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Progress on the Management of Avocado Thrips

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Avocado thrips, *Scirtothrips perseae* Nakahara (Thysanoptera: Thripidae) is the most serious pest that California avocado growers have had to manage to date. After its arrival in California in July of 1996, this insect spread rapidly from the initial site of discovery near Port Hueneme in Ventura County. Avocado thrips was also found at approximately the same time at Irvine in Orange County. As of May 1999, avocado thrips infested 80% of California avocado acreage. Avocado thrips larvae and adults can build to such high densities over the fall through spring period on young leaves on top-worked trees that leaves damaged from feeding can drop. The main source of economic loss attributable to avocado thrips, however, is scarring of immature fruit in spring by feeding thrips. Scarring can be severe enough to render the entire fruit surface brown and a characteristic "alligator skin" appearance results. Fruit that are entirely scarred can continue to size, and flesh within the fruit is a healthy green.

Avocado Thrips and Economic Losses

Economic losses attributable to avocado thrips have been calculated using pack-out records from twenty-two anonymous growers before and after avocado thrips established in their orchards. Pack out records were placed into one of four categories: (1) zero thrips damage, (2) 1-14% of harvested fruit damaged, (3) 15-30% damage, and (4) 30% or more of fruit were damaged. Damaged and undamaged fruit were assigned to either top grade, standards, or culls according to packing house criteria. Revenue earnings were calculated for growers based on pack out records prior to avocado thrips being found in orchards, and these data were compared to earnings after avocado thrips were found in orchards in 1998. Economic data for the twenty-two growers were combined with costs of thrips control incurred by either using biological control agents, Veratran-D (sabadilla), or AgriMek (abamectin). An economic model was developed by Karen Tetter (an agricultural economist at UC Davis) to estimate the effects to growers and consumers of rising production costs, retail prices, and decreases in quality. The model was run using two different chemical control methods (sabadilla and abamectin) and under different expectations of import substitution for domestic supply. Initial results showed an annual short-run loss to avocado growers of between $7.6 and $13.4 million from the combined effects of losses in quality and increased production costs associated with avocado thrips management (Hoddle *et al,* 1999).

Issues of importance to growers regarding avocado thrips control involve efficacy of sabadilla and abamectin applications, and releases of commercially available natural enemies. We discuss below our best current advice for using insecticides and work in progress on natural enemies. We suggest that growers check regularly with their pest control advisor, farm advisor, or the California Avocado Commission for updates on avocado thrips control.

Avocado Thrips and Fruit Scarring

The major priority when using insecticides should be to reduce fruit scarring by avocado thrips on fruit that will be present at harvest. Regular orchard surveys in Ventura County in 1998, revealed that avocado thrips populations were consistently observed on fruit from just under one-quarter to two inches in length. Thrips numbers peaked when fruit were around one inch in length and numbers rapidly declined to zero once fruit were greater than two inches in length.

An important consideration when protecting fruit is the period of scar development. In 1998, in Ventura County orchards with high fruit damage, only two to three weeks of feeding by two to five thrips on fruit ¼ inch to ½ inch in length were necessary for scarring levels to go from zero to 50-75% scarring. Temperature may have an important effect on observed damage levels and time periods over which fruit will remain vulnerable to thrips feeding damage. Temperature affects the rate at which fruit matures (i.e., cool weather will slow fruit development and the window of susceptibility to damage will be extended) and the rate at which avocado thrips populations develop. The time period over which control measures for application of control measures will require regular monitoring of young fruit by trained pest control advisors or growers, for both fruit size and numbers of thrips feeding on fruit.

Avocado Thrips and Insecticides

Sabadilla and abamectin have been cleared for use in controlling avocado thrips, but these products have limitations which need to be considered. Sabadilla applications (Veratran-D plus either sugar or molasses) need to be made when warm weather favors thrips feeding. Sabadilla is a stomach poison and needs to be ingested to be effective. For sabadilla applications to be effective, Dunhill Chemical Company recommends a pH of 4, and the pH should be lowered before adding sabadilla and the bait (either sugar or molasses) to the water. Once materials are added, the pH of the water must be checked again before applications are made. The correct pH is necessary as this increases the persistence of sabadilla after application. Sabadilla is a very selective product that has minimal impact on natural enemies.

The Section 18 for abamectin (Agri-Mek plus narrow range 415 spray oil) applications on avocados requires buffer zones around waterways, houses, and property lines, and a licensed applicator must apply the treatment. The Section 18 also requires zero spray drift onto blooming crops and weeds if bees are visiting.

In Ventura and San Diego trials, we have consistently observed one to two weeks of avocado thrips control with sabadilla and two to four weeks of control with abamectin. After this period, thrips levels increased to densities that were similar to those on untreated trees. Since the major objective of insecticide treatments is to reduce scarring

on young avocado fruit, sprays should not be applied more than one to two weeks before thrips are going to damage immature fruit which will be present at harvest. Both sabadilla and abamectin are relatively non-persistent pesticides which will be most effective if they are applied just when thrips start to damage set fruit.

At this time, there are no data available to support "knock-down"

applications of insecticides to reduce avocado thrips levels on young leaves in advance of their movement to immature fruit. It is highly possible that "knock-down" applications of sabadilla or abamectin could promote the development of resistance to these insecticides in avocado thrips populations. Resistance development to sabadilla and abamectin will severely reduce the chemical control options available for avocado thrips control and use of these insecticides should be reserved primarily for protecting fruit.

The level and duration of control with any treatment is going to vary depending on what insecticide and rate is used, how and when the pesticide is applied, weather patterns during and after treatment, and the availability of young leaves and fruit for avocado thrips to feed on. In general, treatments by air will be less effective and less persistent than those applied with ground air blast sprayers or handguns. When treatments by air are used, it is very important that the tree canopy is agitated by the helicopter prop-wash to ensure sufficient under-leaf coverage. During a 1998 aerial spray trial in Ventura County, insecticides applied above the tree canopy where helicopter prop-wash failed to agitate the tree canopy and resulted in poor avocado thrips control. Conversely, excellent control has been obtained in 1999 trials when applications were made above the canopy which was agitated with strong helicopter prop-wash.

Suggestions for Treatments

Chemical control of avocado thrips with either sabadilla or abamectin will require carefully timed sprays if they are to be effective. Sprays should be applied just as avocado thrips are starting to scar the fruit. Field observations indicate that fruit ¼ - ½ inch in length with two to five immature thrips present on fruit are likely to be conditions under which sprays will be most cost effective in terms of protecting the harvestable commodity. With trials on avocado thrips, we have observed one to two weeks of control with sabadilla and two to four weeks of control with abamectin. If there is concern over the availability of spray equipment, sabadilla treatments should be put on no more than one week in advance of fruit being one-eighth to one-quarter inch in length with significant thrips levels (two to five immature larvae per fruit), and no more than two weeks in advance with abamectin.

Avocado Thrips and Natural Enemies

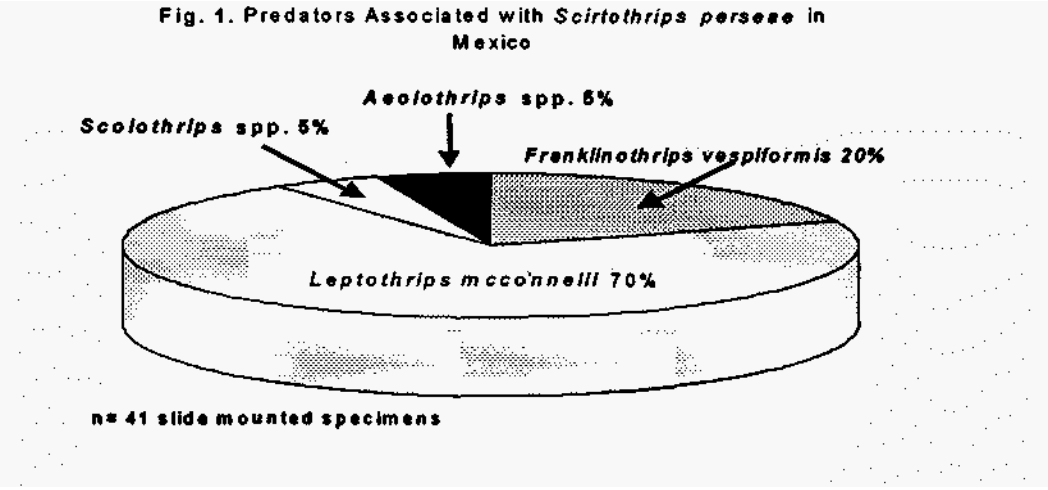
To diversify control options for growers, the efficacy of natural enemies is being studied to determine if biological control agents alone or in combination with selective insecticides (e.g., sabadilla or abamectin) can control avocado thrips as effectively as insecticides alone. Green lacewing larvae are generalist predators that are available from California insectaries as either eggs or larvae. At this time, there are no data available documenting the efficacy of lacewing larvae as biological control agents for avocado thrips suppression. Experiments are currently underway investigating the ability of lacewing larvae alone and in combination with sabadilla to control avocado

thrips in commercial orchards. In addition to work on green lacewings, releases of the adult stage of a new species of predatory thrips *(Franklinothrips* sp.) are being assessed for control of avocado thrips. This new thrips predator is currently being considered for commercialization by European and U.S. insectaries and the biology and efficacy of this natural enemy is being studied in the laboratory and field.

Foreign Exploration for Avocado Thrips Natural Enemies

Foreign exploration for avocado thrips and its natural enemies is ongoing. Surveys have been completed in Mexico and Guatemala. The current known distribution for avocado thrips is from Mexico City south to Oaxaca, through to Guatemala City (see map) and further surveys are planned for Costa Rica and the West Indies.

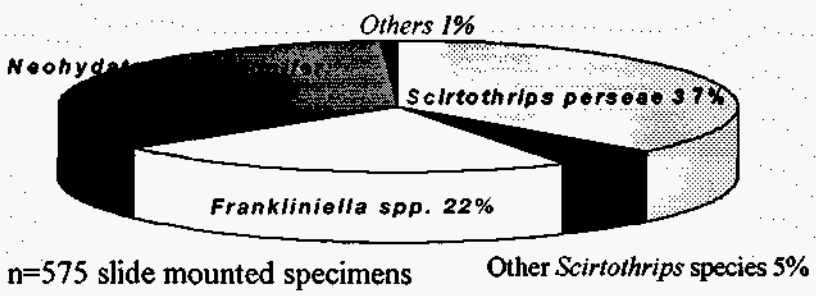
Fig. 1. Predators Associated with *Scirtothrips perseae* in Mexico



The most common natural enemies associated with avocado thrips on avocados in Latin America have been species of predaceous thrips, some of which are not present in California and could be valuable for control of this pest (Fig. 1). Thrips parasitoids (e.g., *Ceranisus* spp. [Hymenoptera: Eulophidae]) have also been collected and identified.

Apart from locating natural enemies and delineating the geographic distribution of avocado thrips, foreign exploration has allowed us to compile a list of other thrips species that are not in California but could be serious avocado pests should they establish here. One species, *Neohydatothrips signifer* Priesner is as common as avocado thrips in Mexico (Fig. 2) but is not known to be present in California. Given the common occurrence *ofScirtothripspersecte* in Latin America on avocados and its pestiferous nature in California, *N. signifer* could also pose a threat to California avocado growers.

Fig. 2. Phytophagous Thrips Collected on Avocados in Mexico



The three most recent avocado pests (avocado thrips, persea mite, and red-banded whitefly *[Tetraleurodes perseae* Nakahara {Homoptera: Aleyrodidae}]) to establish in California were all species new to science at the time of their initial discovery in the USA. This fact highlights three important points:

1) There are probably additional potentially serious avocado pests in Central America that are unknown entities that may be able to establish in California and inflict severe damage to commercially grown avocados. Foreign exploration in Mexico for avocado thrips and its natural enemies has revealed one new species of *Frankliniella* (the western flower thrips group which are serious disease vectors) and at least one other *Frankliniella* species whose identity can not be confirmed but could potentially be a new species as well. In addition, there is at least one species of *Scirtothrips* (same genus at the avocado thrips) whose taxonomic status is undetermined and could be a new species and a potential new pest (Hoddle, unpublished data). Of the 575 slide mounted thrips specimens collected from avocados in Mexico, the thrips fauna has been dominated by two species, the avocado thrips *(Scirtothrips perseae)* and *Neohydatothrips signifer* Priesner (Fig. 2) neither of which were known from avocados in Mexico until foreign exploration work was undertaken in the period 1997-1999. Furthermore, just three species of thrips *(Franliniella cephalica, Heliothrips haemorrhoidalis, Liothrips per sea)* are listed as potential pests by the CDFA and USDA-APHIS and only *F. cephalica* has been collected during extensive exploration efforts for avocado thrips and its natural enemies in Mexico. The insect fauna of Mexican grown avocados appears to be poorly documented and understood.

2) Border inspections intercepted both the persea mite and the avocado thrips on smuggled avocados from Mexico before either pest established in California. This strongly suggests that interception and exclusion policies are extremely valuable in preventing Central American exotic avocado pests from entering California and becoming established. The biology of potentially serious pests, like thrips, for example, makes detection very difficult. Thrips eggs are extremely small and are laid within the tissue of leaves, or the skin of fruit. The numbers of eggs laid within individual leaves and fruit in orchards infested with avocado thrips can easily exceed 20. Just one avocado fruit or leaf entering the U. S. with this number of viable eggs provides a good sized cohort that could establish in a permissive environment (i.e.,abundant food, mild climate, lack of natural enemies).

3) The small numbers of pests intercepted on avocado plants and fruit that are moved into the U.S. from Central America suggests that founding populations of pests may often be very small. Work on thrips used for the biological control of weeds has demonstrated that 33% of carefully managed releases of just 10 thrips into a permissive environment can result in establishment and proliferation (see Memmott *et al.* 1998). The greater the frequency of small introductions, the higher the likelihood of establishment in comparison with fewer introductions of larger numbers of thrips which might go extinct by chance (Memmott *et al.,* 1998). This scenario from weed biological control may apply to the establishment of new avocado pests in California: frequent introductions (either through legal or illegal routes) of small numbers of pests may ultimately lead to establishment.

Avocado Thrips Pupation

An unknown proportion of second instar avocado thrips either fall or jump from trees to complete propupal and pupal development in leaf litter beneath avocado trees. In addition, unknown proportions of thrips larvae probably complete pupal development in cracks and crevices on trees. Substantial work on the pupation behavior and biology of avocado thrips is needed to better understand this aspect of the pest's lifecycle. Increased knowledge of pupation behavior and numbers of thrips larvae remaining and falling from trees to pupate may provide insights for potential new control strategies. Preliminary investigations of avocado thrips pupation in leaf duff in avocado orchards have been conducted by collecting leaf litter below trees.

On six sampling dates, leaf duff and soil were collected from beneath trees in an orchard in Somis, Ventura Co. All material in a one m^2 area beneath the dripline supplying water to avocado trees was collected. Leaf litter was segregated into three strata: (1) A coarse, relatively undecomposed litter which composed the top surface strata. (2) A finer-textured decomposed layer of leaves and twigs which comprised the middle strata. (3) The bottom or third strata consisted of soil collected to a depth of 2.5 cm from the orchard floor immediately below strata 2.

These three layers were sorted individually into 40 liter black plastic containers. A 0.8 cm diameter hole was drilled into the side of each container. A clear plastic 50 milliliter bottle was taped to this hole into which a 10 cm^2 yellow sticky card was placed. Avocado thrips and other invertebrates collected on sticky cards as they moved towards the light were identified and counted. Emergence was measured from samples for approximately one month before leaf duff and soil was discarded. Samples were collected over the period March -July 1998.

Invertebrates collected in vials in the laboratory as they emerged from avocado leaf duff included: avocado thrips, predatory thrips (Phlaeothripidae *[Leptothrips* sp.], Aeolothripidae *[Franklinothrips* sp.]), springtails, spiders, mites (Anystidae, Raphignathidae, & Eupodidae) beetles (Coleoptera: Curculionidae [weevils], Elateridae [click beetles], Carabidae [ground beetles]), Lepidoptera (moth larvae and adults), Crustacea (Isopoda [sow bugs]), (Hymenoptera [para-sitoids]), Orthoptera (Gryllidae [crickets]), Psocoptera (bark lice), and Diptera (flies).

The most numerous arthropod that was collected from leaf duff from avocado orchards was avocado thrips. Table One summarizes numbers of avocado thrips collected on

each sampling date and generalist predators that may attack avocado thrips larvae and pupae in leaf duff.

Table One:
Total numbers of avocado thrips, and generalist natural enemies collected from three strata of leaf duff collected from an avocado orchard in Somis, Ventura Co. over the period March-July 1998.

Strata	Arthropod Group	March 23 1998	April 10 1998	April 23 1998	May 15 1998	June 2 1998	July 2 1998
Top	Avocado Thrips	28	119	474	126	714	651
	Spiders	26	10	12	6	9	16
	Predatory Mites	10	18	11	6	3	15
	Predatory Thrips	0	0	2	3	3	10
Middle	Avocado Thrips		11	50	8	139	19
	Spiders		2	6	4	1	0
	Predatory Mites		1	1	10	0	0
	Predatory Thrips		0	1	0	0	1
Bottom	Avocado Thrips		1	24	0	8	6
	Spiders		1	1	1	0	0
	Predatory Mites		1	0	0	0	0
	Predatory Thrips		0	0	0	0	0

From this study, 89% of adult avocado thrips were collected from strata 1 (top), 10% from strata 2 (middle), and 1% from strata 3 (bottom). Avocado thrips appears to significantly out number generalist predators in leaf duff, and it is probable that the natural enemy fauna present in avocado leaf duff does not inflict significant mortality on avocado thrips larvae and pupae. Manipulating conditions below trees (e.g., application of organic or reflective mulches) may be an effective way to reduce rates of successful pupation by avocado thrips larvae and warrants research.

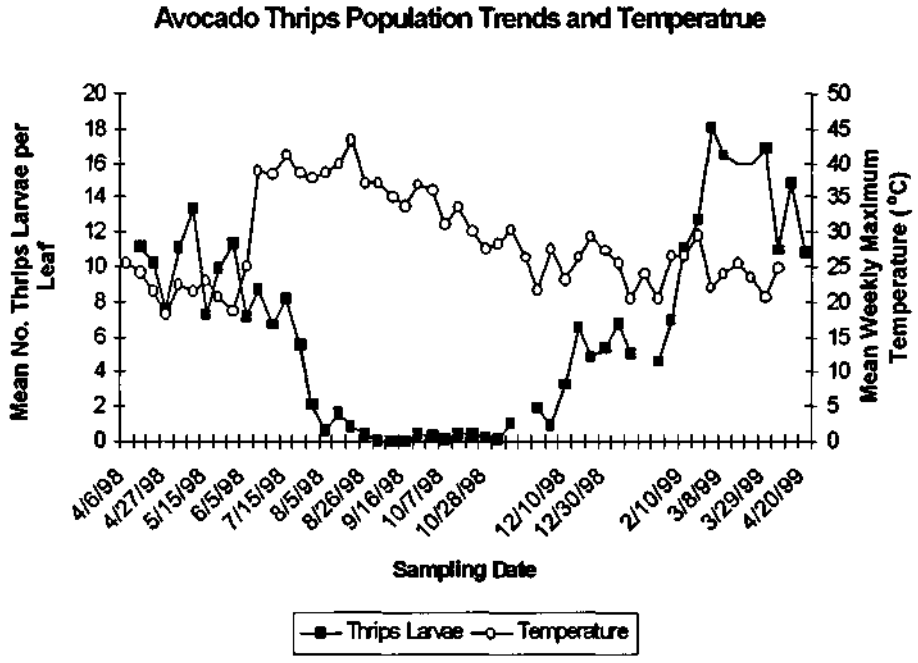
Avocado Thrips Population Declines and Temperature

Laboratory studies have indicated that avocado thrips larvae and adults exhibit highest survivorship, longevity and fecundity at moderately cool temperatures (20-25°C [67-76°F]) and are relatively sensitive to moderately hot temperatures (30°C [86°F]) which cause high larval mortality and reduced adult longevity (Hoddle and Morse, 1997). We speculate that these temperature tolerances optimally coordinate avocado thrips development and reproduction with avocados over spring when plants are producing young leaves and fruit which are suitable for thrips feeding and oviposition.

Avocado thrips numbers have been observed to decline rapidly in the field with the onset of hot summer weather even when there is abundant foliage available for feeding

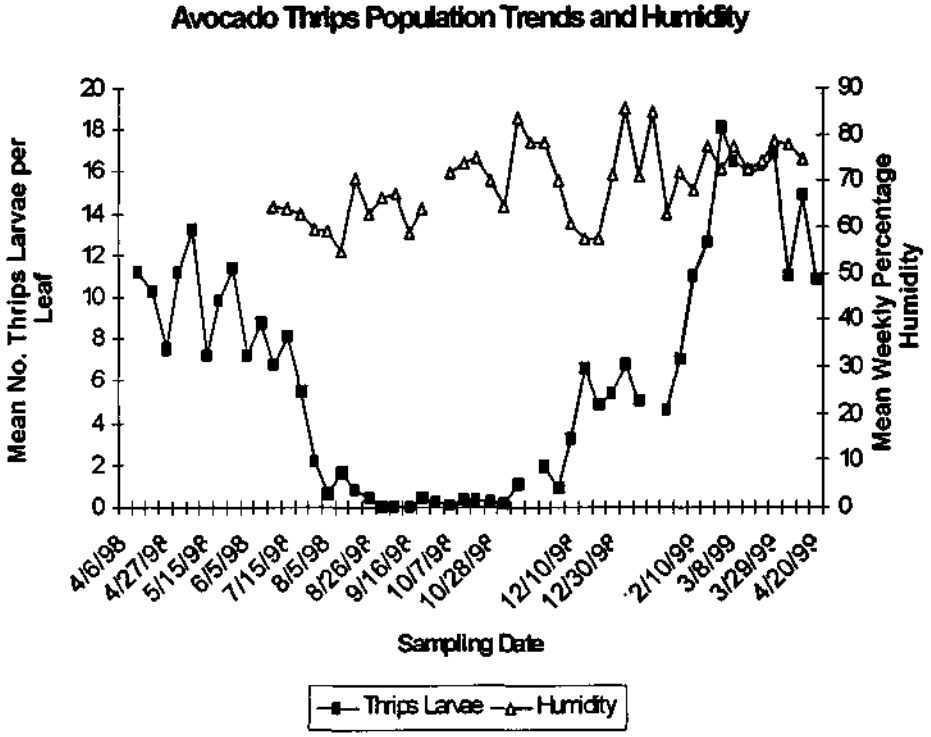
and oviposition. For over 12 months we have investigated the relationship between temperature, humidity, and avocado thrips population dynamics in an orchard in Fallbrook, south California. Every week numbers of thrips larvae on ten $^{3}/4$ expanded leaves on each of 10 top-worked trees (cultivar Reed) were recorded. Average numbers of thrips larvae per leaf were calculated and temperature and humidity were recorded at the site every 30 minutes using electronic data loggers. Population trends for avocado thrips in relation to temperature are shown in Figure 3. These data clearly show that mean weekly maximum temperatures over 30°C (86°F) can cause abrupt declines in numbers of avocado thrips larvae on leaves. Thrips numbers steadily recover when mean weekly maximum temperatures decrease and are within the range 20-25°C (67-76°F). The influence of temperature on thrips numbers is not immediate, and it appears that high daily temperatures (i.e., maximum daily temperature must exceed 86°F) are needed for several consecutive days to cause crashes of avocado thrips populations.

Fig. 3. Population trends for avocado thrips larvae in relationship with temperature in an avocado orchard in Fallbrook California.



At the same Fallbrook site, changes in weekly average percentage relative humidity did not appear to be tightly linked with changes in avocado thrips numbers (Fig. 4).

Fig. 4. Population trends for avocado thrips larvae in relationship with percentage relative humidity in an avocado orchard in Fallbrook California.



Based on the results from this one site, we conclude that mean weekly maximum temperatures in excess of 30°C (86°F) may be an important factor leading to the decline of avocado thrips populations. Additional monitoring of avocado thrips at other avocado orchards in southern and central California is being conducted to verify the relationships between temperature, humidity, and avocado thrips population declines.

Conclusions

Considerable research work is still needed on avocado thrips if this pest is to be managed cost effectively and devised management programs are to be sustainable. Experiments investigating application rates and timings of sabadilla and abamectin are necessary to optimize control with insecticides and to reduce frequency of applications for maximum impact and minimization of resistance development. Work on the pupation biology and behavior of avocado thrips may provide insight on a vulnerable stage of the life cycle that could be susceptible to cultural practices that manipulate the environment under orchard trees. Continued foreign exploration in Central America will enable the further documentation of potential additional thrips pests that are not in California but could establish in this state. Exploration efforts will also identify natural enemy species that can be considered for importation into quarantine and later establishment in California avocado orchards for control of avocado thrips.

Background Reading

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Memmott, J. Fowler, S. V. and Hill, R. L. (1998). The effect of release size on the probability of establishment of biological control agents: gorse thrips *(Sericothrips staphylimis)* released against gorse *(Ulex europaeus)* in New Zealand. *Biocontrol Science and Technology*:* 103-115.

Morse, J. G., Hoddle, M. S., Phillips, P., Faber, B., and Yee, W. (1999). Making decisions on timing treatments for avocado thrips control. A four page newsletter published by the California Avocado Commission. Available free from the California Avocado Commission. Call Betty Bohrk at 1-800-344-433.

strip in 4/c map

Known Locations of Avocado Thrips in Latin America