BIOLOGICAL CONTROL OF CITRUS THRIPS, *Scirtothrips citri*, BY PREDACEOUS PHYTOSEIID MITES

Lynell K. Tanigoshi

Department of Entomology
Washington State University
Pullman, Washington USA

Introduction

Acari of the family Phytoseiidae are important predators of spider mites. Since the taxonomic treatises of Nesbitt (1951) and later by Chant (1959), over 1000 described taxa have been listed by Moraes et al. (1986). This represents a conservative 10-fold increase for species descriptions over the last thirty years. During this period, research efforts have also been directed toward the study of phytoseiid population ecology and predatory interactions with tetranychid spider mites, especially those on agricultural crops (e.g., tree fruit, avocado, citrus, greenhouse vegetables and cotton). Research on the diets of phytoseiid mites indicate that many species are facultative and general predators that readily feed and reproduce on pollen and nectar; mites in the families Tydeidae, Tenuipalpidae, Tarsonemidae and Eriophyidae; immature instars of whiteflies and thrips; and honeydew secretions of aphids and armored scales (McMurtry & Rodriguez 1987).

General field and laboratory observations by Kennett & Flaherty (1974) in the San Joaquin Valley of California and Bravo-Mojica (1975) at the University of California-Riverside during the mid-1970s indicated that the phytoseiid mite, *Euseius tularensis*, preys on larvae of the citrus thrips, *Scirtothrips citri* (Moulton). Earlier, Swirski & Dorzia (1969) in Israel reported that the phytoseiids, *E. hibisci* (Chant), *Amblyseius limonicus* and *Typhlodromus occidentalis* (Nesbitt) readily fed and reproduced on larvae of the castor thrips, *Retithrips syriacus* (Mayet).

Research on biological control has been done by several University of California entomologists to evaluate the predatory potential of native and introduced phytoseiids to regulate the citrus red mite, *Panonychus citri* (McGregor), a key pest of citrus. These researchers have concluded that: 1) *E. hibisci* and *E. tularensis* are facultative predators, 2) population growth and peak densities of *E. tularensis* coincide with or follow those of citrus thrips and not *P. citri* in early spring, 3) *E. tularensis* population growth is correlated with seasonal patterns and abundances of air borne pollen, and 4) both phytoseiid species undergo major numerical increases in April and May and commonly attain two-six active stages per leaf by mid-June (Tanigoshi et al. 1985). This work and my laboratory studies with both predators suggest that these species undergo a dietary switch from pollen in early spring to early generation citrus thrips larvae during early citrus bloom, this at a time when the overwintering eggs of *P. citri* have not yet eclosed (Tanigoshi et al. 1983, 1984).

Rearing Methods

In the late 1970s we at the USDA in Riverside, Calif. initiated field studies to colonize and/or augment *E. tularensis* in commercial orange groves in Riverside and Tulare Counties, Calif.

Deutonymphs and adults of *E. hibisci* and *E. tularensis* will voraciously attack and kill larvae of the citrus thrips. *E. tularensis* is capable of attacking and killing immature citrus thrips from any angle or body segment (Fig. 1). *E. hibisci* can readily capture and consume citrus thrips larvae, and a minimum of ten thrips per day will support a daily fecundity commensurate to that observed on a diet of ice plant pollen (Table 1).

Figure 1. *Euseius tularensis* sucking the body contents of a second instar citrus thrips (photo by J. K. Clark).

Table 1. Oviposition data for *Euseius hibisci* females reared at about 27°C on different foods for 72 hours

Food	No. eggs/female/day		
	1	2	3
Ice plant pollen[a]	0.67	1.47	1.82
10 Citrus thrips larvae/day	0.72	1.10	1.76
20 Citrus thrips larvae/day	0.53	1.43	1.77

[a] *Malephora crocea*.

Both phytoseiid predators were mass reared on about 40 lima bean plants, *Phaseolus limensis* (Per.) grown in two-gallon polyethylene bags, filled with about 3.78 liters (1 gallon) of coarse vermiculite per

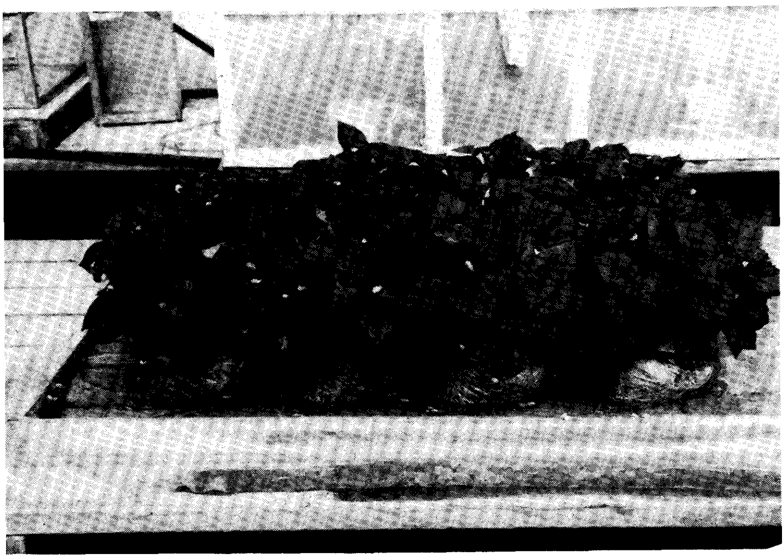

Figure 2. Lima bean plants grown in polyethylene bags and coarse vermiculite for rearing predatory phytoseiid mites to control citrus thrips (photo by M. E. Badgley).

bag, and punctured along the bottom for watering (Fig. 2). After two weeks the seedlings were inoculated with a mixed population of twospotted spider mite, *Tetranychus urticae* and pollen from the ice plant, *Malephora crocea* (Jacq.). Fresh ice plant pollen was dispensed over the plants every 3-4 days. With this system we produced an average of 25 *E. tularensis* life stages per plant per week after four weeks. The plants were then separated and tied into four bundles of 10 plants each, transported to the field and placed within the canopy of citrus trees.

Biology and Distribution of Citrus Thrips and Phytoseiid Predators

The distribution of *E. hibisci* and *E. tularensis* in California is shown in Figure 3. The first species is common to avocado and citrus grown in the coastal and inland valley chaparral biome while the latter species is common on citrus grown in the temperate grassland biome of the Central Valley and the more arid regions of the coastal inland chaparral. Except for their absence in the irrigated areas of the Sonoran Desert, the distribution of both phytoseiids is nearly identical to that of the citrus thrips (Fig. 4). It is thought that both species of *Euseius* are subtropical and Bailey (1964) considered citrus thrips to be endemic to the arid lowland valleys of the southwestern United States.

The adult citrus thrips measures 0.9 mm (female) and 0.7 mm (male); the male is somewhat smaller and not as robust as the female. Both are a yellow-green color. First and second instars measure 0.4 and 0.9 mm, respectively, and the latter instar will actively seek a pupation site between soil particles in litter under the tree canopy. An overwintering generation of eggs is laid in new leaves of the fall growth flush and hatches in the spring. There are 8-12 generations per year in California and development from egg to adult ranges from 13-15 days; females live for 15-20 days and may lay 200 to 250 eggs (Tanigoshi et al. 1981).

Figure 3. Distribution of *Euseius hibisci* (shaded area) and *E. tularensis* (outlined area) in California (from Congdon & McMurtry 1985).

Figure 4. Distribution of *Scirtothrips citri* (shaded area) in California (from Tanigoshi 1981, Tanigoshi & Nishio-Wong 1982).

Citrus Thrips Damage

The critical injury period of citrus fruit for damage by citrus thrips is nearly coincident with the emergence of second generation citrus thrips (Fig. 5). The critical injury period for navel orange fruit scarring extends from early May to about 1 July, after which fruit of >4 cm diameter becomes unfavorable to citrus thrips and they shift their feeding and ovipositional activities to summer flush foliage.

Thrips feeding causes young leaf edges to become misshapened with two thick, white-grey streaks extending along both sides of the leaf midrib (Fig. 6). Stem-end ring scarring of the rind is commonly caused by citrus thrips feeding under and near the sepal when the fruit is pea-sized until it reaches 4 cm in diameter (Fig. 7). At harvest, mature navel oranges develop scabby gray or brown tissue around the stem-end, shoulders and stylar-end of the fruit (Fig. 8). This cosmetic injury is judged unacceptable for the fresh fruit market by Sunkist Growers of California. A cork-like scar tissue forms around citrus thrips ovipositional injury. This scarring, unlike that formed by their feeding activity, disappears when the navel fruit turns orange (Fig. 9).

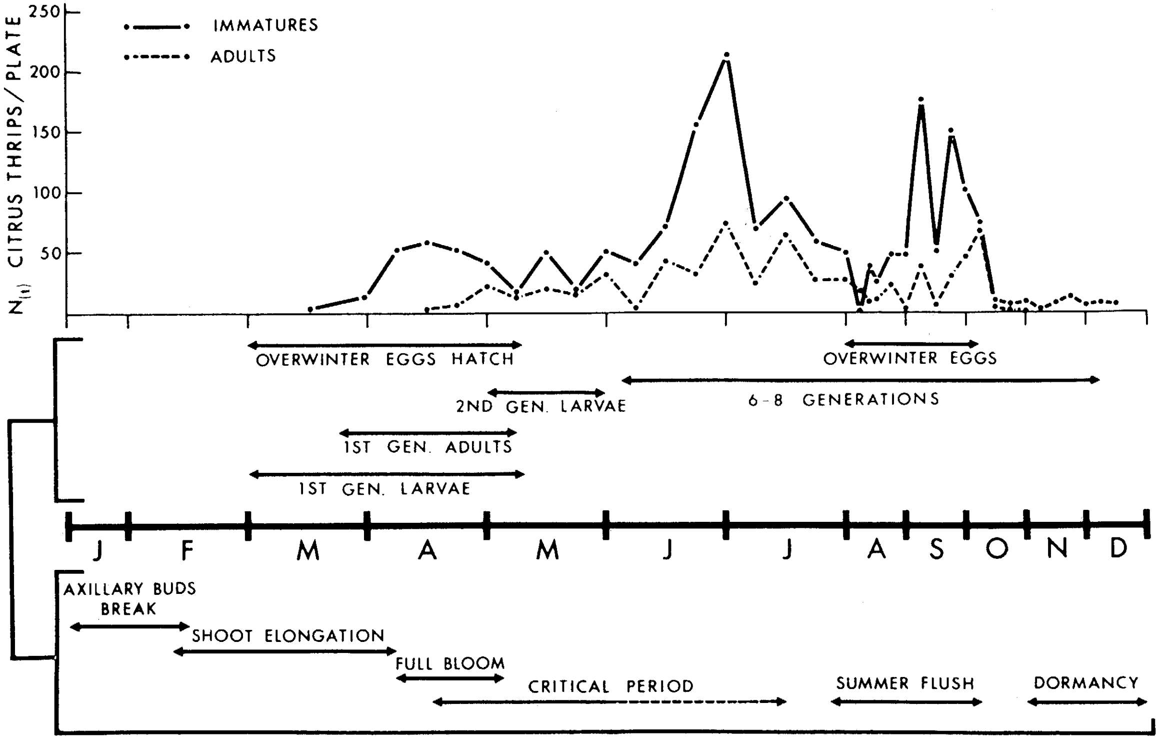

Figure 5. Phenograph of navel orange and *Scirtothrips citri* showing the critical injury period for developing fruitlets, Riverside, Calif., 1974.

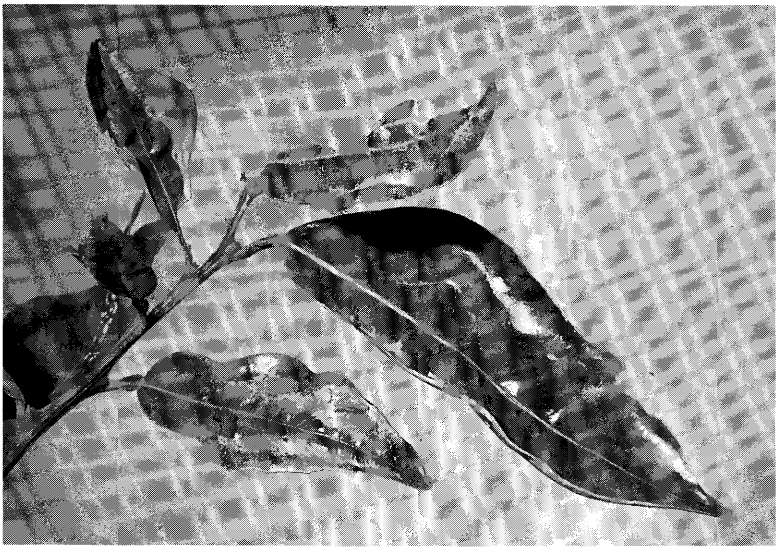

Figure 6. Leaves scarred by citrus thrips feeding (photo by M. E. Badgley).

Figure 7. Citrus thrips injury to pea-sized navel oranges (photo by M. E. Badgley).

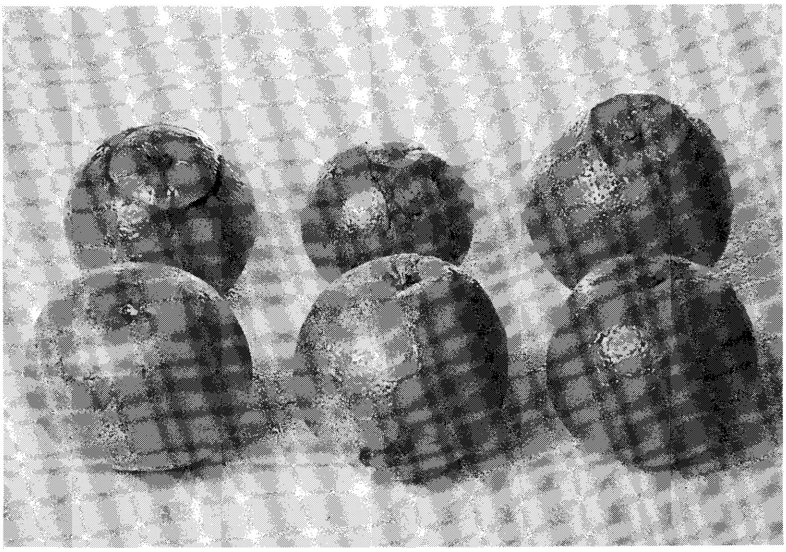

Figure 8. Stem-end navel orange injury (photo by M. E. Badgley).

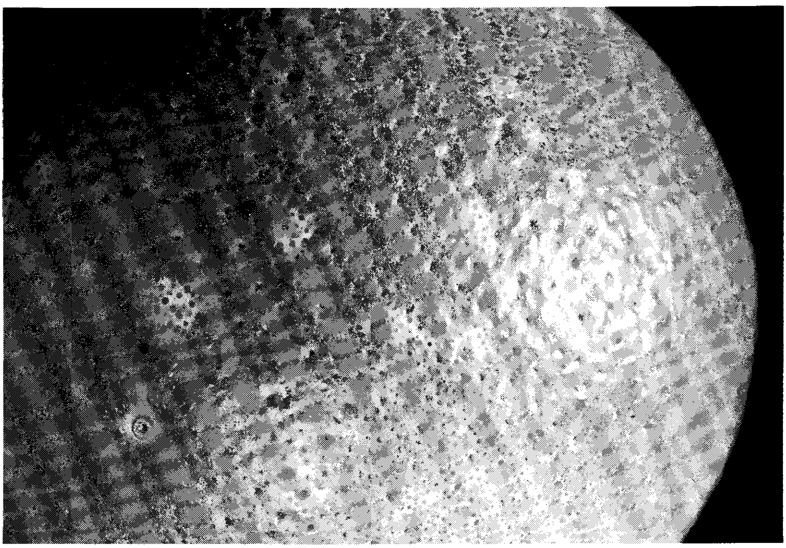

Figure 9. Citrus thrips ovipositional injury (photo by M. E. Badgley).

Thrips Monitoring Methods

To monitor thrips behavior, a modified dispersal-emergence trap was used, made from a 10-cm length of PVC pipe (inside diameter of 20.3 cm) (Fig. 10). A 430 cm^2 clear acetate plate, evenly coated with Tanglefoot (Tanglefoot Co., Grand Rapids, Mich.) was placed over the top of the trap. Therefore, we could continuously monitor migration of 2nd instars to the ground cover debris and adult migration back into the canopy (Tanigoshi 1981, Tanigoshi & Nishio-Wong 1982).

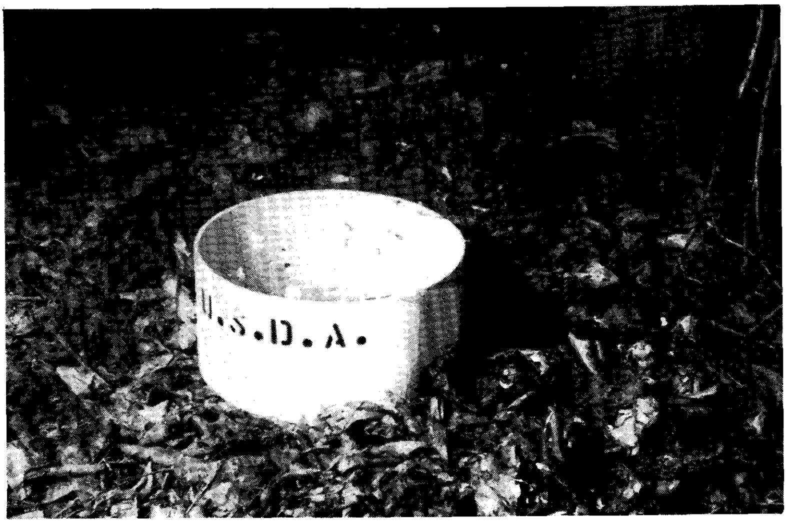

Figure 10. PVC-acetate dispersal-emergence trap for monitoring citrus thrips adult emergence from soil and larval descent into the litter (photo by M. E. Badgley).

This trap, with modifications, also may be suitable for monitoring the behavior of pear thrips, *Taeniothrips inconsequens* (Uzel), particularly for spring adult emergence and diel activity and dispersal patterns of late 2nd instars returning to the forest floor to overwinter. Ventilation ports in the side of the trap should be made to reduce condensation and possibly provide an exit for blackfly adults. Adhesive could be applied to the bottom of the acetate plate to monitor emerging adults and on the top to catch migrating larvae. The sticky acetate plates should be covered with a clear, oversized vinyl folder in the field to minimize contact with Tanglefoot and to allow the plates to be stacked in a refrigerator for later microscopic examination.

This trap could be useful to sugarmakers and researchers for determining the timing of pear thrips emergence on an area-wide scale. The presence of blackflies among emerging thrips would not hinder the determination of the timing of emergence, though thrips density might be difficult to assess. Later in the season when blackflies are absent, the trap could be used to measure diel migration patterns, population levels and dispersion trends of pear thrips larvae under or around a maple tree.

Colored sticky cards may also provide a method of effectively monitoring thrips behavior and density (Moreno et al. 1984). We found a good correlation between the number of citrus thrips caught on fluorescent yellow, polyvinyl cards (7.6 X 12.7 cm, suspended in the southeast quadrant of citrus trees) and PVC-acetate ground traps (Fig. 11). Experimentation with various shapes and color reflectances would

Figure 11. Fluorescent yellow, polyvinyl sticky card trap for monitoring citrus thrips (photo by M. E. Badgley).

be needed to determine the most effective trap design for attracting pear thrips (e.g., white is attractive to many thrips species) and discouraging attraction of other commonly occurring sugarbush insects.

Biological Control Potential of Phytoseiid Mites

I would like to briefly discuss data from 1981-82 supporting our hypothesis that the native phytoseiid, *E. tularensis*, provides economic biological control of early season citrus thrips (Tanigoshi et al. 1985). The hypothesis was tested with chemical exclusion using malathion to eliminate early spring *E. tularensis* predators in navel orange, lemon and grapefruit orchards in Riverside County, Calif. We used the concept of accumulated citrus thrips-days to correlate the duration of citrus thrips feeding to their population density. Populations increasing numerically will exhibit an ever increasing slope for their accumulated citrus thrips-days, while a controlled population will exhibit a flat slope. In addition, 55 outside canopy fruit were evaluated at harvest from each treatment and given a fruit damage index of 0-5. We conservatively estimated that an economic fruit damage index of about 0.300 will yield a minimum of 7-10% fruit cullage.

With the exception of early season population increases of citrus thrips immatures on navel orange control trees in 1981, accumulated immature and adult thrips-days from the other malathion treated navel orange, lemon and grapefruit trees were nearly of the same magnitude and with steeper slopes than that of the control trees where *E. tularensis* responded to early season population increases of citrus thrips (Figs. 12-13). For some unexplainable reason, in the navel orange control trees in 1981, the population of immature citrus thrips underwent an unusual increase from late April to petal fall compared with that of the malathion treated trees. However, the flat accumulated thrips-days curve from 100% petal fall through the critical injury period in the control trees for immatures and adults indicated that *E. tularensis* responded quickly to regulate those early escalating populations. This response occurred during the critical period of the navel orange after petal fall and was directly associated with the occurrence of nearly 1 *E. tularensis* per leaf in early May.

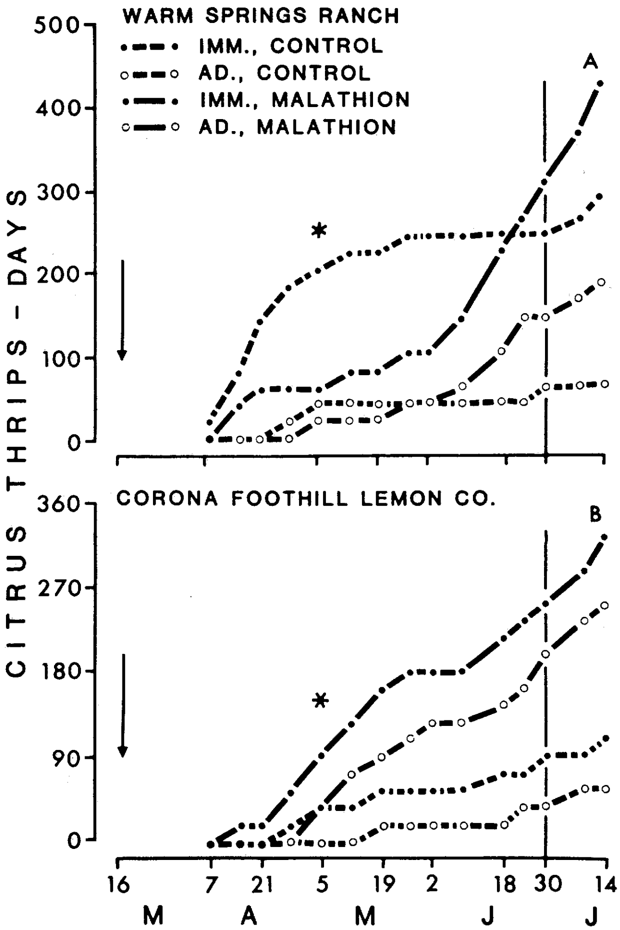

Figure 12. Accumulations of *Scirtothrips citri*-days on PVC-acetate traps placed under navel orange (A) and lemon (B) trees in 1981. Imm. = immatures, Ad. = adults, arrow = treatment date, * = 100% petal fall, vertical line = end of critical injury period (from Tanigoshi et al. 1985).

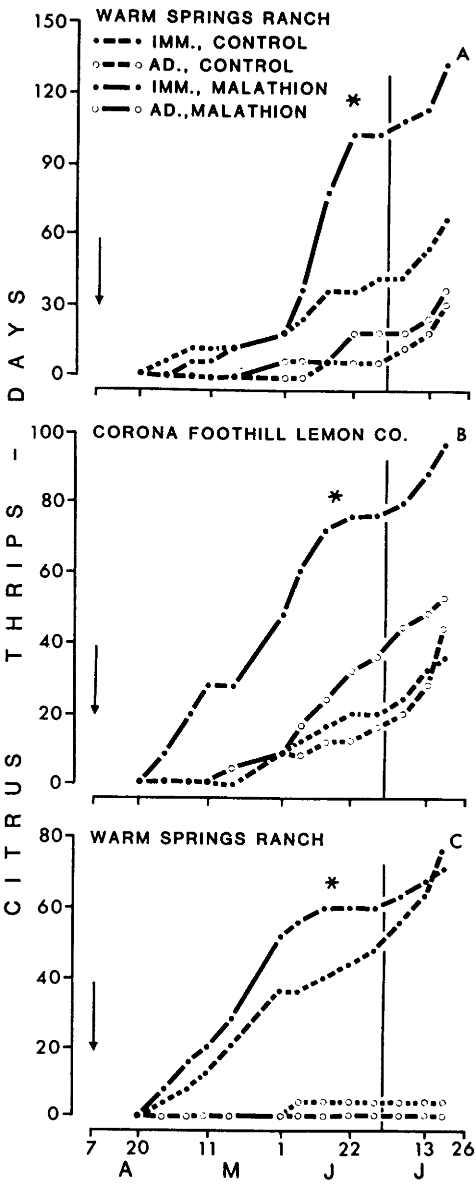

Figure 13. Accumulations of *Scirtothrips citri*-days on PVC-acetate traps placed under navel orange (A), lemon (B), and grapefruit (C) trees in 1982. Imm. = immatures, Ad. = adults, arrow = treatment date, * = 100% petal fall, vertical line = end of critical injury period (from Tanigoshi et al. 1985).

The average fruit damage indices shown in Table 2 indicate that navel orange and lemon fruit in the chemical exclusion plots were economically important and significantly higher than those in the control in 1981. However, because citrus thrips populations in 1982 were low area wide, there were no economic reductions or significant differences in fruit damage indices, though chemical exclusion plots for both orange and lemon were more scarred. These results and population trends of *E. tularensis* support our conclusion that field populations of greater than 0.5 phytoseiids per leaf at petal fall will regulate citrus thrips populations through the citrus fruits' critical injury period.

Table 2. Average fruit injury indices for citrus thrips in citrus plots designed to evaluate the biological status of *Euseius tularensis*

Cultivar	Treatment	1981	1982
Orange	Control	0.2200	0.040
	Chemical	1.2000[a]	0.104
Lemon	Control	0.1130	0.052
	Chemical	0.4350[a]	0.072
Grapefruit	Control		0.024
	Chemical		0.043

[a] Significantly different within cultivar ($P < 0.05$; Student's t test).

The first commercial attempt at colonization and augmentation of phytoseiid predators in the field for control of citrus thrips was initiated in 1978 in Riverside County, Calif. (Tanigoshi & Griffiths 1982). Rather than mass rearing predators, "Valencia" orange terminals infested with *E. tularensis* were taken to six centrally located trees/4 ha. These predators quickly increased and dispersed in and between contiguous trees and adjacent groves within one season. From 1978 to 1981, thripsicide application was reduced from 800 ha to less than 120 ha in this commercial grove. We applied sabadilla (14-16 kg/ha) and sugar (6 kg/ha) to adjust for unfavorable citrus thrips:phytoseiid predator ratios while minimizing negative impact on biological control of scale insects by aphelinid parasitoids.

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