New Developments in Curly Top and Spotted Wilt of Processing Tomatoes

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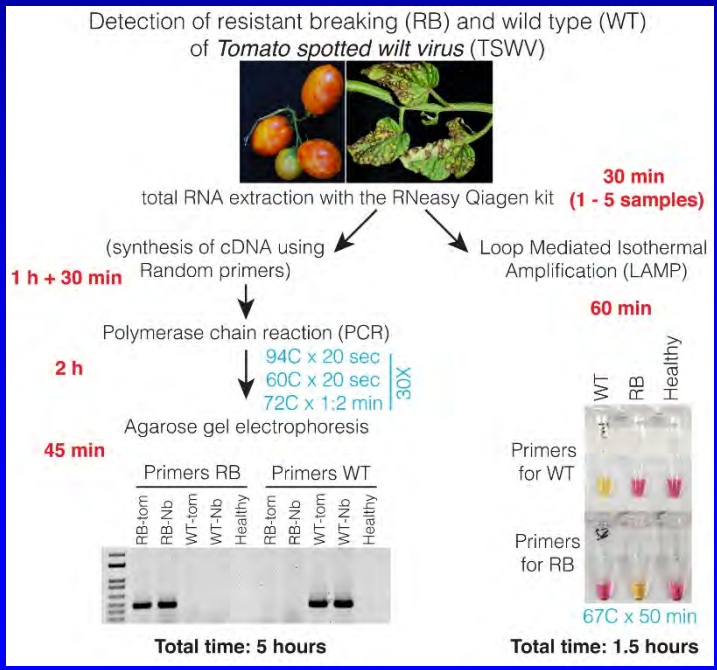
Why virus surveillance?

- Virus landscape is always changing
- Strong network looking for virus symptoms
- Over 30 years of experience
- Diagnostic tests for most CA tomato viruses
- Active in outreach efforts
- For tomatoes includes:
  - -Major viruses (TSWV and BCTV)
  - -Minor viruses (AMV, PZSV, ToNSV)
  - -Exotic viruses (ToBRFV)
- We will always be fighting virus diseases!
- Need to adopt new technologies



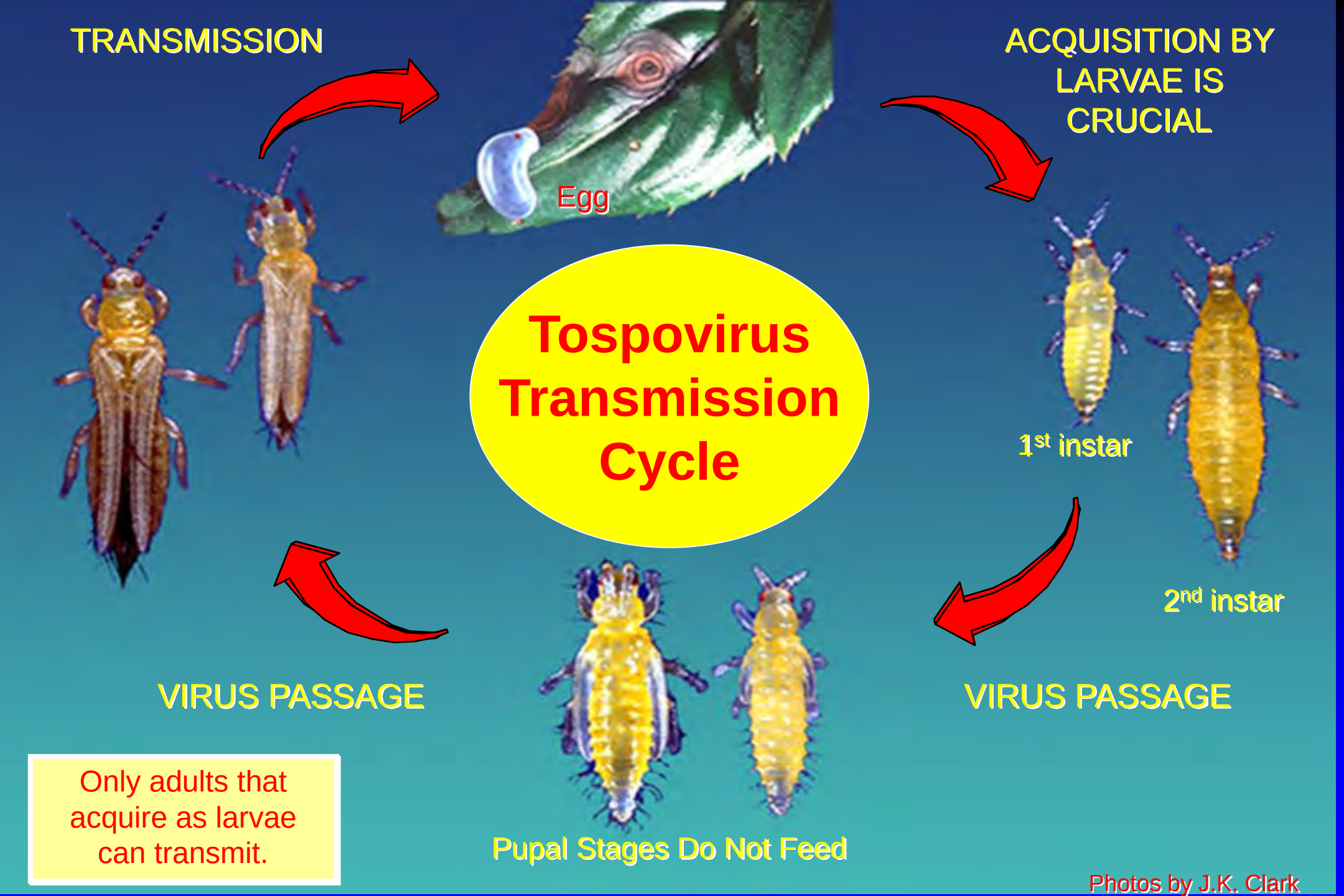
Curly top vs spotted wilt disease of tomato

Property	Curly top	Spotted wilt
Cause	BCTV (DNA)	TSWV (RNA)
Strains/variants	11 strains (five of importance)	RB strains (tomato and pepper)
Vector	beet leafhopper (BLH) tomato not a host	Western flower thrips (WFT) tomato is a host
Transmission by seed or contact or eggs to young	No	No
Predictive model	No	Yes (DD for thrips)
Resistant varieties	No*	Yes*
Tools for detection and screening	Yes	Yes

General information on TSWV and spotted wilt

- **Thrips-transmitted virus, not spread by seed or contact or through eggs**
- **Major thrips vector in CA is Western flower thrips**

- **In CA, crops impacted are tomato, pepper, lettuce and radicchio**
- **Symptoms vary depending on stage of growth that plants are infected**
- **In tomatoes and peppers, spotted wilt can be managed by IPM approach, with a key tool being resistant varieties (tomato with *Sw-5* gene, peppers with *Tsw* gene)**
- **In 2016, a resistance breaking (RB) strain of TSWV emerged in fresh market tomatoes and has now become the dominant strain in Fresno**


TRANSMISSION
ACQUISITION BY LARVAE IS CRUCIAL
Egg
Tospovirus Transmission Cycle
1st instar
2nd instar
VIRUS PASSAGE
VIRUS PASSAGE
Pupal Stages Do Not Feed
Only adults that acquire as larvae can transmit.
Photos by J.K. Clark

Symptoms and impact of tospovirus infection in tomato vary depending on the age of the plant when infected

- Stunting; bronzing, necrosis and yellowing of leaves and ringspots and necrosis in fruits)
- Symptoms vary depending on variety and plant age






TSWV Update-2022

Processing tomato samples tested for tomato spotted wilt virus (TSWV) in 2022

County	Total	TSWV		Negative	Observation
		RB	WT*		
Colusa*	4	2	0	2*	Samples with (-) results were showing leaf necrosis (Fusarium spp., associated symptoms?)
Sutter*	9	7	0	2*	
Yolo*	64	36	0	16	
San Joaquin*	6	1	0	5	
Stanislaus*	1	1	0	0	
Merced	6	6	0	0	
Fresno	32	29	0	3	
Total	122	82	0	28	

- RB TSWV predominant in all counties in 2023!

Typical spotted wilt in Sw-5 varieties

Scorching symptoms with some similarity to spotted wilt observed in 2023

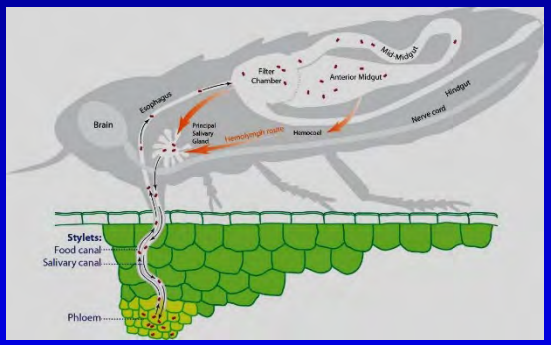
TSWV Update-2022

- RB-TSWV was detected in Northern Counties in 2021 and was the predominant strain detected in 2022
- RB-TSWV was predominant in all seven counties
- Suggests RB-TSWV overwintered and will become established
- Importantly, spread of RB TSWV was slower in the Northern Counties
- DD model predicted Gen 2 peak was 1 May and Gen 3 peak was 1 June
- RB-TSWV was detected in adult thrips captured on YSC in February
- Suggests that OW pupae from the previous season are sources for the next season

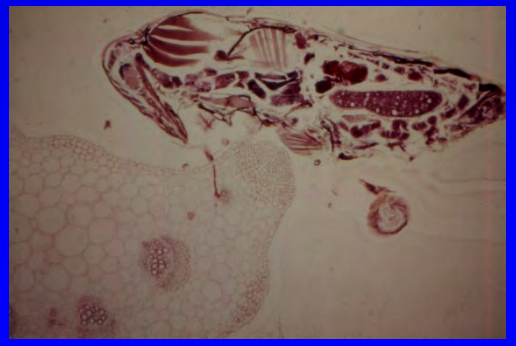
Background information on BCTV and curly top disease

- BCTV is a small plant virus composed of a circular single-stranded DNA genome protected by a protein shell that looks like 2 balls stuck together

- BCTV is composed of 11 strains
- Transmitted by the BLH but not passed to nymphs

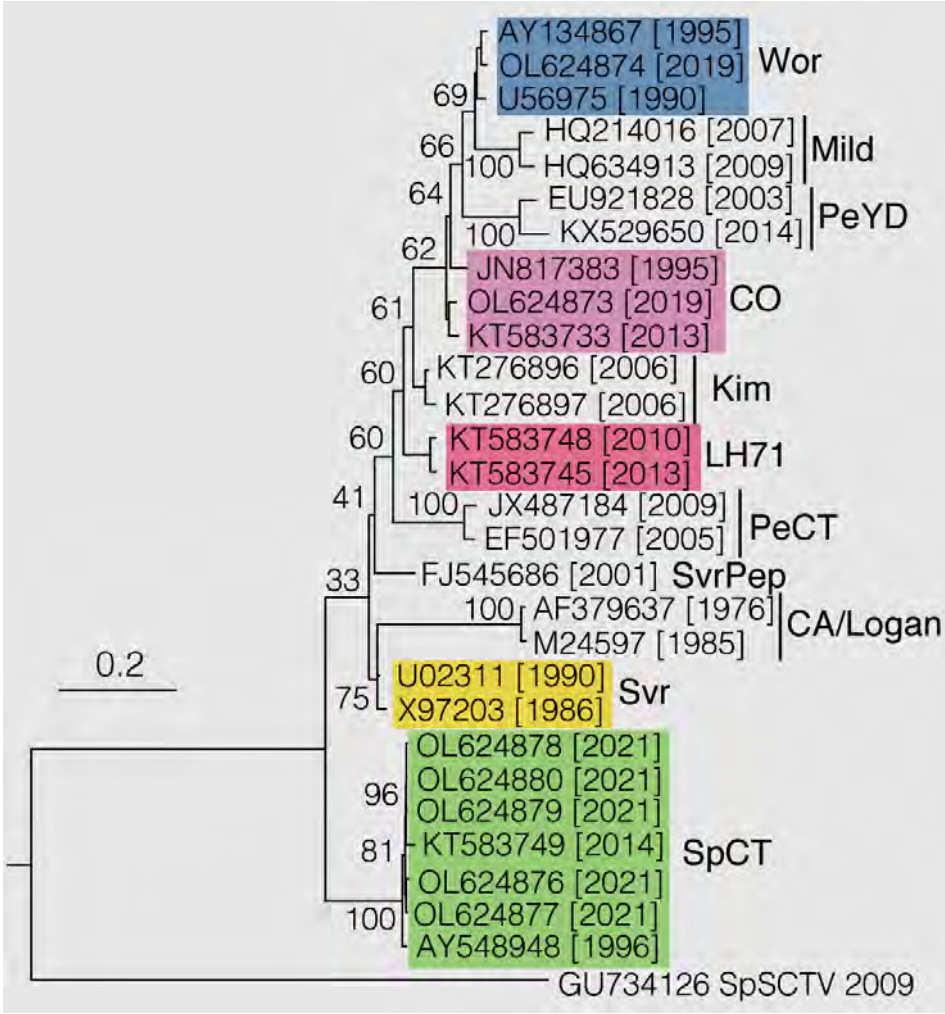


- In CA, the major crop impacted is processing tomato
- BLHs do not reproduce on tomato
- BCTV only infects the food conducting system (phloem) and BLH transmit during 'tasting' of tomatoes but then move on (tomato is a dead end host)



- BCTV can be rapidly (5 hours) and specifically detected in tomato and beet leafhoppers by a multiplex PCR test

Beet curly top virus (BCTV) strains



Mild-type strains:

BCTV-CO

BCTV-Wor

Severe-type strains:

BCTV-LH71

BCTV-Svr

BCTV-CA/Logan

BCTV-SpCT

Symptoms of curly top

- **Early infection** (~1 mo after planting)
  - -Stunted light green plants with upcurled/rolled leaves with vein swelling and purpling (diagnostic)
  - -These plants often die, whereas those infected later may collapse
  - -May be confused with early spotted wilt

- **Late infections** (>1 mo after planting)
  - -Symptoms in newer growth
  - -Fruits are small and ripen prematurely

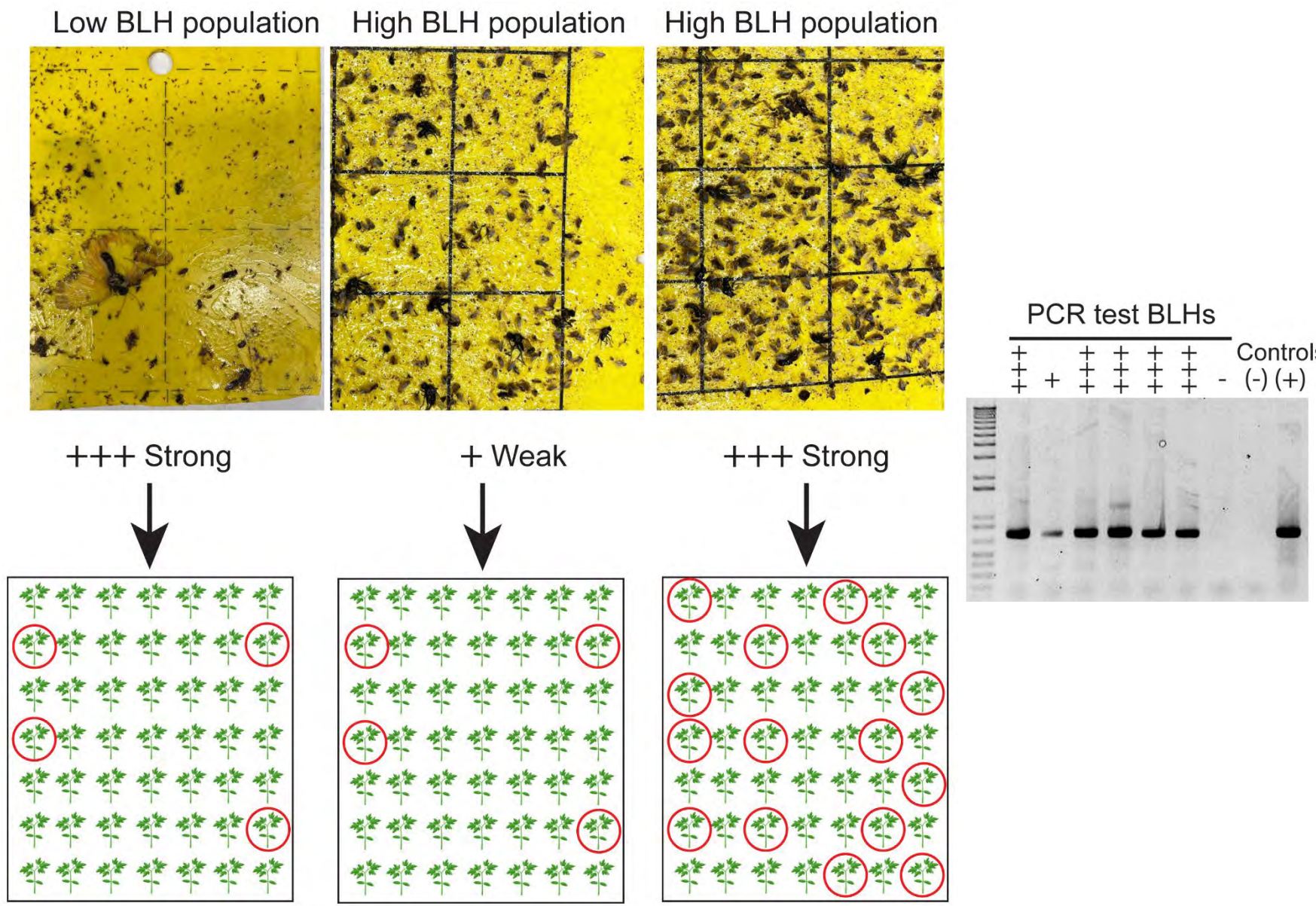
- **Importance of sample collection for PCR testing!**

Curly top disease cycle: Dependent on a migratory insect

Spring: New adults, some with BCTV migrate to the valley floor and search for preferred host

Winter/early spring: females overwinter and breed on annual and perennial weeds that show few symptoms

Fall: adult leafhoppers Migrate to overwintering in the foothills

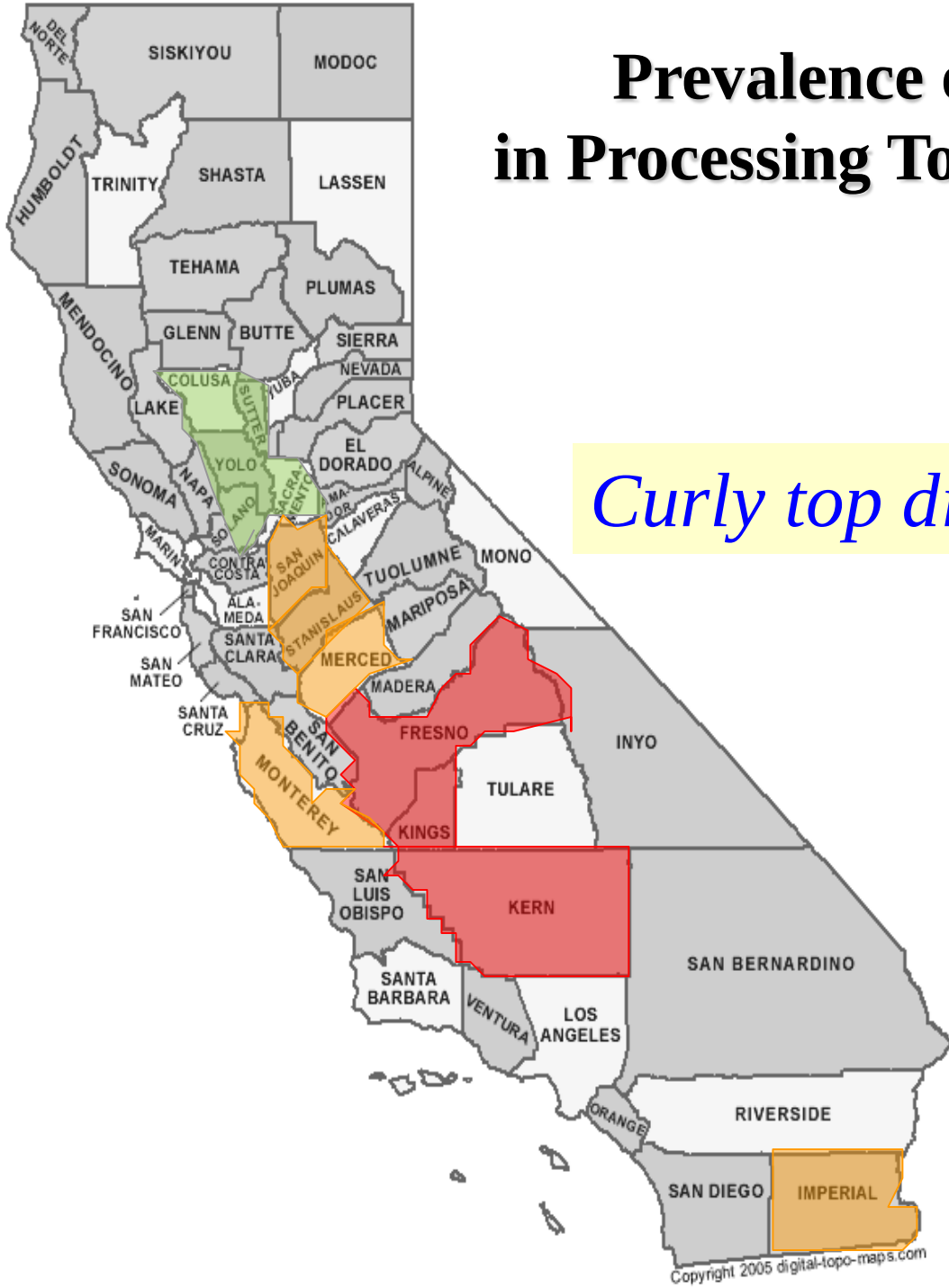

Low BLH population
High BLH population
High BLH population
+++ Strong
+ Weak
+++ Strong
PCR test BLHs
+++
+
+++
+++
+++
+++
-
Controls
(-) (+)

BCTV detection in beet leafhoppers from yellow sticky cards (2022)

Date	# of yellow sticky card	# of hoppers per card	BCTV detection
3/26/22	2	1	NO
4/2/22	5	>1000	NO
4/11/22	4	55	Weak (+)
4/15/22	6	>1000	Weak (+)
4/22/22	6	136	Weak (+)
5/2/22	3	74	Weak (+)
5/24/22	1	53	NO
6/3/22	1	50	NO
6/17/22	2	52	NO

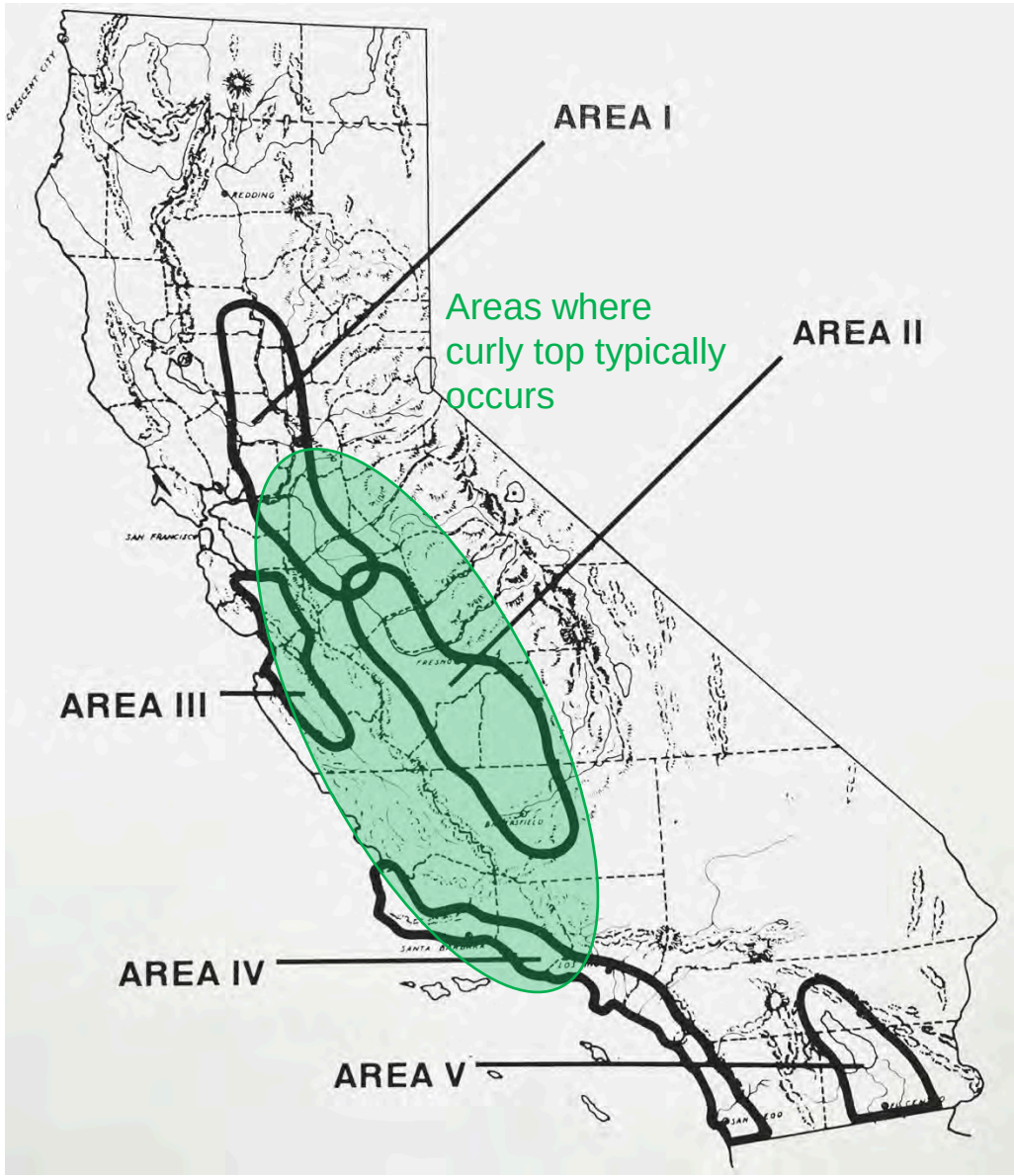
Visiting the monitor fields

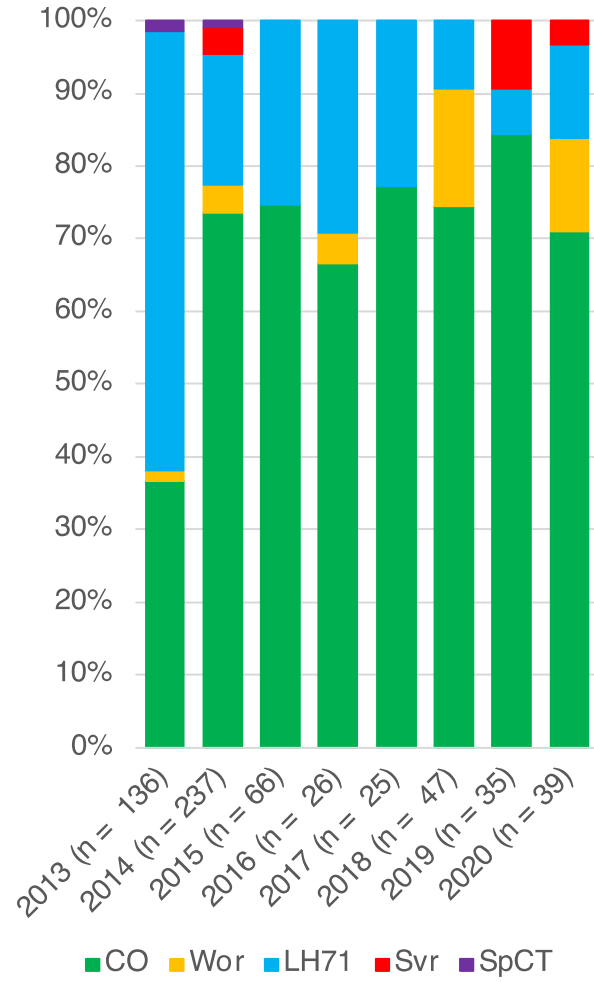
Prevalence of Virus Diseases in Processing Tomatoes of California



Curly top disease

BCTV strains infecting tomato plants since the major 2013 curly top outbreak and to 2020

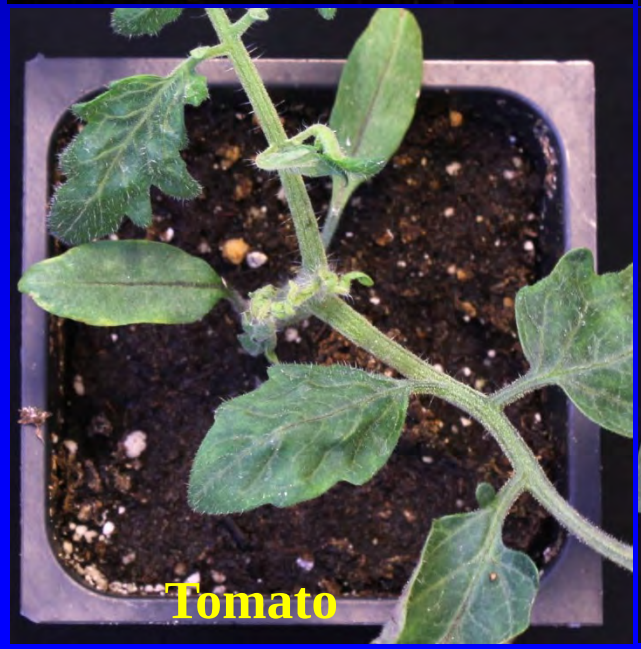




The 2021 curly top outbreak in the Northern Counties was highly unusual

- The incidence of curly top in Northern Counties has been very low
- In 2021, processing tomato fields in Colusa, Glenn, Sutter and Yolo Counties had much higher incidences, as high as 15-20%
- Associated with proximity to foothills and unusual hot dry winds in April and May
- An unusual strain, BCTV-SpCT (spinach curly top), was involved in early infections (April-May)
- However, later outbreaks (after late June) were caused by BCTV-CO

New strain of BCTV associated with curly top outbreaks in Northern California: BCTV-Spinach curly top (BCTV-SpCT)



Where is BCTV-SpCT coming from?

- Surveyed foothills and vegetation surrounding fields having 2021 curly top outbreaks in Yolo and Colusa

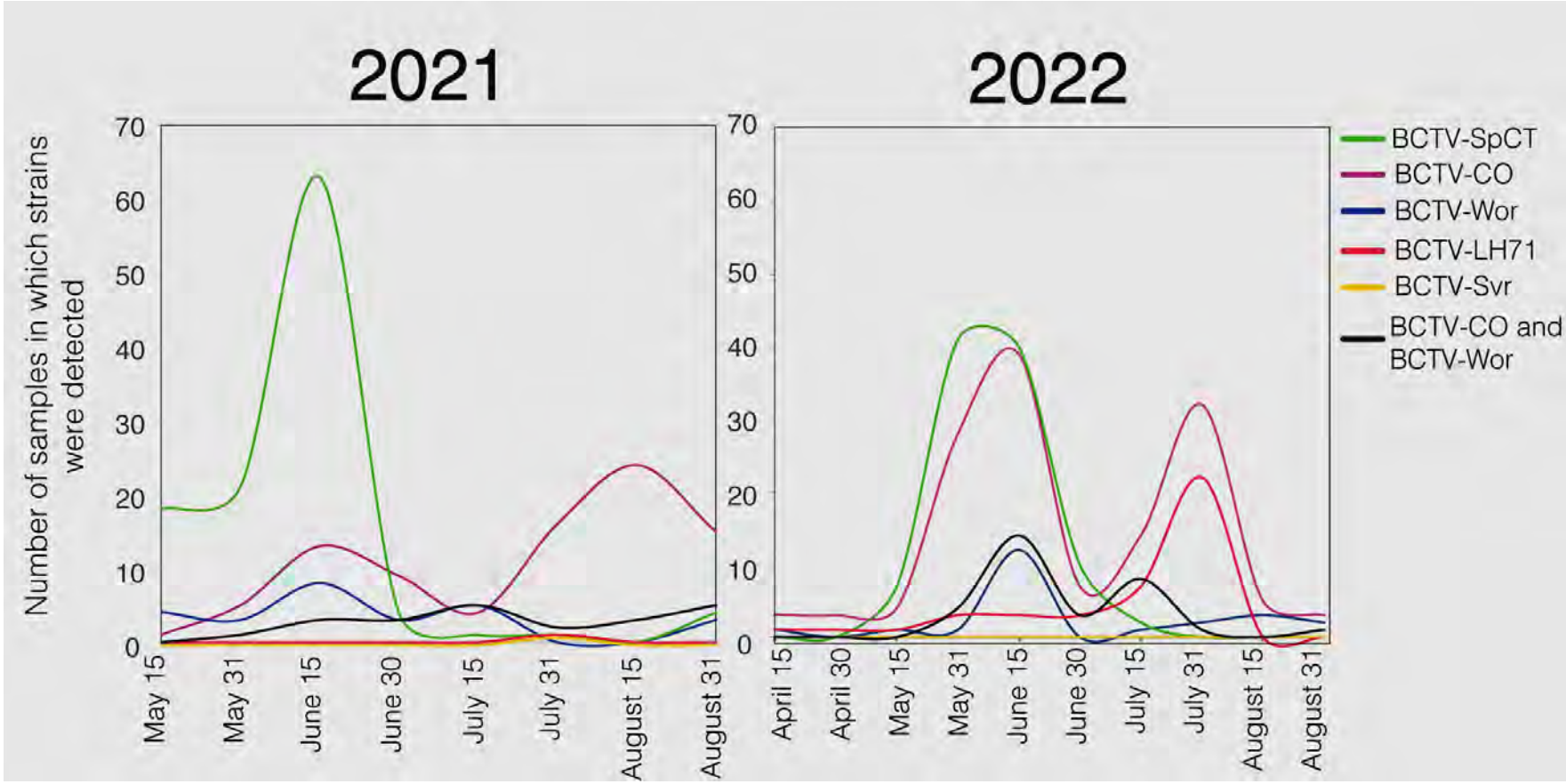
- Very low BLH populations and all negative for BCTV
- Coming from BLH flights from areas 1?
- BCTV-SpCT may have caused curly top is sugar beets and was 'sleeping' in symptomless weeds until an unusual BLH migration event

BCTV detection in tomato samples (2022)

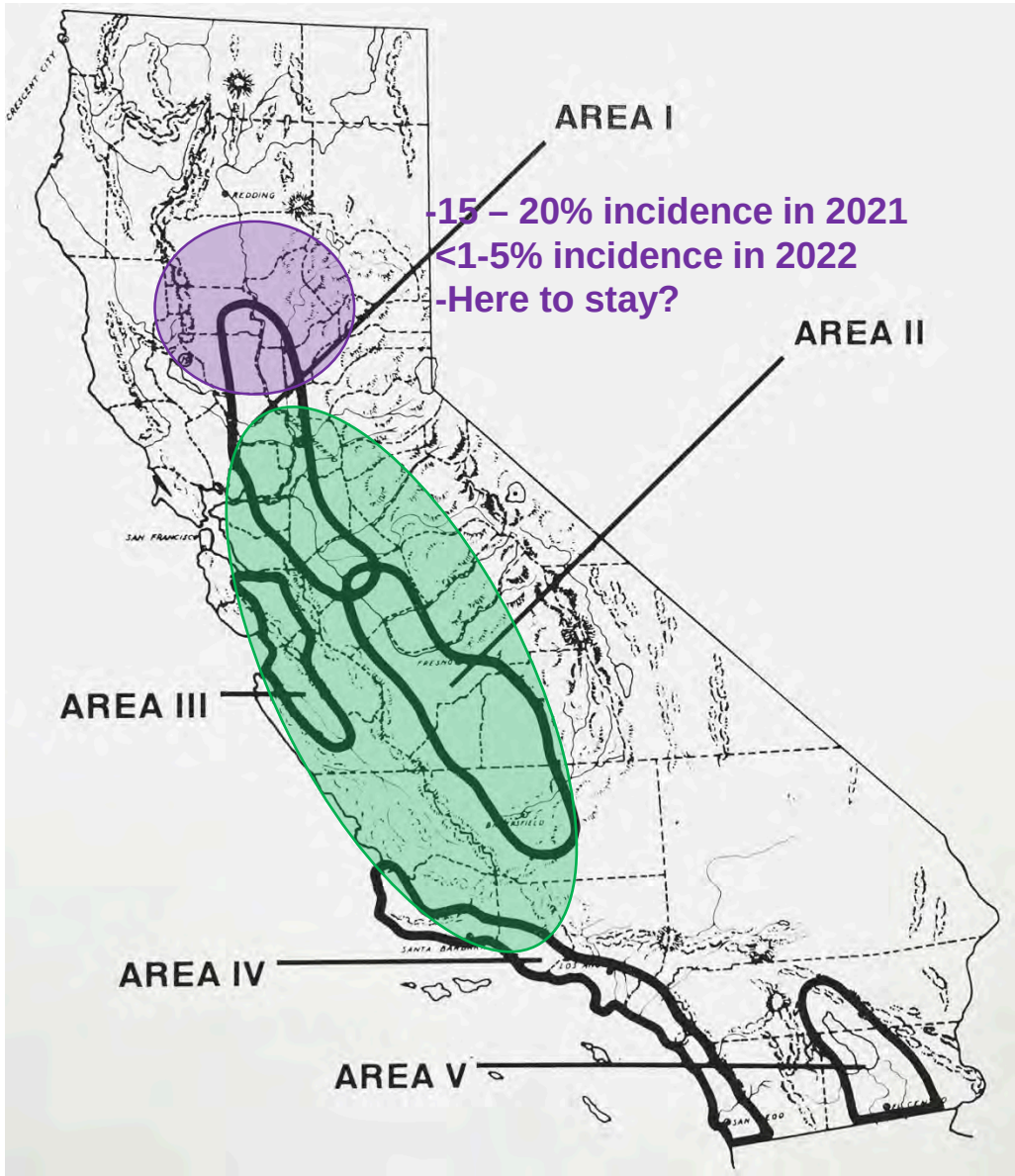
County	No. of samples	Multiplex PCR for mild and severe type BCTV strains				PCR with BCTV strain-specific primers					
		mild-type	severe-type	mixed	Negative	BCTV-SpCT	BCTV-CO	BCTV-Wor	BCTV-LH71	CO+Wor	Other mixed
Colusa	62	22	35	1	4	34	13	3	0	5	1
Yolo	102	23	61	2	16	54	14	7	4	2	1
Glenn	9	8	0	0	1	0	8	0	0	0	0
Stanislaus	30	29	0	0	1	0	28	0	0	1	0
Sutter	1	0	1	0	0	1	0	0	0	0	0
San Joaquin	26	25	1	0	0	1	14	0	0	7	0
Fresno	157	65	47	8	37	4	45	6	27	9	7
Madera	2	2	0	0	0	0	1	1	0	0	0
Kern	12	10	2	0	0	1	9	0	1	1	0
Total	401	184	147	11	59	95	132	17	32	25	9

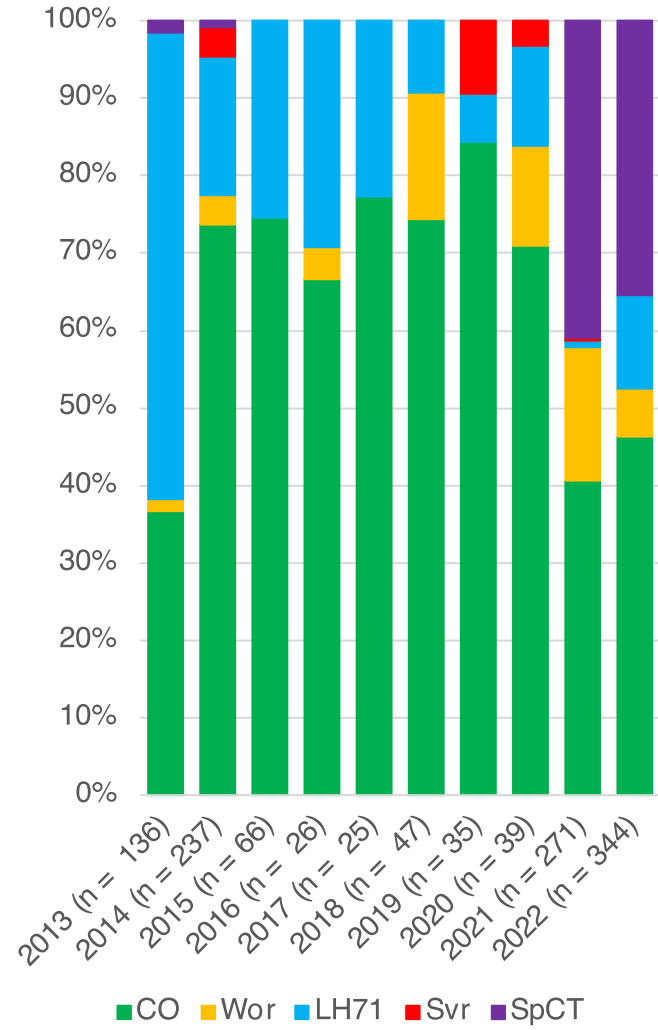
-Curly top reappeared in the Northern counties (Colusa and Yolo) in 2022, and was observed in many fields but at low incidences and did not cause economic loss

-BCTV-SpCT was again the predominant strain associated with early outbreaks


2021
2022
Number of samples in which strains were detected
0
10
20
30
40
50
60
70
May 15
May 31
June 15
June 30
July 15
July 31
August 15
August 31
April 15
April 30
May 15
May 31
June 15
June 30
July 15
July 31
August 15
August 31
BCTV-SpCT
BCTV-CO
BCTV-Wor
BCTV-LH71
BCTV-Svr
BCTV-CO and BCTV-Wor

BCTV strains infecting tomato plants since the major 2013 curly top outbreak-2021 and 2022





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Risk factors associated with curly top outbreaks in Fresno in 2022

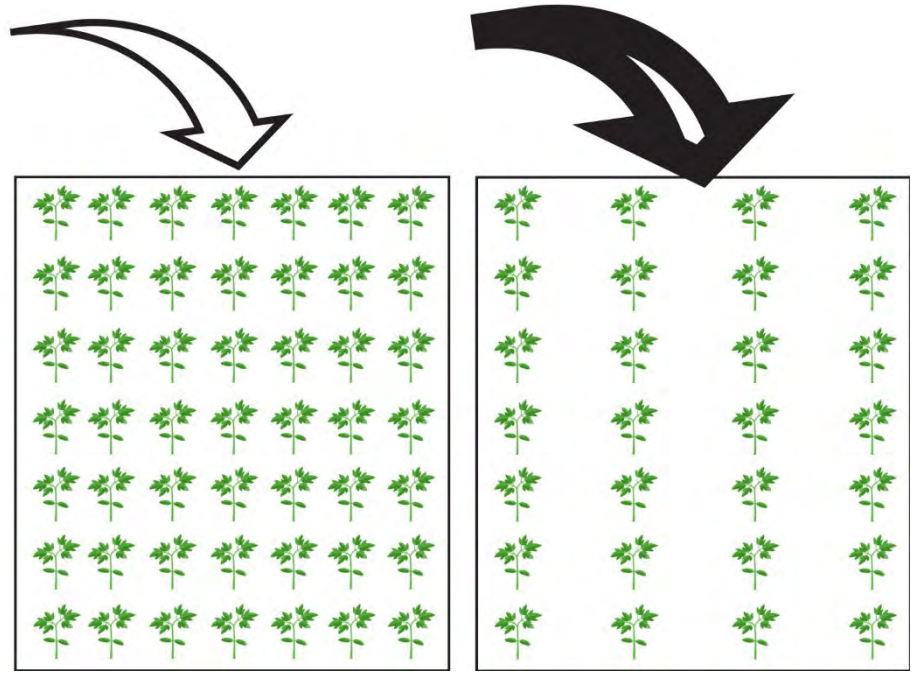
- Most of the Fresno samples can from fields with one of more risk factors: (i) proximity to foothills or weedy fallow fields and (ii) late or sparsely planted fields

Near the foothills

Late planted and near a huge fallow field

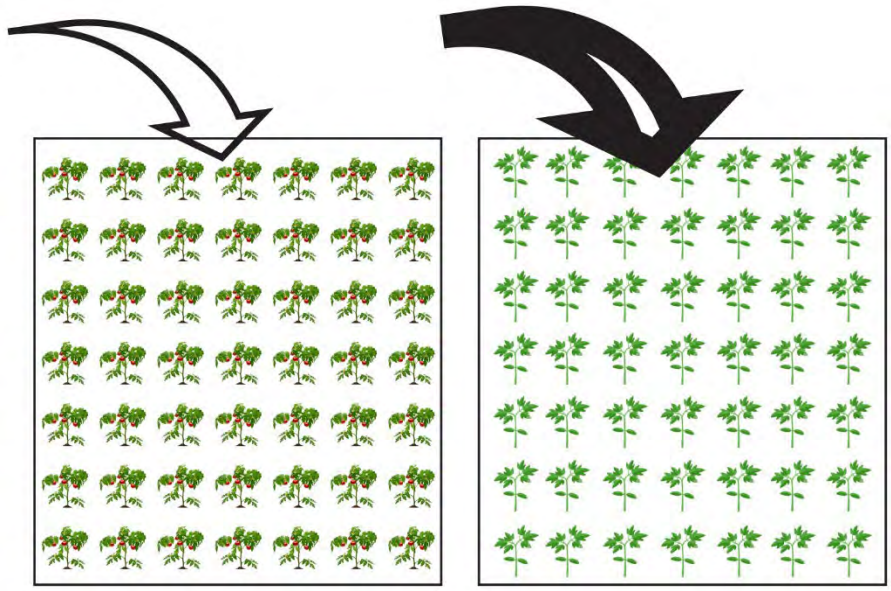
Hot spots for curly top outbreaks

Close to foothills

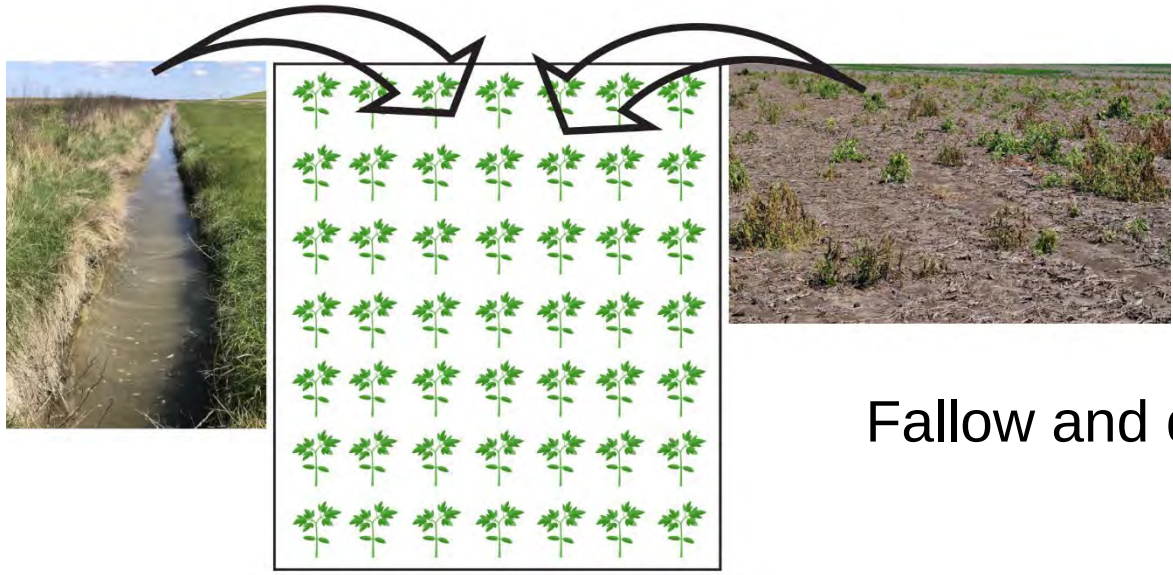


Sparsely planted

Hot spots for curly top outbreaks



Late-planted



Fallow and ditches

An old virus learning new tricks: curly top outbreaks in cucurbits

- In 2022, curly top of cucurbits was more **prevalent** and occurred in more areas
- **Pumpkin and squash** mostly, but also detected in melon in 2022
- **BCTV-CO was the predominant strain** associated with curly top of cucurbits

Mild-type BCTV strains (-CO and -Wor) infecting new hosts

BCTV-CO and BCTV-Wor strains can infect and cause curly top symptoms in hemp and lettuce plants!

An unusual yellowing phenotype associated with curly top of tomato

- Not strain-associated
- Co-infection with Fusarium?
- Cultivar response?
- Leaf scorching symptoms further complicating diagnosis

Acknowledgements

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