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Biological control of *Tetranychus urticae* (Acari: Tetranychidae) with naturally occurring predators in strawberry plantings in Valencia, Spain

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Abstract. Naturally occurring beneficials, such as the phytoseiid mite *Amblyseius californicus* McGregor and the insects *Stethorus punctillum* Weise, *Conwentzia psociformis* (Curtis) and others, controlled *Tetranychus urticae* Koch in 11 strawberry plots near Valencia, Spain, during 1989–1992. The population levels of spider mites in 17 subplots under biological control were low or moderate, usually below 3000 mite days and similar to seven subplots with chemical control. In most of the crops *A. californicus* was the main predator, acting either alone or together with other beneficials. Predaceous insects colonized the crop when tetranychids reached medium to high levels. For levels above one spider mite per leaflet, a ratio of one *A. californicus* per five to ten *T. urticae* resulted in a decline of the prey population in the following sample (1–2 weeks later). These results suggest that naturally occurring predators are able to control spider mites and maintain them below damaging levels in strawberry crops from the Valencia area.

Key words: Biological control, strawberry, *Tetranychus urticae*, *Amblyseius californicus*.

Introduction

The tetranychid mite *Tetranychus urticae* Koch (Acari: Tetranychidae) is one of the most important pests of cultivated strawberries around the world. Studies of yield reduction caused by varying population levels of *T. urticae* have demonstrated its potential for damaging this crop (Wyman *et al*., 1979; Oatman *et al*., 1982; Sances *et al*., 1982; Raworth, 1986). Pesticides are the primary method of control of *T. urticae*. However, there are problems associated with the use of pesticides for the control of this mite because populations develop resistance to acaricides and the chemicals leave residues on fruits.

Biological control of spider mites in strawberries has been tried as an alternative method (see the review in Wysoki (1985)). Several species of natural enemies have

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been reported to prey on *T. urticae* and studies have been conducted in different countries to assess the effect and potential of natural enemies for controlling the pest without the use of pesticides and without economic damage to the crop. Two approaches have been developed for utilizing biological control. These are the mass release of phytoseiids, usually *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) (Oatman and McMurtry, 1966; Oatman *et al*., 1968; Simmonds, 1971; Benuzzi and Nicoli, 1991) and reliance on naturally occurring predators. The first option has been the most common, but biocontrol of spider mites using native predators has also been attempted, mainly with phytoseiids (Oatman and McMurtry, 1966; Fournier *et al*., 1985; Waite, 1987) and also with several insect species (Raworth, 1991).

Strawberries have become a very important crop in Spain. With a production of more than 200 000 t year^{-1} it is the largest European producer and exporter. The phytoseiid *P. persimilis* has been released on an experimental scale for control of *T. urticae* in strawberry fields in Spain (Sánchez Pulido, 1988; González-Zamora *et al*., 1991), but the value of native predators has not been studied. The aim of this work was to determine the identity and abundance of naturally occurring predators in Spanish commercial strawberry plantings and to evaluate their potential for maintaining *T. urticae* populations below economic threshold levels.

Materials and methods

Studies were conducted between 1989 and 1992 in 11 commercial strawberry (*Fragaria x ananassa* Duchesne) plots near Valencia, on the Mediterranean coast of the Iberian Peninsula. Chandler and Pajaro were the most common cultivars sampled, with four plots each, but others such as Douglas, Selva and Oso Grande, with one plot each, were also involved. Plants were planted in summer in double rows on raised beds covered with black plastic and in winter were pruned and covered with low polythene tunnels.

Plots were divided into two to four subplots of 1000–8000 plants with different cultural practices or spray schedules, making a total of 24 subplots. Mites were sampled independently in each subplot and farmers were allowed to control diseases using selective fungicides that were considered safe for mite natural enemies. These included fenarimol, procymidone, propiconazole and vinclozolin (Hassan *et al*., 1987, 1988, 1994) and usually one to three fungicide sprays were applied in each case. Caterpillars were controlled when necessary with *Bacillus thuringiensis*. Acaricides and insecticides that were potentially harmful to beneficials were applied to seven of the 24 subplots to control spider mites (one to four sprays with hexythiazox or fenbutatin-oxide) and western flower thrips *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) (malathion or chlorpyrifos) respectively.

To assess populations of mites and insects a leaflet was taken from mature leaves from each of 40 randomly selected plants per subplot every 1–2 weeks. Leaflets were examined in the field with the aid of a ×12 hand lens for insect predators and then in the first two seasons carried to the laboratory and examined for mites under a dissecting microscope. In the third and fourth seasons mite counts on each leaflet were made in the field using a hand lens. All stages of mites except eggs were counted. Mite days per leaflet was used as an index of the total mite population during the season and calculated by interpolating the mean number of active mites per sample for each day between samples and summing the daily estimates for the whole sample period.

Results and discussion

Tetranychid population trends

Most tetranychids found in the 11 strawberry plantings were *T. urticae* and this species was predominant on almost all sampling dates, representing 98% of the phytophagous mites identified. *Panonychus citri* (McGregor) (Acari: Tetranychidae) was collected from five plots, usually during the winter or early spring and in crops situated near orange orchards which were infested with high populations of the same species. *Tetranychus turkestani* Ugarov & Nikolski (Acari: Tetranychidae) was also identified in one planting. No differences in the sensitivity of strawberry cultivars to spider mite damage were observed. Some differences in the time of population increases of spider mites were observed depending on the season and cultural practices carried out, such as plant pruning (which delayed the increase) or covering the plants with plastic. Most of the crops were planted in August and some of them were infested with tetranychids in autumn. One plot reached high levels, up to 50 mites per leaflet and acaricide sprays were applied in October and December. In general, tetranychid populations decreased in winter and increased again in March or April, reaching a maximum at the end of spring.

Species of natural enemies

Two species of mites and six species of insects were collected regularly as natural enemies, usually associated with colonies of *T. urticae* (Table 1). The most common and abundant predator was the phytoseiid mite *Amblyseius californicus* McGregor (Acari: Phytoseiidae). This species appears to be the main predator of *T. urticae* in the area, not only in strawberries but in all types of horticultural crops. The only other species of phytoseiid identified feeding on *T. urticae* in some plots was *P. persimilis*. Its frequency and abundance was more limited and it usually appeared together with *A. californicus* when spider mites were numerous.

Table 1. Predators of *T. urticae* found on 20 818 strawberry leaflets, from 11 strawberry plots sampled regularly between 1989 and 1992 in Valencia, Spain

Predator species	Number of arthropods	Number of plots (total = 11)[a]
A. californicus	3147	10
P. persimilis	438	6
C. psociformis	384	7
S. punctillum	293	6
Chrysopa spp.	115	9
T. persicae	69	5
D. punctullatus	46	4
S. longicornis	33	5

[a] Number of plots in which at least one individual of the species was found.

Of the predatory insects, *Stethorus punctillum* Weise (Coleoptera: Coccinellidae) and *Conwentzia psociformis* (Curtis) (Neuroptera: Coniopterygidae) were most commonly found preying on *T. urticae*. In several plots they were the main predators of spider mites during some periods of the year. *Stethorus punctillum* was associated with high populations of *T. urticae*, on which it seems to prey specifically, while *C. psociformis* could be observed feeding on other microarthropods as well. Several species of chrysopids were observed in most plots, with their characteristic pedunculated eggs present on all plant parts. However, being less specialized predators of spider mites they did not seem to respond numerically to mite outbreaks. In contrast, *Therodiplosis persicae* Kieffer (Diptera: Cecidomyiidae) was always associated with spider mite colonies and in one plot was present in considerable numbers in spring. Other species occasionally found feeding on *T. urticae* in several plots were *Deraeocoris punctullatus* Fallen (Heteroptera: Miridae) and *Scolothrips longicornis* (Priesner) (Thysanoptera: Thripidae).

The complex of natural enemies of tetranychid mites in strawberry has been studied in California (Oatman *et al*., 1985), Australia (Waite, 1988), Canada (Raworth, 1991; Henderson and Raworth, 1991), Bulgaria (Atanasov, 1990) and Taiwan (Lo *et al*., 1990). While specific names vary, the taxa are very similar, with one or several species of Phytoseiid mites and a group of insects included in the same families and even genus, such as those described from Valencia. *Stethorus* sp. and *Scolothrips* sp. and a species of cecidomyidae are always reported as common predators in those areas.

Biological control

The population trends of spider mites and beneficials observed in six of the 24 subplots sampled are shown in Fig. 1 as an example of the types of population trends of tetranychids and beneficials. In some cases spider mite numbers increased soon

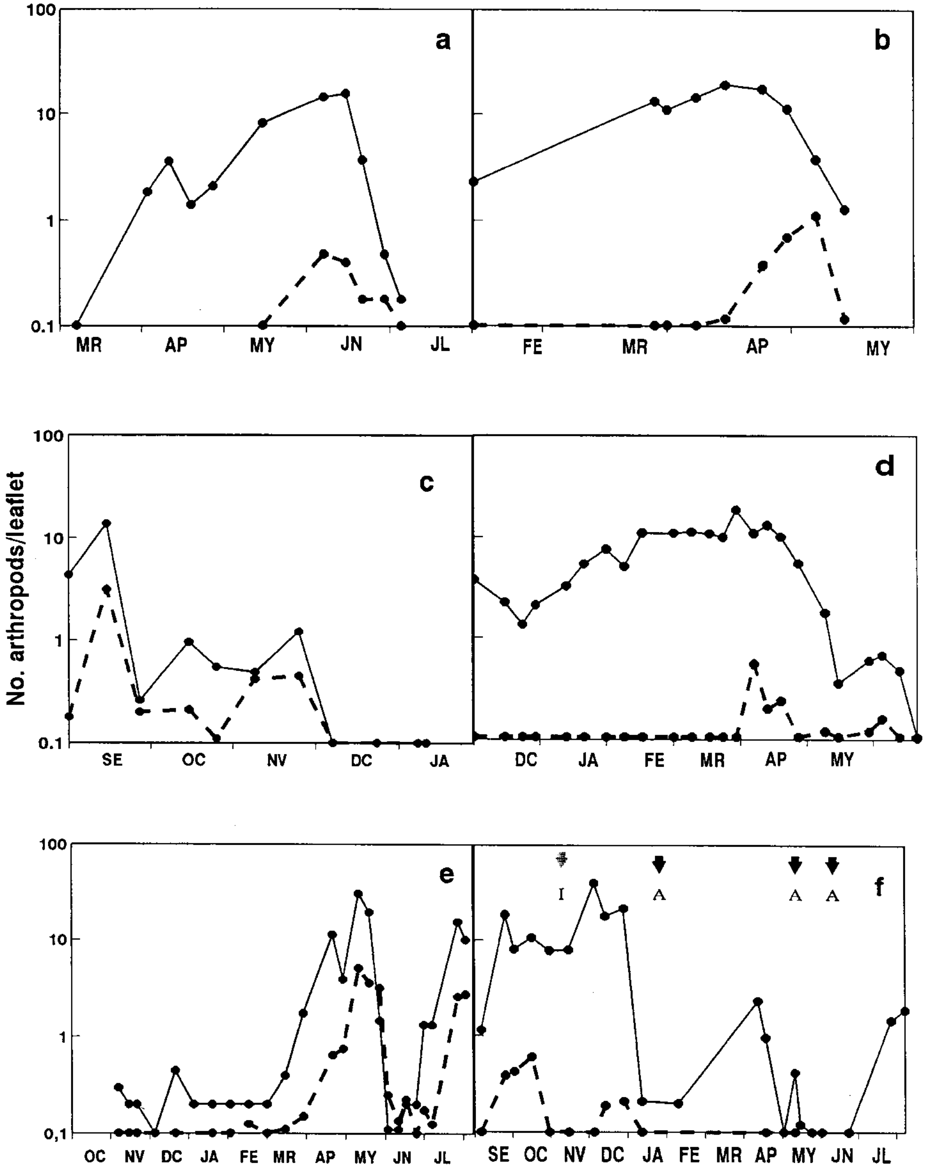

Figure 1. Seasonal population density of *T. urticae* (solid line) and its predators (broken line) on strawberry leaflets in six of the subplots sampled. The arrows indicate applications of insecticides (I) or acaricides (A).

after the summer planting (as in subplots c and f). In others, there was a build up of tetranychid populations, beginning in January or February, followed by an increase in natural enemies in spring that reduced the population of the prey. Sometimes there was a resurgence of tetranychids and natural enemies (as in subplot e). In subplot f, four acaricide sprays were required to control the *T. urticae* population. In the 17 subplots not treated with acaricides or insecticides a numerical increase in naturally occurring predaceous insects and mites always occurred in response to increases in populations of spider mites.

Representation of the population density of spider mites in each of the 24 subplots, either as the maximum number of mites per leaflet or as the accumulated number of mite days (Fig. 2), shows that, in most cases, the mite pressure on the crop was low or moderate. In seven subplots the pressure exceeded 2000 mite days and only one exceeded 3000 mite days. These levels are considered tolerable when compared with results from studies made on threshold levels. In summer plantings Wyman *et al*. (1979) and Oatman *et al*. (1981) found that yield was reduced at levels above 3000 mite days or a maximum of 50–100 mites per leaflet. In winter plantings with new plants the tolerance is lower, economic damage occurring at levels above 1500–2000 mite days or 20–30 mites per leaflet (Oatman *et al*., 1981, 1982; Sances *et al*., 1982; Raworth, 1986). The mean tetranychid abundance in the seven subplots with chemical control (1480 ± 244 mite days) was not significantly different (t-test, $p < 0.001$) from that in the 17 subplots under biological control (1333 ± 298 mite

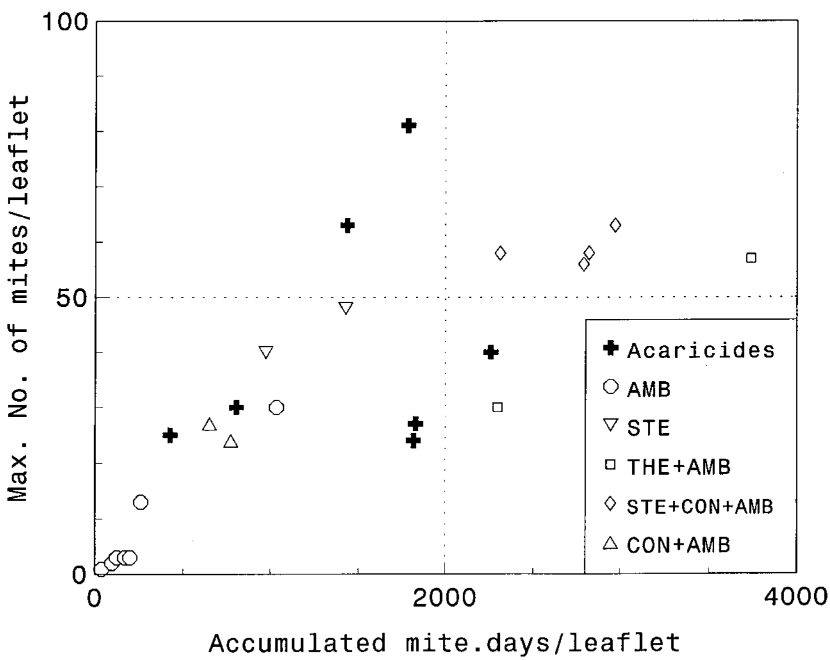

Figure 2. Population levels reached by spider mites in 24 subplots, expressed as accumulated mite days or as maximum number of mites per leaflet and method of control, either chemical (acaricides) or biological (AMB, *A. californicus*; CON, *C. psociformis*; STE, *S. punctillum*; THE, *T. persicae*).

days), showing that naturally occurring predators can provide mite control equivalent to that provided through the application of acaricides. In most crops the biological control agent was the phytoseiid *A. californicus*, either alone or in combination with predaceous insects. In only two subplots was the biological control achieved almost exclusively by beneficial insects, mostly *S. punctillum*. The population density of spider mites in the seven crops where *A. californicus* acted alone was lower (273 ± 130 mite days) than in the other ten subplots where this beneficial mite combined with one or several species of insects (2074 ± 335 mite days). This suggests that predaceous insects colonize a crop only when tetranychid populations reach medium to high levels.

One way of estimating the likely future population trend of spider mites in strawberry when natural enemies are present is to determine the prey : predator ratio needed for effective biological control. From the population dynamics of *T. urticae* and *A. californicus* found in our experimental subplots, we have selected those data points that immediately precede an increase or decrease in spider mite populations on the following sampling date, 1–2 weeks later. Then we have represented the prey : predator ratio as a function of prey density at the time of sampling for each data point, drawing the points that correspond to a population increase in white and

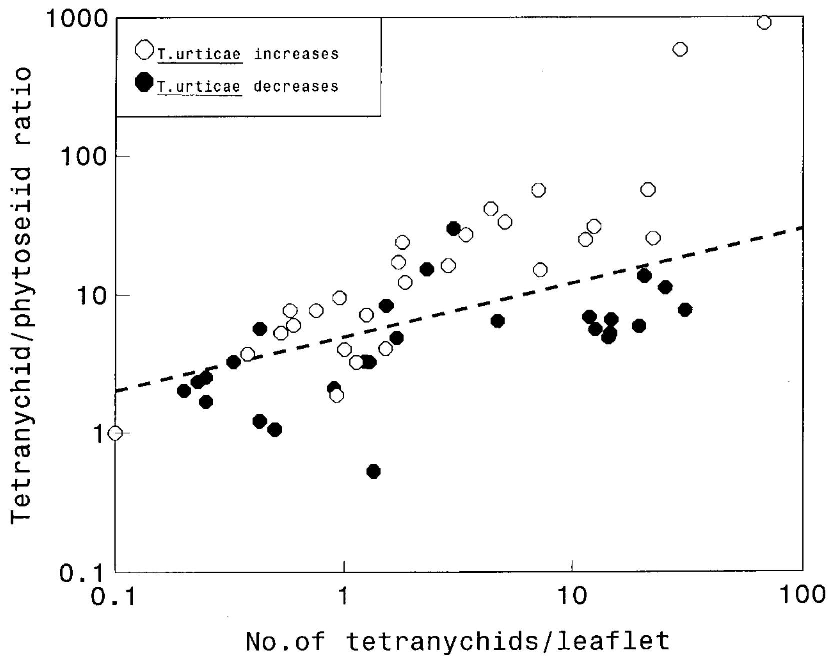

Figure 3. Prey : predator ratios observed in the population trends of *T. urticae* and *A. californicus* which result in an increase or decrease in spider mite population density in the following sampling, 1–2 weeks later.

the points that correspond to a decrease in black (Fig. 3). At between one and ten mites per leaflet, the prey : predator ratio should be between 5 and 10 to achieve a decline in the prey population 1–2 weeks later. The slope of the line that approximately separates both types of points shows that at low prey densities the prey : predator ratio should be lower to achieve a decrease in the population of the prey on the next sampling date. This may be due to the longer time spent by predators searching for prey at low prey densities. Thus, when the spider mite density ranges between 0.1 and 1 mite per leaflet, the prey : predator ratio should be between 1 and 5 for an immediate decrease in the prey population. These figures are similar to those determined by Tanigoshi *et al*. (1983) for *Amblyseius fallacis* Garman feeding on *Panonychus ulmi* Koch (Acari: Tetranychidae) on apples and by Wilson *et al*. (1984) for *Metaseiulus occidentalis* (Nesbitt) (Acari: Phytoseiidae) feeding on *Tetranychus* spp. on almonds.

This research shows that, in strawberry crops from the Valencia area, naturally occurring predators are able to control infestations of spider mites and maintain them below damaging levels. A simplified binomial sampling programme has been developed in the area (González-Zamora *et al*., 1993) and research is being conducted to develop thresholds for spider mites as well as to evaluate the impact of pesticides on their natural enemies. A strategy that involves the monitoring of spider mites and their natural enemies and the use of only chemical sprays that are not detrimental to natural enemies, particularly *A. californicus*, needs to be developed.

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