PROJECT CONCLUDED: FINAL REPORT

Field Management Plan and Biocontrol Rearing System for Citrus Peelminer

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Citrus peelminer pest management requires an ecological approach using techniques such as pheromone traps, a degree day model, and augmentative releases of natural enemies for successful control.

**SUMMARY:**

**Objective 1 - Development of a pheromone lure monitoring system:** Pheromone traps can be used to track citrus peelminer populations, but the lure is still in need of improvement. Pheromone traps seem to be most effective in attracting moths in the early spring (April) and late fall (Sept-October). During the mid-season the number of moths trapped in citrus is very low, and generational peaks are difficult to discern. Male moth flights were observed in traps located in both citrus and non-citrus host crops during the spring and fall, indicating at least one of the chemicals in the lure is essential for attraction of male moths.

Significantly higher numbers of moths observed in traps in the spring and fall compared to the summer months during 2005 ($F = 0.95, df = 9, 96, P = 0.0001$) and 2006 ($F = 0.95, df = 7, 45, P = 0.009$) may indicate variability in attractiveness of the pheromone at different times of the season, or that there is a seasonal change in the chemical components of the natural pheromone produced by females over time.

**Objective 2 - Development of a Degree Day model:** We successfully completed the degree day model. The model was validated in the southern San Joaquin Valley during the 2006 season (see final report below).

**Objective 3 - Biological Control/Introduction and Augmentation:** A colony of the citrus peelminer parasitoid species, *Cirrospilus coachellae* Gates, was developed at UC Riverside (see report “Rearing Peelminer Parasitoids” - Luck, Morse and Grafton-Cardwell) and provided specimens to continue releases into the San Joaquin Valley. Shipments of parasitoids of up to 400 individuals were released approximately every two weeks into 17 citrus orchards and other host plant stands with infestations of peelminer beginning in early August through December 2007.

The first successful within-season recoveries of *C. coachellae* were observed in all 7 release sites examined in October 2007. The recovery of parasitoids was an important milestone for the release program. We will continue to work with *C. coachellae* through the spring of 2008 to monitor for overwintering success of this species. We completed foreign exploration for citrus peelminer parasites in November 2006.

**Objective 4 - Development of ArcIMS Web-based mapping tool:** We again had excellent grower/PCA participation with the interactive web-based mapping pages. Trap data for peelminer activities (moth counts and mining damage was entered by growers and PCAs and Grafton-Cardwell personnel. There were training sessions provided by Grafton-Cardwell. We surveyed 66 citrus orchards each fall during 2005-2006 and evaluated the level of peelminer damage in the region by examining 1,000 fruit in each orchard.
We found that the maximum percentage of fruit mined was 62.5%, 54.9% and 14.6% in 2005, 2006, and 2007, respectively. The reduced peelminer damage in 2007 is likely a combination of factors including the 2007 freezing conditions that lowered peelminer densities as well as growers learning to manage the pest better. Deliverables: we provided regional interactive maps, monthly static maps, and variety reports for growers wishing to better understand peelminer activity and impacts.

Figure 1. **Mining of a grapefruit rind by several citrus peelminer larvae over a two-week period in early summer.**

Figure 2. **Degree day estimates based on 30-year temperature averages from Tulare County for predicting the occurrence of citrus peelminer in pummelo/grapefruit in spring and oranges in summer.** Fruit size is an indicator of susceptibility to attack by citrus peelminer: pummelos that are ~70-75 mm in diameter and oranges that are ~50-60 mm in diameter are at the appropriate growth stage to support larval feeding in fruit rinds.
Final Report:

Citrus peelminer, *Marmara gulosa* Guillen & Davis, continues to be a very challenging pest to manage within the context of the San Joaquin Valley’s citrus production systems. The difficulties are due in part to citrus peelminer’s feeding on the rind of developing fruit (Fig. 1), its extensive and varied host plant utilization, sporadic and unpredictable population fluctuations and a lack of full understanding of its pheromone biology.

The overall objective of the study was to deliver to growers a management plan for peelminer by building the basic tools necessary for monitoring its populations to more effectively use the limited tools available for its control.

Using the Degree Day Model for Citrus Peelminer Management:

**Timing of insecticides:** The stage specificity of all of the current biological and chemical control methods that exist for management of citrus peelminer require prediction and timely treatment of susceptible stages in the field. While multiple classes of insecticides including organophosphate, carbamate, pyrethroid, neonicotinoid, insect growth regulator, fermentation products, or sulfur have been shown to affect development of citrus peelminer in laboratory screenings, efficacy of these materials in the field is limited due to difficulty in obtaining thorough coverage as a result of fruit and tree canopy characteristics (Grafton-Cardwell et al. 2007). One of the most effective insecticides for peelminer control, diflubenzuron (Micromite®), must be applied to the egg stage. Effective application of this material can only be made when unhatched eggs are present on the surface of the fruit and contact with the insect can be made.

**Use of natural enemies:** *Cirrospilus coachellae*, the biological control agent from the Coachella Valley that is being reared and released for control of citrus peelminer in the San Joaquin Valley, prefers late instar larvae as hosts (Guillén et al. 2007). Both early season and late season citrus host multiple generations of peelminer. Releases of *C. coachellae* should be timed to target the late instar larvae of the initial generation attacking fruit. This approach may reduce the numbers of subsequent generations and reduce the overall scarring on fruit. Since parasitoids require host material to be present in the field, some level of damage must be tolerated so that sufficient resources are available for oviposition and development of these natural enemies.

**Monitoring for citrus peelminer:** Citrus peelminer has at least 7 generations per year that attack a wide variety of host plant species from April through October. There appears to be a constant threat from adult moths that are seeking host plants in the appropriate stages to support larval development. Predicting the occurrence and abundance of these lurking populations is extremely difficult.

Our research has shown that peelminer infestations of early season citrus varieties, such as pummelo and grapefruit, can be predicted by monitoring its activities in early spring-time on other host crops such as walnuts. Overwintering populations of peelminer emerge from the larval and pupal stages and lay eggs on the rapidly expanding tissues of deciduous tree species. The first occurrence of males in a trap and verification of first instar larval mining on the green twigs of walnuts can be used as a biofix to predict future generations in citrus and other crops.

Once moths are observed in walnuts, we used the 320 DD per generation model (lower developmental threshold of 12.9°C and 320 DD (°C) or LD = 55°F and 580 DD (°F)) developed from laboratory studies to predict the first occurrence of peelminer in pummelo and grapefruit (Fig. 2). There are two generations of peelminer in walnuts, and other tree crops, before citrus fruit become susceptible. Five generations of peelminer were observed in the field in 2006 attacking pummelos. The biofix in walnuts did not accurately predict the first occurrence of peelminer in late season oranges.

Host plant effects including phenology and suitability of different hosts as resources for larvae are likely playing a role in the inability to calculate all generations throughout the season based upon first occurrence of larvae in walnuts. Therefore, to predict late season attacks on citrus, such as navels, we used the 320 DD per generation model and recalibrated from the first occurrence in pummelos. By monitoring pummelo fruit we predicted the first incidence of larval mining on orange fruit at approximately 640 DD (or two generations) following initiation of larvae on pummelo fruit. Better timing of insecticide sprays for the egg stages can be attained by using these prediction methods. In addition, the minimum size of pummelos that are attacked is ~70-75 mm and the minimum size of oranges that can be attacked is ~50-60 mm.
The recommendation to the growers is to use degree days and fruit size to predict when the first egg laying on the pum- melo/grapefruit group or oranges will occur, and then treat two to three times at monthly intervals with insecticides. Again, excellent coverage on the lower portions of trees is a must to achieve maximum efficacy.

The ultimate role of using natural enemies for management of citrus peelminer is currently in flux. We are continuing to make releases to determine if \textit{C. coachellae} can be established in the San Joaquin Valley. The invasion of the related pest species citrus leafminer, \textit{Phyllocnistis citrella} Stainton, will have an impact on the types and timing of natural enemies working in citrus production orchards. The native parasitoids attack both of these species. We will continue to monitor these populations as events unfold. It is expected that citrus leafminer will have native parasitoids adopt it as a host and keep it under control; this in turn may provide more resources for these natural enemies to attack citrus peelminer. Additional species of natural enemies from other parts of the world are on standby for release into the San Joaquin Valley if native natural enemies do not exert enough control in production settings.