in Greenhouse pepper crops in Campo de Cartagena

Before the introduction of western flower thrips (*F. occidentalis*) in about the mid-1980s, *Thrips tabaci* Lindeman was a secondary pest for pepper crops in southern Spain. The introduction of this exotic thrips occasioned a great disruption in the existing chemical pest control programs and truncated the first attempt to develop integrated pest management (IPM) programs. *Neoseiulus* (*Amblyseius*) *cucumeris* (Oudemans), which had started to be successfully used against *T. tabaci,* following experiences in northern Europe, completely failed to control *F. occidentalis*. *Orius insidiosus* (Say) was later tested with the same unsatisfactory results. Western flower thrips was a more serious pest than *T. tabaci* because of the greater amount of damage produced when it fed on leaves and fruits and, particularly, because of its great ability and efficacy to transmit Tomato spotted wilt virus (TSWV). We cannot be sure whether TSWV was present in the Iberian Peninsula before the appearance of *F. occidentalis* but, it is quite evident that TSWV started to spread soon after the introduction of western flower thrips (Lacasa, 1990).

The peculiarities of the Mediterranean region made it necessary to develop *ad hoc* programs for greenhouse peppers based on native natural enemies. The aim of the first works was to catalogue the main predators and parasitoids of *F. occidentalis*. The anthocorids *Orius laevigatus* (Fieber) and *Orius albidipennis* (Reuter) were among the most common and abundant thrips predators (Lacasa *et al.,* 1996). They occurred in many wild plants and spontaneously colonized pepper crops when pesticide applications were reduced, normally at the end of the growing season (Lacasa *et al.,* 1996). Predatory thrips (*Aeolothrips intermedius* Bagnall and *Aeolothrips tenuicornis* Bagnall), mites [*N. californicus*, *Neoseiulus barkeri* (Hughes) and *Euseius stipulatus* (Athias-Henriot)], mirids [*Deraeocoris punctulatus* (Fallén)] and Eulophids (*Ceranisus menes* Walker) were other minor groups that helped to regulate *F. occidentalis* populations in crops and surrounding habitats.

The first trials to investigate the potential of native *Orius* spp. in controlling *F. occidentalis* in Campo de Cartagena were carried out in 1994 in experimental greenhouses at the IMIDA research farm (Sanchez *et al.,* 1995). The main conclusions drawn from these assays were: (1) *O. laevigatus* quickly established in the crop and reduced *F. occidentalis* population in a short time; (2) *O. albidipennis* spontaneously colonized the crop by the beginning of the summer and reached high densities; and (3) *N. californicus* immigrated to the crop and controlled *Tetranychus urticae* Koch. These preliminary assays formed the basis for the subsequent development of the pepper IPM program in Campo de Cartagena (Sanchez *et al.,* 1995).

Other assays were carried out in the following years in experimental and commercial greenhouses to optimise the use of natural enemies and to assess the economic viability of the program. The first assays in commercial greenhouses were carried out in two commercial greenhouses during the 1995/96 growing season (Sanchez *et al.,* 1997a). *O. laevigatus, O. albidipennis* and *N. cucumeris* were used against *F. occidentalis*. *N. cucumeris* was released at the beginning of the season and during the winter months, when low temperatures made the establishment of *O. laevigatus* difficult. Preliminary trials showed that *F. occidentalis* could be controlled using natural enemies with efficacy levels similar to those obtained by chemical methods (Sanchez *et al.,* 1997a). Further works characterized the

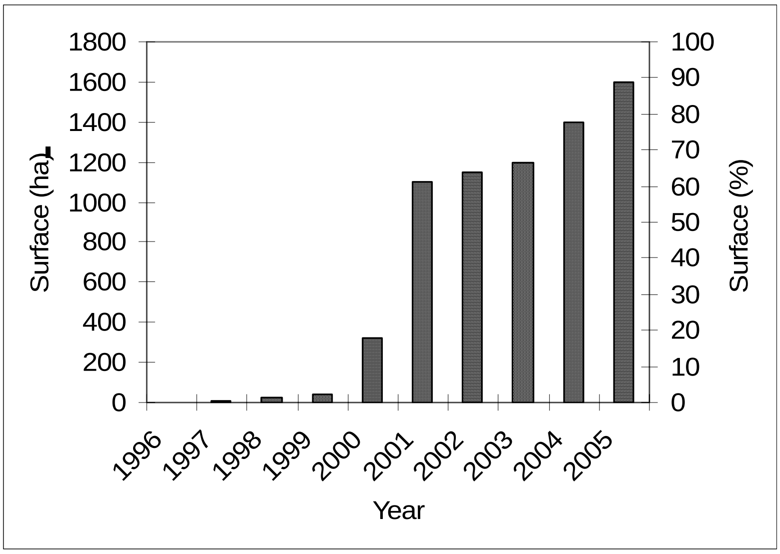

Figure 1. Evolution of the area of pepper greenhouses under IPM in Campo de Cartagena.

biological parameters of *O. laevigatus* and *O. albidipennis* and established release rates in relation to *F. occidentalis* population dynamics (Sanchez & Lacasa, 2002). However, by the mid-1990s the high incidence of TSWV still remained an obstacle to the development of IPM programs.

The study of TSWV epidemiology and the implementation of cultural practices to reduce the incidence of the virus were addressed in subsequent years. The incidence of TSWV depends on the immigration of viruliferous thrips and it spreads in the crop from primary foci. Thus, physical barriers that reduced thrips immigration and cultural practices aiming to reduce primary foci were expected to diminish TSWV incidence. Lacasa *et al.* (1994) had already proved that thrips-excluding meshes in lateral vents of greenhouses delayed thrips immigration and reduced the incidence of TWSV. In subsequent assays, Alcázar *et al.* (2000) concluded that, once TSWV was present in the crop, the virus mainly spread from primary foci. Removing infected plants greatly reduced the final incidence of the virus (Sanchez *et al.*, 1999, Sanchez *et al.*, 2000). The adoption of appropriate cultural practices and the use of resistant varieties, which were available from around 2000, considerably reduced the incidence of TSWV in pepper greenhouses.

In the following years, the area of pepper greenhouses under IPM in the Campo de Cartagena region started to rapidly increase (Figure 1). The increase in pesticide applications to control *F. occidentalis* and the reduction of active ingredients following new European Union norms, encouraged growers to consider natural enemies as an alternative to pesticides for pest control. In less than ten years, almost the entire area switched from chemical to biological pest control programs (Figure 1). When we speak of biological pest control or IPM, we are referring to programs in which pest control is primarily based on predators and parasitoids, with little or no use of pesticides.

A few species such as *Macrosiphum euphorbiae* (Thomas), *Aulacorthum solani* (Kaltenbach) , *Ostrinia nubilalis* (Hübner) or *Nezara viridula* (L.) which were kept under control when chemical control was applied, became secondary pests after the generalised application of biological control. *Bemisia tabaci* Gennadius turned out to be a major pest for both chemical and IPM greenhouses by the end of the 1990s. The first attempts at controlling *B. tabaci* with the parasitoid *Eretmocerus eremicus* Rose & Zolnerowich did not provide satisfactory results (Fernández *et al.*, 2003). The native parasitoid *E. mundus* frequently immigrated to crops providing a good *B. tabaci*. The mass rearing and commercialisation of *E. mundus* made inoculative releases possible. In most cases this aphelinid provides a satisfactory control for *B. tabaci* (Calvo *et al.,* 2002, Urbaneja *et al.*, 2003, Fernández *et al.,* 2003).

Natural enemy and pest management in IPM pepper greenhouses is based on periodic sampling that supports decision-making. Sampling protocols used in research were highly time-consuming and inappropriate for commercial greenhouses. Binomial or presence-absence methods were therefore developed for several pests and natural enemies (e.g. *F. occidentalis, Orius* spp., *Amblyseius* spp., *B. tabaci,* aphids) in order to reduce the cost of sampling without losing precision and accuracy in the estimates (Sanchez *et al.,* 1997b, Guirao *et al.*, 2004).

The extension of the IPM program to commercial greenhouses took place towards the end of the 1990s. The regional agriculture agency (Consejería de Agricultura, Agua y Medio Ambiente de la Región de Murcia) took part in a project with the local growers' association FECOAM (Federación de Cooperativas Agrarias de la Región de Murcia) to help transferring the IPM program from an experimental to a commercial scale. The aim of this collaboration was to train technicians and growers and to help solving problems that arose when applying IPM on a larger scale. Natural enemy producers also played a major role in training and implementing IPM in Campo de Cartagena. Many companies got involved at the sight of a good prospect for a natural enemy market that, with time, was going to be the biggest in the Mediterranean area.

Outcome of the Biological and Integrated pest control programs

One of the major outcomes of IPM was a great reduction in the use of pesticides in pepper greenhouses in Campo de Cartagena. In a survey involving conventional greenhouses that was carried out in 1998 and 1999, we found that, on average, crops were sprayed 27 times in a growing season using 2.5 active ingredients in each application (Sanchez et al. 2000); 33 of these active ingredients were against western flower thrips, 18 against *B. tabaci*, 4 against caterpillars (*Spodoptera exigua* (Hübner) and *O. nubilalis*), 0.5 against *T. urticae* and 5 were used to control fungal diseases [*Botrytis cinerea* Pers. and powdery mildew, *Leveillula taurica* (Lév.)]. In greenhouses under IPM, most of the sprays were used against caterpillars (8.5 with *Bacillus thuringiensis* Berliner) and to control fungal diseases.

Reducing the number of spray applications in IPM has many advantages relating to the busy spray calendar of the conventional chemical control. (1) It reduces health risks for growers and consumers. Growers are much happier to release natural enemies than to handle chemical products. Releasing natural enemies is much safer and does not require all the safety measures associated with the use of chemical products. (2) It reduces the negative environmental impact on surrounding ecosystems. (3) Returning times are greatly reduced and this gives growers more freedom and confidence in harvesting and commercialising their produce. (4) Production in IPM greenhouses is generally higher than in greenhouses under chemical control: (i) pepper plants grow better when the intensity of such treatments is reduced; (ii) in "parral" type greenhouses, chemicals are normally applied from lateral openings using a spray cannon; in most crops, a gradient in plant growth can be observed from the lateral to the middle of the greenhouse due to the impact of applications at high pressure: the production of plants from the first three or four lateral rows is always very low; (iii) the growing season has extended by a few months since biological pest control is applied due to the lower incidence of TSWV.

The incidence of TSWV experienced a great reduction in pepper greenhouses in the years following the establishment of biological pest control in Campo de Cartagena. In the mid-1990s, many pepper crops were removed by the beginning of July and the incidence of TSWV in many greenhouses was close to a hundred percent at the end of the growing season. This situation had completely changed by the beginning of 2000. In a survey carried out in 2002, involving 96 randomly selected IPM greenhouses and 75 using chemical methods, the incidence of TSWV was 1.2% and 1.1%, respectively. Most of the pepper varieties used (92.8% and 98.7% for IPM and chemical greenhouses, respectively), were TSWV sensitive (e.g. Herminio, Spirit, Fiesta and Velez); TSWV-resistant varieties (e.g. Requena) only represented 7.2% and 1.3% for IPM and chemical greenhouses, respectively. In 2003, in a survey carried out in 174 IPM pepper greenhouses, the incidence of TSWV was 0.87% and the percentage of TSWV-resistant varieties was 10%.

Although it is difficult about the factors responsible for the reduction in the incidence of TSWV in pepper crops, there are good reasons to believe that the change in pest control strategies may have played an important role. It is quite unlikely that resistant varieties were entirely responsible for the reduction in the incidence of the virus, among other reasons, because the area devoted to these varieties had been much smaller than that devoted to susceptible ones. The reduction of the population of viruliferous thrips at a global level might have been one of the main factors contributing to the fall in the impact of TSWV. In greenhouses under chemical control, western flower thrips populations reach high densities at the end of the growing season once pesticide applications stop. At the end of the growing season many plants may be infected with TSWV and young larvae feeding on these plants may produce abundant generations of viruliferous thrips. Adults may immigrate and infect susceptible crops as well as wild plants, which may serve as virus inoculum for the subsequent growing season. In IPM greenhouses high *Orius* spp. populations keep thrips density low at the end of the growing season. Thus, the immigration of infected thrips to potential hosts and the contribution to global TSWV inoculum is expected to be much lower for pepper crops under IPM than for those under chemical control.

Future development

Crops under biological pest control are dynamic systems and new problems will tend to arise that will make it necessary to adjust the program. One of the advantages of IPM is that periodic sampling provides information about the state and the evolution of the system. This information is used for immediate decision making, but may also be used to establish management strategies at broader geographical and temporal levels. Over the last few years we have been involved in integrating all of these data within a Geographical Information System (GIS) (Sanchez *et al.* 2005). This GIS may be a very useful tool for establishing management strategies for controlling pests and natural enemies in line with the local problems and the environmental conditions of each area.

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