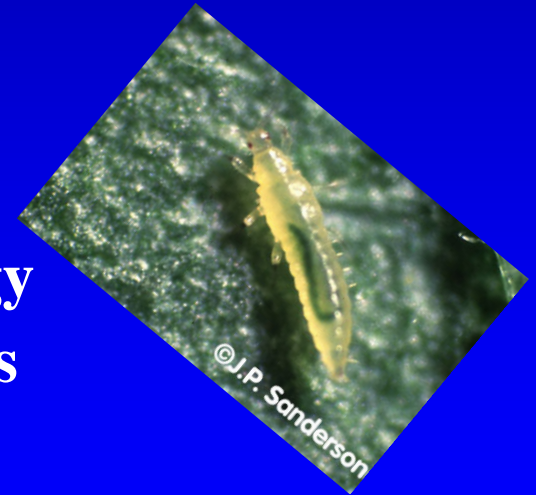


Tomato spotted wilt virus and Curly top update

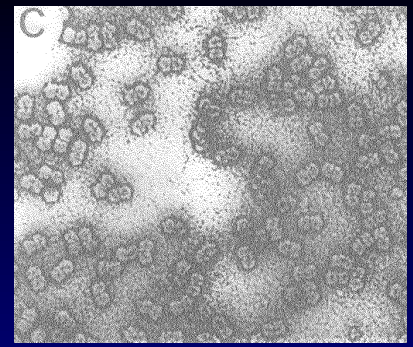


Robert L. Gilbertson
Department of Plant Pathology
University of California Davis



Curly top is caused by *Beet curly top virus (BCTV)*

- A **geminivirus** with a very **wide host range** including **crops and weeds**
- Some plants infected with BCTV develop **curly top disease** (e.g., tomatoes), whereas **others show no symptoms** (species of weeds)
- BCTV is **only transmitted by the beet leafhopper** (not seed-transmitted or by contact)
- Exists as a **complex of strains**



Beet curly top virus



Symptoms of BCTV infection in tomato



Beet leafhopper vector

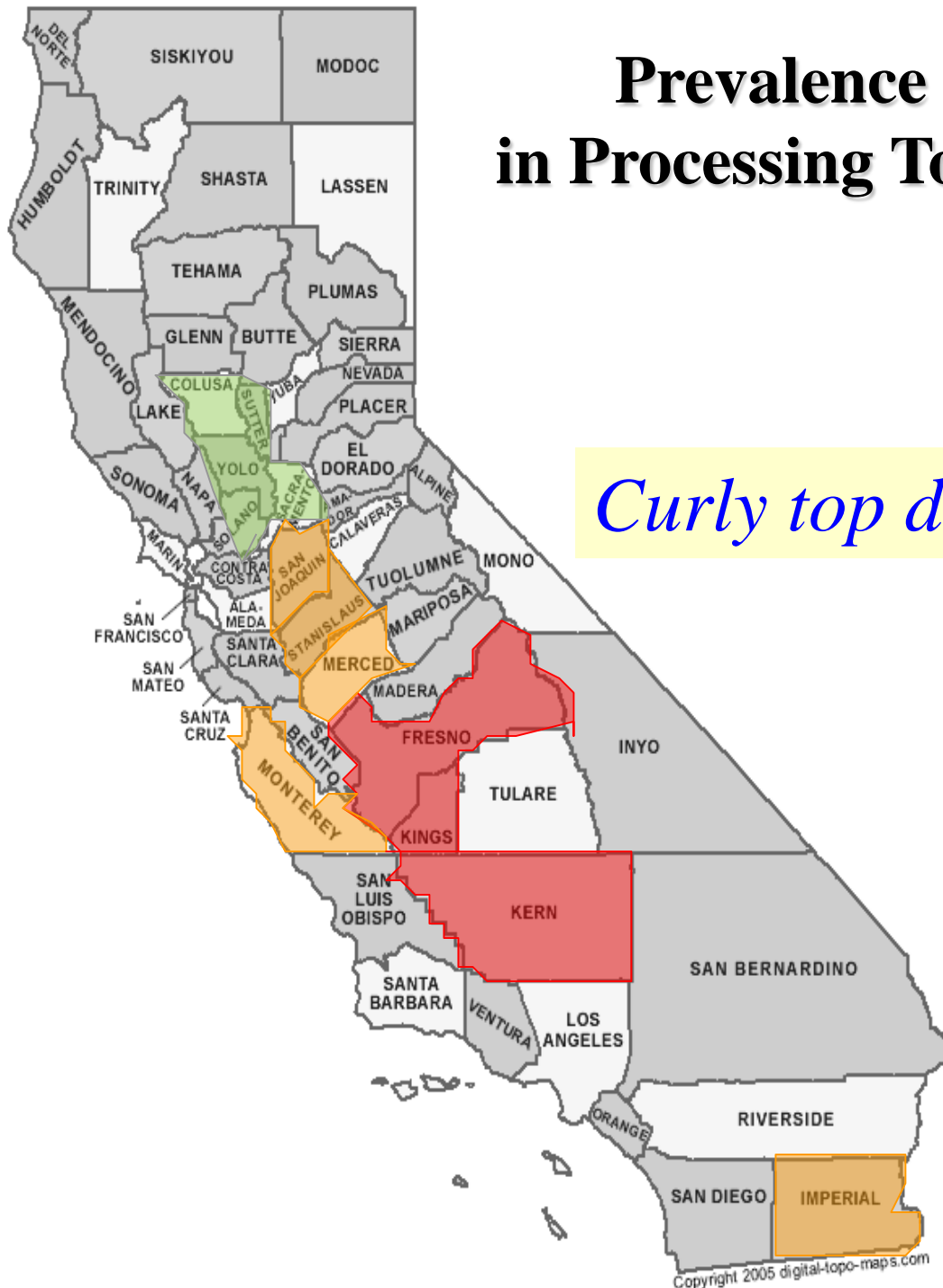
Curly top symptoms: Tomato

- 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**
- Fruits are small and ripen prematurely



Prevalence of Virus Diseases in Processing Tomatoes of California

Curly top disease



Curly top disease cycle: Dependent on a migratory insect



Winter/early Spring:
Adult females overwinter
and breed on annual and
perennial plants



Fall:
Adult leafhoppers
migrate for overwintering
in the foothills



Spring:
Viruliferous adult
leafhoppers migrate to the
valley floor and feed



Multiple generations on the
valley floor

Curly top management: A difficult challenge

- Curly top is a **sporadic and unpredictable disease**
- **California Department of Food and Agriculture (CDFA)** operates a **Curly Top Control Program (CTVCB)** that targets the beet leafhopper with insecticide sprays based on **monitoring leafhoppers**
- **Cultural practices** can help, such as not planting next to foothills or heavy plant populations
- Currently, there are **no commercially available curly top-resistant tomato varieties**

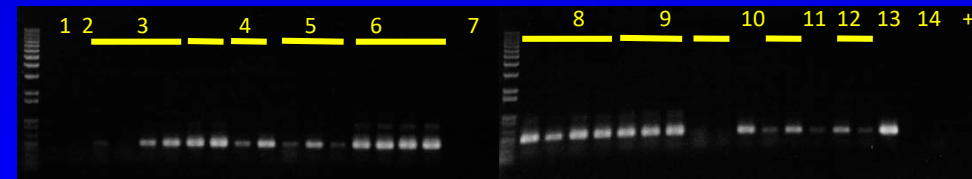


Curly top outbreak of 2013

- Losses of **~1 million tons** (~\$100 million)
- Associated with **high beet leafhopper populations with high BCTV titers**
- Appearance of curly top in **new locations**, e.g., San Joaquin County and in **new crops**, e.g., melon



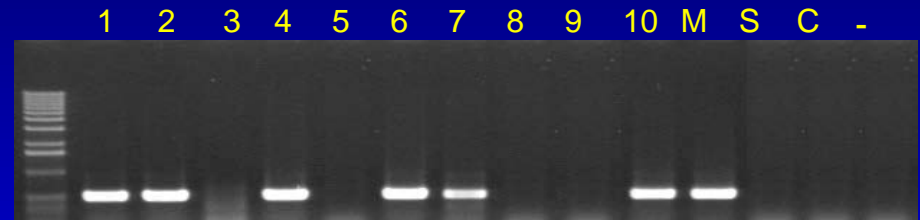
Tomato field with 90% curly top in Fresno Co.



High BCTV titers in most of the leafhopper samples

We have developed new methods for detection of BCTV and screening plants for resistance

- Rapid and specific **PCR test for BCTV**
 - Detection of the virus in crops, weeds and leafhoppers
 - ID viruses/strains
 - Predict curly top severity and target areas for spraying



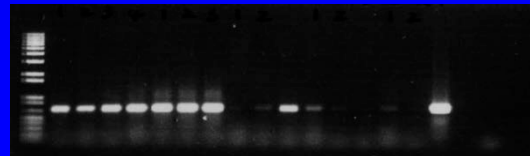
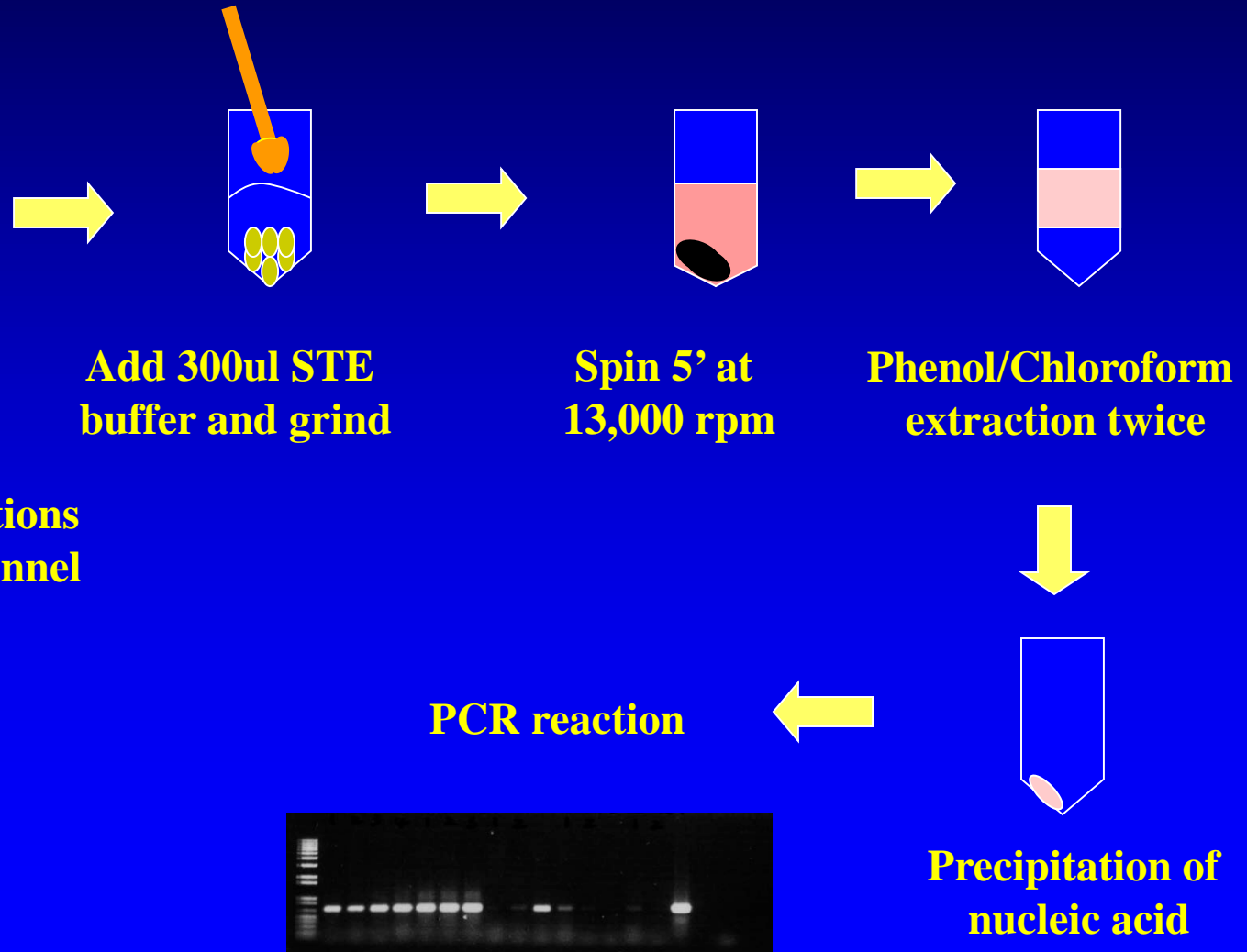
- **Agroinoculation method** for curly top
 - Vector independent screening for resistance
 - Rapid, efficient and reliable



PCR Detection of BCTV in beet leafhoppers

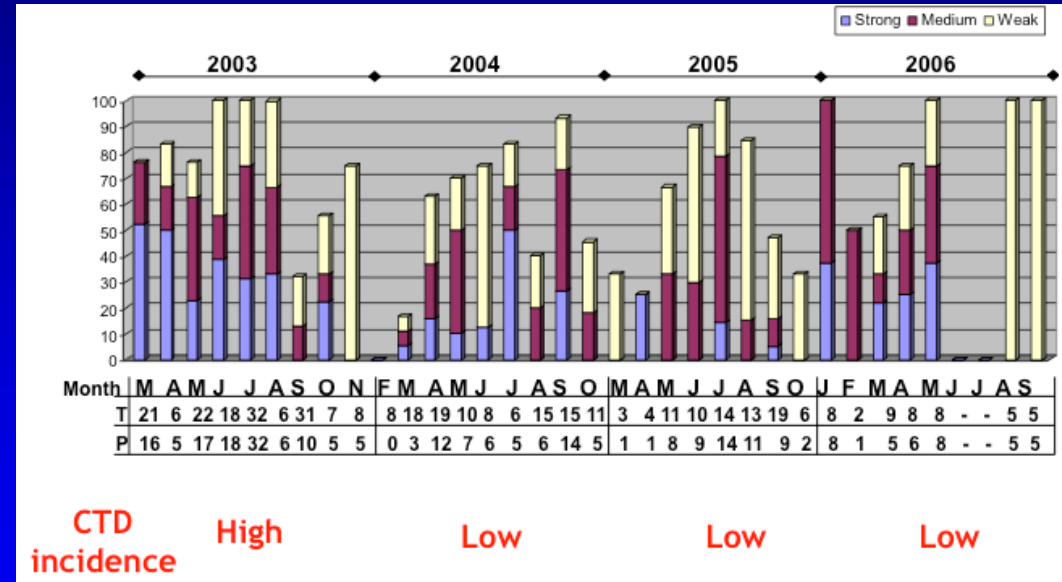


Monthly leafhopper collections
from CDFA CTVCP personnel

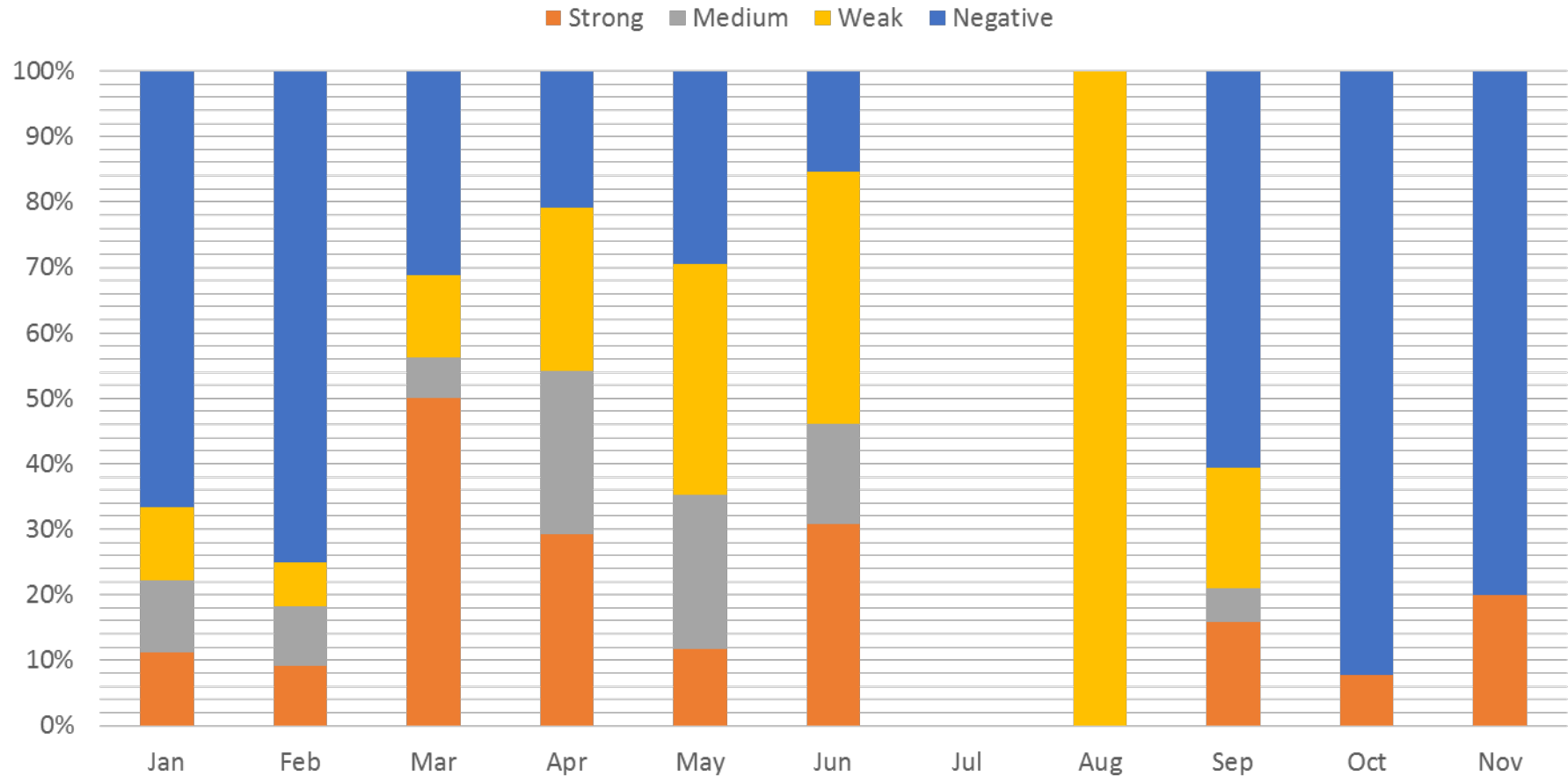


Model for predicting curly top outbreaks in a growing season: Bad years are correlated with high populations of leafhoppers with high levels of BCTV early in the growing season

- Using the PCR detection method and leafhoppers provided by the CTVCB), it was established that bad outbreaks of curly top in tomato were correlated with high populations of leafhoppers carrying high levels of BCTV early in the growing season (i.e., February-April)

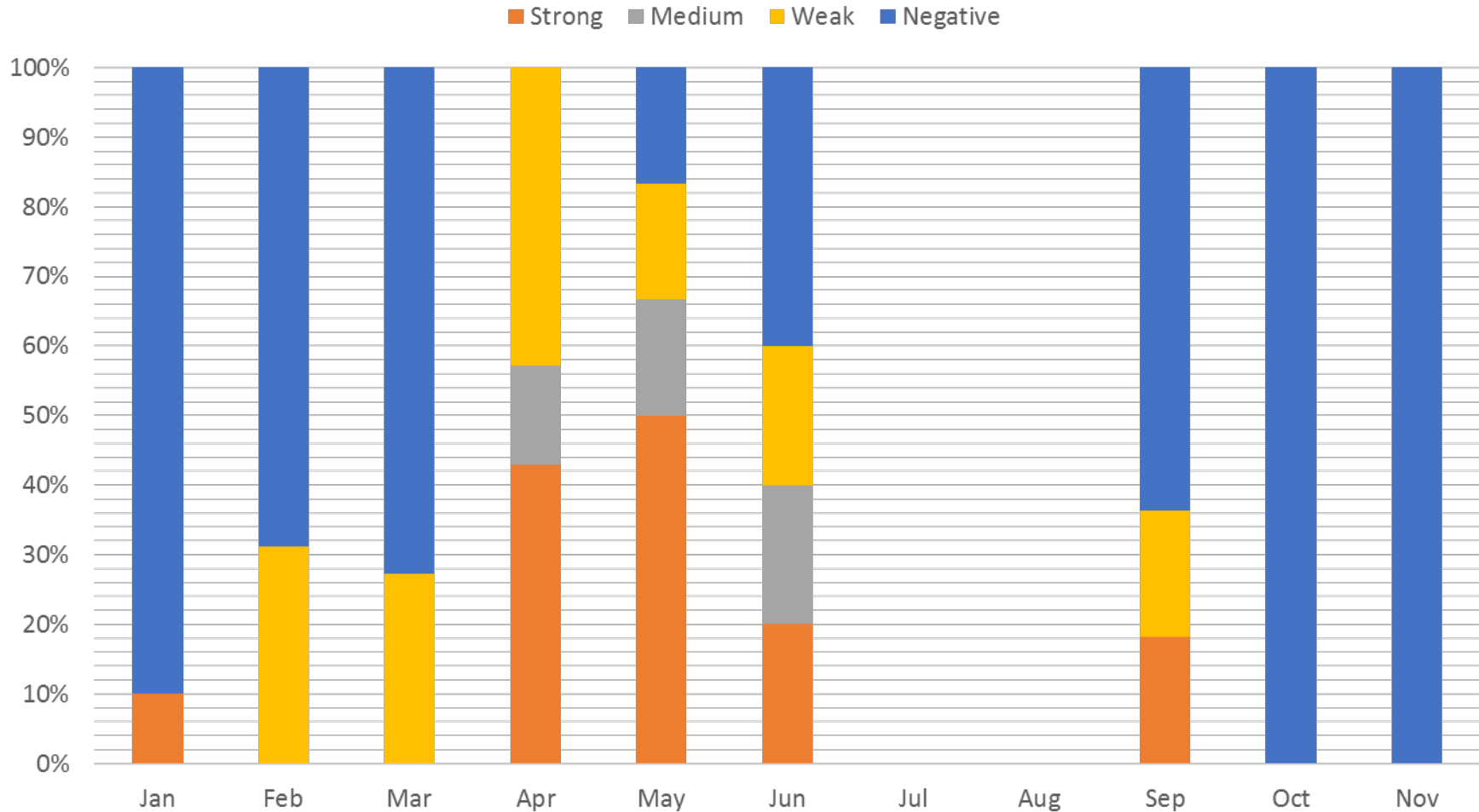


Percentage of beet leafhopper samples positive for BCTV: Fresno Co. 2016



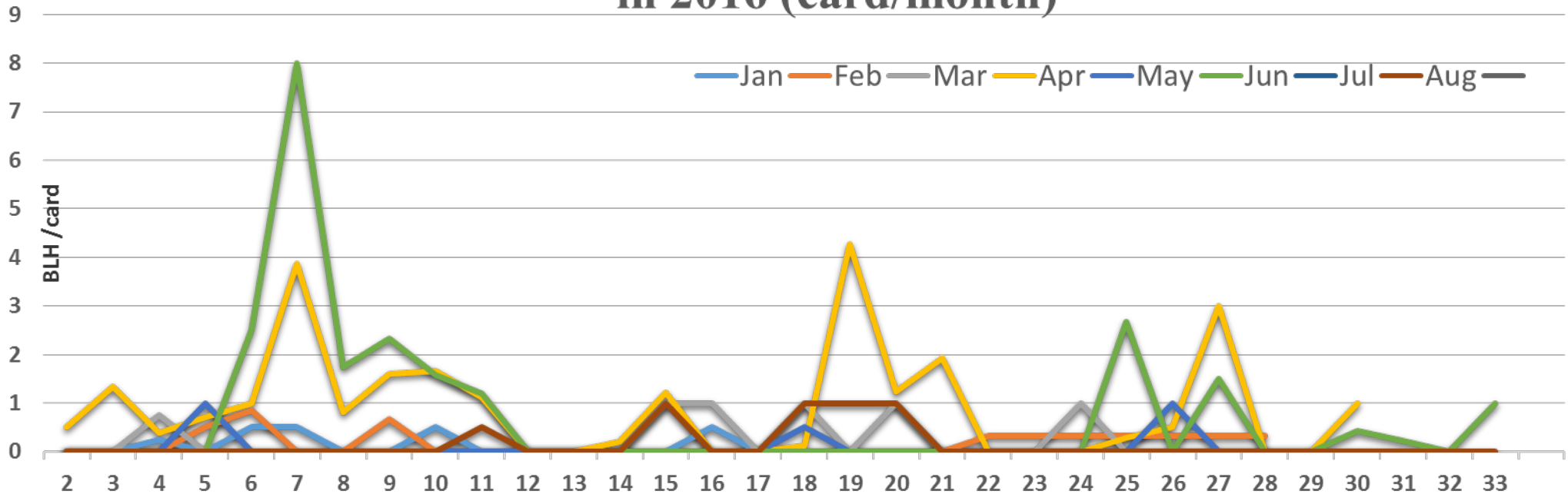
Beet leafhopper populations in February-April: Low to moderate

Percentage of beet leafhopper samples positive for BCTV: Kern Co. 2016



Beet leafhopper populations in February-April: Low to moderate

Average BLH counts in monitored fields in Fresno/Kings Co. in 2016 (card/month)



- Very low BLH populations in winter months
- Increased in March and especially in April
- Dropped in May, with some peaks in June
- Low numbers during the rest of the summer

Incidence of curly top disease in 2016

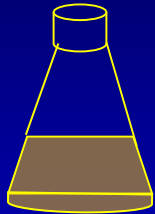
Site	Location	Fields surveyed	Average CTV	Range of incidences
1-6	Southern Fresno Co.	11	3.6	0-8.5
7-11	NW Huron (198) into Lemoore	15	3.6	0-17
	Oakland Ave.	5	0.3	0-2
14-18	Lassen and Mt. Whitney/Five Points	11	1.0	0-5
	Cantua Creek-Organic*	2	25.0	18.8-32
20-22	Manning	6	0.3	0-1
25-28	Nees Ave (Firebaugh) Northern Fresno	16	2.9	0-12.7
30-33	Corcoran	19	4.8	0-11.3



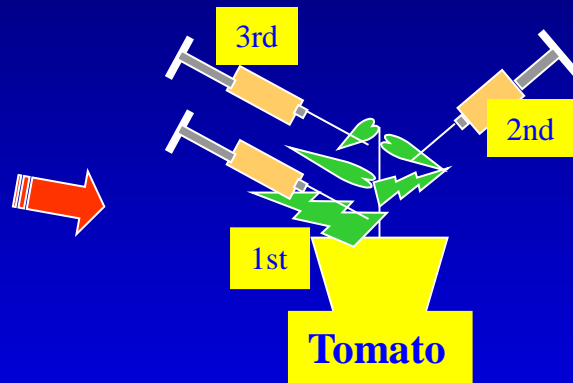
Overall curly top incidence in 2016: Low/Moderate

Agrobacterium-mediated inoculation for screening tomato tomato varieties and germplasm for resistance to BCTV

BCTV



48 hr old liquid culture of *Agrobacterium tumefaciens* containing the viral DNA



Observe symptom development

Check for virus infection
(by PCR)



**Curly top resistance has been identified in breeding lines with
Ty genes from the World Vegetable Center**



We have generated a breeding line (line 20) with introgressed *Ty* genes that has high levels of curly top resistance



Conclusions

- Model **correctly predicted** a low to moderate curly top year in 2016
- Application of the PCR test is allowing for **prediction of severe BCTV outbreaks and a better understanding of virus biology**
- Leafhopper populations on the valley floor **peaked in April-June**
- **BCTV resistance** has been identified and seed companies are working on development of resistant varieties

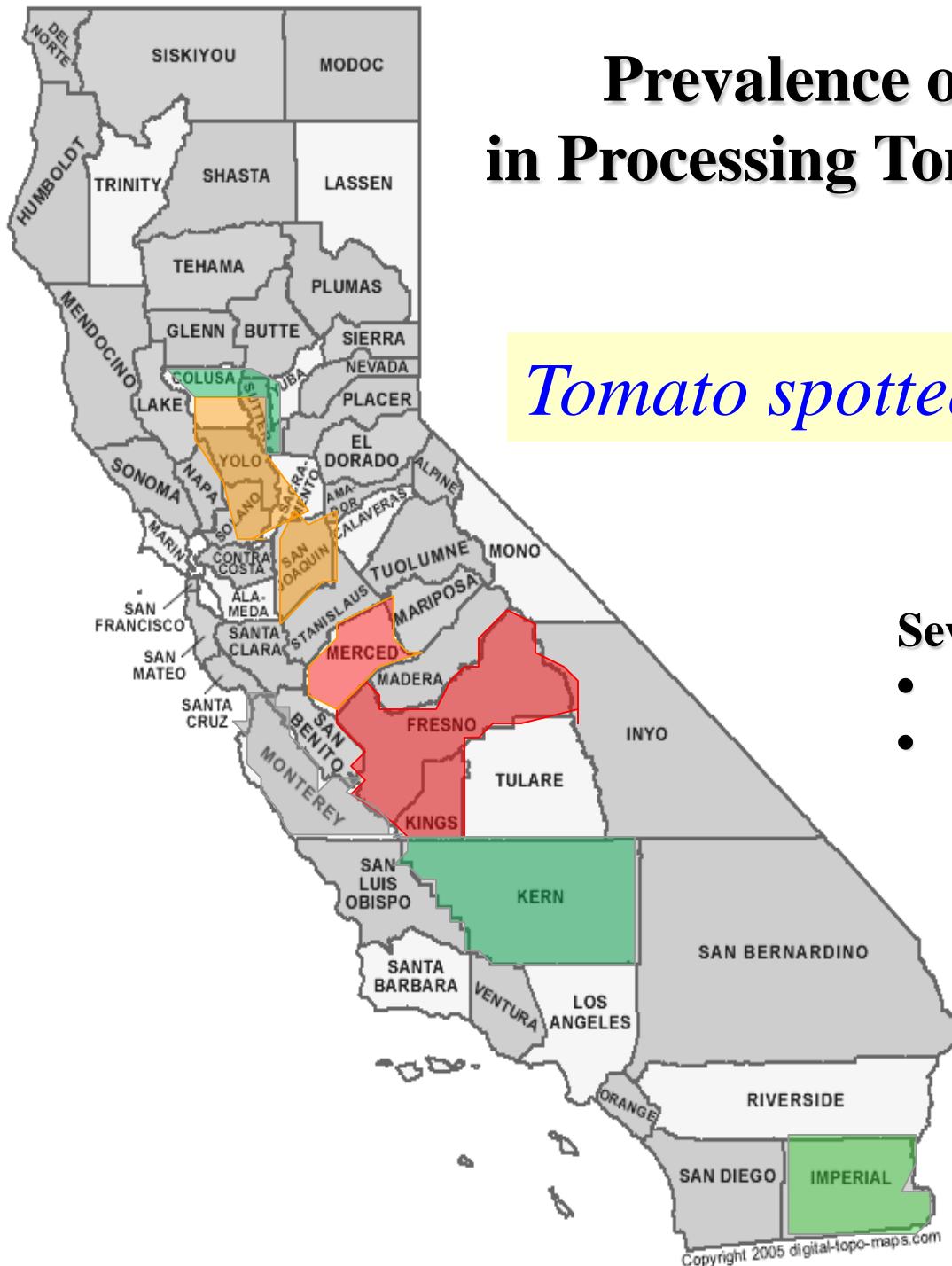
Tomato spotted wilt diseases caused by *Tomato spotted wilt virus (TSWV)*

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



Prevalence of Virus Diseases in Processing Tomatoes of California

Tomato spotted wilt virus (TSWV)



Severe yield losses can occur when:

- high thrips populations
- high level of virus inoculum

An IPM program has been developed for thrips and TSWV in processing tomatoes in California

-Allowed for effective management of the virus

-Substantial reduction in yield losses due to the virus.

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



...ges
...anato
...thrips
...virus
...minimize
...stance in

...ected at the seed-
...read.

...ound fields.

at:
...and destroy old tomato plants
...crops/volunteers after harvest on a

...eds/volunteers in fallow fields, non-
... or idle land near next year's tomato

Insecticide for Thrips Management (trade name (common name))	Resistance management class
Radiant (spinetoram)	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: rgilbertson@ucdavis.edu).



Supported in part
by the
California Tomato
Research Institute

Appearance of a resistance-breaking strain of *Tomato spotted wilt virus* in the Central Valley of California in 2016

- In the spring of 2016, typical and **severe symptoms of TSWV** were observed in Sw-5 fresh market tomatoes in **Cantua Creek and Firebaugh (Fresno Co.)**
- **Immunostrip and RT-PCR/sequencing** tests revealed only TSWV infection
- Raised the issue of the emergence/introduction of a **resistance-breaking (RB) strain**
- RB strains have been reported from Europe (Spain and Italy) and have been **associated with specific amino acid substitutions in the viral movement protein (NSm), including ‘YPT’**



Identification of TSWV RB strain

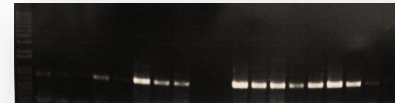
Typical tospovirus symptoms



Test for TSWV with immunostrips



Confirm TSWV by RT-PCR



Confirm RB strain by RT-PCR of NSm gene

Amino acid (aa) sequence

MDTSK GKILLNTEGTSSFGTYESDSITESEGY
 DLSARMIVDTNHHISNWKNDFVGN GKQ
 NANKVIKI **YPT**WDSRKQYMMISRIVIWVC

aa substitution C to Y in 118 position or T to N in 120 position

RB strain

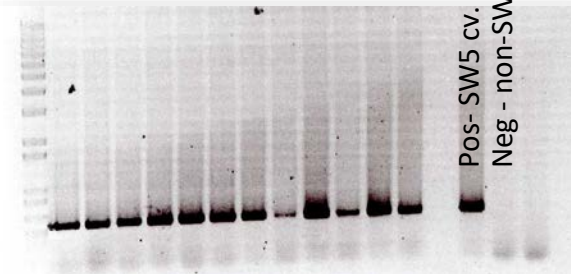
MDTSK GKILLNTEGTSSFGTYESDSITESEGY
 DLSARMIVDTNHHISNWKNDFVGN GKQ
 NANKVIKI **CPT**WDSRKQYMMISRIVIWVC

no aa substitution in 118 or 120 position (CPT)

WT strain

Confirm tomato is a resistant variety by PCR for SW-5

Pos- SW5 cv.
 Neg - non-SW5 cv.



TSWV isolates infecting fresh market Sw-5 varieties have the RB motif 'YPT'

TSWV Isolate	Location collected from/tested with TSWV and TMV immunostrip	Symptoms	NSm Motif
SW19	Firebaugh, Fresno Q-99 Fresh Mkt Tomato (Sw-5) TSWV +, TMV -	Typical TSWV symptoms in leaves concentric rings in fruits	YPT Resistance Breaking (RB)
SW21	Cantua Creek, Fresno Q27 Fresh Mkt Tomato (Sw-5) TSWV +, TMV -	Typical TSWV symptoms in leaves concentric rings in fruits	YPT (RB)
SW24	Fresno Proc Tomato (no Sw-5) TSWV +, TMV -	Typical TSWV symptoms in leaves concentric rings in fruits	CPT Non-RB
T36	Yolo Proc Tomato (no Sw-5) TSWV +, TMV -	Typical TSWV symptoms in leaves concentric rings in fruits	CPT Non-RB

TSWV strains with the 'YPT' motif infect fresh market tomato cultivars following mechanical inoculation

Mechanical inoculation of Sw-5 fresh market varieties with putative TSWV RB strains

Tomato Variety	Infected/Inoculated plants with TSWV Isolates				
	SW5 Gene	SW19 RB Isolate	SW21 RB Isolate	SW24 Non RB	T36 Non RB
HM 1794	Yes	3/10	2/10	0/10	0/10
HM 1795	Yes	2/10	3/10	0/10	0/10
Q 27	Yes	1/10	2/10	0/10	0/10
H 8504	No	0/10	0/10	0/10	0/10

TSWV strains with the 'YPT' motif infect processing tomato varieties following mechanical inoculation

Mechanical inoculation of Sw-5 processing varieties with putative TSWV RB strains

Processing tomato experiment							
						Nsm Sequence	
Variety	SW5	isolate	Infected/total	SW5	Nsm	YPT	CPT
BQ273-1	yes	SW19 RB TSWV	6/10	+	+	+	-
BP2-1	yes		10/10	+	+	+	-
DRI319-1	yes		5/10	+	+	+	-
HM3887-1	yes		1/10	+	+	+	-
H5608-1	yes		7/10	+	+	+	-
H8504-1	no		3/10	-	+	+	-
N6366-1	no		1/10	-	+	+	-
BQ273-1	yes	SW21 RB TSWV	1/10	+	+	+	-
BP2-1	yes		3/10	+	+	+	-
DRI319-1	yes		4/10	+	+	+	-
HM3887-1	yes		1/10	+	+	+	-
H5608-1	yes		0/10	+	-	-	-
H8504-1	no		3/10	-	+	+	+
N6366-1	no		3/10	-	+	-	+

Conclusions

- Outbreaks of **spotted wilt in Sw-5 fresh market tomato fields** in the spring and fall of 2016 were **due to a resistance breaking (RB) strain of TSWV**
- RB strain was **detected only in Fresno County in 2016, and mostly in fresh market varieties**
- The RB strain likely **emerged by mutation** in response to **increased planting of Sw-5 varieties** (~50% of processing tomato varieties now possess Sw-5)
- RB strain **was less fit in a non-Sw-5 background**
- Important to monitor for the **survival and spread of RB strains** in the Central Valley in 2017

Acknowledgements



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- **Dr. Ozgur Batuman**
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