Proceedings VI World Avocado Congress (Actas VI Congreso Mundial del Aguacate) 2007.
Viña Del Mar, Chile. 12 – 16 Nov. 2007. ISBN No 978-956-17-0413-8.

POTENTIAL INDIGENOUS AND EXOTIC PREDATORS FOR THE BIOLOGICAL CONTROL OF THE NEWLY INTRODUCED PERSEA MITE, *Oligonychus perseae* IN AVOCADO ORCHARDS OF ISRAEL

E. Palevsky[1], Y. Maoz[1], S. Gal[1], Y. Argov[2], M. Berkeley[2], M. Zilberstein[3], M. Noy[3], Y. Izhar[4], J. Abrahams[5] and M. Coll[6]

[1]Agricultural Research Organization (ARO), Newe-Ya'ar Research Center, Ramat Yishay, 30095, Israel, palevsky@volcani.agri.gov.il
[2]Israel Cohen Institute for Biological Control, Plant Production and Marketing Board, Citrus Division, POB 80 Bet Dagan, 50250, Israel
[3]Extension Service, Ministry of Agriculture and Rural Development, POB 30 Bet Dagan, 50250, Israel
[4]Western Galilee R&D, MP Oshrat, 25212, Israel
[5]Soil Conservation and Drainage Unit, Upper Galilee Ministry of Agriculture, Sefad, Israel. [6]Department of Entomology, The Hebrew University of Jerusalem, POB 12, Rehovot 76100, Israel,

Oligonychus perseae is a new pest of avocado in Spain and Israel. In Israel, while monitoring persea mite on field, we observed *Euseius scutalis* (Phytoseiidae) feeding on *O. perseae* within torn nests and outside of the nests. Subsequently, laboratory studies were performed to evaluate this predator effectiveness. To enhance biological control, the exotic predator *Neoseiulus californicus* was released in 2004 and 2005. To determine whether other generalist predators can feed upon and tear the nests of persea mite, insects and arachnid predators were collected from avocado trees using a beating tray, placed individually on newly infested leaf discs and monitored for several days. Although *E. scutalis* reduced adult persea mite populations in the lab with or without torn nests, egg predation was improved by tearing the nests. Seasonal *O. perseae* levels following *N. californicus* releases were reduced by 30%, but leaf damage was still considerable. In our no-choice bioassays on leaf discs, we observed nest tearing and predation by green lacewing *Chrysoperla carnea*, dusty wing *Conwentzia* sp. and others. Developing methods for augmentation and conservation of *E. scutalis* and nest-tearing predators may prove valuable for enhancing persea mite control. *Euseius scutalis,* as other species of *Euseius,* feed on avocado and other pollens that are abundant on avocado leaves from spring to summer. Extending the period of pollen availability by the establishment of cover crops that would release wind-borne pollen, such as Rhodes grass, could be a viable way of keeping high *E. scutalis* populations, thereby preventing persea mite outbreaks.

Key words: *Oligonychus perseae*, *Euseius scutalis*, *Neoseiulus californicus*, avocado, pollen.

POTENCIALES DEPREDADORES NATIVOS Y EXOTICOS PARA EL CONTROL BIOLOGICO DE LA RECIENTE INTRODUCCIÓN DEL ÁCARO DE LA PALTA, *Oligonychus perseae* EN HUERTOS DE PALTO EN ISRAEL

E. Palevsky[1], Y. Maoz[1], S. Gal[1], Y. Argov[2], M. Berkeley[2], M. Zilberstein[3], M. Noy[3], Y. Izhar[4], J. Abrahams[5] y M. Coll[6]

[1]Agricultural Research Organization (ARO), Newe-Ya'ar Research Center, Ramat Yishay, 30095, Israel, palevsky@volcani.agri.gov.il; [2]Israel Cohen Institute for Biological Control, Plant Production and Marketing Board, Citrus Division, POB 80 Bet Dagan, 50250, Israel; [3]Extension Service, Ministry of Agriculture and Rural Development, POB 30 Bet Dagan, 50250, Israel; [4]Western Galilee R&D, MP Oshrat, 25212, Israel;. [5]Soil Conservation and Drainage Unit, Upper Galilee Ministry of Agriculture, Sefad, Israel. [6]Department of Entomology, The Hebrew University of Jerusalem, POB 12, Rehovot 76100, Israel,

Oligonychus perseae es una nueva plaga del palto en España e Israel. En este último, durante monitoreos en terreno sobre este ácaro, se observó a *Euseius scutalis* (Phytoseiidae) alimentándose sobre *O. perseae* dentro de nidos destruidos y fuera de los nidos. Posteriormente, se realizaron estudios de laboratorio para evaluar la eficacia del depredador. El depredador exótico *Neoseiulus californicus* fue liberado en 2004 y 2005 con el objeto de mejorar el control biológico. Para determinar cualquier otro depredador polífago que se alimente del ácaro de la palta y que destruya sus nidos, se recolectaron insectos y arañitas depredadoras desde paltos utilizando un paraguas japonés, y fueron puestos individualmente sobre discos de hojas recientemente infectadas y se monitorearon durante algunos días. Aunque *E. scutalis* redujo las poblaciones adultas del ácaro de la palta en laboratorio con o sin destrucción de nidos, la depredación de huevos mejoró con la destrucción de los nidos. Los niveles de *O. perseae* estacionales, luego de la liberación de *N. californicus*, decayeron un 30%, pero el daño de la hoja aún era considerable. En nuestro bioensayo aleatorio sobre discos de hojas se observó la destrucción de nidos y depredación por parte del depredador *Chrysoperla carnea*, *Conwentzia* sp. y otros. El desarrollo de métodos para el incremento y conservación de *E. scutalis* y depredadores destructores de nidos puede resultar valioso para el aumento del control del ácaro de la palta. *Euseius scutalis,* como otras especies de *Euseius,* se alimenta de polen de palta y otros tipos de polen, abundantes sobre las hojas de palto en primavera y verano. La extensión del periodo de disponibilidad de polen por medio del establecimiento de cultivos protectores que liberan polen arrastrado por el viento, tales como la grama Rhodes, podría hacer viable el mantenimiento de altas poblaciones de *E. scutalis*, y de ese modo prevenir brotes del ácaro de la palta.

Palabras claves: *Oligonychus perseae***,** *Euseius scutalis***,** *Neoseiulus californicus*, palta, polen.

Introduction

The persea mite, *Oligonychus perseae* Tuttle, Baker and Abbatiello, is a pest of avocado in Central and North America. The mite colonizes the bottom of the leaf, spinning densely woven nests along the leaf veins. The Hass cultivar is very susceptible whereas Reed is resistant (Kerguelen and Hoddle, 2000).

Oligonychus perseae was first discovered in Israel in the autumn of 2001 in several avocado plots located in the Western Galilee. Since then, it has spread to the growing areas (from North to South) of the Upper Galilee, Jezriel Valley, Efraim Hills, Carmel Coastal Plain, Hefer Valley and Rehovot-Lachish, causing extensive foliar damage and leaf drop in most of these regions.

To identify the indigenous predatory mite fauna on avocado, a survey was conducted in 2002 and 2003. Subsequently, laboratory studies were performed to evaluate the efficacy of the dominant indigenous phytoseiid predator, *Euseius scutalis* (Athias-Henriot). In the field while monitoring for persea mite we observed *Euseius scutalis* (Phytoseiidae) feeding on *O. perseae* within torn nests and outside of the nests. To determine whether other generalist predators can feed upon and tear the nests of persea mite, insect and arachnid predators were collected from avocado trees and assessed in laboratory experiments. To improve persea mite control, the exotic predatory mite *Neoseiulus californicus* (McGregor) was released in 2004 and 2005. Inundative releases of this predator have significantly reduced persea mite levels in California (Hoddle *et al,* 2000).

Materials and methods

Survey of indigenous phytoseiid predators

In 2002-2003, pest and predatory mite populations were monitored fortnightly from 5 plots in the Upper and Western Galilee between April-November and once a month during the cooler months of December-March. At least 5 sites were sampled per plot, 1 tree per site, 10 leaves per tree, were randomly collected from tree perimeters. Pest mites were counted in situ using a quick field counting method (Machlitt, 1998). For predatory mite count and identification, the 10 leaves were then washed in 400 cc of 70% ethanol, the plant matter discarded and the ethanol stored in plastic containers. In the laboratory, the ethanol wash was poured into a Petri dish and examined under a stereo microscope. Predatory mites were then removed with a micropipette, cleared in lactic acid and mounted in Hoyer's medium. Phytoseiid species were identified according to Swirski *et al* (1998).

Predation efficacy of Euseius scutalis on leaf discs

Preliminary laboratory leaf disc trials indicated that *E. scutalis* cannot enter intact nests of the persea mite. To determine the predation potential of *E. scutalis* when persea nests are intact vs. torn, we conducted efficacy trials on leaf discs. One day prior to the beginning of the experiment, 6 female persea mites were transferred to each leaf disc. By the next day, all mites were found within their densely woven nests with their freshly laid eggs. Four treatment combinations were compared: 1) intact nests with 1 female predator/disc; 2) intact nests without a predator; 3) torn nest with 1 female predator/disc; and 4) torn nest without a predator. The two-way factorial experiment (2 predation levels x 2 nest conditions) was replicated 20 times, the experiment was conducted for 5 days (the duration of the egg stage). Pest and predator eggs and adults

were counted daily, then the nests in treatments 3 and 4 were gently torn using a fine needle, making sure not to damage any of the mites. Experiments were conducted at 24±1^{0}C, 43±2% RH, 16:8 L:D. Data were sqrt(x+0.5) transformed before being subjected to ANOVA (JMP5.0.1a; SAS Institute, Inc.).

Field evaluations of the exotic predatory mite *Neoseiulus californicus*

One shipment of a few thousands mites of *N. californicus* were received from Koppert (Berkel en Rodenrijs, Netherlands) at the Israel Cohen Institute for Biological Control (ICIBC), November, 2002. This strain was originally collected in California, reared by Biotactics (Romoland, California) and then sent to and subsequently cultured by Koppert, Netherlands (KNL). At ICIBC, *N. californicus* were reared in small containers on *Tetranychus cinnabarinus* Koch eggs. Trials, conducted in plots in different geographic regions (5 plots in total), were initiated in spring to early summer when the first persea mites were detected. Two releases of 2000 mites/tree, with a fortnight interval between releases were performed. Pest and predator population levels were monitored fortnightly at each plot on 5 release and 5 control trees (blocked design, control tree located at least 2 trees away from release tree) as described under "survey of indigenous phytoseiid predators" above. Following the decline of pest mites, total cumulative mite days (CMDs) of the pest were calculated (Palevsky et al., 1996). Using this parameter we evaluated the effects of predator release, location and their interaction. The block effect of each location was considered by nesting the block within location.

Nest tearing and predation by insect and arachnid predators

To determine whether predators can feed upon and tear the nests of persea mite, insect and arachnid predators were collected from avocado trees using a beating tray technique, placed individually on newly infested leaf discs (as described, under "laboratory predation efficacy trials of *E. scutalis"* above) and monitored for several days.

To determine the impact of these nest-tearing predators on field populations, the proportions of abandoned intact nests, ripped nests with and without live mites, were assessed in an organic avocado orchard (Kibbutz Gaaton) in 2006. Based on our laboratory observations, we interpreted: 1) the abandoned intact nests as nests that were not attacked by predators, 2) ripped nests with no live mite as nests that were attacked (motiles and eggs either eaten or fled) and 3) ripped nests that still contained live mites as nests that a predator frequented but did not consume all prey, creating an opportunity for intra-guild facilitation (i.e., providing opportunity for other predators to prey on the now exposed mites). In this orchard, as in the orchards that *N. californicus* were released (see above), no chemical treatment was applied for persea mite control.

Results and discussion

Survey of indigenous phytoseiid predators

In all five avocado plots, predatory mites were readily detected (Table 1). *Euseius scutalis* was by far the most predominant species accounting for more than 96% of all collected predatory mites (n=1586).

Table 1. Predatory mites found (number and percent of each species) in a survey of indigenous phytoseiid predators conducted in 2002-2003 in the Western and Upper Galilee, Israel.

Tabla 1. Ácaros depredadores encontrados (número y porcentaje de cada especie) en un catastro de phytoseiidos depredadores nativos realizado en 2002-2003 en el oeste y alto de Galilea, Israel.

Location	Predatory mite species		
	Amblyseius swirskii	*Typhlodromus athiasae*	*Euseius scutalis*
Rosh Haniqra	0	1	67
Yechiam	0	46	154
Gaaton	0	3	634
Yodfat	2	5	45
Hagoshrim	0	2	627
Total	2	57	1527
Relative %	0.1%	3.6%	96.3%

Predation efficacy of *Euseius scutalis* on leaf discs

For female adult persea predation, the interactive effects of predators (*E. scutalis*/control) and nests (intact/torn) were not significant ($P = 0.384$; $F = 0.7$; $DF = 1,76$). *Euseius scutalis* significantly lowered population levels of female adult persea mite ($P < 0.0001$; $F = 732.6$; $DF = 1,76$) regardless of whether the nests were torn ($P < 0.0001$; $F = 448.5$; $DF = 1,38$) or not ($P < 0.0001$; $F = 316.0$; $DF = 1,38$) (Figure 1A, lower case letters). In contrast, the significant effect of tearing the nests on persea mite levels ($P = 0.006$; $F = 7.9$; $DF = 1, 76$) was probably due to handling as this effect was significant on the control discs ($P = 0.013$; $F = 6.7$; D F= 1,38) but not when the predators were present ($P = 0.175$; $F = 1.9$; $DF = 1,38$) (Fig. 1A, upper case letters).

The interaction between predator and nest treatments was significant for persea egg predation ($P < 0.0001$; $F = 17.6$; $DF = 1,76$). *Euseius scutalis* significantly lowered persea egg levels ($P < 0.0001$; $F = 732.6$; $DF = 1,76$) when nests were intact ($P < 0.0001$; $F = 42.2$; $DF = 1,38$) or torn ($P < 0.0001$; $F = 246.6$; $DF = 1,38$) but the effect of the latter was far more substantial (Figure 1B, lower case letters). Tearing the nests also affected predation efficacy ($P < 0.006$; $F = 7.9$; $DF = 1,76$); this is attributed to accessibility of the prey to the predator as the effect was significant on discs bearing the predator ($P < 0.0001$; $F = 61.8$; $DF = 1,38$) but not on the control discs ($P = 0.151$; $F = 2.2$; $DF = 1,38$) (Figure 1B, upper case letters).

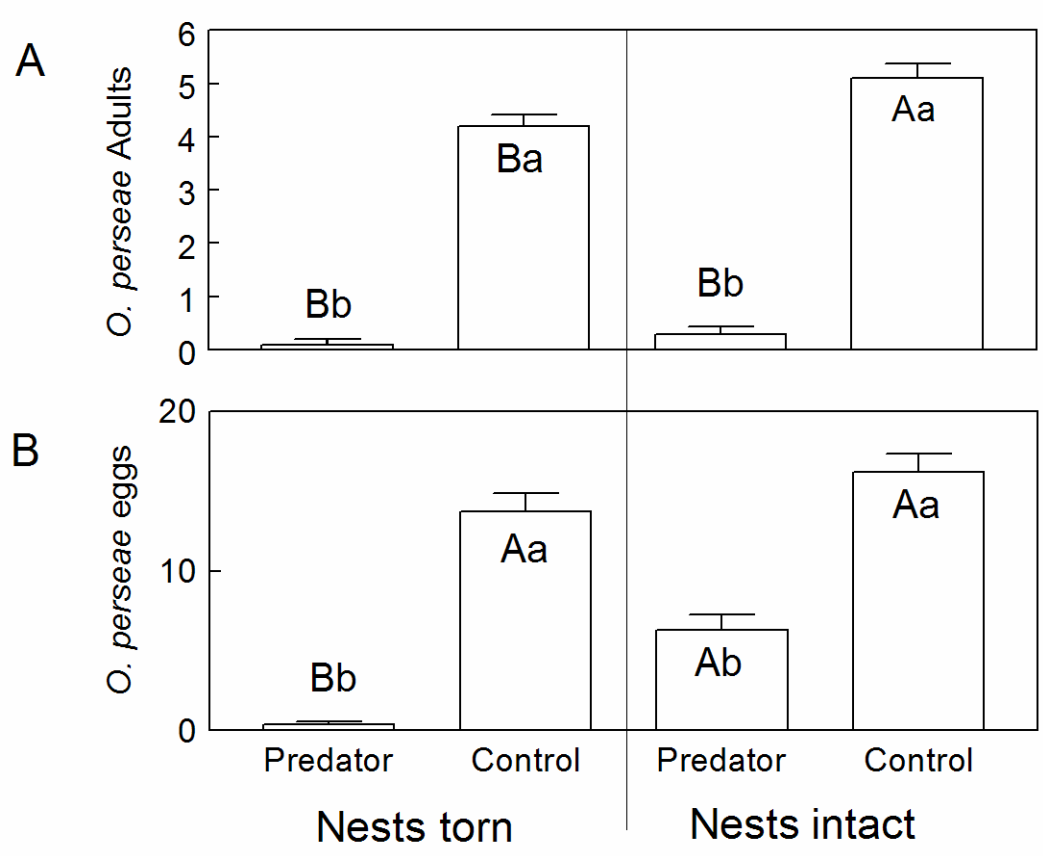

Figure 1. Mean number of *Oligonychus persea* adults (A) and eggs (B) (plus standard errors) remaining after a 5 day period on leaf discs with and without one *Euseius scutalis* female adult. Nests were gently torn once a day, using a fine needle, taking care not to damage any of the mites. Within each chart (A and B), columns followed by a different lower case letter indicate a significant difference between predator and control treatments. Different uppercase letters are indicative of a significant difference between torn and intact nests within the same predator treatment ($P<0.05$, Tukey's test).

Figura 1. Número promedio de adultos de *Oligonychus persea* (A) y huevos (B) (más el error standart) que quedaron después de un período de 5 días sobre discos de hojas con y sin un adulto hembra de *Euseius scutalis*. Los nidos fueron suavemente rasgados una vez al día con una aguja fina, cuidando de no dañar ningún ácaro. En cada uno de los gráficos (A y B), columnas seguidas con diferentes letras minúsculas indican una diferencia significativa entre el tratamiento con depredador y el control. Diferentes letras mayúsculas son indicativas de diferencias significativas entre nidos rasgados e intactos dentro del mismo tratamiento con el depredador ($P<0.05$, Test de Tukey).

Field evaluations of the exotic predatory mite *Neoseiulus californicus*

The effects of *N. californicus* releases ($P = 0.0022$; $F = 12.32$; DF = 1,20) and location ($P < 0.0001$; $F = 23.52$; DF = 1,20) of release plots were both significant while their interaction was not ($P < 0.0807$; $F = 1.33$; DF = 1,20). Despite a significant reduction of 30% in seasonal CMDs following *N. californicus* releases, leaf damage was still considerable and similar to control trees. Phytoseiid predators recovered from all release plots were mostly of the species *E. scutalis* ranging from 78-95% (Figure 2).

Nest tearing and predation by insect and arachnid predators

In our no-choice bioassays on leaf discs we observed nest tearing and predation by green lace wing *Chrysoperla carnea* (Stephens), dusty wing *Conwentzia* sp., a spider *Chiracanthium mildei* Koch, heteropteran *Creontiades pallidus* Rambur and a predatory thrips (still be identified).

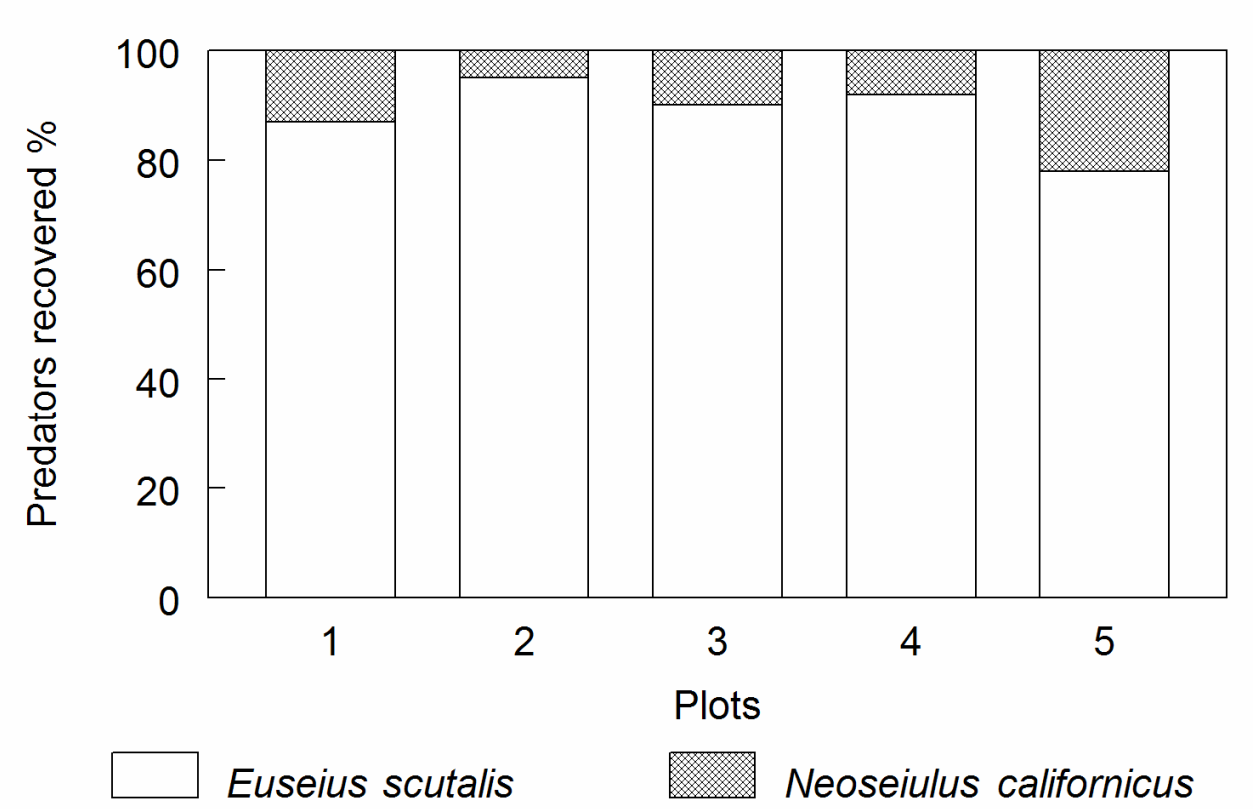

Figure 2. Proportion of phytoseiid predator species (indigenous *E. scutalis* and exotic *N. californicus*) recovered from five avocado release plots of *N. californicus*.

Figura 2. Proporción de phytoseiido depredador de especies (nativo *E. scutalis* y exótico *N. californicus*) recuperados desde cinco parcelas de liberación de *N. californicus.*

Nest tearing predators (see ripped empty nests, Figure 3) were active from the first detection of persea populations. From May through August 2006, equal proportions of nests were attacked (ripped empty nests, Figure 3) or not (intact empty, Figure 3) by

predators. From September onwards, most of the nests were preyed upon, reaching a peak of 84% by the end of 2006. The level of ripped nest containing live mites was minimal throughout the season.

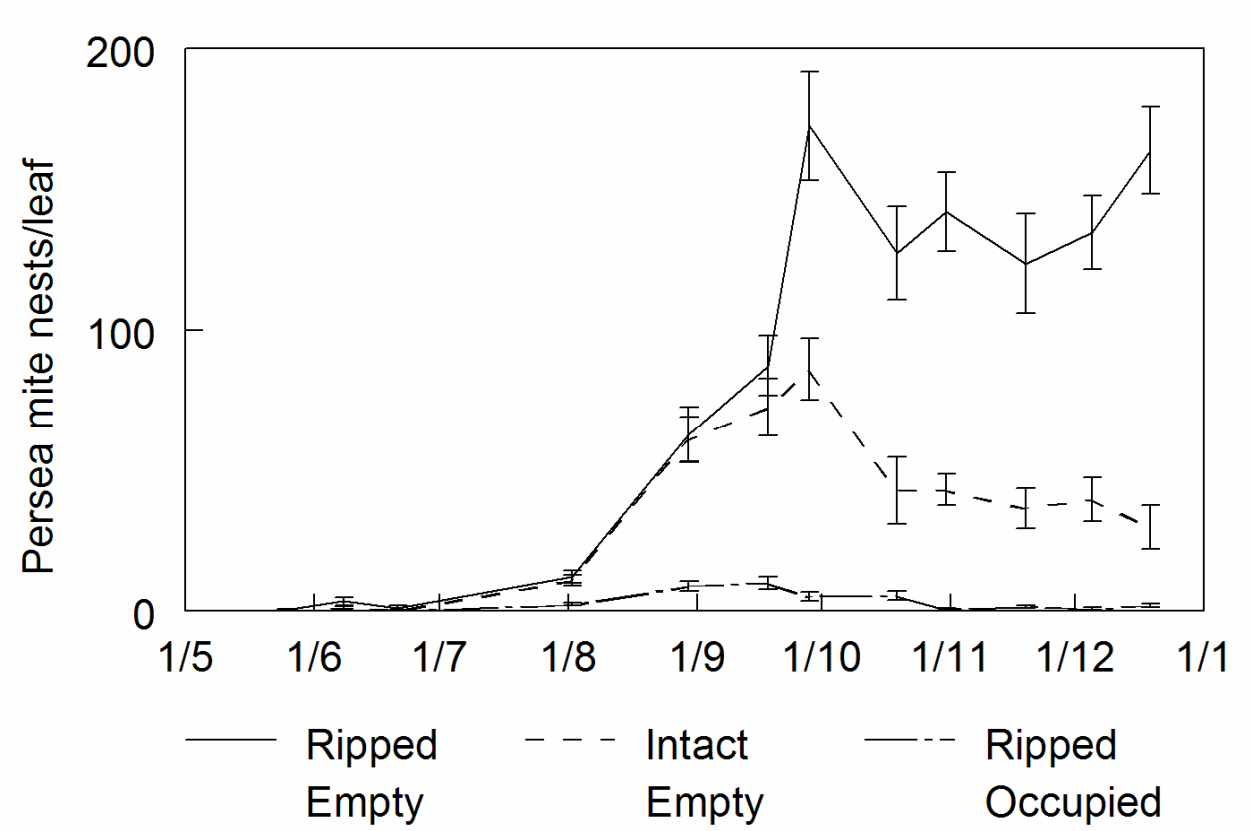

Figure 3. Mean number of abandoned intact nests, and ripped nests with and without live mites per leaf (plus/minus standard errors) in an organic avocado orchard (Gaaton, 2006).

Figura 3. Número promedio de nidos abandonados intactos, y nidos rasgados con y sin ácaros vivos por hojas (suma/resta del error Standard) en un huerto orgánico de aguacate (Gaaton, 2006).

The indigenous predatory mite *E. scutalis* is the dominant phytoseiid in avocado orchards in Israel. This was observed first in our survey in Western and Upper Galilee in 2002-2003 and then again when we released and monitored the recovery of the exotic *N. californicus* in all avocado growing regions in the country in 2004-2005. Although we did succeed in recovering *N. californicus* at all release sites, its effect on mitigating persea mite seemed minimal and its population levels were negligible compared to those of *E. scutalis.* Possibly, inter-specific competition between these two predators is

preventing the establishment of *N. californicus*. While *E. scutalis* reduced adult persea mite populations in the lab (on leaf discs) with or without torn nests, egg predation was improved by tearing the nests. Intra-guild facilitation between nest-tearing predators and *E. scutalis* does not seem to be very important because the level of torn nests housing live prey was consistently low. Prey fleeing the torn nests, however, would serve as suitable food for leaf-grazing *E. scutalis*. Developing methods for augmentation and conservation of *E. scutalis* and nest-tearing predators may prove valuable for enhancing persea mite control. *Euseius scutalis,* as other species of *Euseius,* feed on avocado and other pollens that are abundant on avocado leaves from spring to early summer. Extending the period of pollen availability by the establishment of cover crops that would release wind-borne pollen, such as Rhodes grass, could be a viable way of keeping *E. scutalis* populations high, thereby preventing persea mite outbreaks (Smith and Papacek, 1991).

Acknowledgements

We are indebted to the avocado growers that participated and assisted in the field trials. We would like to acknowledge the Chief Scientist of Agriculture and the Plant Production and Marketing Board of Israel for their financial support. This manuscript is a contribution of the Institute of Plant Protection, Volcani Center, ARO, Israel.

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