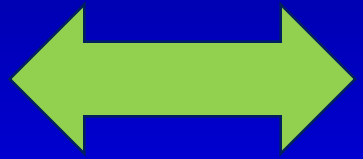
The 2013 Outbreak of *Beet curly top virus* in tomato and other crops: What we know and what we don't know



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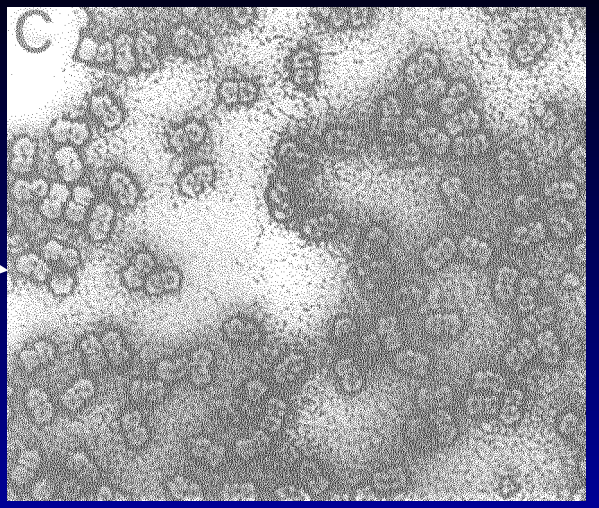
North San Joaquin Valley Processing Tomato Meeting and The California Tomato Growers Association (CTGA) Annual Meeting: January 27, 2014

Plant Viruses

- **Parasitic genetic elements** (RNA or DNA) covered by a protective protein shell
- Most important pathogen of animals (HIV, influenza); **second most important pathogen of plants**
- Viruses **take over the cellular machinery** of the plant and spread throughout the infected plant
- This results in the **development of various types of disease symptoms**
- **Plant-to-plant spread** of viruses most commonly occurs via **insects** (also via seed, nematodes, etc.)
- Plant viruses can be very **difficult to diagnose and control**



Plant virus particles (virions)

Plant virus symptoms

Symptoms of virus infection

- **Symptoms vary considerably** depending on the virus/host combination
- Most common symptom is **stunted growth**
- Most conspicuous symptom is **mosaic or mottling** of leaves
- Other symptoms include **distorted growth** and **crumpling, curling, necrosis, ringspots, and yellowing** of leaves

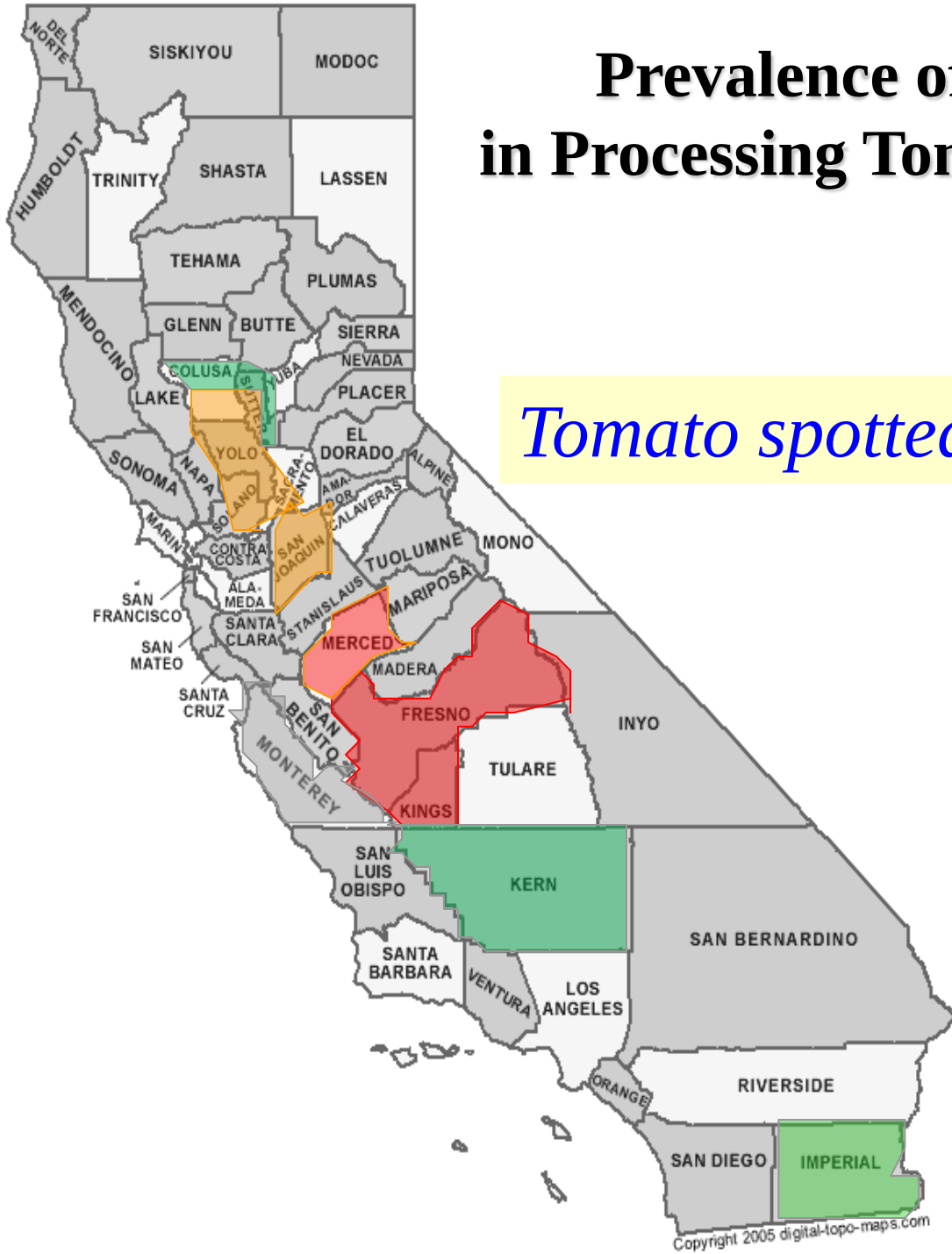
Some insect-transmitted viruses affecting tomatoes in California

- ***Beet curly top virus*** **(BCTV)** — **Leafhopper-transmitted**
- ***Alfalfa mosaic virus*** **(AMV)**
- ***Cucumber mosaic virus*** **(CMV)**
- ***Tobacco etch virus*** **(TEV)**
  Potato virus Y **(PVY)**

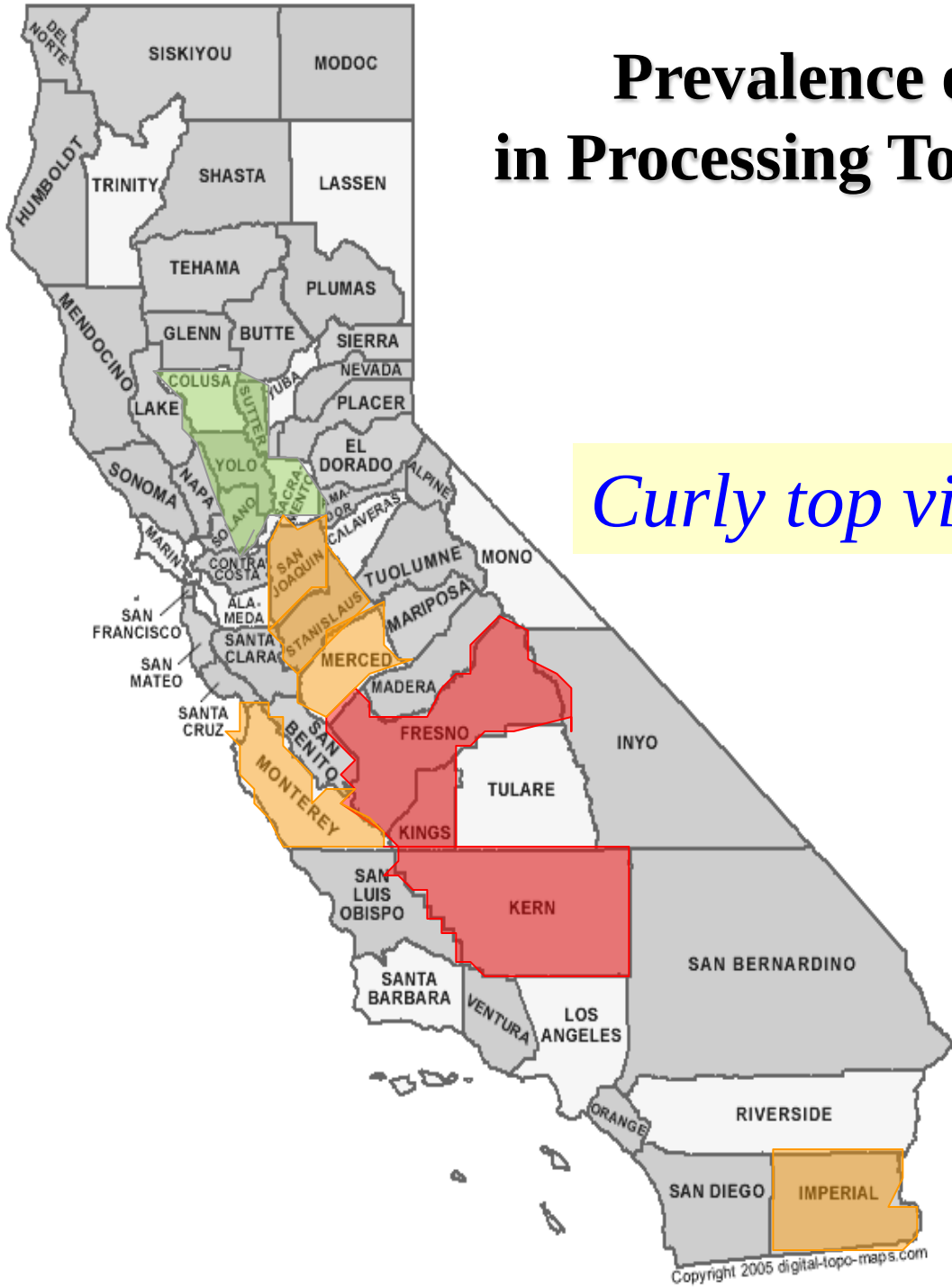
  Aphid-transmitted
- ***Tomato spotted wilt virus*** **(TSWV)** — **Thrips-transmitted**
- **Tomato necrotic spot virus (ToNSV)** — **Thrips-associated**
- ***Tomato yellow leaf curl virus*** **(TYLCV)** — **Whitefly-transmitted**

Prevalence of Virus Diseases in Processing Tomatoes of California

Tomato spotted wilt virus (TSWV)

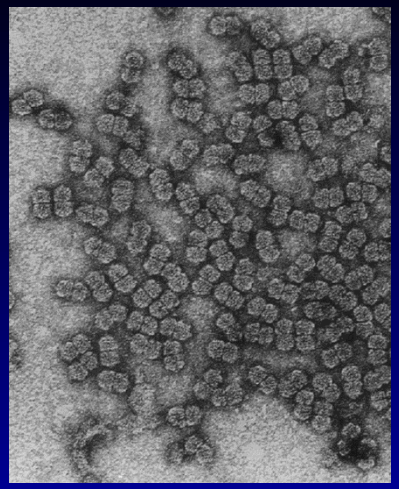


Prevalence of Virus Diseases in Processing Tomatoes of California



Curly top virus(es) (CTV)

Beet curly top virus (BCTV) belongs to the family *Geminiviridae*, genus *Curtovirus*



- All geminiviruses have a circular ssDNA genome contained in twinned virus particles
- Some are transmitted by whiteflies (begomoviruses) whereas others are transmitted by leafhoppers (curtoviruses and mastreviruses)
- Curly top of tomato in California is caused by two curtoviruses:
  Beet mild curly top virus (BMCTV) and
  Beet severe curly top virus (BSCTV)
- The symptoms caused by these viruses in tomato are similar and they are often present in mixed infections in plants and leafhoppers

Curly Top Disease

- Disease of vegetable and field crops (beans, peppers, sugar beet and tomato)
- Introduced into the Western United States in the early 1900's
- Historically caused losses to sugar beet production in western states
- Became less of a problem with the development of resistant varieties and reduced sugar beet production
- Very destructive to tomatoes
- Remains a disease that has the potential to cause substantial losses, but only in certain years

Curly top symptoms: Tomato

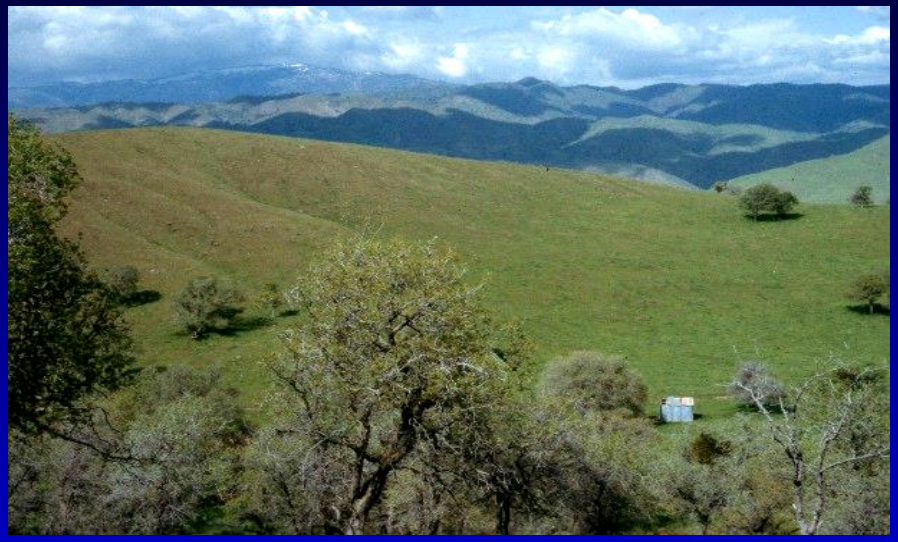
- In tomato, plants show stunted growth and upcurled leaves with dull green-yellow color and purpling of the veins
- Plants infected at a young age may die
- Plants infected later are stunted with yellow upcurled leaves with purple veins
- No necrosis in leaves or fruits
- Fruits are small and ripen prematurely
- Early in disease development, curly top symptoms can be confused with tomato spotted wilt

Vector: Beet leafhopper (*Circulifer tenellus*)

- Curly top viruses are only transmitted by the beet leafhopper, *Circulifer tenellus*, not mechanically or by seed
- Transmission begins early in the season as leafhoppers migrate from the foothills to the agricultural valleys, but also occurs during the growing season

- Curly top viruses are transmitted persistently (no replication in the leafhopper) and are acquired in transmitted in minutes-hours
- Tomato, pepper, lettuce and cucurbits are not preferred hosts
- Preferred hosts are sugar beets and members of sugar beet family
- Can be 3-5 generations in California

Curly Top Disease Cycle



Spring: adult leafhoppers migration

Multiple generations on the valley floor

Fall: adult leafhoppers migrate for overwintering in the foothills

Curly top management

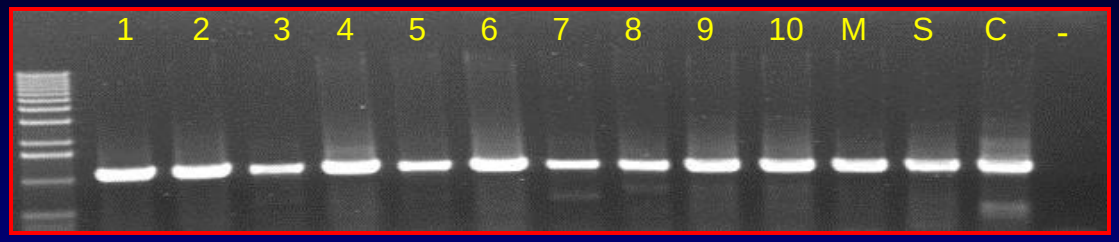
- Curly top is a sporadic and unpredictable disease
- CDFA Curly Top Control Program (CTVCB) targets the vector by insecticide sprays based on monitoring leafhopper populations
- Cultural practices can help, such as not planting next to foothills or heavy plant populations
- There are no commercially available curly top-resistant tomato varieties

New Detection Tools for Curly Top Virus Offer an Opportunity for Improved Understanding of the Disease and Management Strategies

- PCR detection in the plant
  - -rapid detection
  - -ID viruses involved
  - -ID host plants
- PCR detection in the beet leafhopper vector
  - -potential predictor of curly top
  - -target areas for spraying

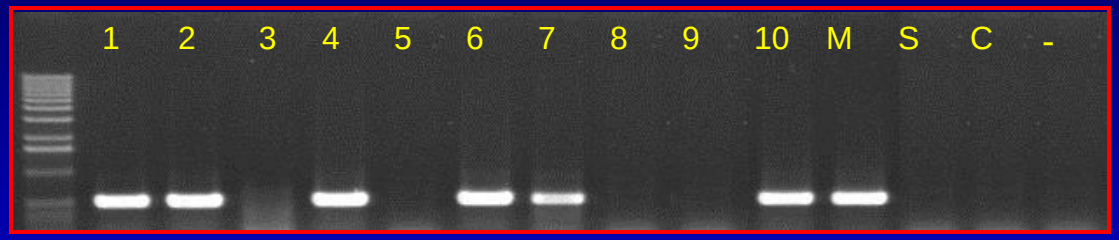
PCR is currently the best method for detection of curly top viruses

General CTV primers



1.1 kb

BMCTV



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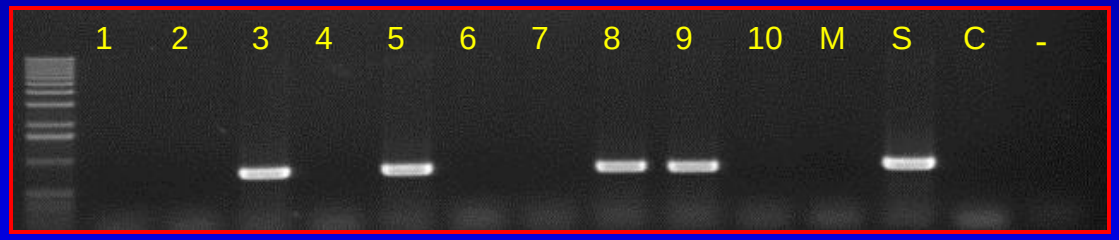
BSCTV



0.7 kb

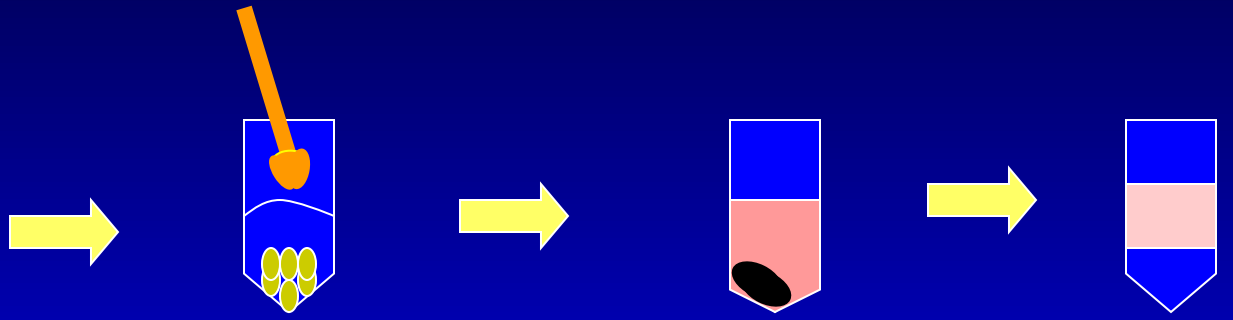
BCTV

0.9 kb

Lanes 1-6 were plant samples; lanes 7-10 were leafhopper samples; lane M was BMCTV positive; lane S was BSCTV positive; lane C was BCTV positive; lane"-" was negative control.

PCR Detection of CTVs in beet leafhoppers over time and space

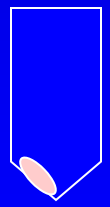
Monthly leafhopper collections from CDFA CTVCP personnel



Add 300ul STE buffer and grind

Spin 5' at 13,000 rpm

Phenol/Chloroform extraction twice

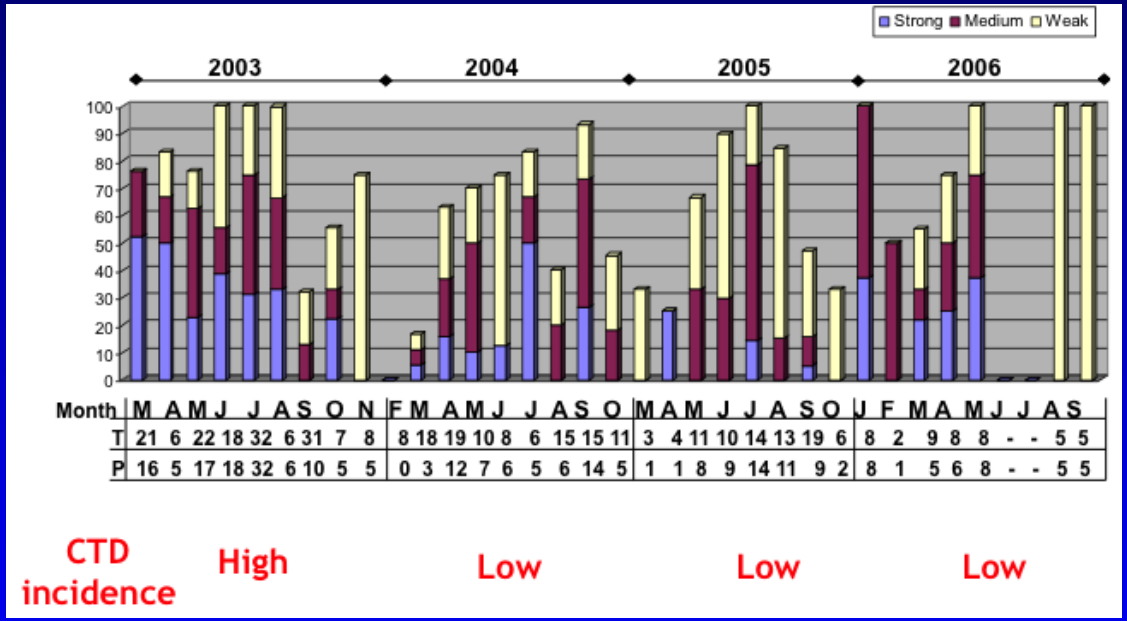


Precipitation of nucleic acid

PCR reaction

Curly Top Outbreaks Correlated with High Populations of Virus-Carrying Leafhoppers Early in the Growing Season

- Using **new molecular tools** for curly top virus and **leafhoppers** provided by the Curly Top Virus Control Board (CTVCB) a study was conducted to **ID factors associated with disease outbreaks**



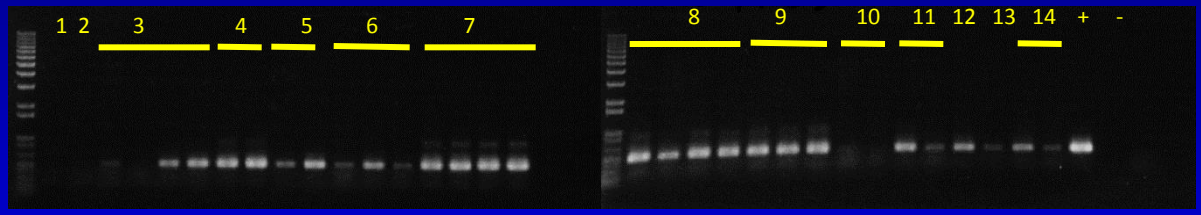
- The highest levels of curly top in tomato were correlated with **high populations of virus-carrying leafhoppers early in the growing season (i.e., February-April)**

Curly Top Outbreak of 2013

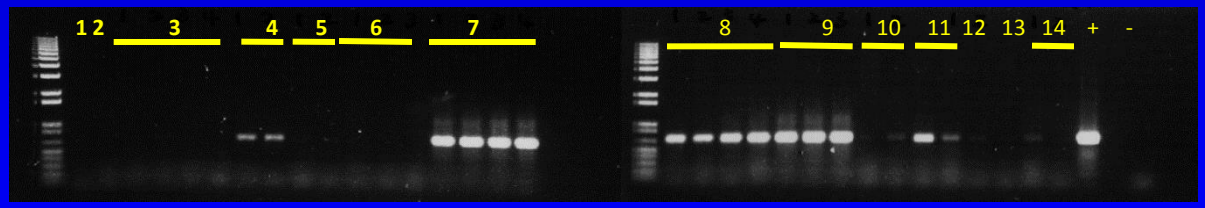
- In 2013, beet leafhopper populations detected in the foothills by the CDFA CTVCB were approx. 5X higher than normal

- High levels of BMCTV and BSCTV were detected in leafhopper samples sent to our laboratory in March and April

Detection of curly top viruses in leafhoppers collected by the CDFA CTVCB in 2013



BMCTV



BSCTV

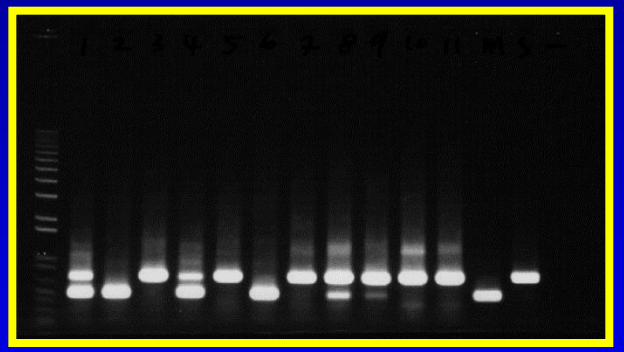
Curly Top Outbreak of 2013

- **Tomatoes with curly top symptoms** started to be received for testing in late March and **most were positive for curly top virus**

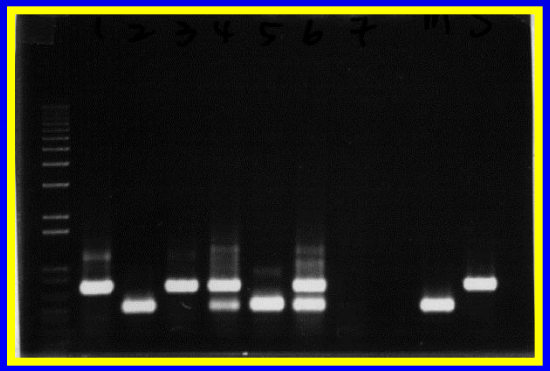
- High **incidences of curly top** developed in many fields and losses were highest in Fresno and Kern

- Curly top affected tomato fields were found far **beyond the western foothills and also in San Joaquin County**

Tomato field with 90% curly top in Fresno Co.



Samples from Kern Co. 4/23/2013



Samples from Fresno Co. 4/30/2013

Curly Top Outbreak of 2013

- **Curly top was also detected in other crops, including cucurbits, which normally do not have the disease**

- **New strains of curly top were associated with the 2013 outbreak**

Cantaloupe field in Fresno Co. with severe curly top

Honeydew melon plant with curly top

Canteloupe plant with curly top

Why was curly top so severe in 2013?

- Favorable conditions for the **beet leafhoppers**
- Favorable conditions for the **hosts of the virus** in the foothills or the valley (in 2012 growing season before migration)
- **Changes in leafhopper behavior**, such as populations remaining on the valley floor
- **New more virulent strains of BCTV** that have a wider host range or are transmitted more efficiently

A need for improved understanding and management of curly top virus

-The 2013 outbreak may indicate a change in some aspect of the disease triangle

-The spray program alone was not able to manage the disease in 2013

-There are increasing limitations on the spray program

-A comprehensive research project to address these questions has been initiated with the goal of applying new approaches and technologies for the development of an effective IPM program for curly top

Host: over 300 species

Environment

Pathogen:

✧ more diverse than we thought

This project brings together a diverse and integrated research team

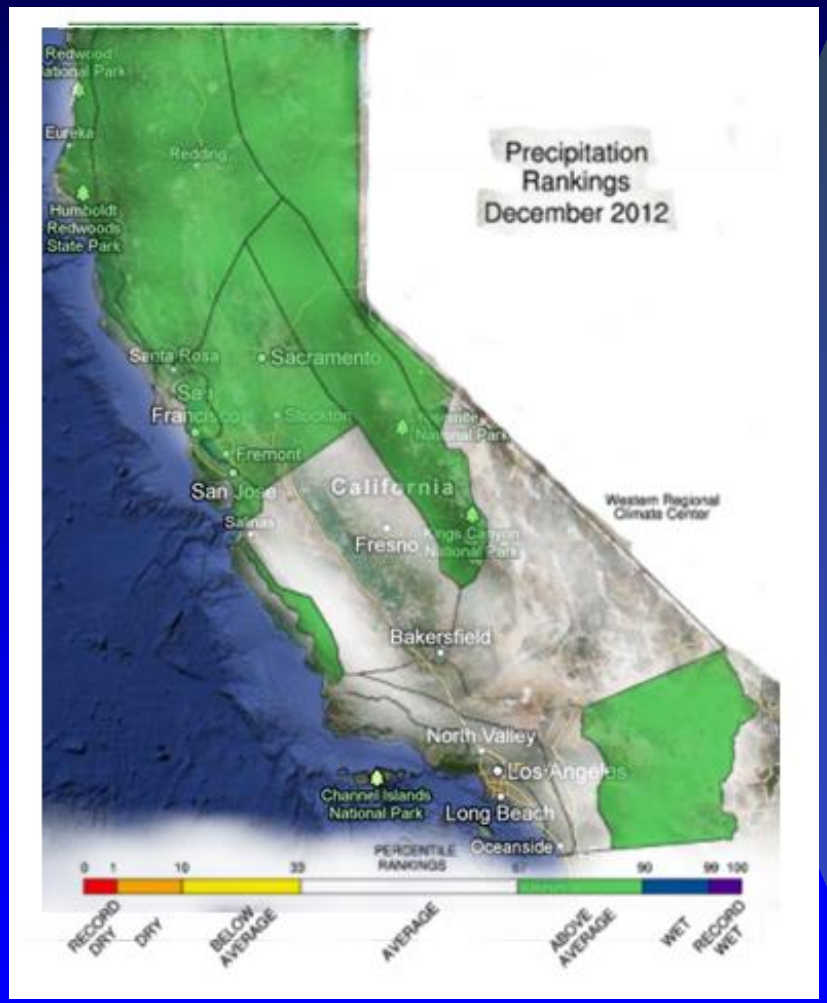
-Combines expertise on the virus, the vector and virus epidemiology
-Includes researchers from UC and USDA
-Will allow for application of new technologies and will reveal new insights, including whether changes in the virus were associated with the 2013 outbreak
-Integrated team that will address:
  -Curly top virus: Bob Gilbertson (UCD)
    Bill Wintermantel (USDA), Li-Fang Chen (UCD*)
  -Beet Leafhopper: Eric Natwick (UCCE)
  -Virus epidemiology: Neil McRoberts (UCD)
  -Field aspects: Tom Turini (UCCE)
-This team will work closely with CTVCB personnel

Integrated Curly Top Virus Management

- Develop curly top resistant tomato varieties
- Identify deterrents to prevent leafhopper feeding on tomatoes
- Use the PCR method to detect curly top virus in the leafhoppers collected by the CTVCB to better predict bad curly top years and more accurately target areas for spraying
- Monitor beet leafhopper populations on the valley floor and search for potential inoculum sources during the winter
- Use an epidemiological approach to correlate environmental and weather factors with curly top outbreaks for improved prediction of bad curly top years

Curly top resistance has been identified in a tomato line (20) possessing genes known to confer resistance to whitefly-transmitted *Tomato yellow leaf curl virus*

Epidemiological studies will be used to determined factors favoring high leafhopper populations



WINTER Foothills population

High rainfall promotes foothills weed growth and large population size

SUMMER Crop area population

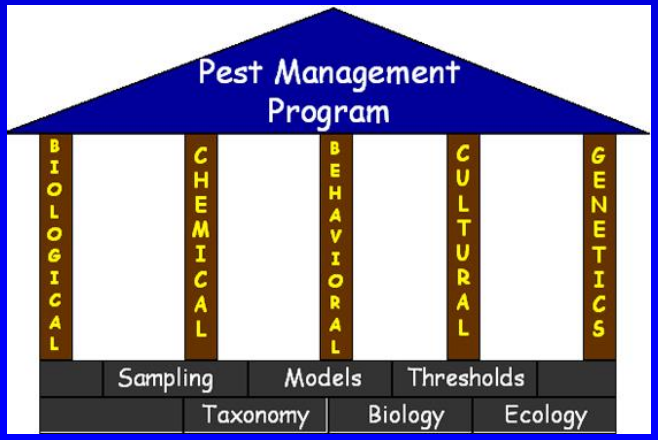
Dry spring promotes early death in foothill weeds, so large migration to crops?

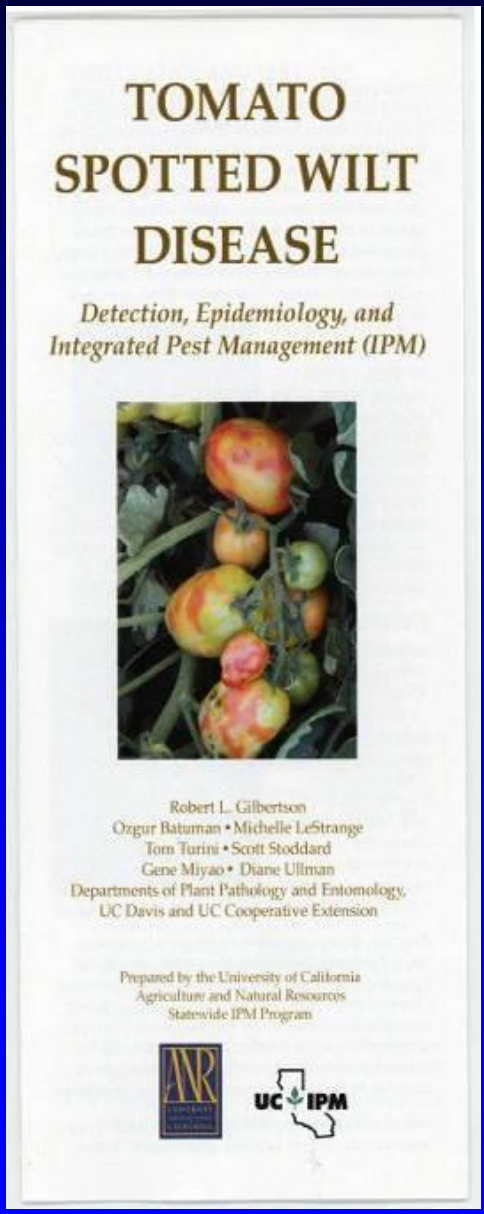
FALL Migration to hills

Warm fall promotes migration back to hills?

IPM for thrips and of tomato spotted wilt

- **An effective IPM package, based upon knowledge of the biology of virus, vector and virus-vector interaction has been developed for thrips and TSWV and made available to growers**
- **The use of all of some components of this IPM package has helped reduce economic losses due to TSWV**
- **It is critical to use the multi-pronged IPM approach and not depend only on one or two management strategies (i.e., insecticides or resistant varieties)**





IPM for thrips and TSWV

- **Before planting**
  - -Calculate **risk assessment** for fields and make decisions to lower risk
  - -**Varietal selection**
    - -**Plant TSWV resistant varieties** (with *Sw*-5 gene) especially in hot-spot areas or late-planted fields
    - -Varieties without the *Sw-5* gene vary in susceptibility
  - -Field selection and planting time (avoid hot-spots, planting near fields with bridge crops or late planting dates)
  - -**Plant TSWV- and thrips-free transplants**

IPM for thrips and TSWV

- During the season
  - -Monitor fields for thrips (yellow sticky cards) or use predictive degree-day model and manage thrips with insecticides at early stages of crop development and when thrips populations begin to increase
  - -Rotate insecticides to minimize development of insecticide resistance in thrips
  - -Monitor fields for TSWV and remove infected plants early in development and when percent infection is low (<5%)
  - -Weed control in and around fields and in near-by orchards

Chemical Control of Thrips

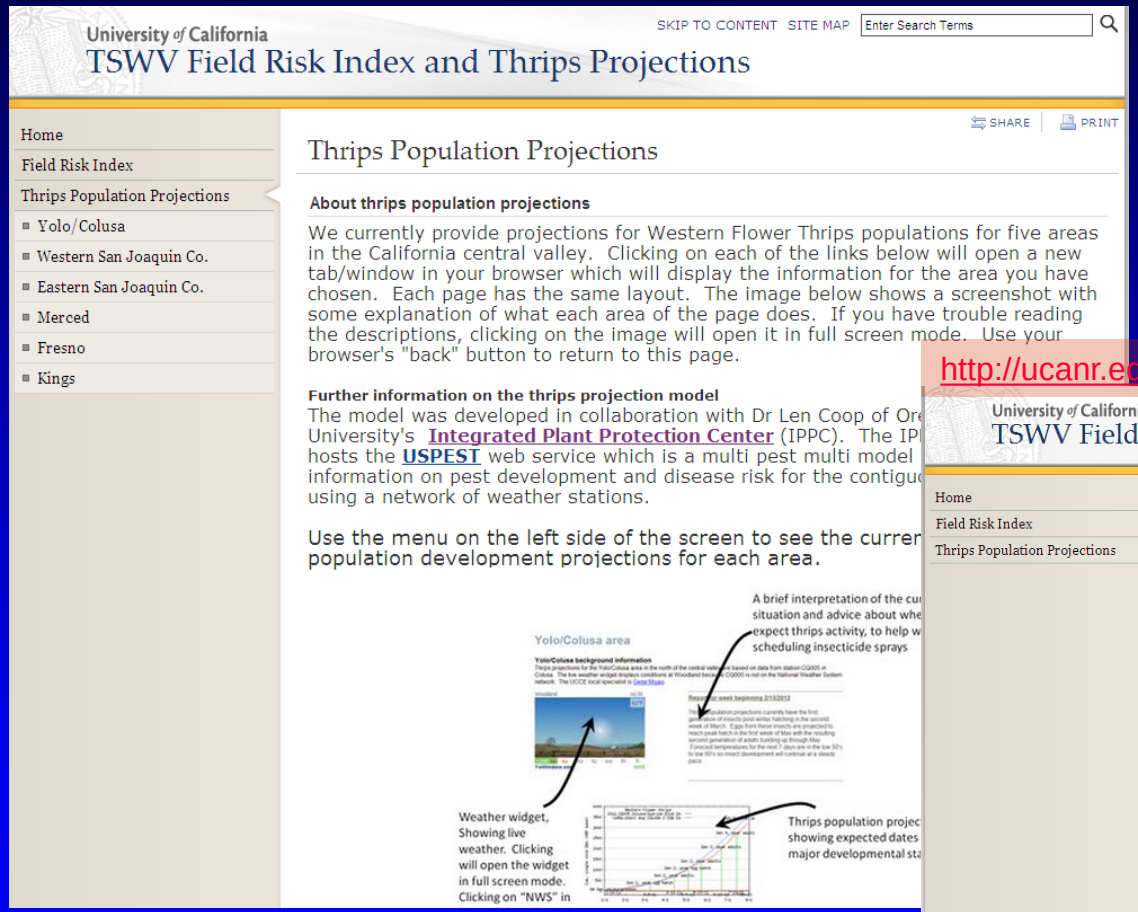
- It is important that thrips management be implemented when populations begin to increase or immediately following detection of TSWV symptoms
- Critical to reduce the number of virus-carrying adults by controlling larvae early in the season
- Best materials in trials: Dimethoate, Lannate (methomyl), Radiant (spinetoram), and Mustang (*zeta*-cypermethrin)+Beleaf (flonicamid)
- However, the effect was not long-lasting (7-10 days)
- Neonicotinoids (e.g., imidicloprid, thiamethoxam) were not effective
- Need for additional materials for thrips control (Movento [spirotetramat] and Requiem [Chenopodium extract] are possibilities])

IPM for thrips and TSWV

- **After harvest**
  - **-Promptly remove and destroy plants after harvest**
  - **-Minimize/avoid 'bridge' crops that are TSWV/thrips reservoirs and overlap with tomato/pepper (e.g., radicchio, lettuce, fava bean)**
  - **-Control weeds/volunteers in fallow fields, non-cropped or idle land and orchards**

Give it a try: Read the codes with your Smartphone to visit web pages!

http://ucanr.edu/sites/TSWVfieldriskindex/Thrips_Population_Projections/



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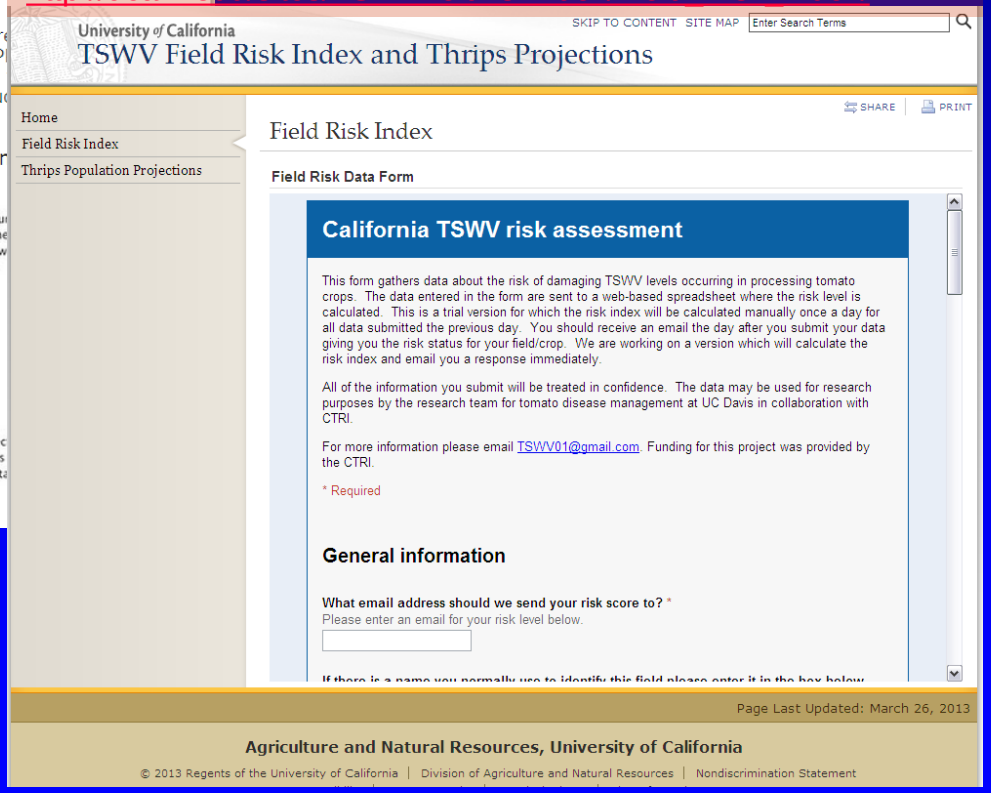
http://ucanr.edu/sites/TSWVfieldriskindex/Field_Risk_Index/



Acknowledgements

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