SUMMARY OF THE PROBLEM:

Between 1914 and 2007, a quarantine protected California avocado groves from pests that might be introduced into the state along with fresh, imported avocados. Soon after Mexican avocados were first allowed entry on 1 February 2007, live specimens of several species of armored scales (Family Diaspididae) not believed to be present in California were detected on Hass avocados entering the state from Mexico. In order to determine if this was a dangerous situation, we examined fruit entering California via the Blythe border station and found eight species of scales, seven of which are believed to be exotic to the state (Morse et al. 2009). Over an 8-month period, September 2007 - April 2008, we estimated that 67 million Mexican Hass avocados entered California and based on samples from 140 trucks containing 15.6% of the total volume of fruit entering the state, approximately 47.6 million live, sessile scales (first instars and older that can’t move from where they are attached; including females which can produce more crawlers) and an additional 20.1 million live eggs and crawlers (the life stages that can establish new populations; some species produce eggs and other species hatch eggs internally and birth live crawlers) were imported. The only species found on Mexican avocados believed to already be present in California was latania scale (*Hemiberlesia lataniae*), which is a parthenogenetic species (females only). Interestingly, latania scale was relatively rare on Mexican avocados but a common species (and one that was previously unknown) was the very similar *Hemiberlesia* sp. near *lataniae*, which is a sexually reproducing species. The other 6 exotic species found were *Abgrallaspis aguacatae*, *Abgrallaspis perseae*, *Acutaspis albopicta*, *Diaspis miranda*, *Diaspis* sp. near *miranda*, and *Pinnaspis strachani*.

How dangerous a situation is this? USDA-APHIS allowed the fruit importations because they believe live scales on fruit pose a “low risk” to pest establishment. We disagree with this assessment, partly because we have determined that scale crawlers can disperse to new environments by hitch-hiking on flying insects (via Project # 65102).

If one or more of these exotic armored scales were to establish on California avocados, how serious a pest would they be? We don’t really know the answer to this. On many crops, armored scales can be severe pests unless they are controlled by natural enemies (e.g., California red scale on citrus, San Jose scale on many deciduous crops). In some cases, it is possible to return to the country the scale originated from and find natural enemies, which can control it effectively. However, in the absence of good biological control, exotic armored scales could be severe pests on California avocados and would be difficult to control chemically, especially with treatments applied by helicopter (in contrast to many pests, thorough spray coverage is often needed for effective control of armored scales).
OUR RESEARCH APPROACH:

If one or more of the exotic armored scales found on Mexican avocados were to establish in California to a degree such that eradication is not feasible, a preferred method of management would be biological control. For example, latania scale was once quite common on California avocados (38% of 27,868 trees surveyed in 1930 were infested according to Mackie 1931). Presently, latania scale is not present at high levels in CA avocado groves (but it appears to be present at low levels in many groves) and we believe the reason is that natural enemies introduced for control of California red scale on citrus (in the 1950’s or earlier) moved onto avocados and controlled latania scale. We do not know to what degree parasitoids and predators already present in California would control some or all of the 7 species of exotic scales found on Mexican avocados.

Our project has 3 objectives:

**OBJECTIVE 1. Survey California avocados for armored scale species present on the crop.**

It is important to know what the more common species of armored scales are on avocados in California and to develop data that suggests whether or not one or more of the 7 exotic species found on Mexican fruit have already established in the state.

**OBJECTIVE 2. Survey for natural enemies associated with armored scales on California avocados.**

This objective is important for two reasons. First, we need to know what parasitoids and predators are present on armored scales on California avocados so we can test these species to see if they will attack the exotic Mexican scales. Second, we need to compare key parasitoids and predators present in California versus those that are found attacking armored scales in Mexico. For exotic scales that might establish in California, this would help us prioritize Mexican species for possible importation and release (once permits for this have been obtained).

**OBJECTIVE 3. Initiate cultures of the more important natural enemies that are found and test their ability to attack various exotic armored scales that are reared in UCR’s Quarantine facility.**

Our first step under this objective is to develop colonies of key armored scales so that we have the infrastructure to evaluate armored scale parasitoids and predators. We will then test the more common natural enemies against Mexican armored scales inside UCR’s Quarantine facility (we have a permit allowing us to rear these scales as part of Project # 65105).

PROGRESS TO DATE:

**Surveys of California Avocado Groves for Scales and Parasitoids.** To date, we have surveyed a large number of California avocado groves and found 4 armored scale species. The 4 scale species identified are latania scale (*Hemiberlesia lataniae*), greedy scale (*Hemiberlesia rapax*), California red scale (*Aonidiella aurantii*), and oleander scale (*Aspidiotus nerii*). All reports from growers and PCAs of their having armored scales in their groves were investigated and data recorded. We believe the general impression is that armored scales are rare. However, when we search groves we are working in for other purposes (avocado thrips, persea mite), we often find low levels of armored scales. This is actually very good news – scales are present and appear to support low but persistent natural enemy populations, i.e. biological control is currently very good for the scale species we already have in California. The key question is whether the parasitoids we have would control the exotic Mexican scales or not. The average numbers of armored scales present on Mexican fruit was 0.71 live scales and an additional 0.34 live eggs or crawlers per fruit (Morse et al. 2009). We don’t know if this level of scales was present because biological control of armored scales in Mexico is poor or because pesticide use had excluded biological control agents.
We have not found any of the 7 species of exotic Mexican armored scales in California to date.

We have identified 4 species of parasitoids to date (many more samples remain to be run) that are relatively common in California avocado groves. In order of frequency, they are (1) *Signiphora* sp. 1 nr *flavopalliata*, (2) *Signiphora* sp. 2 nr *flavopalliata*, (3) *Plagiomerus diaspidis*, (4) *Aphytis* sp. 1 nr *diaspidis* (nr = near, meaning the identified species is very similar but not the same as that species). In addition, 4 species are relatively rare: *Signiphora* sp. 3 nr *flavopalliata*, *Aphytis* sp. 2 nr *diaspidis*, *Aphytis lignanensis*, and *Plagiomerus* nr *diaspidus*. We also have 4 species with a clear genetic sequence that is different from each of the above 8 species but whose identify is unknown at present (they match no known genetic sequence in GenBank and we do not yet have an adult that can be slide mounted and sent to an expert for taxonomic identification).

What are our future plans for this portion of the project? First, we have recently collected a large number of parasitoids with the assistance of Mr. Reuben Hofshi and Ms. Antonieta Ortiz Cardemil, a visiting scientist from INIA, La Cruz, Chilean Ministry of Agriculture. Ms. Cardemil is rearing out a number of parasitoids to the adult stage and slide mounting them for identification. Second, we have a number of additional specimens to run for genetic analysis. Once we have done this, we plan to initiate 1-2 parasitoid colonies using the most common species present in California. Relatively little is know about the biology of these parasitoids and we want to determine which will readily attack exotic armored scales that might be introduced from Mexico (we can do this safely inside UCR’s Quarantine facility).

**Research with Scale Infested Squash Out-plants.** One problem with our survey for parasitoids of armored scales in California is that biological control of scales is quite strong (this is very good news for the industry). Most fruit contain relatively few live scales and only a fraction of those contain parasitoids. We expected this would be the case and our plan is to more accurately survey for parasitoids using “out-plants”. The concept of out-plants is that we rear scale on butternut squash to the ideal stage for parasitism in the laboratory and place it in the field for perhaps a week to allow parasitoids to parasitize the scale. We then return the squash to the lab and rear out parasitoids to the adult stage. Based on research on both soft and armored scales on citrus, out-plants can be a highly effective means of surveying for natural enemies of scale insects. This research is progressing but it is too early to tell how successful it is going to be.

**SELECTED REFERENCES**


**ACKNOWLEDGMENTS**

We owe a real debt of gratitude to Mr. Reuben Hofshi and the Del Rey Packinghouse for their assistance in providing us with scale infested fruit when they detect such fruit passing across their pack-line. This has very much increased the number of grove sites we have been able to sample for armored scales and their parasitoids. In addition, Reuben and the F.A.R. Insectary in Corona have been very helpful in assisting with field out-plants as described above.