Asian Citrus Psyllid, Huanglongbing, and Biocontrol Efforts in California

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Mark S. Hoddle
Entomology, UC Riverside

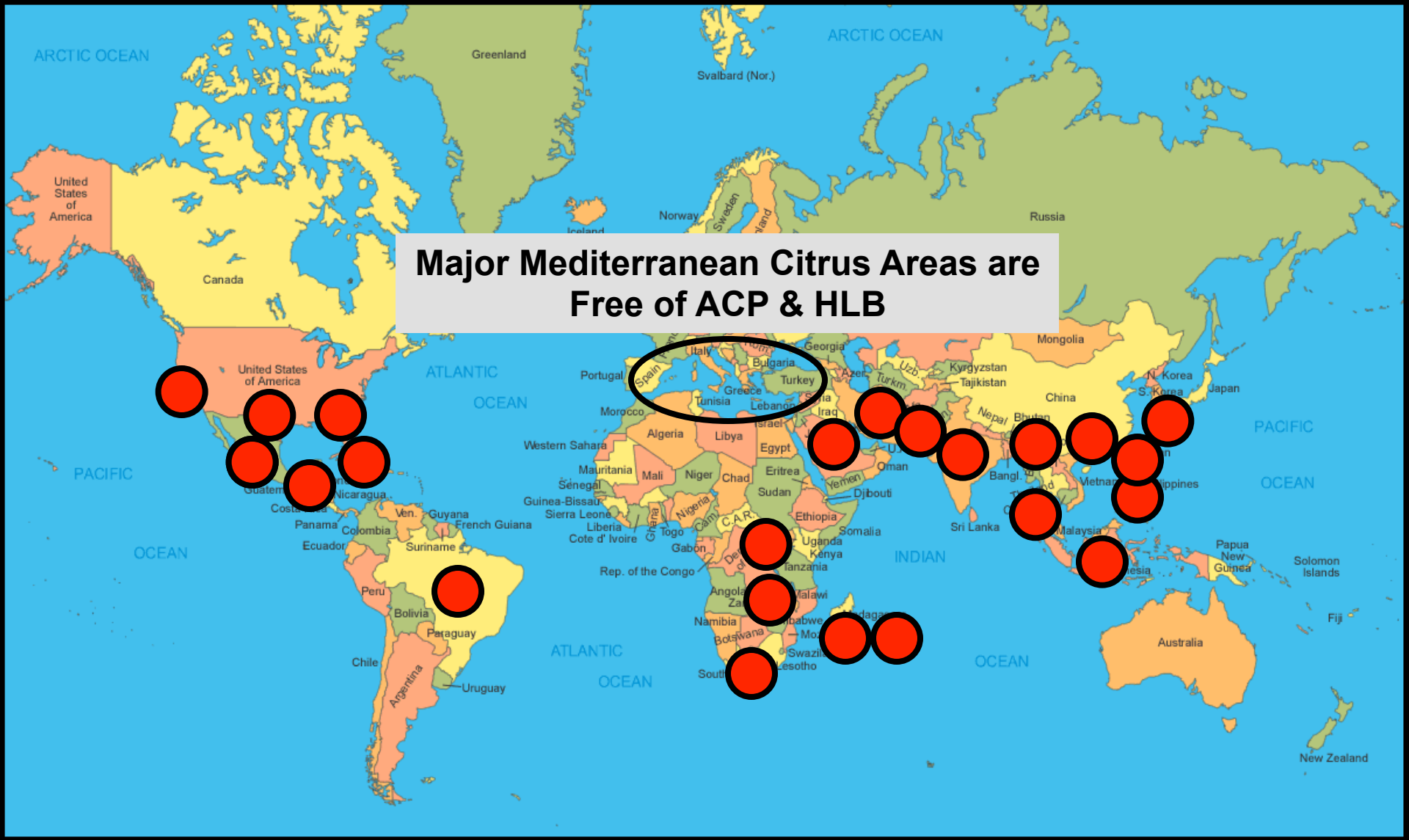
What Will We Talk About?

- ACP & HLB biology & distribution
- The problem in Florida, USA
- The problem in California, USA
- Work in Pakistan and ACP biocontrol in California
- Will citrus go extinct?
- Websites for more information

Asian Citrus Psyllid – *Diaphorina citri* (Kuwayama 1908) (Hemiptera: Psyllidae)

- ACP area of origin the Punjab region of India-Pakistan?
- Widespread in Asia and the Arabian Peninsula
- It is a global citrus pest because it vectors HLB, a lethal citrus pathogen
- Seven species in the genus *Diaphorina*
  - *D. citri, D. amoena, D. auberti, D. communis, D. murrayi, D. punctulata,* & *D. zebrana*
- Partial invasion history
  - Taiwan (1907?)
  - USA
    - Florida (1998)
    - Texas (2001)
    - Alabama (2008)
    - California (2008)
  - Costa Rica (2003)
  - Honduras (1989?)
  - Reunion Island
  - Argentina (1997)
  - Brazil (1942)
  - Caribbean (1998 - Guadeloupe)
  - Mexico (2003)

ACP & HLB Distribution



ACP Life Cycle

Average number eggs laid at 28°C is 748

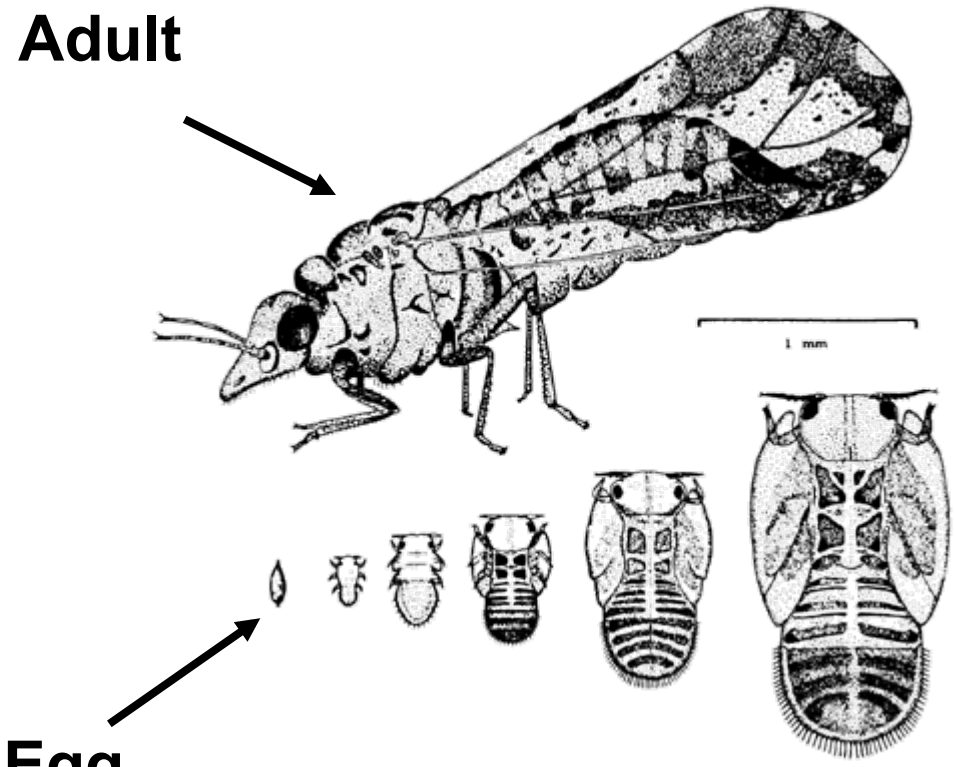
Optimal Temperature for Development is 25-28°C

Eggs hatch in 2–4 days

Five nymphal instars complete development in 11-15 days

Adults can live for several months

The psyllid has an egg stage, 5 wingless intermediate stages called nymphs, and winged adults



Where to Look for Eggs

The Nymphs

4th and 5th instar nymphs are large and can be seen with the naked eye. Honey dew excretions may betray the presence of nymphs

Wing pads on a 5th instar nymph

Honey dew excretions

Feeding Damage

ACP can inject “toxic” saliva into plants as they feed and this can cause growth distortions

High density ACP populations on citrus terminals

Distorted growth from ACP feeding

Host Plants for ACP

- **Citrus and plants in the Rutaceae (Sapindales) are highly preferred. Especially**
  - ***Citropsis* spp.**
  - ***Citrus* spp.**
  - ***Bergera* *(Murraya)* *koenigii***
  - ***Murraya exotica***

Native to the Indian sub-continent

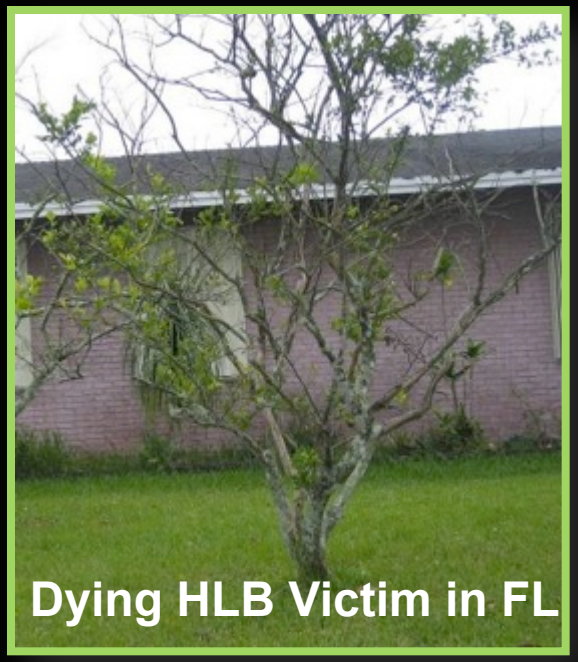
Huanglongbing – Yellow Shoot Disease

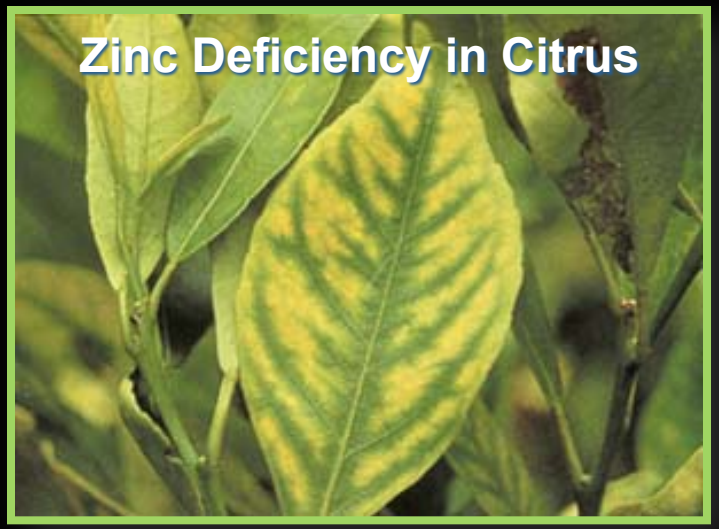
- Causal agents are gram negative phloem-dwelling bacteria
  - *Candidatus* Liberibacter asiaticus
  - *Candidatus* Liberibacter africanus
  - *Candidatus* Liberibacter americanus

Koch's postulates not demonstrated. Can't culture bacteria

- No cure for this disease
  - Disease restricted to citrus & close relatives

Candidatus Liberibacter asiaticus





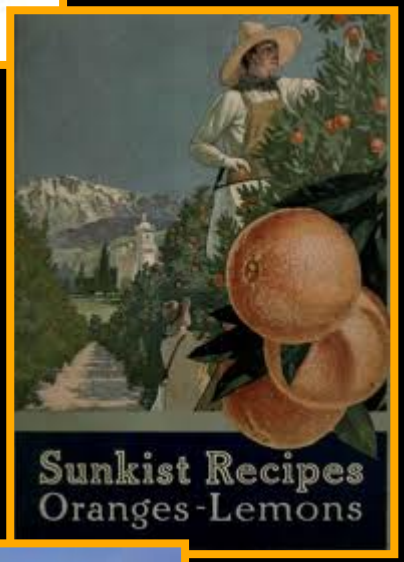
The Florida Citrus Industry

- Florida's citrus industry valued at US$9.3 billion
- ACP first found in 1998
- HLB detected in 2005
  - Now infects all 32 citrus producing counties in FL
- ~621,000 acres of citrus in Florida
  - >60,000 acres of trees destroyed by 2009
- Three pronged management approach
  - Produce new plants in screened facilities
  - Area wide insecticide management of ACP
  - Removal of infected trees

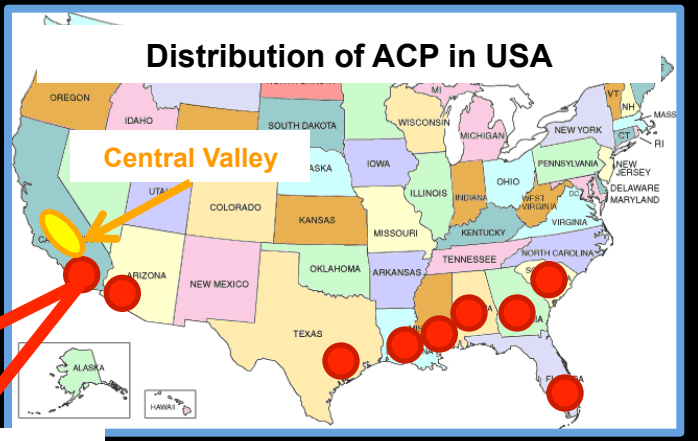
Slowed not eliminated HLB spread

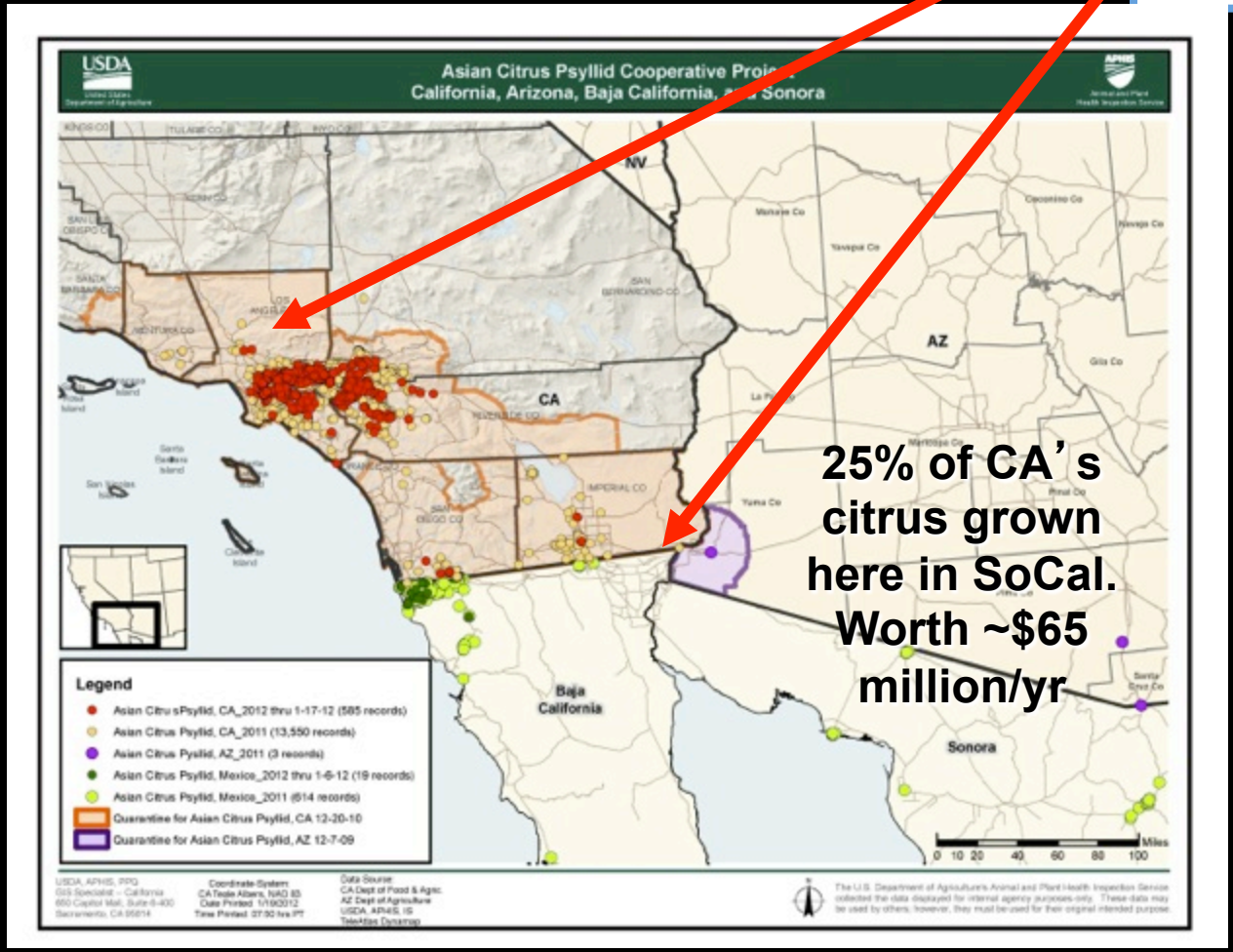
The California Citrus Industry

- CA second largest citrus producer in USA after FL
  - 66% of crop = oranges
    - 75% are navels & 25% valencias
    - 80% are for fresh consumption; 30% exported
    - Worth $580 million/yr
  - lemons = 25% of crop
    - CA grows 87% of US lemons
    - 66% for fresh market
    - Worth $295 million/yr
  - grapefruit = 6%; tangerines = 3%
  - 3.2 million tons of fruit harvested per season from ~250,000 acres
  - All CA citrus is worth ~$1.2 billion/yr



Distribution of ACP in California





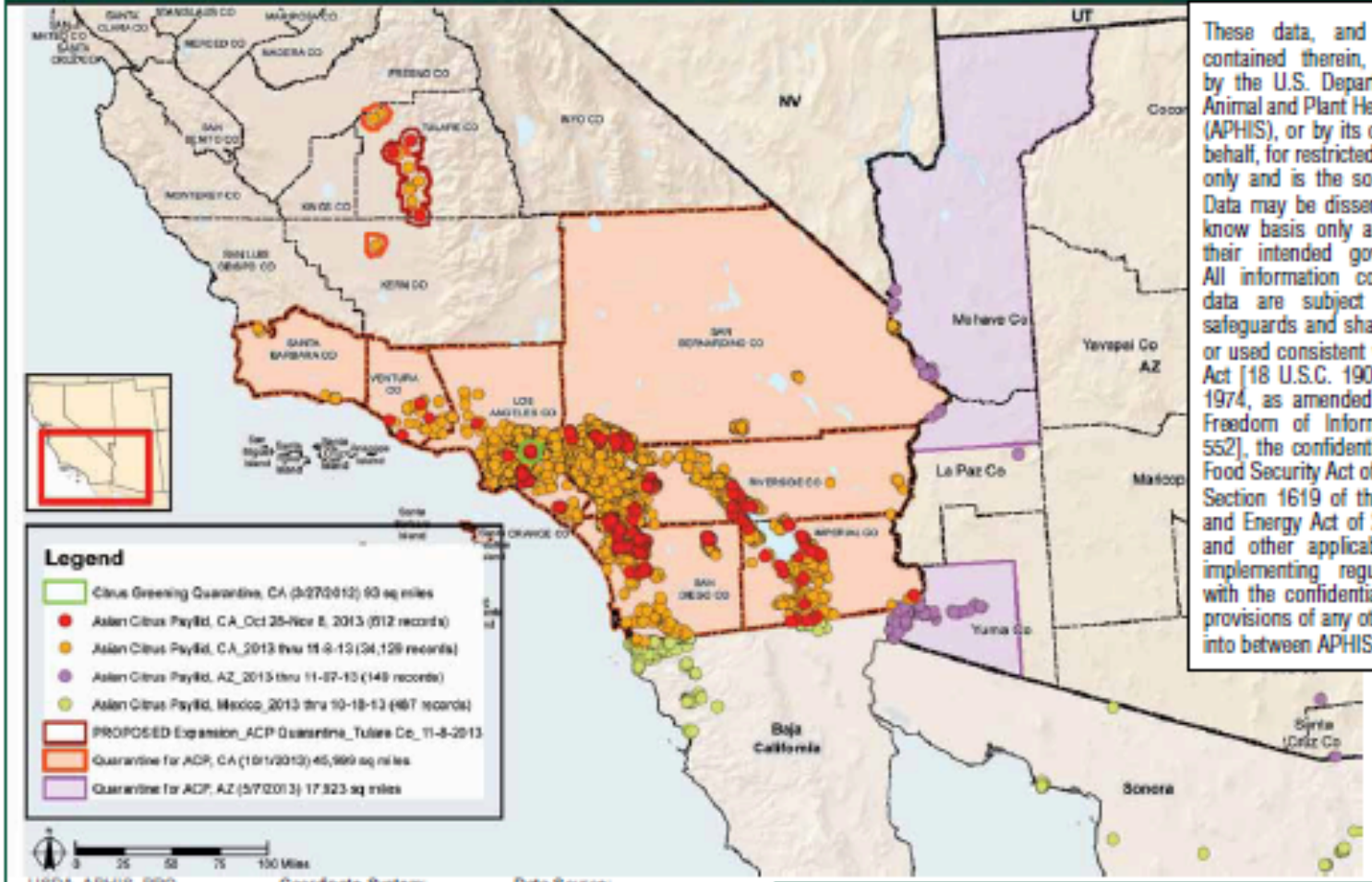
25% of CA's citrus grown here in SoCal. Worth ~$65 million/yr

ACP & HLB Found in:

1) CA (+ HLB)
2) FL (+ HLB)
3) TX (+ HLB)
4) LA (+ HLB)
5) GA (+ HLB)
6) SC (+ HLB)
7) AZ (- HLB)
8) MS (- HLB)
9) AL (- HLB)

USDA United States Department of Agriculture

Asian Citrus Psyllid Cooperative Program
California, Arizona, Baja California, and Sonora



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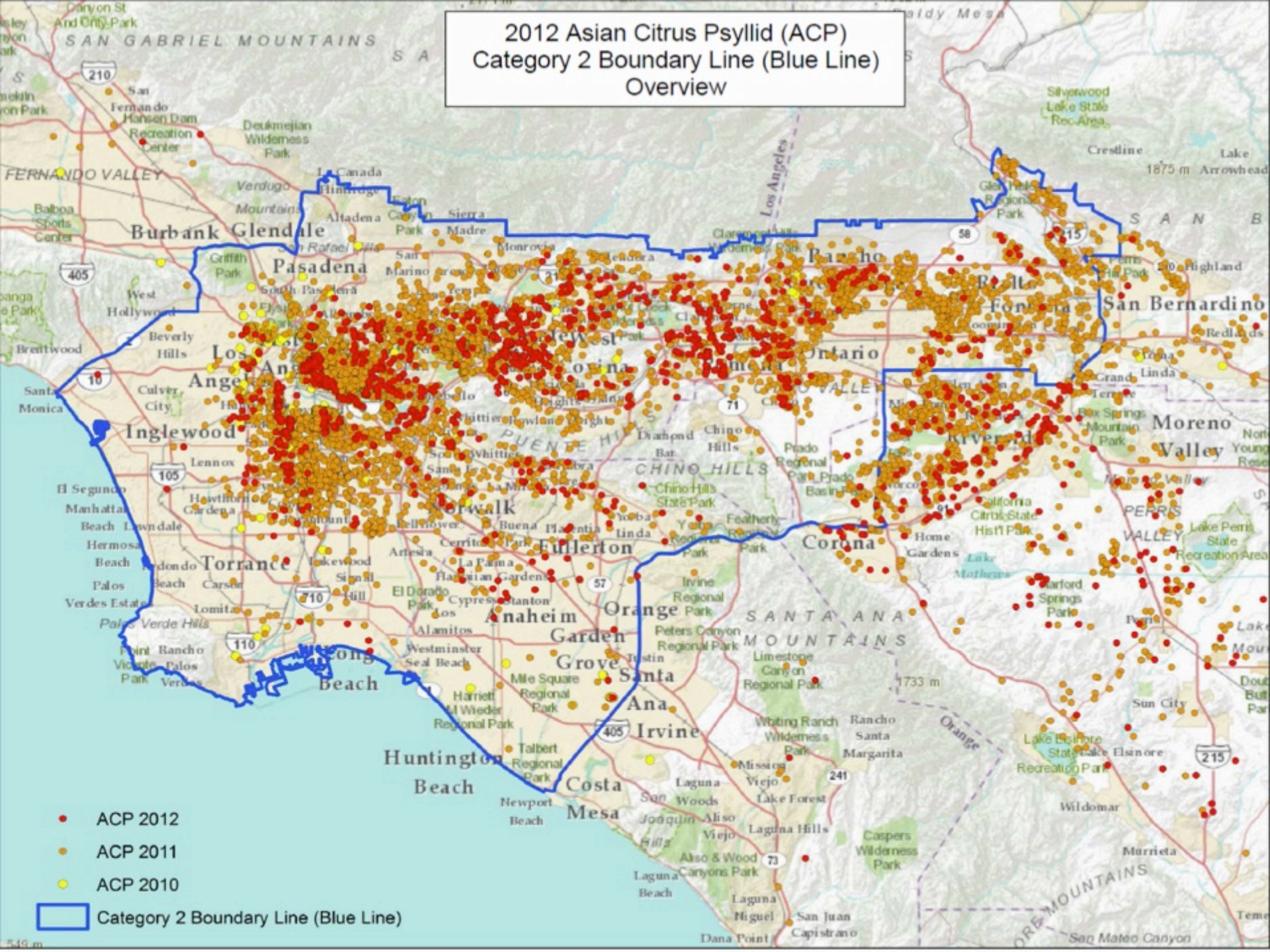
Date Printed: 11/14/2013
Time Printed: 11:15 hrs PT

Data Source:
CA Dept of Food & Agriculture
USDA, APHIS, PPQ
USDA, APHIS, IS
TeleAtlas Dynamap

Map of Asian citrus psyllid detections, ACP quarantines and HLB quarantines in California and neighboring portions of Arizona and Mexico through November 8, 2013.


Shafter
Oildale
Bakersfield
Lamont
Arvin
Tehachapi
California City
Mojave National Preserve
Barstow
Rosamond
Los Padres National Forest
Quartz Hill
Lancaster
Palmdale
Adelanto
Santa Clarita
Hesperia
Apple Valley
Angeles National Forest
San Fernando
San Bernardino National Forest
Yucca Valley
Twentynine Palms
Highland
Fontana
Yucaipa
Desert Hot Springs
Joshua Tree National Park
Pasadena
Pomona
Ontario
Riverside
Moreno Valley
Banning
Brea
Norco
Fullerton
Corona
San Jacinto
Palm Springs
Indio
Inglewood
Torrance
Orange
Santa Ana
Perris
Hemet
La Quinta
Beach
Costa Mesa
Irvine
Lake Elsinore
Wildomar
Blythe
Temecula
San Juan Capistrano
Dana Point
Fallbrook
Valley Center
Escondido
Vista
Oceanside
Ramona
Salton Sea
Encinitas
Solana Beach
Brawley
Imperial
Winter Gardens
San Diego
Calexico
Mexicali
Chula Vista
Tijuana
San Luis Río Colorado
Isla Vista
Oxnard
Thousand Oaks
Moorpark
Simi Valley
Santa Paula
Goleta
Channel Islands

2012 Asian Citrus Psyllid (ACP) Category 2 Boundary Line (Blue Line) Overview



CDFA Spray Program

- ACP infestations are high in LA County
- 2010 Census Data indicates there are 3,425,736 housing units in LA
- 65% (2,216,170) 4 housing units or less – good for citrus
- Crude surveys suggest that 36% of residences have 1^{+} citrus in LA
  - 735,954 residences with citrus
- CDFA treated 46,941 residences by Oct 2011
  - 6% of properties with citrus treated in LA
    - Cost $4,702,435 or $100/residence
      - Resistance development documented in Florida (Tiwari et al. 2011 Pest Management Science 67: 1258-1268)
      - 35x resistance to Imidacloprid; cross resistance to thiamethoxam before it was used; Resistance building to chlorpyrifos, malathion, danitol

Is HLB in California?

- HLB was detected in Hacienda Heights, LA County in April 2012
  - Backyard pummelo with a lemon graft that may have originated from Asia & shared by a group of citrus grafting enthusiasts

The First HLB Positive Tree in CA Prior to Eradication

Is HLB in California?

- It is highly likely other HLB infestations are in CA
  - Plants smuggled into CA from Asia have been intercepted at airports
    - Some plants have been contaminated with ACP and infested with HLB
    - How many infected plants are in people's gardens waiting for ACP to arrive?

Citrus in Nurseries in Quarantine Areas Have Tags

Don’t Move Plants out of Quarantine Areas!

Managing ACP Infested Yard Waste

- Dry material down for ~ 2 weeks before putting it in yard waste bin
- Double bag fresh waste then put it in the trash
- Chip and shred material to dry it out before disposing

Homeowner Treatment Options

- Systemics
  - Imidacloprid ground treatments – Most effective when applied during June-October (good time for root uptake).
    - Bayer Advanced Fruit, Citrus & Vegetables
      Monterey Fruit Tree & Vegetable Systemic Soil Drench

- Foliar treatments
  - Applied by spray to the leaves when psyllids are present. Avoid exposing bees.
    - Sevin (carbaryl)

Management Options

- **Biological Control**
  - Use of natural enemies, in particular parasitoids of great interest for suppressing ACP populations
    - First work on ACP parasitoids conducted by Husain & Nath (1927) in the Punjab of Pakistan
      - Study sites: Sargodha, Lyallpur, and Gujranwala
      - Trees dry up, fruit is insipid, leaves fall to ground (HLB symptoms)
    - Nine species of parasitoid associated with ACP nymphs
      - No adult or egg parasitoids recorded
      - Hyperparasitoids exist
      - 1 species named from this project, *Tamarixia radiata*

Overview of ACP BioControl

- Classical biocontrol of ACP has focused on the use of parasitoids, in particular *Tamarixia radiata* and *Diaphorencyrtus aligarhensis*
- Parasitoids are native to the home range of ACP. *Tamarixia* considered the more effective
  - Introduction of *Tamarixia* into Reunion Island spectacular ACP control. Very good control in Mauritius and Puerto Rico. Oceanic Island effect?
  - Use of *Tamarixia* in Florida has provided mixed results

Tamarixia radiata (Waterston) (Hymenoptera: Eulophidae)

- First described from specimens collected from lemons in Lyallpur, Punjab, 2 Jan 1921
  - Solitary ecto-endoparasitoid
  - Arrhenotokous: 1.8♀ : 1♂
  - At 25°C egg-adult = 24 days
  - Attacks 3rd, 4th, & 5th instar ACP
  - Females live 12-24 days
  - Females lay 166-300 eggs
  - Kills ACP via host feeding too

Adult Female and Male *Tamarixia*

Female *Tamarixia* have clubbed antennae

Male *Tamarixia* have setose or plumose antennae

Tamarixia Stinging ACP

Tamarixia Riding ACP

BioControl of ACP with *Tamarixia* in Florida

- Introduced into Florida in 1999-2001 from Taiwan and South Vietnam
- Established and spread, early surveys indicated just 1-2% parasitism over this period
- Recent evaluations indicate parasitism ~20% ranges 39-56% reaching 100% in some areas depending on time of year
- Is parasitism under estimated in FL?
  - Predators eat parasitized ACP & mummies

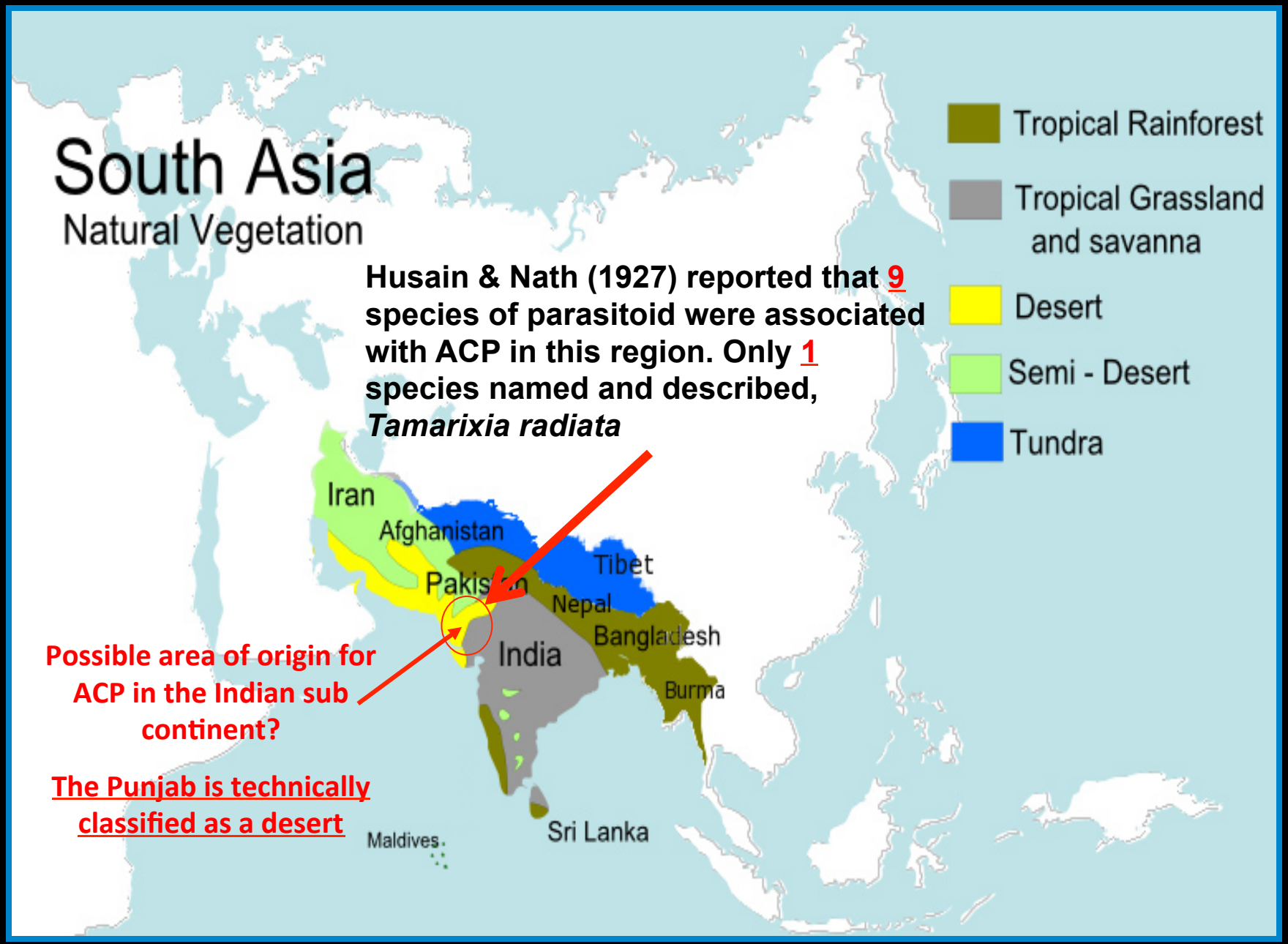
Studies by Qureshi et al., 2009, Qureshi & Stansly 2009

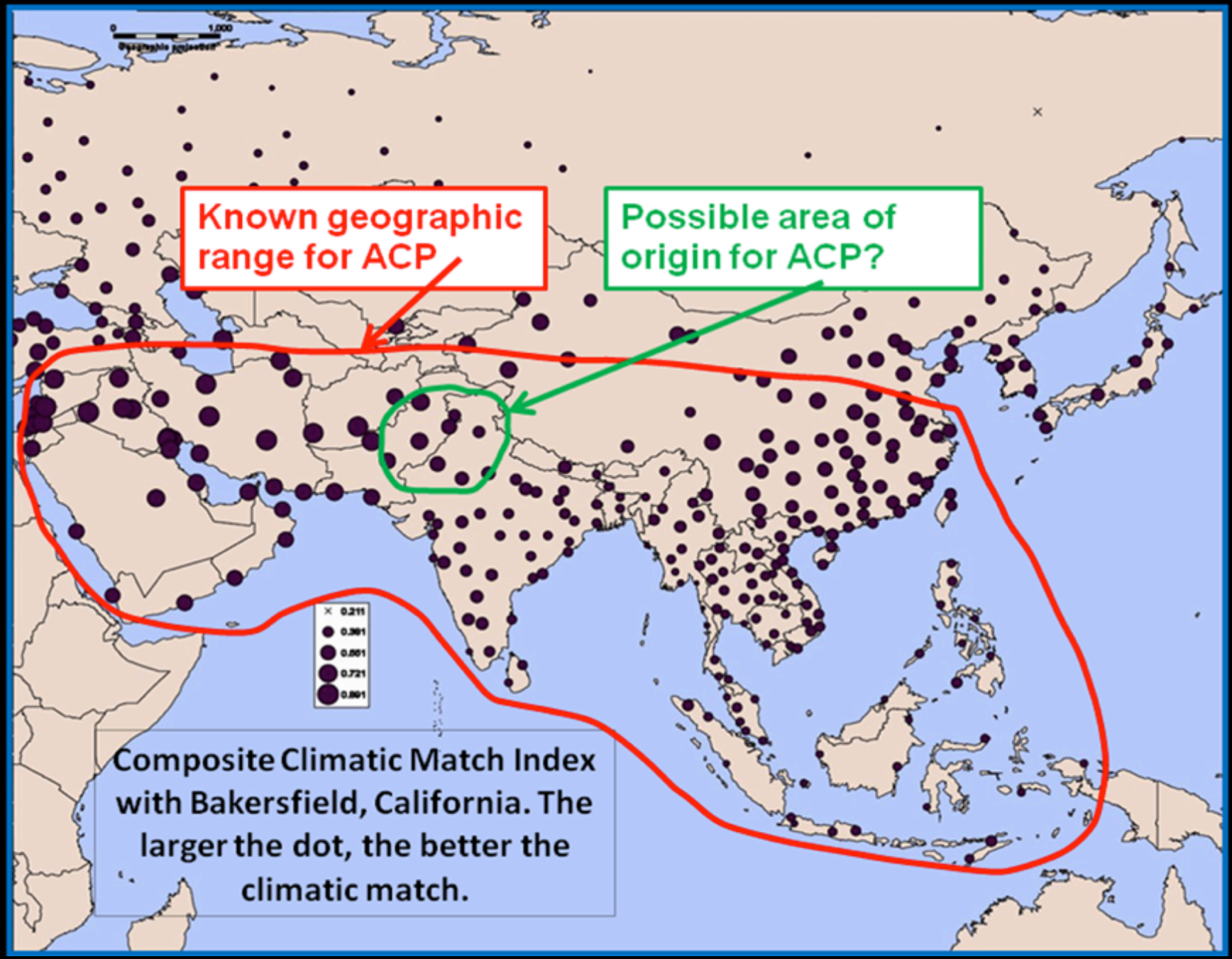
What are the BioControl Options for California?

- CA citrus growers have several options available for biocontrol of ACP
  - Do nothing and see what happens
    - Wait for *Tamarixia* to arrive in CA by accident either from FL or via Mexico
    - Wait for ladybugs to move onto high density ACP populations
    - Spray insecticides
      - Not an option for organic growers or home owners, possible large reservoirs for ACP
  - Import and release ACP parasitoids from native areas with a similar climate to CA

Developing a BioControl Program in CA with *Tamarixia*

- Parasitoids from Punjab of Pakistan are of most interest for establishment in CA because of the very good climatic match to the major citrus growing regions of CA
- Punjab has a ~70% climate match with the Central Valley
  - There are three seasons in the Pakistan Punjab:
    - (1) cool (October to February [similar to Tule Fog Season in Central Valley),
    - (2) hot (March-June), and
    - (3) monsoon (July-September)


South Asia
Natural Vegetation
Tropical Rainforest
Tropical Grassland and savanna
Desert
Semi - Desert
Tundra
Husain & Nath (1927) reported that 9 species of parasitoid were associated with ACP in this region. Only 1 species named and described, *Tamarixia radiata*
Iran
Afghanistan
Pakistan
Tibet
Nepal
Bangladesh
India
Burma
Sri Lanka
Maldives
Possible area of origin for ACP in the Indian sub continent?
The Punjab is technically classified as a desert


Known geographic range for ACP
Possible area of origin for ACP?
0.211
0.361
0.501
0.721
0.861
Composite Climatic Match Index with Bakersfield, California. The larger the dot, the better the climatic match.

Tamarixia Collections in Pakistan

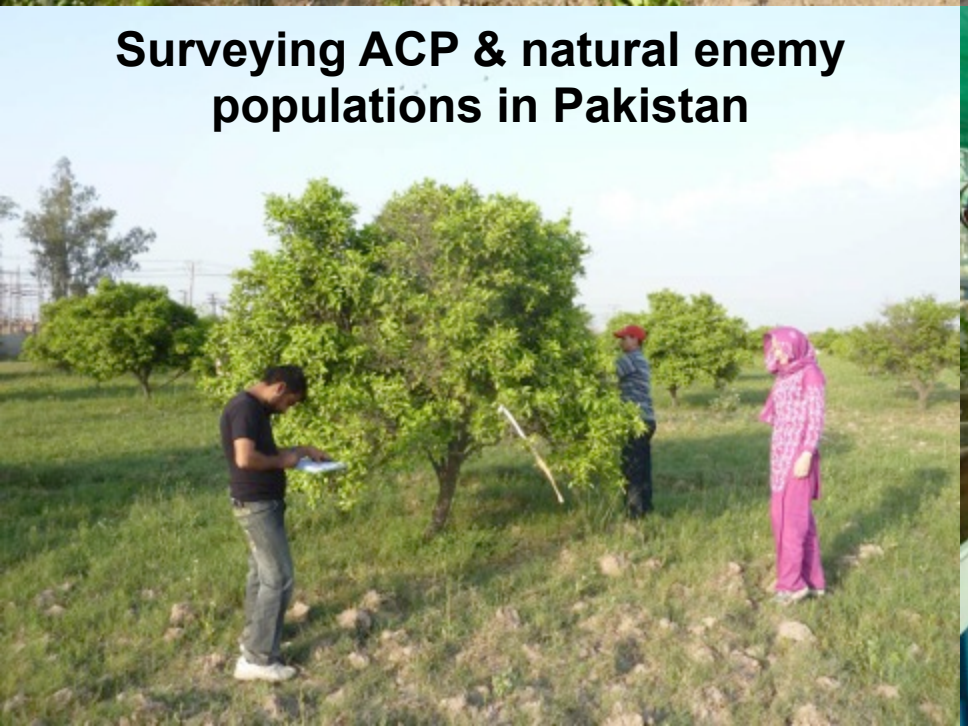
Pakistan Collections

- **September 2010**
  - Reconnaissance completed in Pakistan
  - Demonstrated it was feasible to collect & rear ACP parasitoids
- **March 10 to April 10 2011**
  - Set up long-term replicated phenology studies
  - Collected ~ 200 parasitoids
- **June 4-13 2011**
  - ~400 parasitoids returned to UCR
- **Oct. 23-28 2011**
  - > 1,000 parasitoids returned to UCR
- **June 16-23 2012**
  - > 1,000 parasitoids returned to UCR
- **April 15-22 2013**
  - > 400 parasitoids returned to UCR

A malaise trap to sample for citrus pests and natural enemies

Preparing ACP nymphs collected in the field for parasitoid rearing

Surveying ACP & natural enemy populations in Pakistan



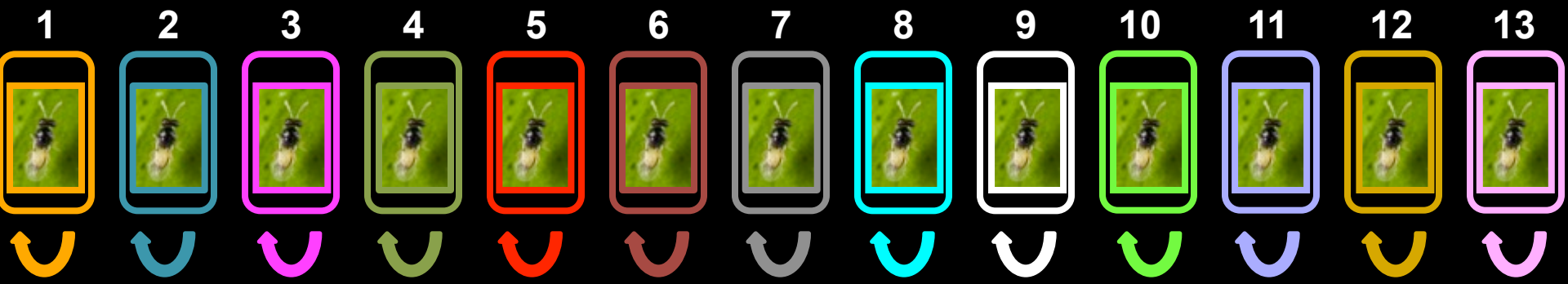
Rearing ACP & natural enemies in greenhouses in Pakistan



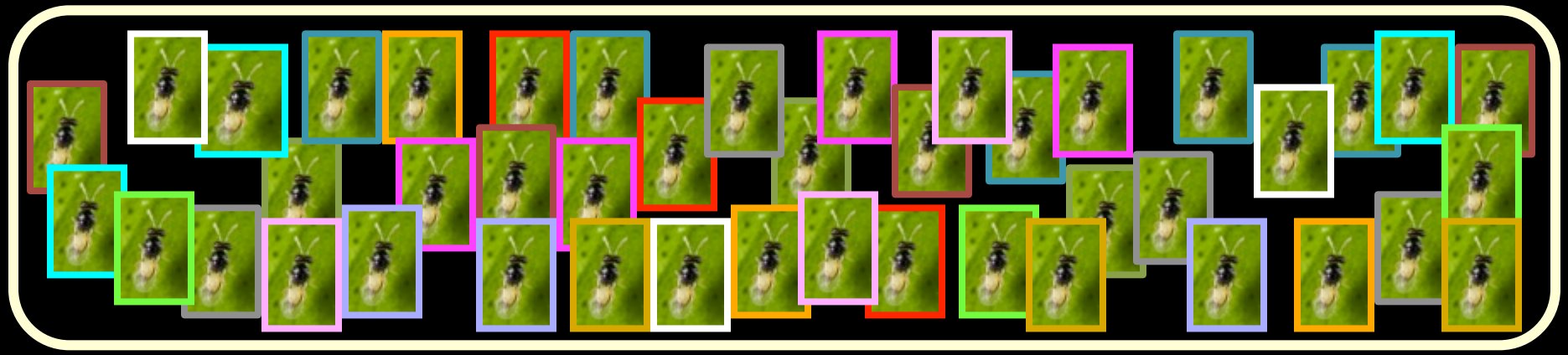

CLING FILM
POI6(a)
4-9-11
LIVE #1
(2)
4-9-11
LIVE #1
(7)
4-9-11

ACP Natural Enemies Collected in Pakistan are Returned to the Insectary & Quarantine Facility at UC Riverside for Safety Testing

Establishment of IsoCage Lines in Quarantine



Iscoage lines added to mongrel cage for crossing to reconstitute genetic variation

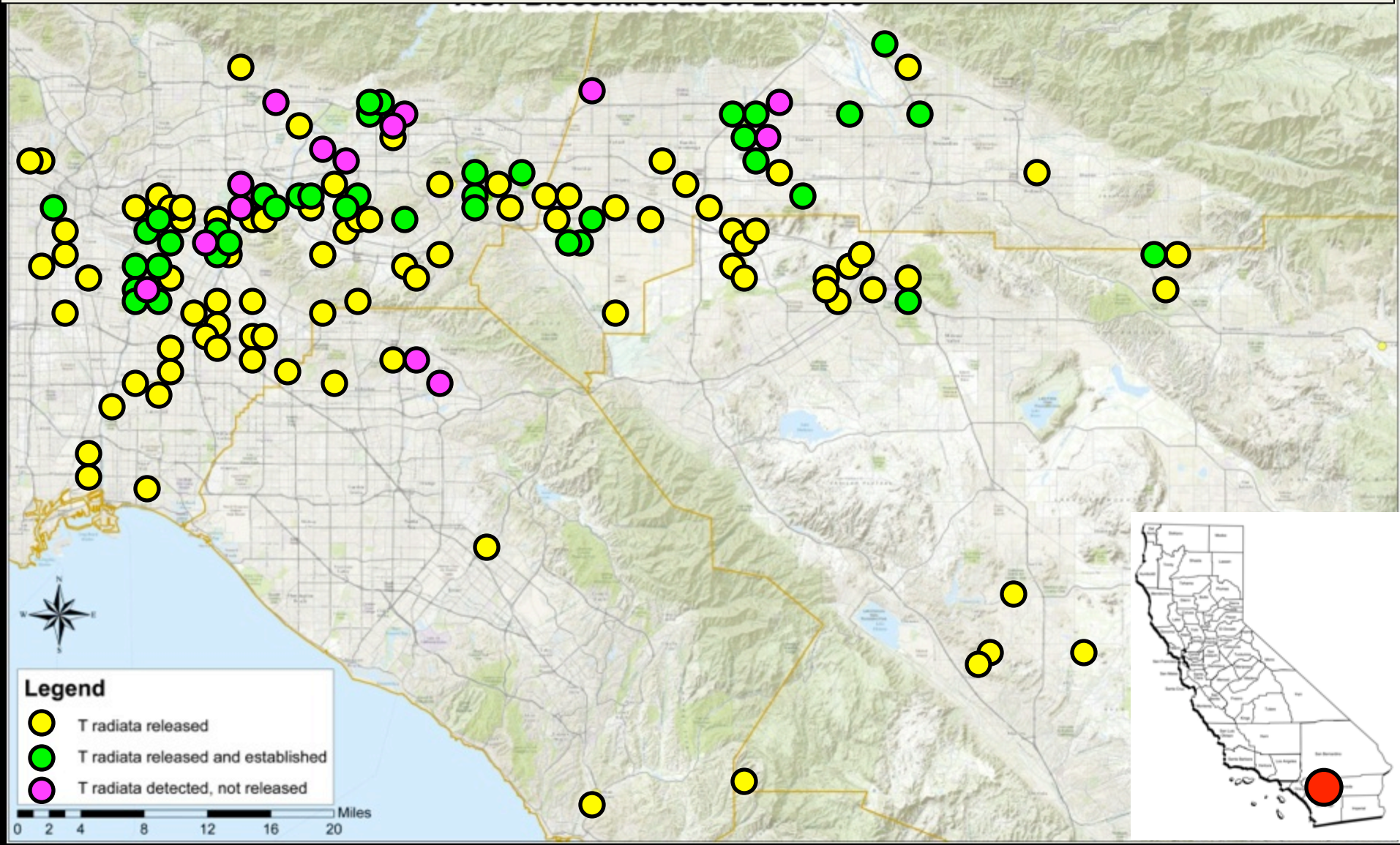


Hybrids released into field

Releasing the Pakistani Parasitoids

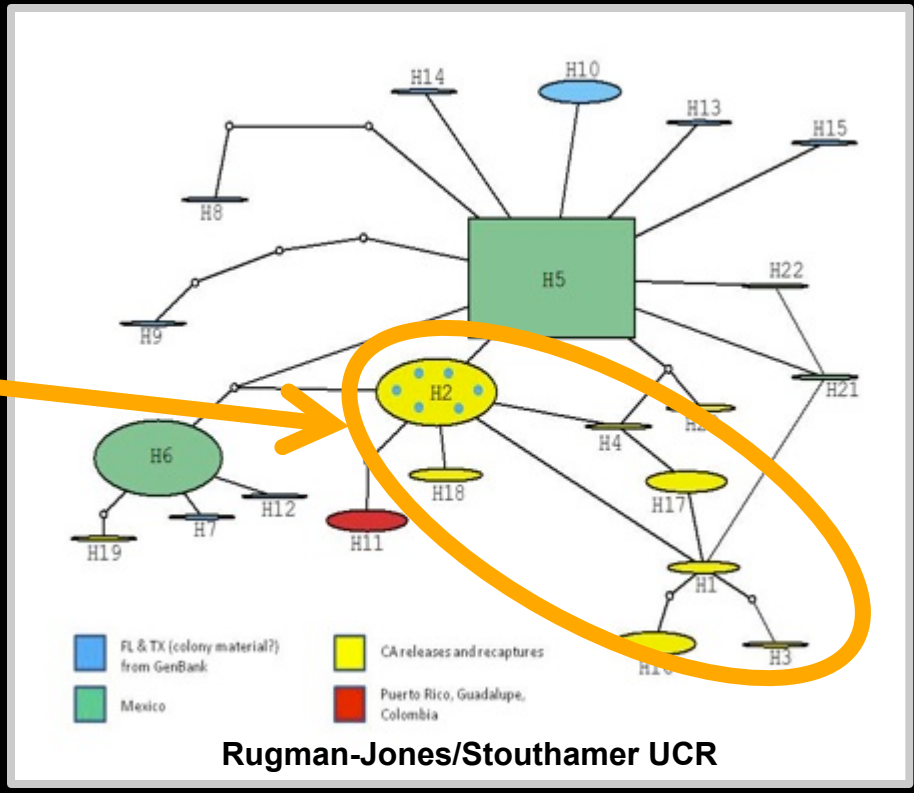
- Safety testing for *Tamarixia* is completed
  - Second parasitoid, *Diaphorencyrtus*, is in the queue for safety testing
- Environment Assessment Report for *Tamarixia* was submitted to APHIS, 6:00pm, 15 Nov 2011
- USDA issued release permit 7 Dec 2011
- *Tamarixia* released at UC Riverside, 20 Dec 2011
  - ~28,000 *Tamarixia* released by Feb 2013
  - Tentative establishment observed at ~25% of 160 release sites
  - Natural spread documented to sites ~ 5-8 miles from release sites
  - No parasitism of ACP observed at non-release sites
    - Is ACP benefiting from natural enemy-free space in CA??

Dec 2013 >280,000 *Tamarixia* released >450 release sites, 350 zip codes, 64 cities, 6 Counties (LA, ORA, SBD, RIV, SD, IMP)

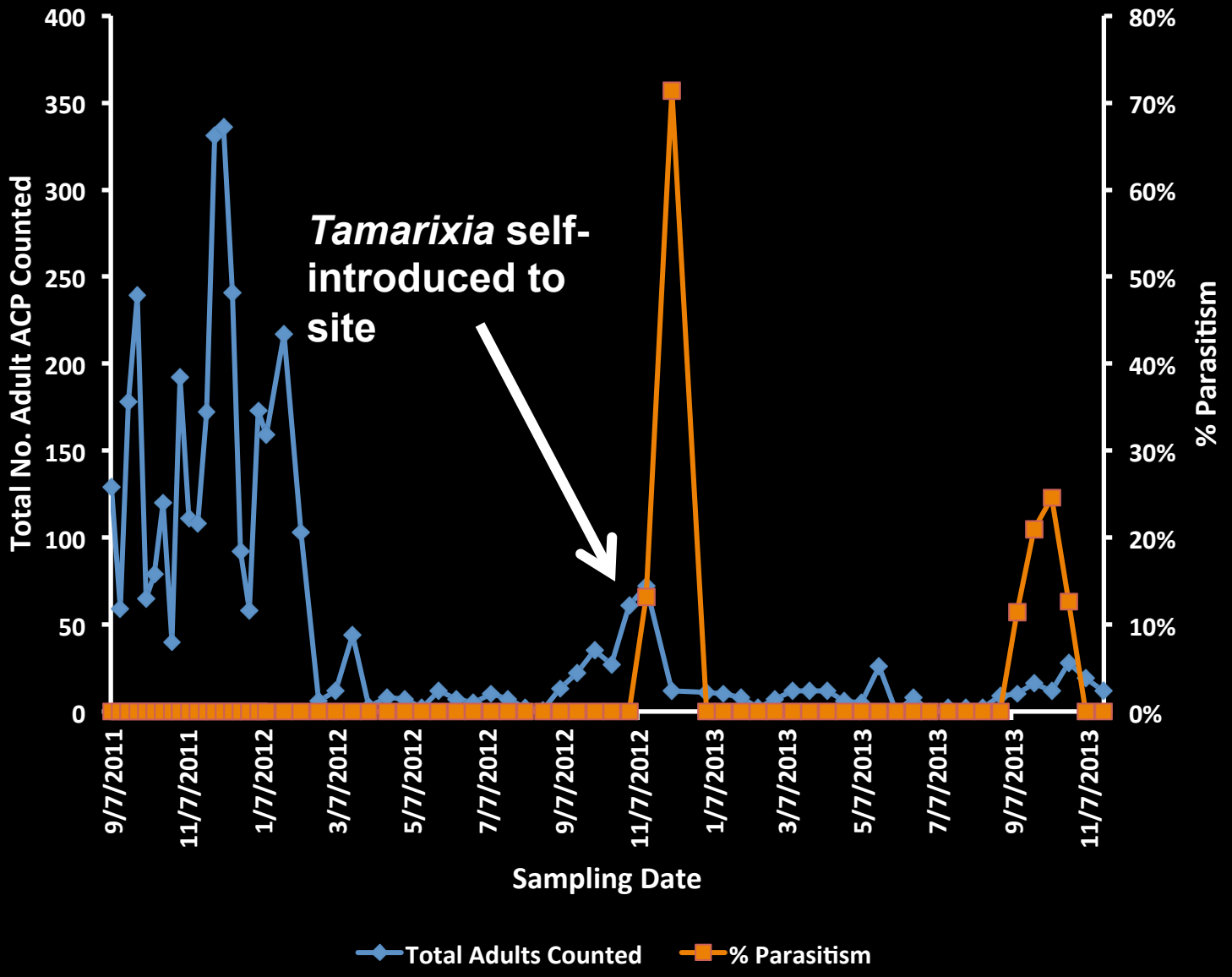


Release Survey Summary

- > 28,000 *Tamarixia* (75% ♀) released by Feb 2013 at > 160 sites in urban areas
  - Establishment likely in 33% of release sites
    - Parasitism found ~ 5-8 miles from some release sites
    - DNA confirms field recovered parasitoids are of Pakistani origin
      - Haplotype networks within Pakistan clade confirm high levels of diversity
    - No detection on non-Pakistani haplotypes



ACP Trends on Limes at Penn Mar, LA County



Ants tending ACP nymphs

ACP mummies from which *Tamarixia* has emerged in Bell Gardens

Tamarixia female foraging on a patch of ACP in Azusa

Tamarixia parasitizing ACP in the field in Los Angeles

A Biocontrol Impediment is Argentine Ant

- Argentine ant is ubiquitous in the urban environment
  - > 90% of properties are infested with this ant
- This ant readily attends ACP colonies
  - >55% of colonies have ants present
  - Ants patrol ACP colonies and harvest dry honeydew to return to the nest
- Ants present ACP parasitism = 12%.
- No ants parasitism = 90%

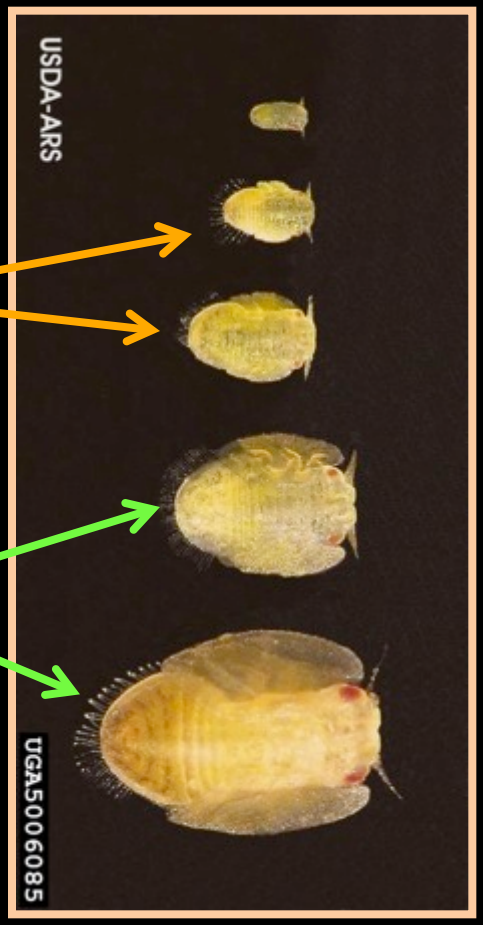
Diaphorencyrtus Updates

- EAR completed and submitted 1 Nov. 2013
- Document was 84 pages in length
- Still under review – was informed that it will likely require a NAPPO review as this natural enemy is not yet established in Nth America despite FL releasing thousands since 1999 with material from Taiwan and Vietnam
- New material from China released over 8/2007 to 10/2009
- No recoveries made in FL
  - Why? – Competition from *Tamarixia*, inbreeding depression, sensitivity to pesticides (Rohrig et al., 2012; Fla Entomol.)

Second ACP Parasitoid: *Diaphorencyrtus* is Waiting in Quarantine for Release

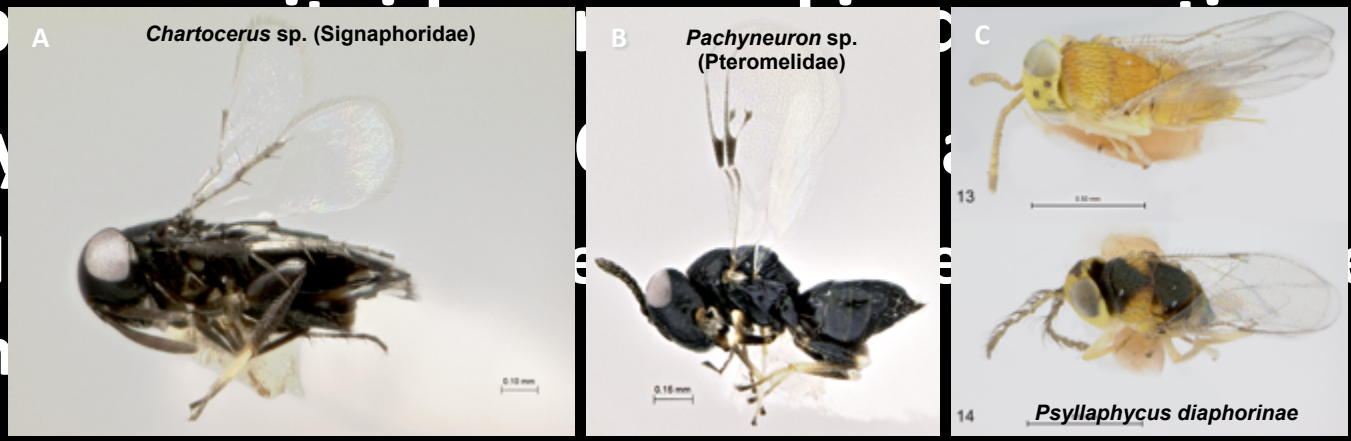
Diaphorencyrtus

Tamarixia



Background

- *Diaphorencyrtus* is heavily attacked by hyperparasitoids in its home range
- Hyp
- May
  - N
    in



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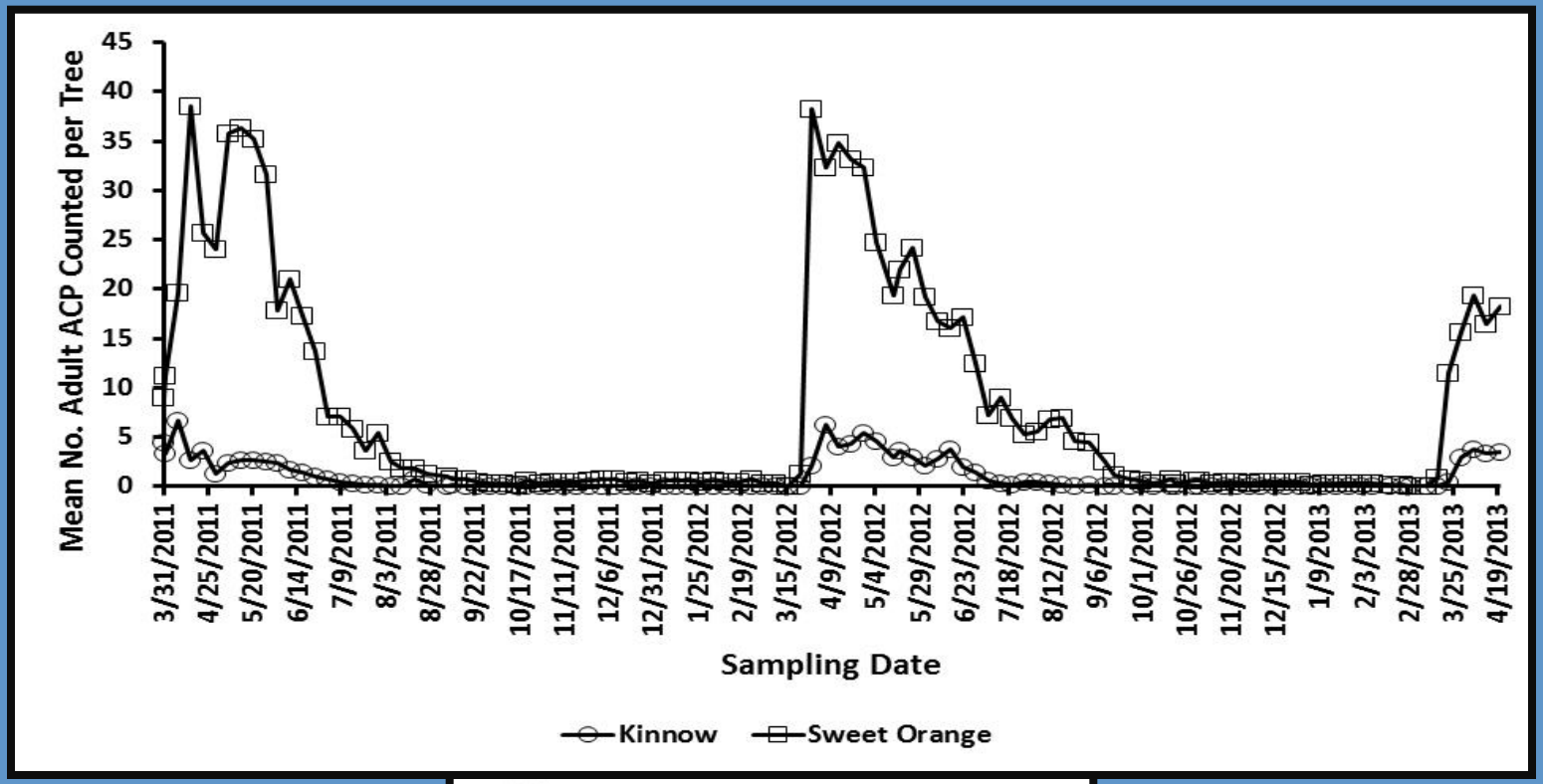
Who Pays for this Program?

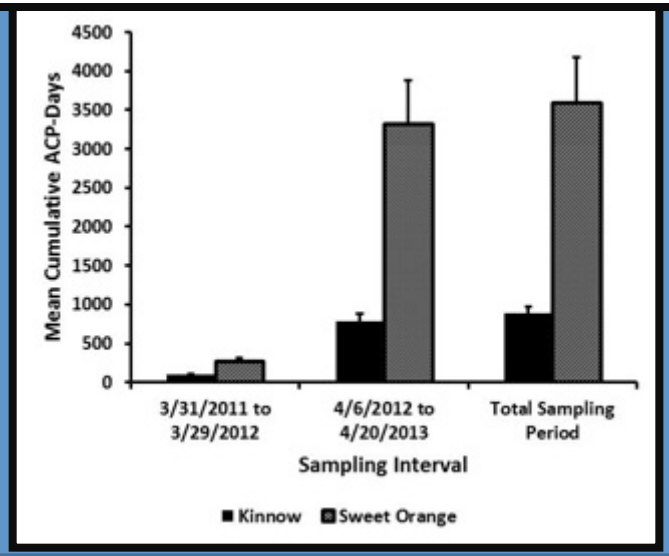
- CA growers have an organization
  - Citrus Research Board (CRB)
  - Growers tax themselves
    - $0.07 (US) per 40lb box of fruit
    - ~$3+ million (US) in research funds
- California Citrus Pest and Disease Prevention Committee
  - $$ from CRB for ACP control programs
- USDA (Federal) & CDFA (State) provide some $$ support
- Univ. of CA provides expertise

What is the Future for Citrus?

- Commercial citrus production will not go extinct
- Kinnow is still grown in Pakistan
  - 70 yrs after introduction = 80% of citrus production
    - Sweet oranges ~15% of production
    - Lemons, limes, etc. very rare
- New varieties of citrus will be developed
- Genetic engineering may be needed
- Multiple management tactics needed

ACP Population Trends on Kinnow and Sweet Orange in Pakistan





Mandarin from CA Planted in Multan, Pakistan

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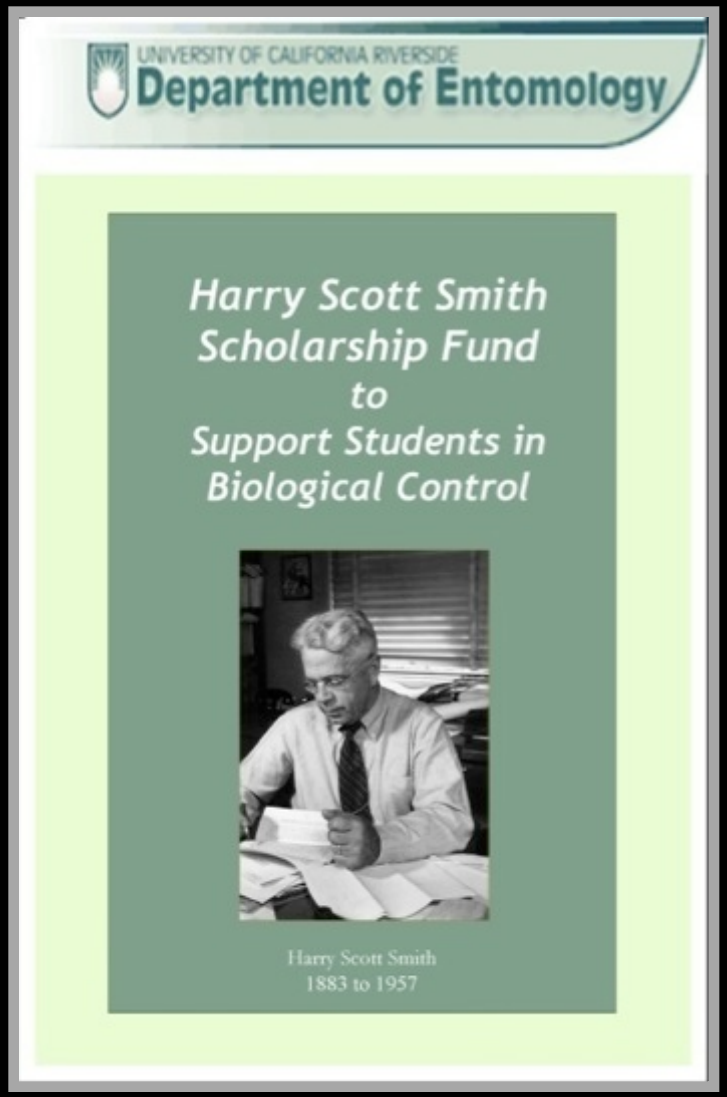
- **Cooperators:** Colleagues at UAF, Pakistan, Raju Pandey, Paul Rugman-Jones, Anna Soper & Richard Stouthamer (all UCR), Kris Godfrey (CDFA/UCD), Mike Pitcairn (CDFA)

Please Support Biocontrol Students at UC Riverside



www.CaliforniaCitrusThreat.org

This web site, funded by the Citrus Research Board, provides users with basic information about ACP, HLB, and how to respond

Follow the action on Facebook And Twitter

¿Se quedará California sin cítricos?

Esto podría suceder si el psílido asiático de los cítricos y la enfermedad que transmite se establece en el estado.

Debemos detenerlo – antes de que sea demasiado tarde.

La peligrosa plaga: el psílido asiático de los cítricos

- Un insecto diminuto (3-4 mm), del tamaño de un áfido.
- Se alimenta de las hojas y tallos de los cítricos.
- Es portador de la enfermedad Huanglongbing (HLB) la cual mata las plantas. También se le conoce como el enverdecimiento de los cítricos.
- Este insecto ya se ha encontrado en el Sur de California.
- Representa una seria amenaza para la producción y cultivo de cítricos en California.

La enfermedad: Huanglongbing (HLB)

- Hace que las hojas se tornen de un color amarillento con moteado. (ver foto a la izquierda)
- Produce frutos amargos, incomibles y deformes.
- Daña la apariencia y reduce el valor de los árboles de cítricos.
- Es mortal para los árboles de cítricos.

La solución: todos jugamos un papel importante

- La detección y eliminación del psílido es la primera línea de defensa contra la enfermedad.
- Es ilegal traer árboles de cítricos a California provenientes de otros estados o países, porque podrían estar infectados con HLB. Asegúrese de plantar sólo árboles de cítricos cultivados en California y que hayan sido certificados como libres de enfermedades.
- Inspeccione sus árboles con frecuencia en busca de señales del insecto o de la enfermedad.
- Si sospecha que sus árboles tienen el psílido asiático de los cítricos, ¡actúe de inmediato! Llame a la línea directa de CDFA al **800.491.1899** o comuníquese con el Comisionado de Agricultura de su condado. ¡No pierda un minuto para hacerlo!

Para conocer más acerca del psílido asiático de los cítricos y el HLB, visite el sitio

PeligranCitricosEnCalifornia.org

En este sitio se pueden descargar materiales impresos en inglés, español, chino y otros idiomas.

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More Information on ACP and the Biocontrol Program

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