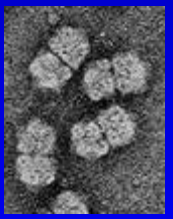
Tomato spotted wilt and Curly top virus: Management Update

Robert L. Gilbertson
Department of Plant Pathology
University of California Davis



South Sacramento Valley Processing Tomato Production Meeting
January 9, 2014

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[E] (ToNSV)** — **Thrips-associated**
- ***Tomato yellow leaf curl virus*****[E] (TYLCV)** — **Whitefly-transmitted**

Thrips and TSWV have emerged as important constraints on processing tomatoes in California

Western flower thrips
(*Frankliniella occidentalis*)

Tomato spotted wilt disease
caused by *Tomato spotted wilt virus*

CTRI has supported a project on thrips/TSWV with the following objectives:

- Develop an understanding of when and where thrips and TSWV gain entry into California processing tomatoes
- Determine dynamics of thrips populations and spotted wilt disease development
- Identify potential inoculum sources (vegetables and tree crops, weeds, ornamentals, etc.)
- Assess various thrips control strategies
- Apply knowledge of thrips and TSWV to develop a regional integrated pest management (IPM) program
- Minimize economic losses due to thrips and TSWV

Locations of Monitored Fields in Central Valley of California

Nevada

Yolo and Colusa Counties (2009-14) Tomato transplanting starts in mid March

San Joaquin County (2013-14) Tomato transplanting starts in mid March

Merced County Surveyed in 2008-2012

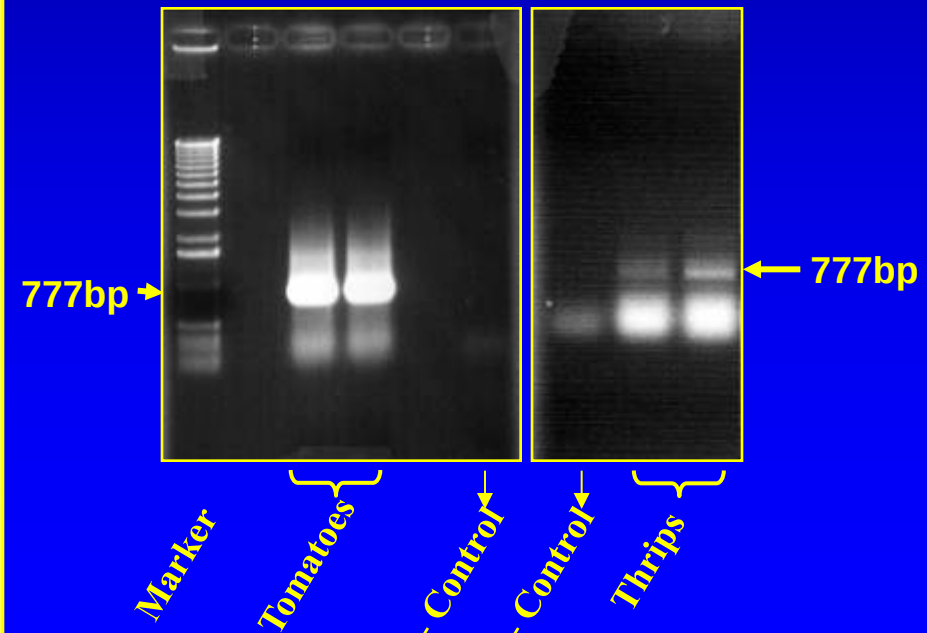
Fresno and Kings Counties Surveyed in 2007-2012

Pacific Ocean

Mexico

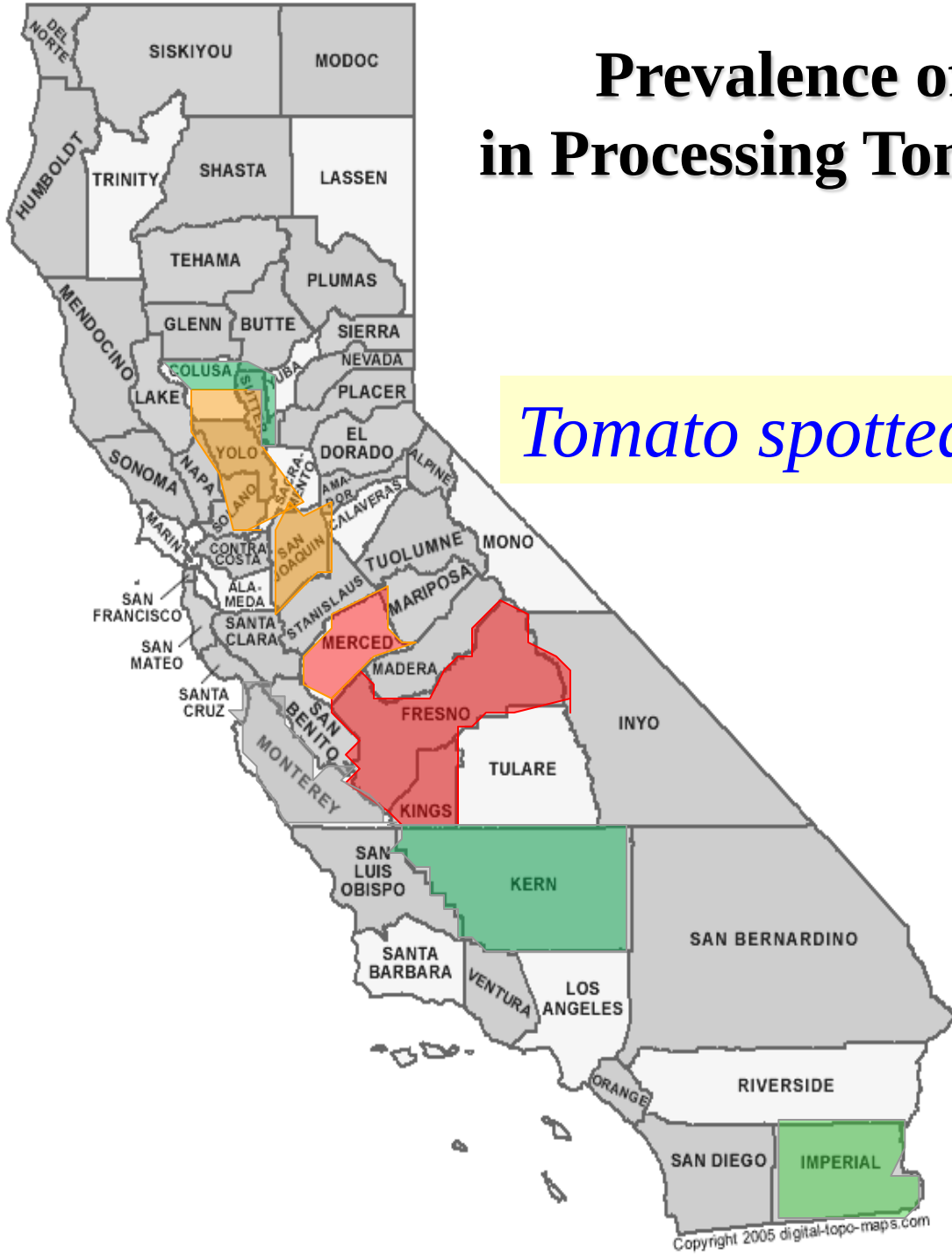
Monitoring thrips and TSWV in tomato fields

- Direct-seeded and transplanted processing tomato fields
- Thrips will be monitored with yellow sticky cards
- Virus incidence will be determined from randomly selected rows by visual inspections
- TSWV infection will be confirmed with immunostrips or RT-PCR

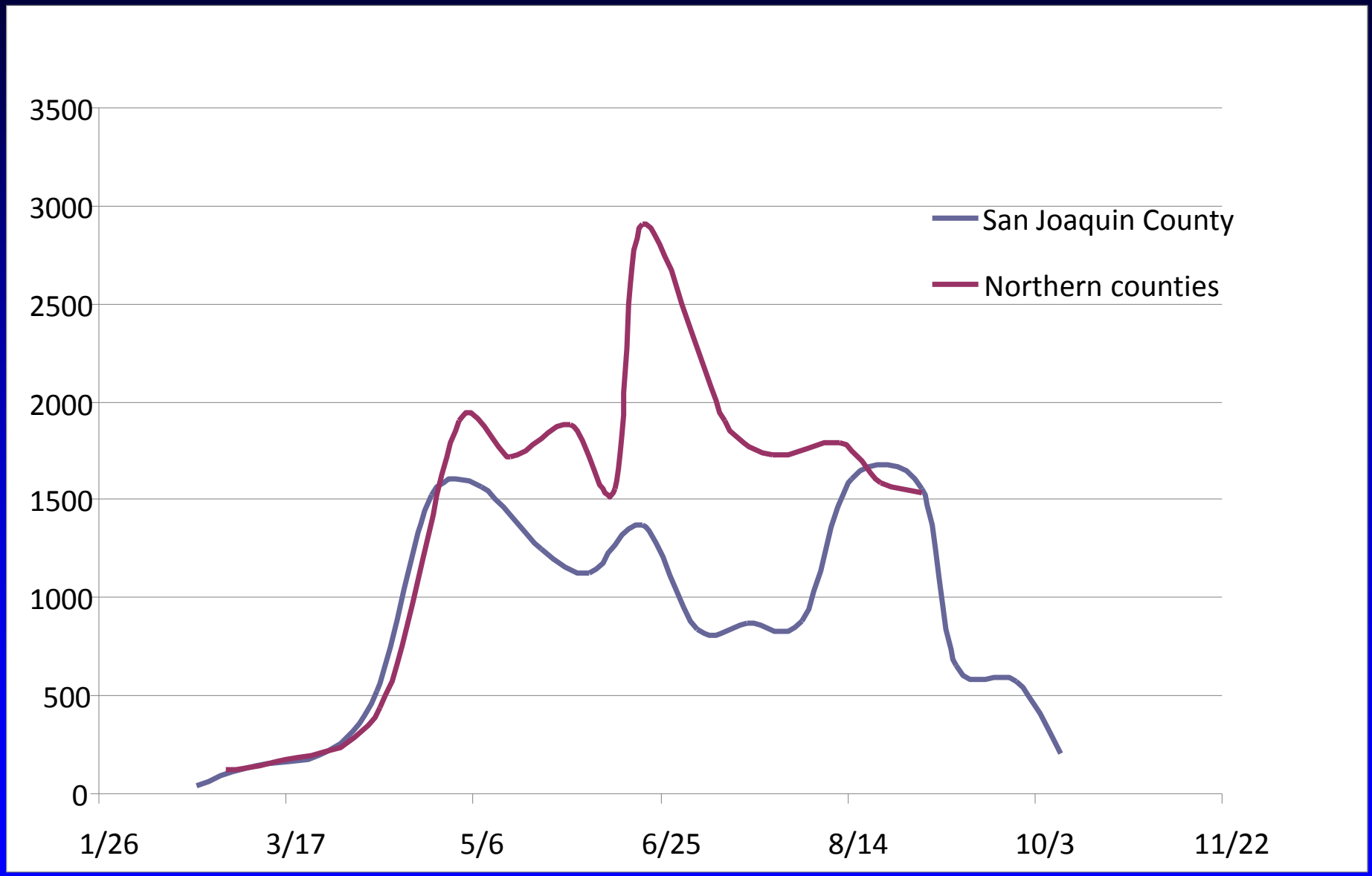


Prevalence of Virus Diseases in Processing Tomatoes of California

Tomato spotted wilt virus (TSWV)



Average Thrips Populations per card in monitored fields 2013



Tospovirus Transmission Cycle

TRANSMISSION

Egg

ACQUISITION BY LARVAE IS CRUCIAL

1st instar

2nd instar

VIRUS PASSAGE

Pupal Stages Do Not Feed

VIRUS PASSAGE

Only adults that acquire as larvae can transmit.

Photos by J.K. Clark

Thrips populations

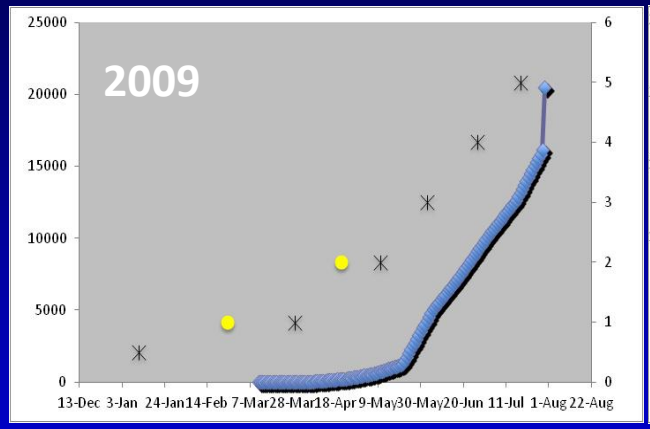
- Thrips populations **begin to increase in March/April**; **peaked from May-July**; and slowly declined until late fall (October) to winter when populations are lowest
- Relative populations varied from year-to-year
- Detection of larvae in tomato flowers indicates **thrips reproduction on tomato**
- All were identified as **western flower thrips**

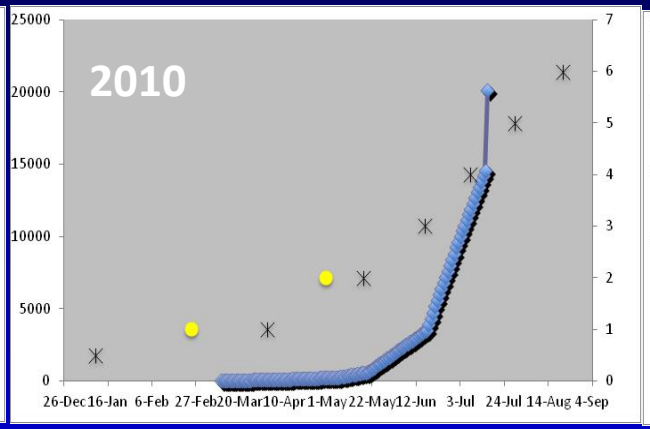
Development of a model for predicting thrips populations

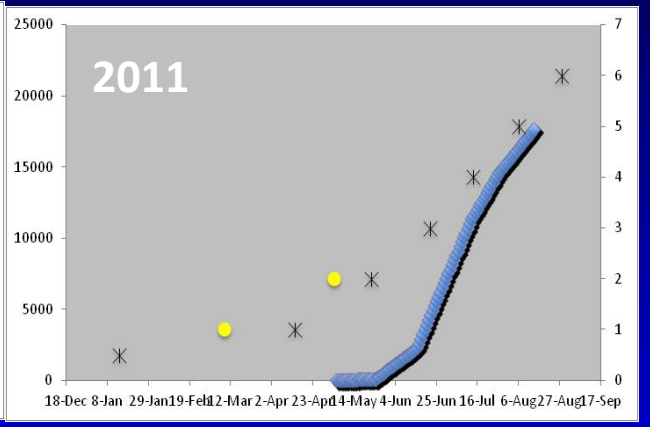
- Current program involves **direct monitoring efforts and grower alerts** to allow for optimal timing of thrips management
- Developed a **degree-day model** to predict when thrips populations will begin to develop to allow growers to time spray applications
- Comparing the actual thrips **counts with the predictions made by the model**
- Long-term goal is to **replace direct monitoring** with the predictive model and develop an **effective approach for providing growers information** to know when to spray

Thrips generation predictions vs. card counts

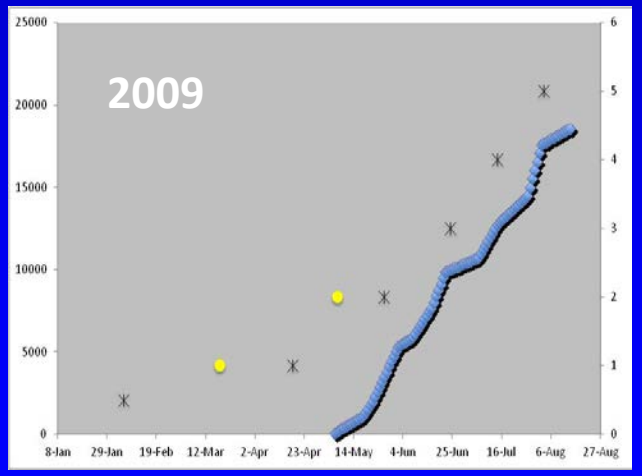
Yolo/Colusa

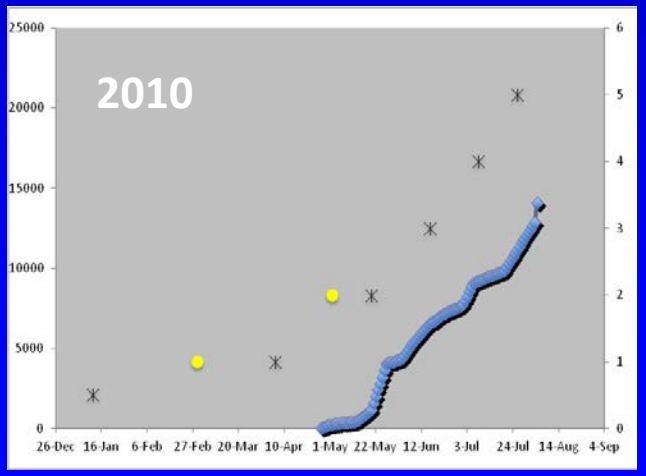


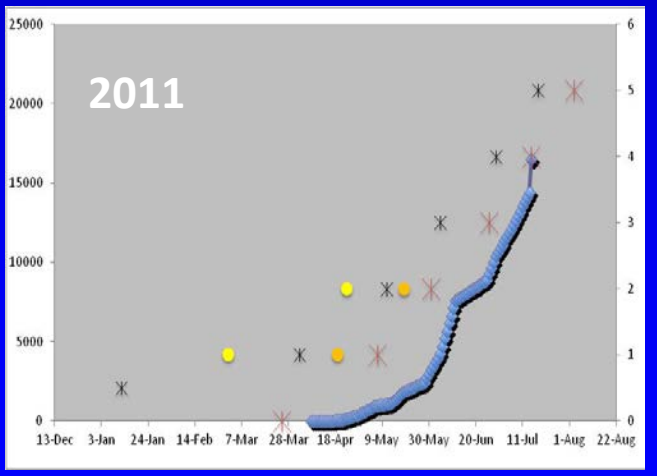




Fresno







TSWV-Inoculum Sources

- **Weeds: winter surveys** revealed very low incidences in TSWV in most weeds and almond orchards; exceptions were **unplowed fallow fields** and **buttercup weeds** in walnut orchards
- **Bridge crops: radicchio** can have high levels of TSWV infection (Merced), **fava bean** can also be a bridge crop (Northern counties) as well as **spring lettuce** (Fresno County)
- **Overwintering thrips** emerging from soil

Radicchio with TSWV symptoms

Fava bean with TSWV symptoms

Weed survey results for TSWV incidence in 2013

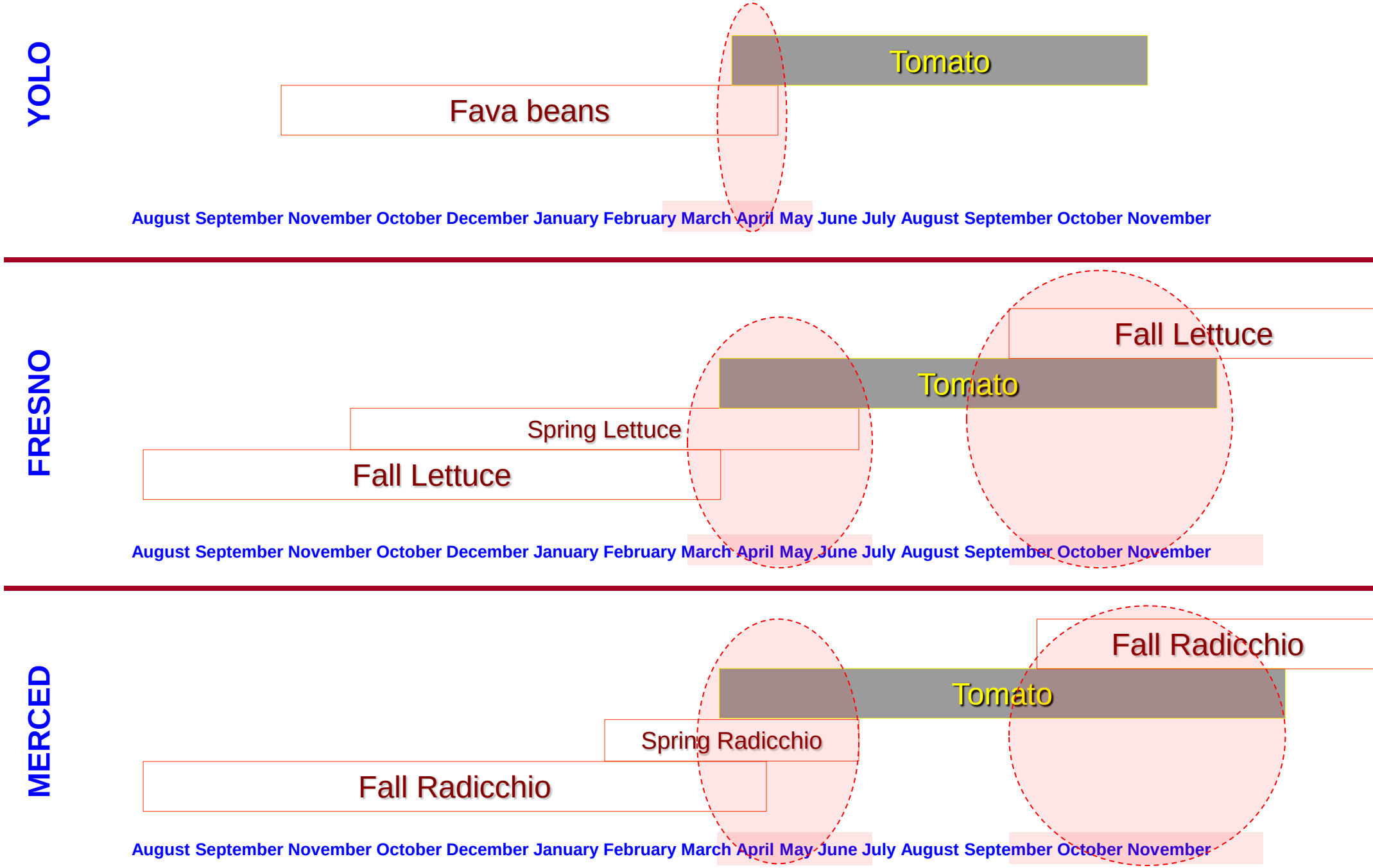
Weed [a]	Tested (+)	Weed [a]	Tested (+)
Chinese lantern	**10 (1)**	Curly dock	3 (0)
Bindweed	22 (0)	**Malva**	**135 (5)**
Filaree	42 (0)	**Datura**	**1 (1)**
Pineapple weed	**4 (1)**	Monocots	9 (0)
Sowthistle	**34 (4)**	Shepherd's purse	15 (0)
Prickly lettuce	22 (0)	Fiddler neck	3 (0)
London rocket	15 (0)	Pigweed	4 (0)
Buckhorn Plantain	8 (0)	Turkey mullein	5 (0)
Lamb quarters	17 (0)	Groundsel	3(0)
Poison hemlock	26 (0)	Tree tobacco	12 (0)
Pennywort	5 (0)	Nettle	4 (0)
Rough-seeded Buttercup	**149 (128)**	Bermuda buttercup	18 (0)
Wild radish and Mustard	34 (0)	Other common weeds	28 (0)

(+), number of plants tested positive for TSWV by immunostrips and/or RT-PCR.
a, Total weed samples from all counties surveyed in 2013

Rough-seeded buttercup: An important TSWV reservoir host?

NEW POTENTIALLY IMPORTANT TSWV WEED HOST IDENTIFIED IN SAN JOAQUIN AND NORTHERN COUNTIES: BUTTERCUP!

Disease symptoms in rough-seeded buttercup (*Ranunculus muricatus*) weeds infected with TSWV

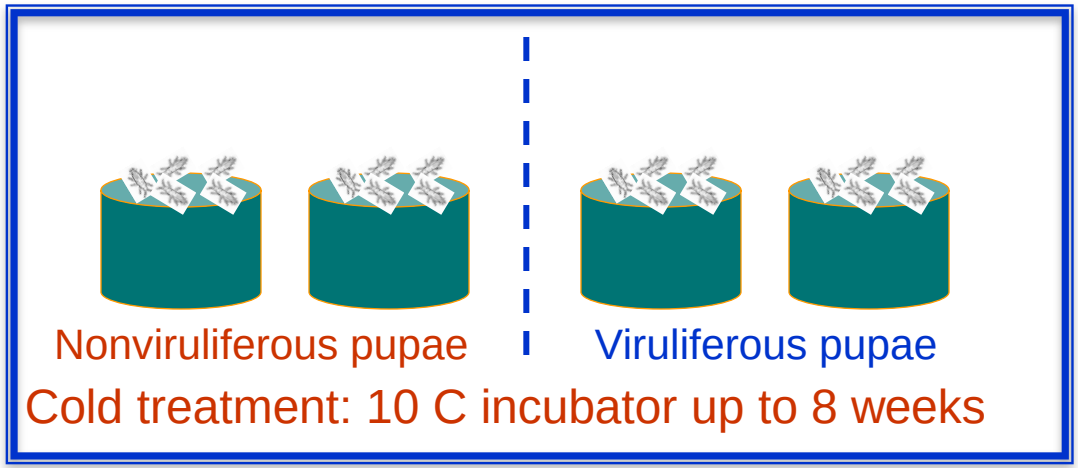

YOLO
Tomato
Fava beans
August September November October December January February March April May June July August September October November
FRESNO
Fall Lettuce
Tomato
Spring Lettuce
Fall Lettuce
August September November October December January February March April May June July August September October November
MERCED
Fall Radicchio
Tomato
Spring Radicchio
Fall Radicchio
August September November October December January February March April May June July August September October November

Overwintering assays for thrips emerging from soil under cold conditions

Nonviruliferous thrips colonies

1st instar of nonviruliferous thrips feed on TSWV-infected Datura for 48 h AAP

Virus acquisition



Increase 2 C every week after 8 weeks of 10 C treatment

1. Count numbers of emerged adults every 2-3 days
2. Transfer adult thrips to healthy young plants to check virus transmission

Development of a risk assessment index for thrips and TSWV in processing tomato fields

- A **risk index** for thrips and TSWV for individual tomato fields has been developed
- **Based upon point values assigned** based upon production practices that minimize or favor development of thrips/TSWV
- **Examples of factors include:** variety, planting date, plant population, insecticide application, thrips populations, proximity to TSWV-susceptible crops, TSWV history in the growing area, etc.

TSWV Risk Index (TRI)

Tomato spotted wilt virus **Risk Index for Tomatoes-2012**

Tomato Variety[1]	Examples	Risk Index Points
a,b,c	stunted plt w less fruit, very severe, dead like	50
d,e,f	Res. size plt w less fruit, severe symptoms	40
g,h,i	Nor. size plt w many fruits severe symptoms	30
j,k,l	Nor. plt w many fruits some symptoms	20
m,n,o	Vigor.Plt w many fruits almost no symptom	10
p,q,r	with SW5	-35
Planting Date[2]		
Prior to February 1	First planted fields in any given region	10
February 1-29	week or two later than first planted fields	15
March 1-15	week earlier than recommended period	10
March 16- April 31	Recommended period (Majority of fields)	5
May 1-20	week or two later than majority of fields	15
May 21- June 5	tree week or more later planted from major	25
After June 5	latest planted fields in a given region	35
Plant Population[3]		
Less than 1 plant per foot	single row (7000 per acre)	35
2 to 3 plants per foot	double row (9000 per acre)	15
More than 3 plants per foot	double row but more dens (>9000 per acre)	5
Planting Method		
Direct seeded		10
Transplanted		5
Proximity to Known Bridge Crops		
adjacent	radicchio, lettuce, fava, weed/fallow field, pepper or tomato	25
less than 1 mile radius distance	(if TSWV confirmed add 20 more points)	15
1-2 mile radius distance	(if TSWV confirmed add 10 more points)	10
greater than 2 mile or None	(if TSWV confirmed add 5 more points)	5
Proximity to Thrips Source		
adjacent	wheat, pea, alfalfa or weedy patches etc.	20
less than 1 mile radius distance		15
1-2 mile radius distance		10
None		5
At-Plant Insecticide		
None		15
for other pests (+ thrips)		10
specifically for thrips		5
Weed situation/Herbicide use		
w/out herbicide but weedy	In-field ONLY weed population	15
w/out herbicide but not so weedy		10
w/out pre emergence herbicide or NO weed		5
Total Points (0-225)	**Risk of Losses Due to TSWV**	
Less than or equal to 95	**Low**	
Greater than 100 or equal to 150	**Moderate**	
Greater than 150	**High**	

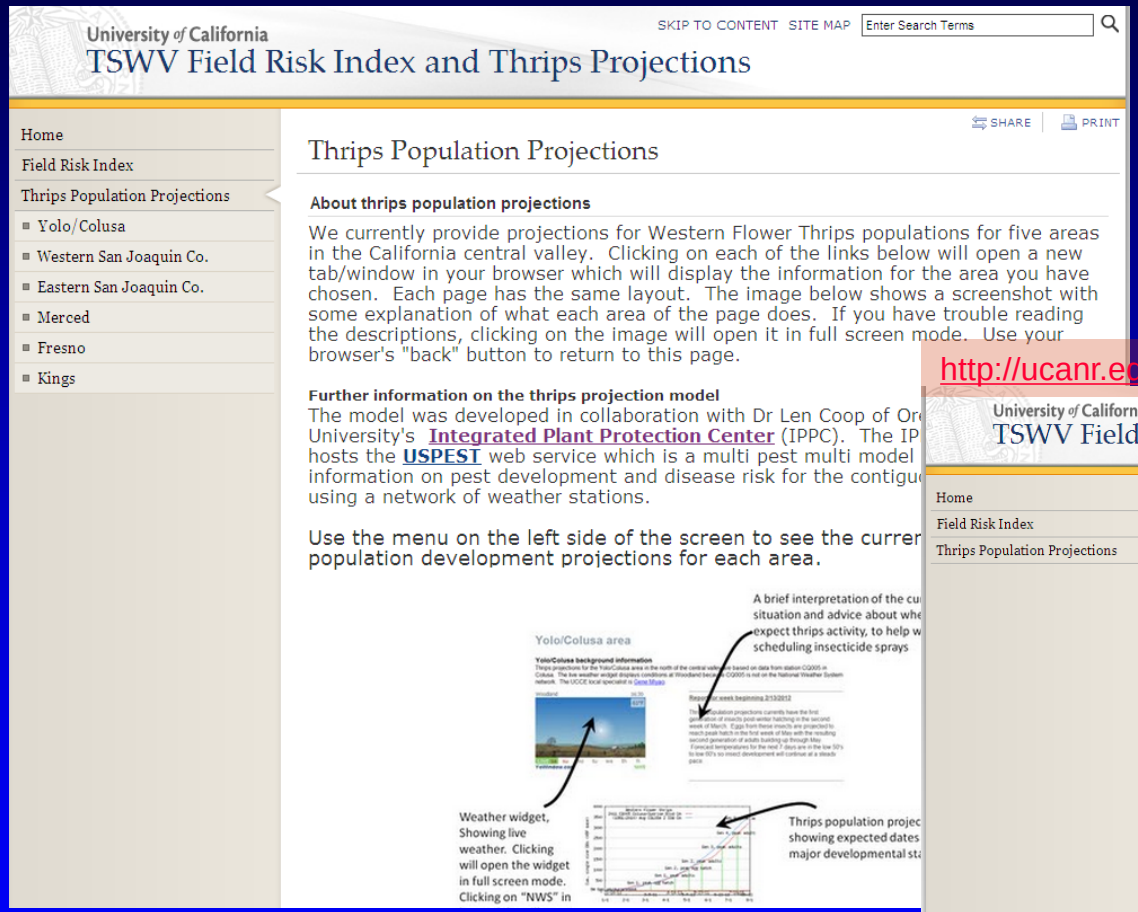
TSWV Risk Index (TRI)

Monitored Fields in 2013

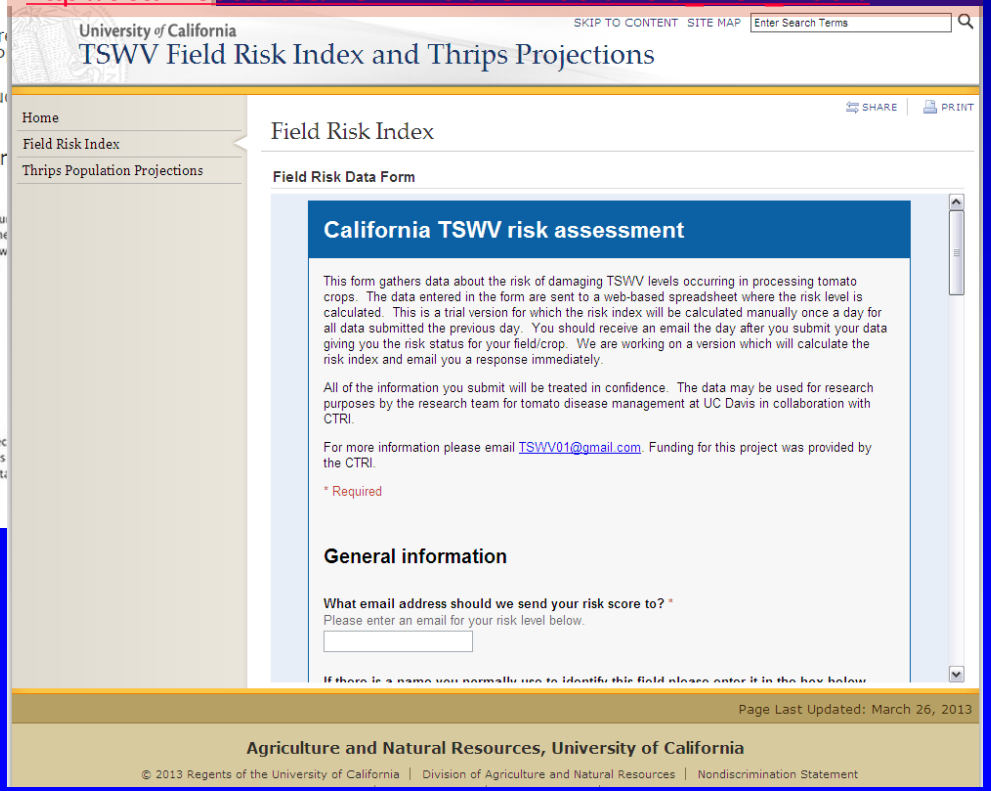
	Northern Counties	TSWV %	TRI
RO	Winters, Yolo	<1	low
BF	County Line, Colusa	20	high
AO	County Line, Colusa (SW-5 variety)	<1	low
PR	Dixon, Solano	2	moderate
EG	Robin, Sutter	4	moderate
YL	Yolo Town, Yolo	3	moderate
	San Joaquin County		
BR	Bean Ranch, Thornton	20	high
BW	HWY 4, Byron/Brentwood	4	moderate
DL	Delta Rd, Tracy	1	moderate
CP	Copperopolis Rd, Linden	3	high
AL	Alpine Rd, Linden	2	moderate

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

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



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



An IPM program has been developed for thrips and TSWV in processing tomatoes in California. It has been summarized in a recently prepared flyer

TOMATO SPOTTED WILT DISEASE

Detection, Epidemiology, and Integrated Pest Management (IPM)

Robert L. Gilbertson
Ozgur Batuman • Michelle LeStrange
Tom Turini • Scott Stoddard
Gene Miyao • Diane Ullman
Departments of Plant Pathology and Entomology,
UC Davis and UC Cooperative Extension

Prepared by the University of California
Agriculture and Natural Resources
Statewide IPM Program

UC IPM

Some Insecticides for Thrips Management	
Trade name (common name)	Resistance management class
Radiant (spinetoram) and Success (spinosad)	5
Dimethoate	1B
Lannate (methomyl)	1A
Beleaf (flonicamid)	9C

Mention of trade names is for illustration purposes only and is not an endorsement by UC Cooperative Extension or UC IPM

If you have additional questions or need assistance in testing for TSWV or developing thrips/TSWV management strategies, contact your county farm advisor or Robert L. Gilbertson at UC Davis (telephone: 530-752-3163 and e-mail: rlgilbertson@ucdavis.edu).

Supported in part by the California Tomato Research Institute

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

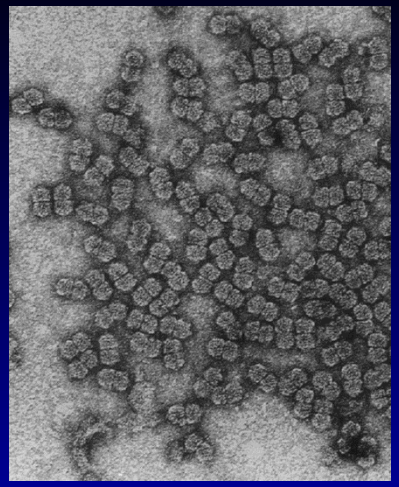
Chemical Control of Thrips

- 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**

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*)

- BMCTV and BSCTV 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

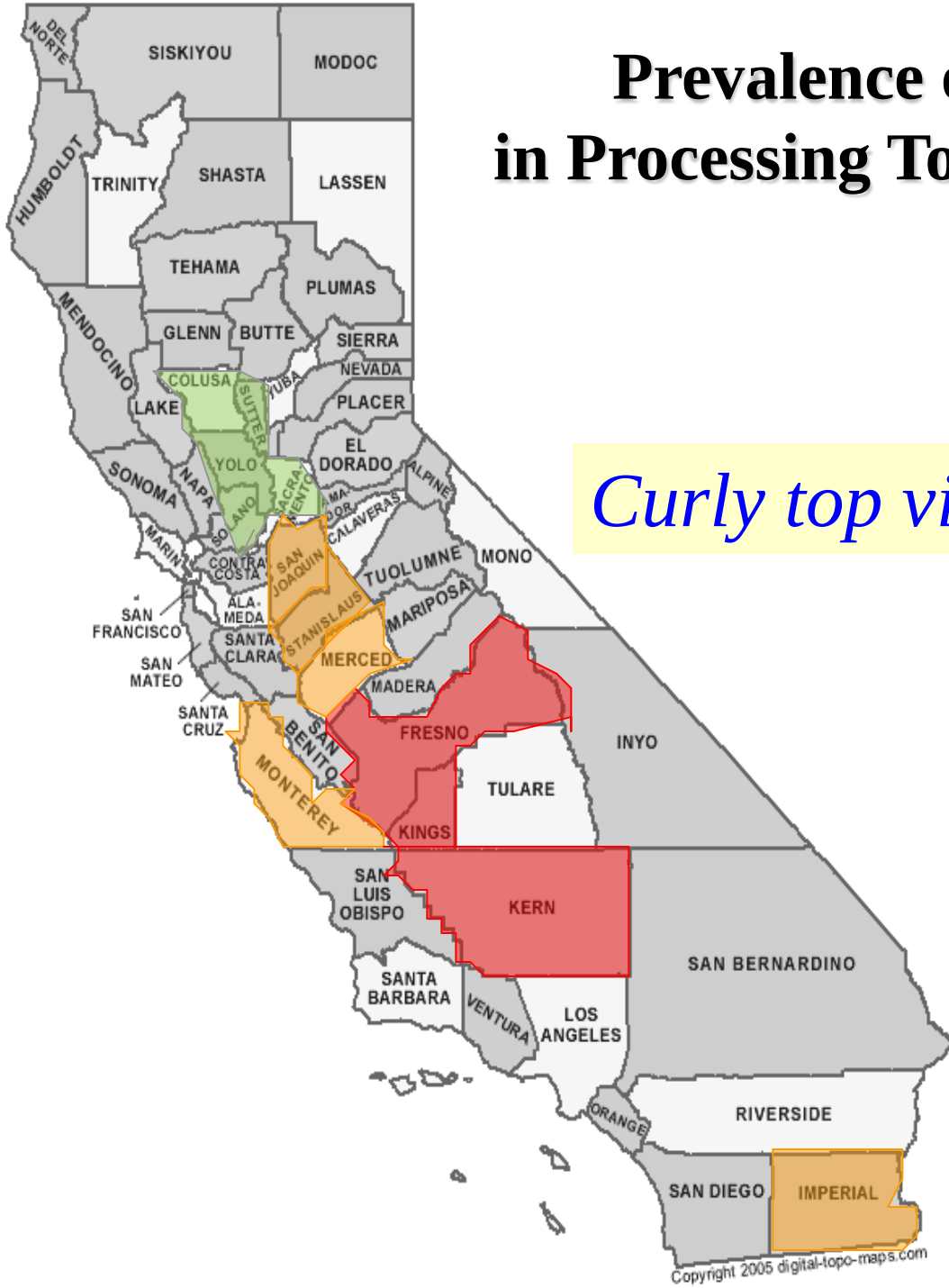
Curly Top Disease Cycle

Spring: adult leafhoppers migration

Multiple generations on the valley floor

Fall: adult leafhoppers migrate for overwintering in the foothills

Prevalence of Virus Diseases in Processing Tomatoes of California



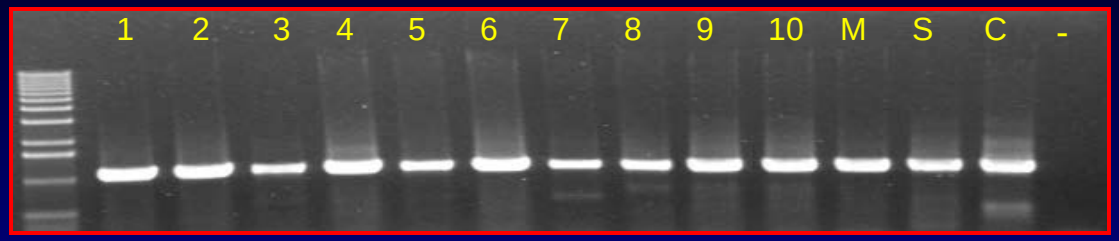
Curly top virus(es) (CTV)

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**

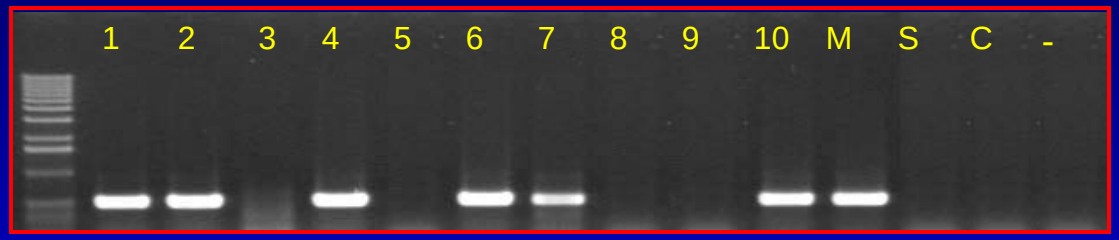
PCR is currently the best method for detection of curly top viruses

General CTV primers



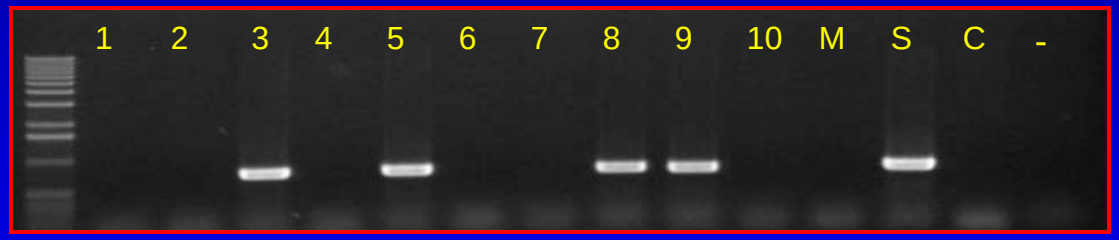
1.1 kb

BMCTV



0.5 kb

BSCTV



0.7 kb

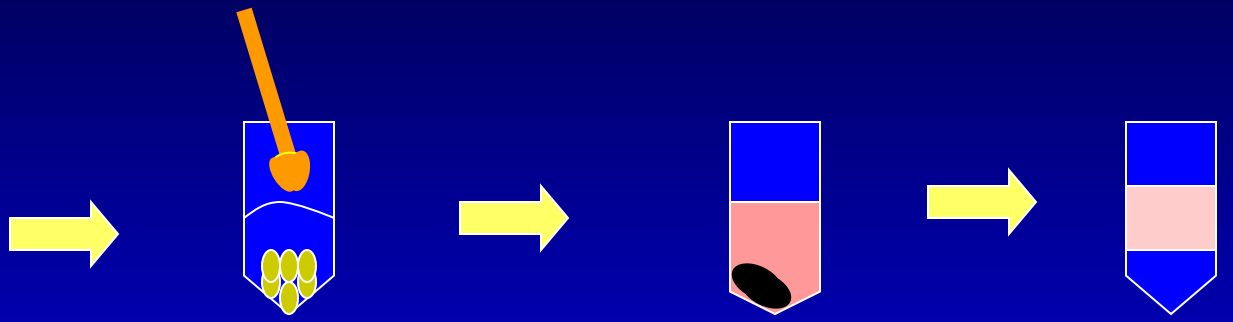
BCTV

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

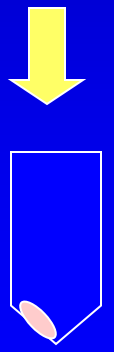
Monthly leafhopper collections from CDFA CTVCP personnel



Add 300ul STE buffer and grind

Spin 5’ at 13,000 rpm

Phenol/Chloroform extraction twice

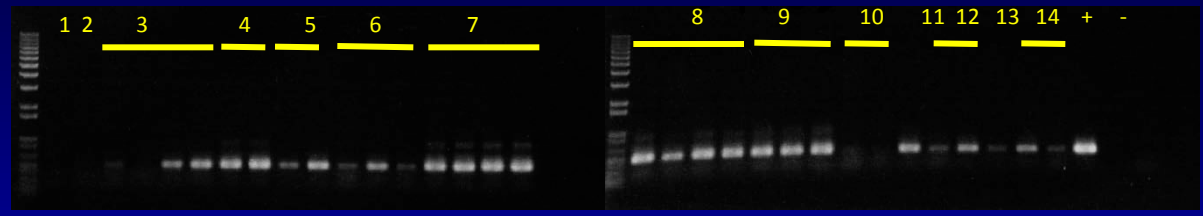


Precipitation of nucleic acid

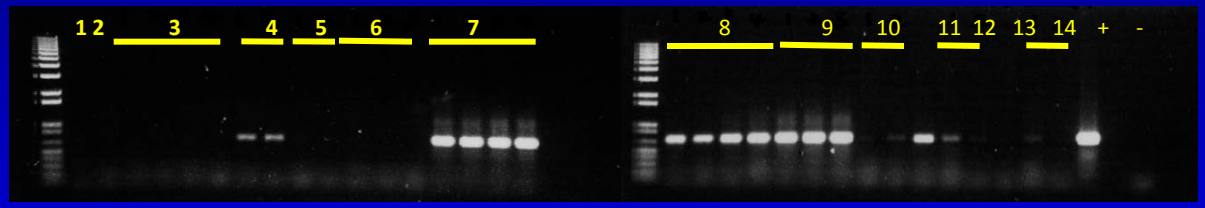
PCR reaction

Curly Top Outbreak of 2013

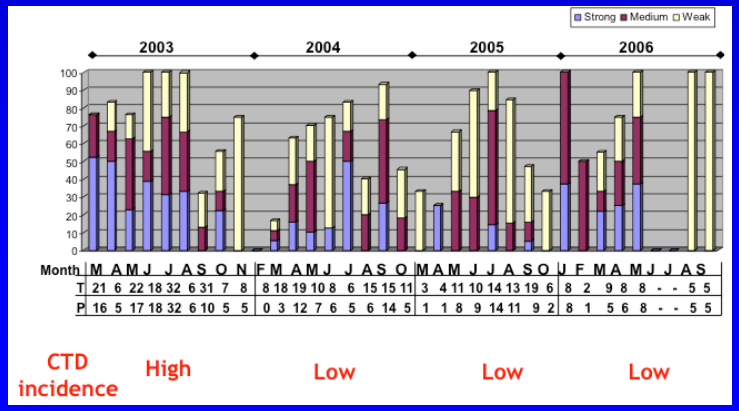
- In 2013, CDFA detected beet leafhopper populations in the foothills that were ~5X higher than normal
- High levels of BMCTV and BSCTV were detected in leafhopper samples sent to our laboratory in March and April
- Previous studies had associated high leafhopper populations with high levels of virus, early in the season, with curly top outbreaks in tomato



BMCTV

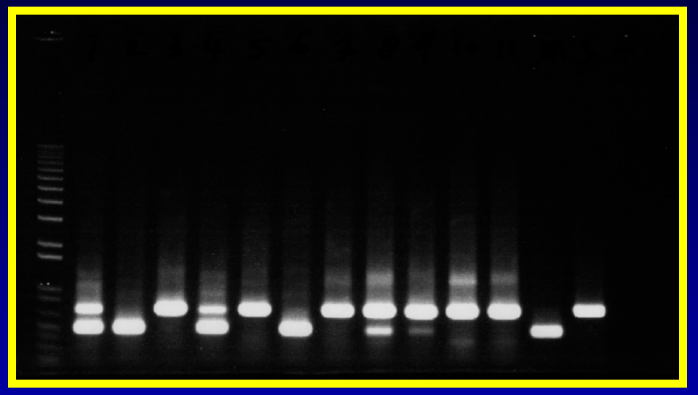


BSCTV

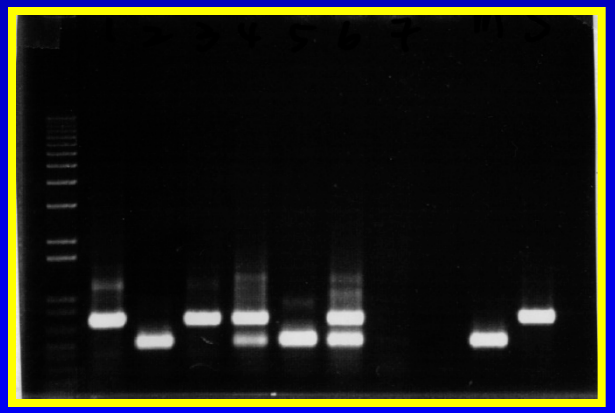


Curly Top Outbreak of 2013

- **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**
- **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



Samples from Kern Co. 4/23/2013



Samples from Fresno Co. 4/30/2013
Sample 7 from Yolo Co. was negative

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:

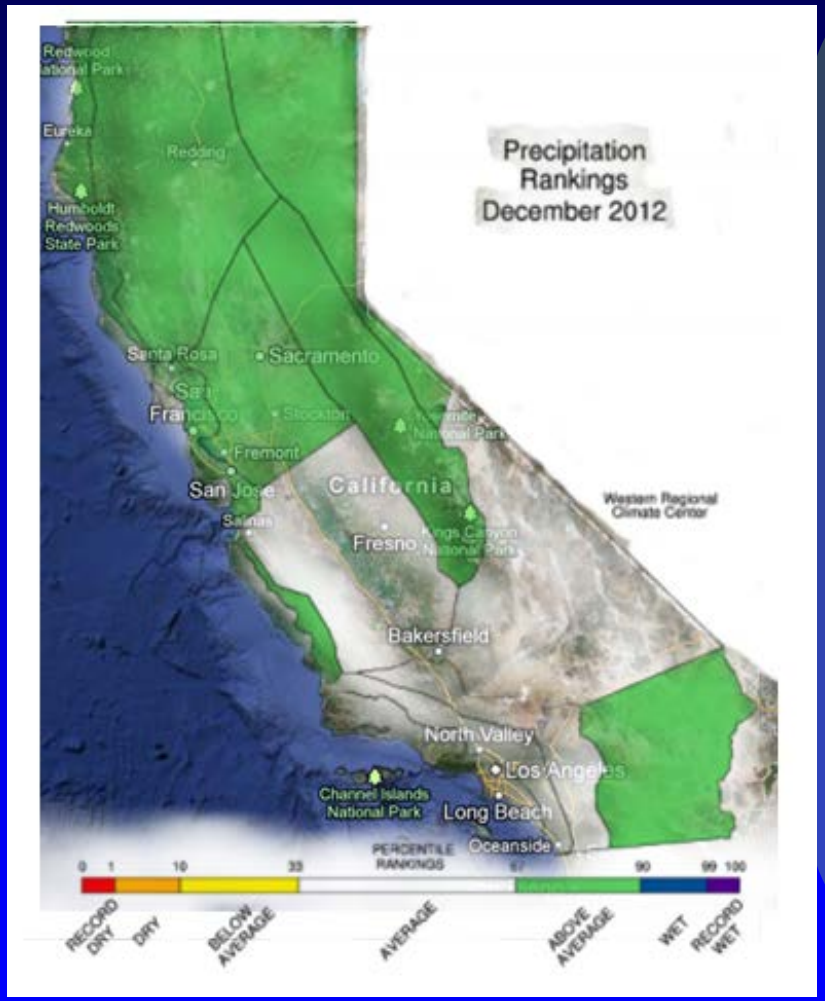
✧ more diverse than we thought

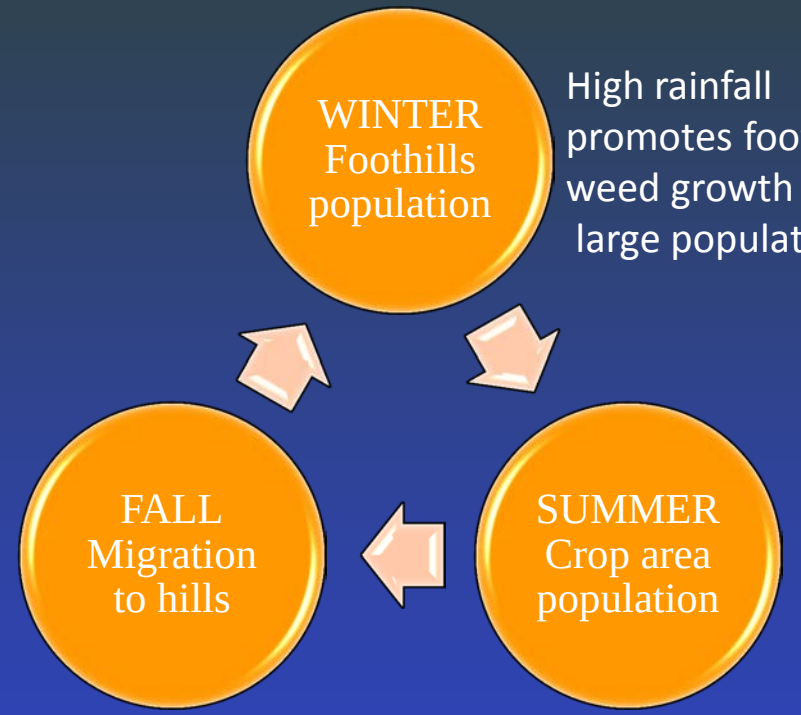
Curly Top Virus Management

- 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 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

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





Management of tomato spotted wilt and curly top

- 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 to TSWV substantially
- 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)
- Efforts are underway to develop a similar approach for curly top disease