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Control of the Carmine Spider Mite *Tetranychus cinnabarinus* Boisduval by the Predatory Mite *Phytoseiulus persimilis* (Athias-Henriot) in Protected Strawberries in Aydın, Turkey

İbrahim ÇAKMAK*, Hüseyin BAŞPINAR
Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, 09100 Aydın - TURKEY
Nilgün MADANLAR
Ege University, Faculty of Agriculture, Department of Plant Protection, 35100 İzmir - TURKEY

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Abstract: The potential of the predatory mite *Phytoseiulus persimilis* (Acarina: Phytoseiidae) to control the carmine spider mite *Tetranychus cinnabarinus* (Acarina: Tetranychidae) on strawberries (cv. ´Camarosa`) grown under plastic tunnels was investigated in 2 fields during the 2001 and 2002 growing seasons in Aydın, Turkey. Three study plots, grower's practice, chemical control and biological control, were established. The population of *T. cinnabarinus* was controlled in the grower's practice plots by using 1 or 2 acaricide applications. However, it was suppressed with only 1 acaricide application in the chemical control plots at a population level below economic threshold levels. When the pest population level reached 2-3 individuals per leaflet in the biological control plots, *P. persimilis* was released once at the rate of 1 predator to 20 prey. Predatory mites provided an effective control 15-20 days after release, and no additional release was needed during the rest of the growing season. However, when *T. cinnabarinus* populations were high (11 mites per leaflet) early in the season, control by *P. persimilis* proved ineffective. In addition, no significant difference was found in strawberry yields among the 3 treatments, either in terms of fields or years.

Key Words: Strawberry, *Tetranychus cinnabarinus*, *Phytoseiulus persimilis*, natural enemies, Turkey

Aydın İlinde Örtü Altı Çilek Alanlarında Zararlı *Tetranychus Cinnabarinus* Boisduval'a Karşı Avcı Akar *Phytoseiulus persimilis*'le Savaş Olanakları

Özet: Bu çalışmada 2001-2002 yıllarında Aydın ilinde örtü altı çilek alanlarında zararlı *Tetranychus cinnabarinus* Boisduval (Acarina: Tetranychidae)'a karşı *Phytoseiulus persimilis* (Athias-Henriot) (Acarina: Phytoseiidae)' in biyolojik savaşta kullanılma olanakları ve diğer savaş yöntemlerine göre başarı şansı araştırılmıştır. Üretici parsellerinde en az bir yada iki akarisit uygulaması yapılarak *T. cinnabarinus*'un populasyonu kontrol edilebilmiştir. Bununla birlikte kimyasal savaş parsellerinde zararlının populasyonu ekonomik zarar eşiği altında tutularak sadece bir akarisit uygulamasıyla baskı altına alınmıştır. Biyolojik savaş parsellerinde, kırmızıörümceğin populasyon yoğunluğu 2-3 birey/yaprakçık olduğunda avcı:av oranı 1:20 olarak avcı akar *P. persimilis* salımı gerçekleştirilmiştir. Bir kez gerçekleştirilen avcı akar salımı ile zararlı populasyonu 15-20 günlük bir sürede baskı altına alınmış ve üretim sonuna kadar başka bir savaşa gereksinim duyulmamıştır. Bununla birlikte, *T. cinnabarinus*'un başlangıç populasyonu yüksek (11 birey/yaprakçık) olduğunda, *P. persimilis*'in zararlıyı baskı altına alamadığı ve böyle durumda kimyasal savaşa gereksinim duyulduğu ortaya çıkmıştır. Ayrıca çalışmanın yapıldığı her iki tarla ve yıllar göz önünde bulundurulduğunda, üç uygulama arasında bitki verimleri açısından istatistiki anlamda fark bulunmamıştır.

Anahtar Sözcükler: Çilek, *Tetranychus cinnabarinus*, *Phytoseiulus persimilis*, doğal düşmanlar, Türkiye

Introduction

Due to its high market value, strawberry is produced by many growers in Turkey. In the province of Aydın, some 10,978 t of strawberry are produced on 320 ha each year, accounting for 3.4% of Turkey's total strawberry production. Eighty percent of this production in Aydın comes from the district of Sultanhisar (State Institute of Statistics, 2000). Strawberries are produced under plastic tunnels for early fruit ripening and increasing yield.

* Correspondence to: icakmak@adu.edu.tr

Three species of spider mite, *Tetranychus cinnabarinus* Boisduval, *T. urticae* Koch, and *T. turkestani* (Ugarov & Nikolski) (Acarina: Tetranychidae), are detrimental to strawberries in Aydın. Of these species, *T. cinnabarinus* is the most common in the region. *T. cinnabarinus*, seriously damages both leaves and fruits, and is controlled by excessive acaricide use (Çakmak et al., 2003). However, acaricide use results in the development of strains of spider mites that are highly resistant to pesticides. In addition, the use of acaricides can result in high residues on strawberries, which are consumed fresh and with their skins (Oatman et al., 1967; Easterbrook et al., 2001), and the use of pesticides is detrimental to the environment. Therefore, efforts have been made to apply biological controls against this mite in this crop.

The predatory mite *Phytoseiulus persimilis* (Athias-Henriot) (Acarina: Phytoseiidae) has been studied extensively with respect to its potential for biological control of tetranychid mites on many crops including strawberry (Helle and Sabelis, 1985). *P. persimilis* was introduced from Hohenheim University, Stuttgart, Germany to Turkey in 1988 as a biological control agent (Kazak and Şekeroğlu, 1990). Various researchers have studied the effect of the Hohenheim strain of *P. persimilis* in controlling *T. cinnabarinus* on strawberries in Turkey (Kazak et al., 1992; İnci, 1996; Kısmalı et al., 1999). Subsequently natural colonies of *P. persimilis* were first detected from Kaledran, Alanya and Hatay along the Mediterranean coast of Turkey in 1989-1991 (Şekeroğlu and Kazak, 1993). In subsequent surveys in Kaledran and Alanya *P. persimilis* was not found, due to habitat destruction. In contrast, *P. persimilis* had a very wide distribution on both natural and agricultural plants in Hatay (Şekeroğlu and Kazak, 1993). The potential of the Hatay strain of *P. persimilis* to control *T. cinnabarinus* on field grown strawberry in İçel was studied by Kazak et al. (2002). However, the Hatay strain of *P. persimilis* has not been investigated in protected strawberries in Turkey.

In this study, the effectiveness of the Hatay strain of *P. persimilis* to control *T. cinnabarinus* was investigated, as an alternative to acaricides in 2 commercial strawberry fields utilizing plastic tunnels in Aydın, Turkey. However, the release studies of *P. persimilis* were compared with grower's practice and chemical control.

Materials and Methods

Experiments were conducted during the 2001 and 2002 growing seasons in commercial strawberry fields (*Fragaria ananassa* Duch. cv. 'Camarosa') in the district of Sultanhisar in Aydın, Turkey. A total of 5500 Camarosa strawberries were planted in an area of approximately 0.1 ha on August 10, 2000. The strawberries were planted in 4 rows on raised beds, mulched with black polyethylene plastic, and drip-irrigated in both fields. In winter, they were covered with high polyethylene tunnels. At the beginning of January, the plants were pruned and the leaves removed from the field. In both fields and years, the polyethylene covers were removed in early June.

Different control practices to suppress *T. cinnabarinus* were studied in 3 'walk-in' tunnels for each field. Each tunnel was approximately 200 m long for each control practice and divided into 3 sub-plots of 50 plants x 4 rows for each replicate. Culture practices were the same as those recommended for commercial production. The same fungicide program was followed. The fungicides used were fenhexamid, cyprodinil + fludioxonil and pyrimethanil.

The treatments in the 2 fields (fields A and B), grouped as 3 applications, were as follows:

1- Grower's practice: Since large populations of spider mites on control plots would cause a high yield loss, we were not able to use control plots without regulating spider mite densities. Instead, we used the grower's practice as a control. We followed the grower's applications of pesticides and other applications. Growers applied an acaricide, chlorfenapyr (Pirate®, 360 g a.i., Basf), on March 26, and May 21, 2001, and May 6, 2002, in field A; and on May 14, 2001, and March 11 and May 27, 2002, in field B, recording their effects on pest populations.

2- Chemical control: We aimed to control *T. cinnabarinus* by using an acaricide when the pest population level reached the economic injury level (EIL) (15 active stages per leaflet for strawberry) (Turkish Ministry of Agriculture and Rural Affairs, 1995). Chlorfenapyr was sprayed on March 26, 2001, and April 29, 2002, in field A, and on April 30, 2001, and June 3, 2002, in field B.

3- Biological control: This treatment was aimed at assessing the potential of *P. persimilis* in controlling spider mites. A native strain of *P. persimilis*, originating from Hatay in Turkey, was reared continuously on bean plants, *Phaseolus vulgaris* L. cv. 'Barbunia', infested with *T. cinnabarinus* under controlled conditions of 25 ± 2 °C, 65 ± 10% RH and 16:8 L:D. When predatory mites were numerically dominant, all plants were harvested, wrapped in tissue paper, placed in plastic bags and kept in a refrigerator. Predator releases were carried out using disks of 2-3 cm^2 cut from bean leaves and harboring ~20 eggs and active stages of *P. persimilis* (Kazak et al., 2002). When the density of spider mites had reached 2-3 individuals per leaflet (active stages), *P. persimilis* was released at the rate of 1 predator to 20 prey (Kısmalı et al., 1999). The total level of *P. persimilis* was calculated using the following formula: (number of *T. cinnabarinus* per leaflet) x (number of leaflets per plant) x (number of plants in plot) / the ratio of release. *P. persimilis* was released on March 26, 2001, and March 25, 2002, in field A and on May 7, 2001, and May 6, 2002, in field B by placing one piece of the bean leaves on which *P. persimilis* and *T. cinnabarinus* had been reared per strawberry plant in each plot.

Mite Sampling: The population densities of *T. cinnabarinus* and *P. persimilis* were monitored weekly from January 26 to July 16, 2001, in both fields. In 2002, plots were sampled weekly from February 11, through June 17, 2002, in both fields. Out-of-season samples were taken at 2-week intervals during summer, autumn and winter in 2001 to determine whether *T. cinnabarinus* and *P. persimilis* were present at these times in the experimental plots. At each sampling date, 90 leaflets were randomly selected from each of the treatments. Prey and predator counts were done using a stereo binocular microscope (magnification 10 x).

The randomized complete block design with 3 replicates was used in each treatment and year. Yield records were kept for each plot from April through June for both years. One-way ANOVA was used to compare the effectiveness of control practices on the population of *T. cinnabarinus* and yield records. Means were compared at P = 0.05, and Duncan's multiple range test was used to separate means (SPSS, Chicago, IL, USA).

Results

Field A

In 2001, populations of *T. cinnabarinus* were found in all plots in the fields in late-January (Figure 1). Mite populations increased gradually until mid-July, and reached a peak that averaged 16.4 active stages per leaflet in the chemical control plot on March 26, compared with 20.2 and 10.6 active stages per leaflet in the biological control plot and the grower's practice plot, respectively, during April 16 to May 21 (Figure 1). When predators were released, the numbers of spider mites were 11.06 active stages per leaflet in the biological control plot at the end of March. During the 20-day period after the release, the density of mites increased from 11.06 to 20.2 individuals per leaf. Although *P. persimilis* reached its highest population level with 1.74 individuals per leaflet on April 16, it was incapable of suppressing the prey population. Acaricide was sprayed on April 16 to prevent exceeding the EIL of the pest population. After acaricide was sprayed, the pest population did not reach levels that would require release of predators until the end of the growing season.

Compared to the numbers for 2001, lower numbers of *T. cinnabarinus* were observed in all plots in 2002, except in the chemical control plot (Figure 1). The highest weekly mean numbers of *T. cinnabarinus* were 4.6, 16.5 and 2.5 active stages per leaflet in the biological, chemical, and grower's practice plots, respectively, from April 15 to May 6 (Figure 1). In addition, *P. persimilis* reached a peak that averaged 1.9 active stages per leaflet in the biological control plot on April 29 (Figure 1). *P. persimilis* took over quickly after its release at the end of March, and controlled spider mite populations in the biological control plots.

Field B

In 2001, populations of *T. cinnabarinus* were found in the field from late-March to mid-July in all plots (Figure 1). The highest weekly mean numbers of *T. cinnabarinus* were 14.3, 1.8 and 8.2 active stages per leaflet in the chemical, biological, and grower's practice plots, respectively, from April 30 to May 14 (Figure 1). When the population level of the pest was 1.81 active stages per leaflet, the release of *P. persimilis* at the beginning of May provided an effective control of spider mites after 15-20 days. *P. persimilis* reached a peak that averaged 0.4 active stages per leaflet in the biological control plot

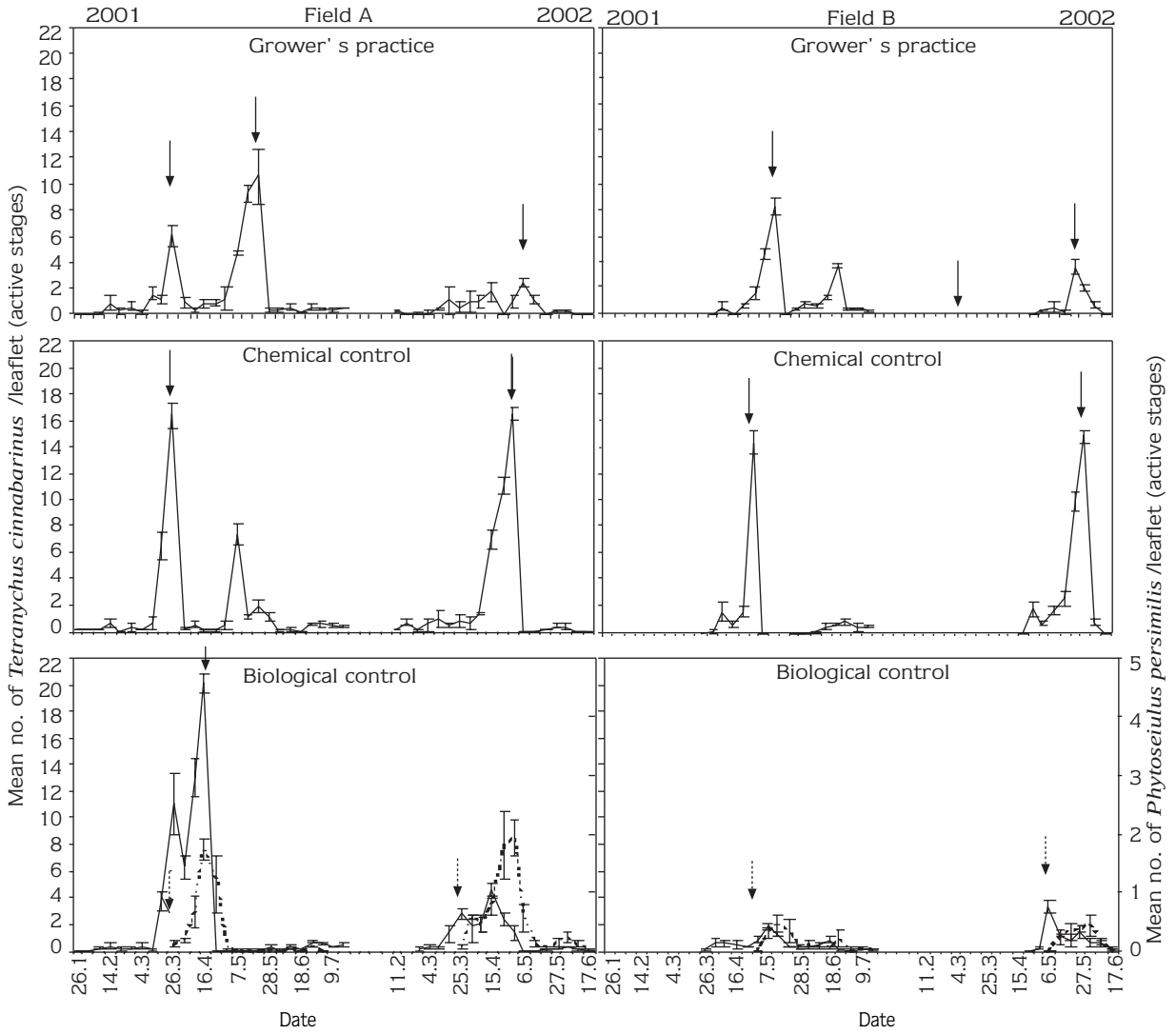

Figure 1. Seasonal populations of *Tetranychus cinnabarinus* and *Phytoseiulus persimilis* on strawberries (cv. 'Camarosa') in fields A and B in Sultanhisar, Aydın, Turkey, in 2001 and 2002 (solid arrow, acaricide spray; dashed arrow, predator release; solid line, *T. cinnabarinus*; broken line, *P. persimilis*).

on May 14 (Figure 1). No additional release was needed for the rest of the growing season (Figure 1).

In 2002, populations of *T. cinnabarinus* in all plots were found 1 month later than in 2001 (Figure 1). The highest weekly mean numbers of *T. cinnabarinus* were 3.2, 3.6, and 14.8 active stages per leaflet in the biological control, grower's practice, and chemical control plots, respectively, from May 6 to June 3 (Figure 1). When the spider mite population was 3.26 active stages per leaflet, *P. persimilis* was released in May and prevented the population growth of *T. cinnabarinus* (Figure 1). The highest weekly mean numbers of *P. persimilis* were 0.4 active stages per leaflet in the biological control plot on June 3 (Figure 1).

Mean numbers of *T. cinnabarinus* in the grower's practice, chemical control and biological control plots during 2001 and 2002 are given in Table 1 for the 2 fields. In field A in 2001 there were no significant differences in the average numbers of *T. cinnabarinus* among the 3 treatments. The highest population of spider mites occurred in the biological control plot (Table 1). In contrast to the previous year, significant differences were found in the average numbers of *T. cinnabarinus* among the 3 treatments in 2002. In addition, the total mean

Table 1. Total mean number of *Tetranychus cinnabarinus* on strawberries (cv. 'Camarosa') under different control practices in 2 fields in Sultanhisar, Aydın, Turkey in 2001 and 2002 (mean ± S.E. per leaflet).

	Field A		Field B	
	2001	2002	2001	2002
Grower's practice	1.66 ± 0.32 a* (n = 2340)	0.62 ± 0.11 b (n = 1710)	0.89 ± 0.21 a (n = 2340)	0.36 ± 0.12 b (n = 1710)
Chemical control	1.52 ± 0.40 a (n = 2340)	2.15 ± 0.58 a (n = 1710)	0.80 ± 0.31 a (n = 2340)	1.69 ± 0.51 a (n = 1710)
Biological control	2.28 ± 0.57 a (n = 2340)	0.93 ± 0.18 b (n = 1710)	0.35 ± 0.05 a (n = 2340)	0.43 ± 0.11 b (n = 1710)
	$F_{2.7016} = 1.325$, $P > 0.05$	$F_{2.5126} = 7.695$, $P < 0.01$	$F_{2.7016} = 2.470$, $P > 0.05$	$F_{2.5126} = 9.939$, $P < 0.001$

* Numbers followed by the same letter within a column are not significantly different according to Duncan's test ($P > 0.05$).

numbers of *T. cinnabarinus* were lower in all plots, except for the chemical control plot, than those found in 2001. In field B there were no significant differences in population levels of *T. cinnabarinus* among the control methods in 2001. In contrast, significant differences were found in 2002. The highest spider mite populations were observed in the grower's practice plot in 2001 and in the chemical control plot in 2002. In addition, total mean numbers of *T. cinnabarinus* in 2002 were higher in all plots except in the grower's practice plot than in 2001 (Table 1).

There were no significant differences in strawberry yields among the 3 treatments (Table 2).

Discussion

The population of *T. cinnabarinus* was controlled in the grower's practice plots by using 1 or 2 acaricide applications. On the other hand, Çakmak et al. (2003) reported that acaricides are sprayed by growers at least 2 or 3 times to control *Tetranychus* spp. on strawberries in Aydın. During the growing season in the Çukurova region strawberries are sprayed with acaricides at least 4 or 5 times and at an excessive dosage, delivered with high-volume spray applicators (Bayat et al., 1998). This study indicates that one acaricide application alone can successfully suppress the pest populations throughout the growing season in the chemical control plots in terms of both fields and years. Hence, even without the use of biological control, pesticide use can be severely reduced without any effect on crop yield.

We showed that *P. persimilis* was successful in controlling spider mites after release at a predator:prey ratio of 1:20. Crop yields and the density of spider mites were similar when using biological control or when using acaricide. This shows the potential for using biological control for the important pest *T. cinnabarinus*.

Although effective predator:prey ratios have not yet been determined, studies conducted with other mite systems suggest that a ratio of 1:20 (6:120) is a reasonable estimate (Raworth, 1990). Bonomo et al. (1991) noted that releases of *P. persimilis* at a 1:10 predator:prey ratio gave effective control of the mite *Tetranychus urticae* when the density of the pest was low (1-2 per leaf). Similarly, Kısmalı et al. (1999) reported that the best results were obtained when releasing *P. persimilis* at ratios of 1:20 and 1:30. On the other hand, in small trials in southern England, Gould and Vernon (1978) showed that at least 5 *P. persimilis* per plant were needed to control red spider mites on strawberries grown in cloches or low plastic tunnels. Port and Scopes (1981) found that the introduction of at least 2 predators per plant in March was required to control red spider mites in England. Gauthier et al. (1998) showed that when 2 releases of *P. persimilis* were carried out on strawberries in France, 4-5 weeks were needed to reduce prey populations.

Table 2. Strawberry yields under different control practices in 2 fields in Sultanhisar, Aydın, Turkey in 2001 and 2002 (kg 20 m^{-2}).

	Field A		Field B	
	2001	2002	2001	2002
Grower's practice	125.12 a*	62.97 a	83.87 a	95.51 a
Chemical control	125.39 a	67.08 a	87.50 a	103.61 a
Biological control	123.70 a	62.10 a	93.88 a	92.74 a

* Numbers followed by the same letter within a column are not significantly different according to Duncan's test ($P > 0.05$).

However, *P. persimilis* was not able to control *T. cinnabarinus* in field A in 2001, as the population of spider mites was high (11 active stages per leaflet) before the predator release. If spider mite numbers are relatively high early in the season, it is advisable to reduce the numbers of the pest with an acaricide spray before or during the period of establishment of the predator or, alternatively, to increase the predator: prey ratio (Janssen and Sabelis, 1992). Similarly, Waite (1988) reported that *P. persimilis* gave effective control of the pest when it was released onto strawberry with low levels of two-spotted spider mite (TSM) infestation in Southeast Queensland, Australia. Spicciarelli et al. (1992) reported that phytoseiid mites give good control of TSM, if 1 mite is released per plant when the infestation of TSM has reached 2 individuals per leaf and when about 30% of leaves are infested.

The results suggest that *P. persimilis* has considerable potential for biological control of *T. cinnabarinus* in protected strawberry in Sultanhisar, Aydın. On the other hand, strawberry plants were not attractive to spider mites during July and August. The population level of spider mites was therefore low during this period, which is in agreement with the results reported by Dabrowski et al. (1971) and Kısmalı et al. (1999). Since the reproduction of *P. persimilis* depends on the availability of spider mites as prey, it often disappears from the strawberry after reducing pest mites. In the absence of tetranychid mites repeated predator releases are required for every new spider mite infestation. In addition, *P. persimilis* does not function well at temperatures above 30 °C or at humidity below 60% RH. These conditions are not favorable for *P. persimilis* during the summer in Aydın. Other predatory species that are better adapted to these conditions should be tested in further studies to control *T. cinnabarinus*, either alone or in combination with *P. persimilis*.

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