Final Scientific Report

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Project Title: Use of multiple biological control agents for control of western flower thrips

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Institutions

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Keywords *not* appearing in the title and in order of importance. Avoid abbreviations.

Intraguild predation; *Orius insidiosus*; *Orius laevigatus*; *Amblyseius swirskii*; *Amblyseius degenerans*; *Steinernema felpiae*; *Frankliniella occidentalis*; Prey switching; Preference; Predatory mite; Predatory bug; Entomopathogenic nematode

Abbreviations commonly used in the report, in alphabetical order:

WFT (western flower thrips)

Budget: IS: \$ 150,000.00

US: \$ 150,000.00

Total: \$ 300,000.00

Signature
Principal Investigator

Signature
Authorizing Official, Principal Institution

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ABSTRACT: The western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), is a serious widespread pest of vegetable and ornamental crops worldwide. Chemical control for *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) on floriculture or vegetable crops can be difficult because this pest has developed resistance to many insecticides and also tends to hide within flowers, buds, and apical meristems. Predatory bugs, predatory mites, and entomopathogenic nematodes are commercially available in both the US and Israel for control of WFT. Predatory bugs, such as *Orius* species, can suppress high WFT densities but have limited ability to attack thrips within confined plant parts. Predatory mites can reach more confined habitats than predatory bugs, but kill primarily first-instar larvae of thrips. Entomopathogenic nematodes can directly kill or sterilize most thrips stages, but have limited mobility and are vulnerable to desiccation in certain parts of the crop canopy. However, simultaneous use of two or more agents may provide both effective and cost efficient control of WFT through complimentary predation and/or parasitism. The general goal of our project was to evaluate whether suppression of WFT could be enhanced by inundative or inoculative releases of *Orius* predators with either predatory mites or entomopathogenic nematodes. Whether pest suppression is best when single or multiple biological control agents are used, is an issue of importance to the practice of biological control. For our investigations in Texas, we used *Orius insidiosus* (Say), the predatory mite, *Amblyseius degenerans* Berlese, and the predatory mite, *Amblyseius swirskii* (Athias-Henriot). In Israel, the research focused on *Orius laevigatus* (Fieber) and the entomopathogenic nematode, *Steinernema felpiae*. Our specific objectives were to: (1) quantify the spatial distribution and population growth of WFT and WFT natural enemies on greenhouse roses (Texas) and peppers (Israel), (2) assess interspecific interactions among WFT natural enemies, (3) measure WFT population suppression resulting from single or multiple species releases. Revisions to our project after the first year were: (1) use of *A. swirskii* in place of *A. degenerans* for the majority of our predatory mite and *Orius* studies, (2) use of *S. felpiae* in place of *Thripinema nicklewoodi* for all of the nematode and *Orius* studies. We utilized laboratory experiments, greenhouse studies, field trials and mathematical modeling to achieve our objectives. In greenhouse trials, we found that concurrent releases of *A. degenerans* with *O. insidiosus* did not improve control of *F. occidentalis* on cut roses over releases of only *O. insidiosus*. Suppression of WFT by augmentative releases *A. swirskii* alone was superior to augmentative releases of *O. insidiosus* alone and similar to concurrent releases of both predator species on cut roses. In laboratory studies, we discovered that *O. insidiosus* is a generalist predator that ‘switches’ to the most abundant prey and will kill significant numbers of *A. swirskii* or *A. degenerans* if WFT become relatively less abundant. Our findings indicate that intraguild interactions between *Orius* and *Amblyseius* species could hinder suppression of thrips populations and combinations of these natural enemies may not enhance biological control on certain crops. Intraguild interactions between *S. felpiae* and *O. laevigatus* were found to be more complex than those between *O. insidiosus* and predatory mites. In laboratory studies, we found that *S. felpiae* could infect and kill either adult or immature *O. laevigatus*. Although adult *O. laevigatus* tended to avoid areas infested by *S. felpiae* in Petri dish arenas, they did not show preference between healthy WFT and WFT infected with *S. felpiae* in choice tests. In field cage trials, suppression of WFT on sweet-pepper was similar in treatments with only *O. laevigatus* or both *O. laevigatus* and *S. felpiae*. Distribution and numbers of *O. laevigatus* on pepper plants also did not differ between cages with or without *S. felpiae*. Low survivorship of *S. felpiae* after foliar applications to sweet-pepper may explain, in part, the absence of effects in the field trials. Finally, we were interested in how differential predation on different developmental stages of WFT (*Orius* feeding on WFT nymphs inhabiting foliage and flowers, nematodes that attack prepupae and pupae in the soil) affects community dynamics. To better understand these interactions, we constructed a model based on Lotka-Volterra predator-prey theory and our simulations showed that differential predation, where predators tend to concentrate on one WFT stage contribute to system stability and permanence while predators that tend to mix different WFT stages reduce system stability and permanence.

ACHIEVEMENTS

Significance of main scientific achievements: A growing trend among biological control programs is to use two or more species of natural enemies to suppress populations of insect pests. Biological control programs for ornamental and vegetable crops often use combinations of predators, parasitoids, nematodes or pathogens against arthropod pests. We addressed a basic issue for biological control, whether the use of one or multiple species of natural enemies is the most efficacious and cost efficient approach for the end user. Ideally, our findings will improve recommendations and release protocols for biological control agents in both field and greenhouse crops. Progress in this direction will contribute to the development of management programs for important pests, such as WFT, that minimize insecticide input and enable commercial growers in Texas and Israel to meet both market demand and legislative requirements for their crops. This research is timely because consumer demand for pesticide-free-products, government enforcement of environmentally-safe cultural practices, and the threat of widespread resistance in many pests to registered products has created new opportunities for biological control in high-value greenhouse crops.

Our findings should broaden our general understanding of interspecific interactions among natural enemies. Such information is essential for optimal use of polyphagous predators, such as *Orius* and *Amblyseius* species, and entomopathogenic nematodes for control of insect pests on either ornamental or vegetable crops. *Amblyseius swirskii* is quickly becoming one of the most widely sold biological control agents for both whiteflies and thrips in the US and Israel. Findings from our studies will contribute to the more effective use of this predatory mite on crops of economic importance to both Texas and Israel. In greenhouse crops, inoculative or augmentative releases of predatary mites are often used as a 'first line of defense' against thrips because they are inexpensive and have a good rate of establishment in many crops. If predatory mites are unable to suppress severe thrips infestations, anthocorids are often released as a corrective measure. Until our studies, there has been a lack of empirical data to verify the efficacy and cost effectiveness of such release strategies or the consequences of intraguild predation by *Orius* species on predatory mites. Our findings indicate that intraguild interactions between *Orius* and *Amblyseius* species could hinder suppression of thrips populations and certain combinations of these natural enemies may not enhance biological control on certain crops. Although predatory mites alone may not provide sufficient control of WFT on some greenhouse crops, we would advise careful investigation before using concurrent releases of *Orius* species and predatory mites to improve control. To our knowledge, these studies are also the first to verify intraguild interactions among entomopathogenic nematodes and *Orius* species. Presently, the vulnerability of commercially available strains of entomopatogenic nematodes to desiccation on foliage or within floral structures appears to minimize the direct impact of these control agents on either *Orius* species or WFT. However, our predation model predicts that parasitism of WFT life stages by nematodes within the soil may have destabilizing effects on populations of WFT and / or *Orius* within the crop. Therefore, the strategy of combining soil applications of *S. felpiae* and augmentative releases of *Orius* species

for control of WFT should be further investigated in future studies. Overall, our project has provided significant insights on fundamental issues of importance to biological control, such as intraguild predation, while contributing to the development of practical alternatives to chemical control of WFT and other thrips species.

Details of Cooperation: To facilitate collaboration between the Texas and Israel teams, Dr. Itamar Glazer, (the senior Israeli investigator) was scheduled to interact with the Texas team at College Station and present a special seminar to the Texas A&M Department of Entomology during March 9, 2005. Unfortunately, Dr. Glazer's trip was cancelled due to severe weather conditions on the US East coast during March 8. As a result, the Texas team instead held a conference by phone on March 9 with Dr. Glazer. During this telephone conference, we accomplished the following: (1) reviewed the research goals of each team and objectives to be accomplished before the first semi-annual joint report, (2) addressed Dr. Glazer's questions regarding collection and mass rearing of *T. nicklewoodi* which the Israeli team would be using for their part of the project. At a later date, the Texas team also provided Dr. Glazer with photos of *T. nicklewoodi* and *F. occidentalis* infected by *T. nicklewoodi* for use in presentations of his work. During 2006 and 2007, both Texas and Israel team members had 'face-to-face' interactions that resulted in productive exchanges of ideas, information, and scientific cooperation. Dr. Andrew Chow and Dr. Moshe Coll both participated in the 14th International Entomophagous Insects Workshop during June 11-15 of 2006 at Newark, DE. They met many times during the workshop and provided updates on each team's progress, discussed issues relating to joint progress reports, and exchanged insights on data and experiment design. During these discussions, Dr. Coll shared results from his studies evaluating the use of *Orius laevigatus* and *Amblyseius cucumeris* for control of WFT on strawberry crops. These studies were completed for a different project but comparisons of Dr. Coll's studies with the Texas team's studies using *O. insidiosus*, *A. degenerans*, and *A. swirski* against WFT on cut roses confirmed similar patterns of interaction between WFT, predatory bugs, and predatory mites on these different crops. This exchange of information between Dr. Coll and Dr. Chow provided the Texas team with invaluable insights that assisted with the planning and execution of the Texas studies during the third year of the project.

Both Dr. Andrew Chow and Dr. Amanda Chau were in Israel from May 30 – June 14 of 2007. During this visit, Dr. Glazer and the Texas scientists reviewed the progress of their current collaborative project and discussed avenues for future collaborations with ARO personnel. The Texas scientists also met with research and development personnel from Israeli insectaries. During their meeting with Dr. Shimon Steinberg (Bio-Bee Sde Eliyahu Ltd), the Texas scientists discussed alternative strategies for the use of predatory mites with *Orius* species for control of thrips and spider mites on greenhouse crops. Thanks to facilitation by Dr. Glazer, the Texas scientists had several opportunities to interact with commercial producers of orchard, field, and greenhouse crops. This 'first hand' opportunity to view Israeli agricultural systems and learn about the concerns of Israeli producers will greatly enhance the ability of the Texas team to develop future research

programs that will benefit both Texas and Israeli agriculture. Finally, the Texas scientists interacted with Dr. Moshe Coll and his research team at the Hebrew University of Jerusalem campus at Rehovot. Both teams shared ideas and experiences relating to the joint project, provided updates on progress for the project, and discussed avenues for publication of their research.

LIST OF PUBLICATIONS

Peer-Reviewed, Refereed Journal Articles

Miller, E, and M. Coll. Predicting the dynamics of predator-prey systems from empirical data. Ecology [Submitted and currently under review].

Chow, A., Chau, A. and K. M. Heinz. Prey switching and intraguild predation by *Orius insidiosus* (Hemiptera: Anthocoridae): implications for control of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on cut roses with *Amblyseius* (*Typhlodromips*) *swirskii* (Athias-Henriot) (Acari: Phytoseiidae). Agricultural and Forest Entomology [Submitted Nov. 27 / 2007. Reviewed March 2 / 2008. Under revision. Manuscript # AFE(2007)923].

Chow, A., Chau, A. and K. M. Heinz. 2008. Compatibility of *Orius insidiosus* (Hemiptera: Anthocoridae) with *Amblyseius* (*Iphiseius*) *degenerans* (Acari: Phytoseiidae) for control of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on greenhouse roses. *Biological Control* 44: 259-270.

Editor-Reviewed Journal Articles

Chow, A., Chau A., and K. M. Heinz. 2008. Control of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on greenhouse roses with *Amblyseius* (*Typhlodromips*) *swirskii* (Athias-Henriot) (Acari: Phytoseiidae) and *Orius insidiosus* (Hemiptera: Anthocoridae). *IOBC/WPRS Bull.* 32 (In press).

Editor-Reviewed Published Proceedings

Chow A., Chau A., and K. M. Heinz. 2007. Two predators are better than one! Combining *Amblyseius swirskii* and *Orius insidiosus* for control of thrips on greenhouse roses. Proceedings of the Southern Nursery Association Research Conference 52.

Chow A., Chau A., and K. M. Heinz. 2006. Are two predators better than one? Effects of combining a predatory mite and a predatory bug for control of western flower thrips on greenhouse roses. Proceedings of the Southern Nursery Association Research Conference 51.