Maize Lethal Necrosis:

History and Control in the Western Hemisphere

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Maize Lethal Necrosis

Maize chlorotic mottle virus (MCMV)

1) Potyvirus – *Sugarcane mosaic virus* (SCMV); *Maize dwarf mosaic virus* (MDMV); or, *Wheat streak mosaic virus* (WSMV)
2) Other viruses – *Maize rayado fino virus; Maize mosaic virus?*
3) Stress

- MLN caused by interaction of at least two factors.
- Today—
  - Discovery of MCMV
  - History and distribution of MLN in Peru, the U.S. and China
  - Possible reasons for disease spread (and non-spread) in these regions
  - Approaches to MLN control
  - Virus resistance in maize

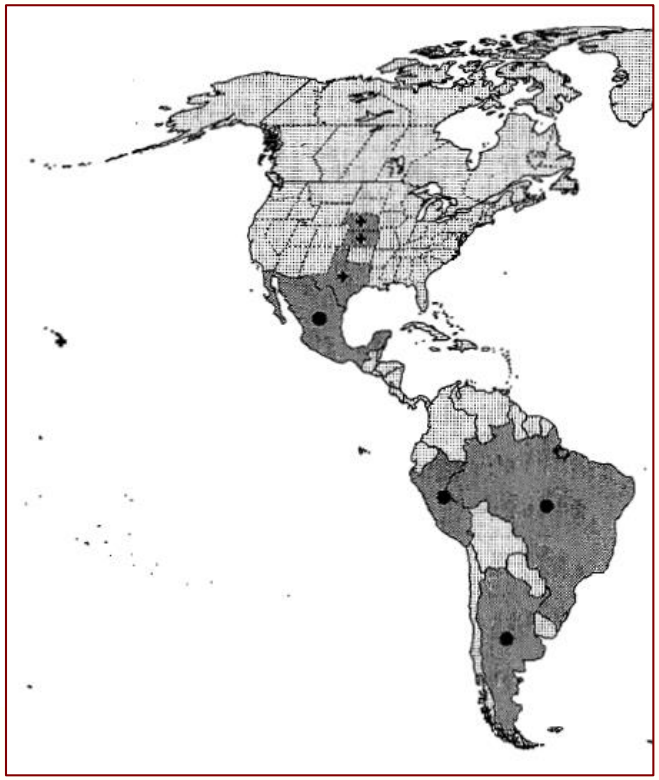
Discovery of MCMV in Peru

- In 1971, *Maize chlorotic mottle virus* (MCMV) was first found in valleys of the Department of Lima .
- First symptoms included fine streaks that coalesce to form chlorotic mottling. Epinasty and necrosis followed
- Plants were mottled; growth was stunted. Male flowers had hard panicles, short rachis and few spikelets. Fewer and malformed ears were produced.
- Yield loss >50% in inoculated plots; 10-15% under natural infection
- Hosts included maize and a number of other grasses, but no dicots.
- MCMV is icosahedral 30 nm particles.
- In synergistic interactions with *Maize rayado fino virus* infected plants produce no ears.

Castillo Loayza (1976) In: *Proceedings* Int Maize Virus Disease Workshop, OARDC

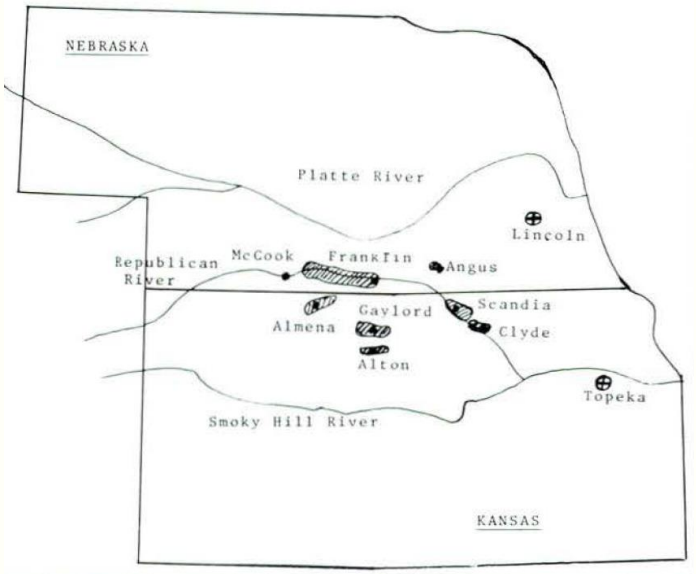
MCMV in the Western Hemisphere

Year	Location
1971	Peru
1976	Kansas
1979	Texas
1980	Brazil
1982	Argentina
1990	Hawaii



Discovery of MCMV and CLN in the U.S.

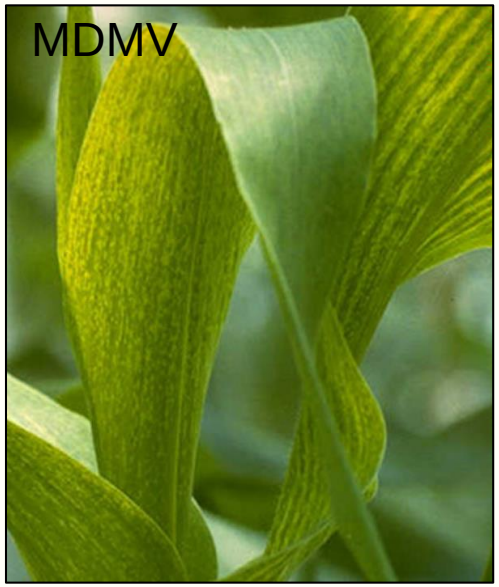
- In 1976, maize in Kansas developed unknown symptoms:
  - Mosaic on leaves and husks
  - Leaf necrosis progressing inward from the margins
  - Premature plant death
  - Tassel necrosis
  - Poor ear development, no seed set.
- **Three** viruses were present in samples:
  - MCMV – similar to the Peru virus
  - MDMV - *Maize dwarf mosaic virus*
  - WSMV - *Wheat streak mosaic virus*

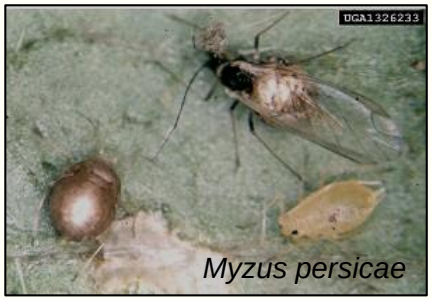


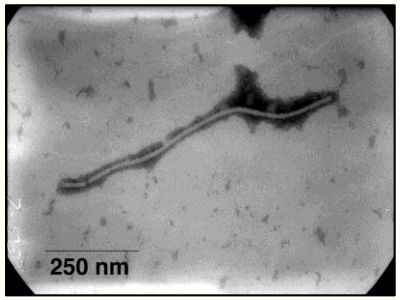
Niblett & Claflin.1978. Plant Dis. Rep. 62:15-19.

Maize-infecting Potyviruses

Virus	Abbrev.	Distrib.	Primary Vector(s)
Maize dwarf mosaic virus	**MDMV**	**WW**	**Aphids**
Sugarcane mosaic virus	**SCMV**	**WW**	"
Zea mosaic virus	ZeMV	Israel	"
Johnsongrass mosaic virus	JGMV	U.S., Aust.	"
Sorghum mosaic virus	SrMV	U.S.	"
Wheat streak mosaic virus	**WSMV**	**N. Am, Mid East, Europe**	**Wheat curl mite**





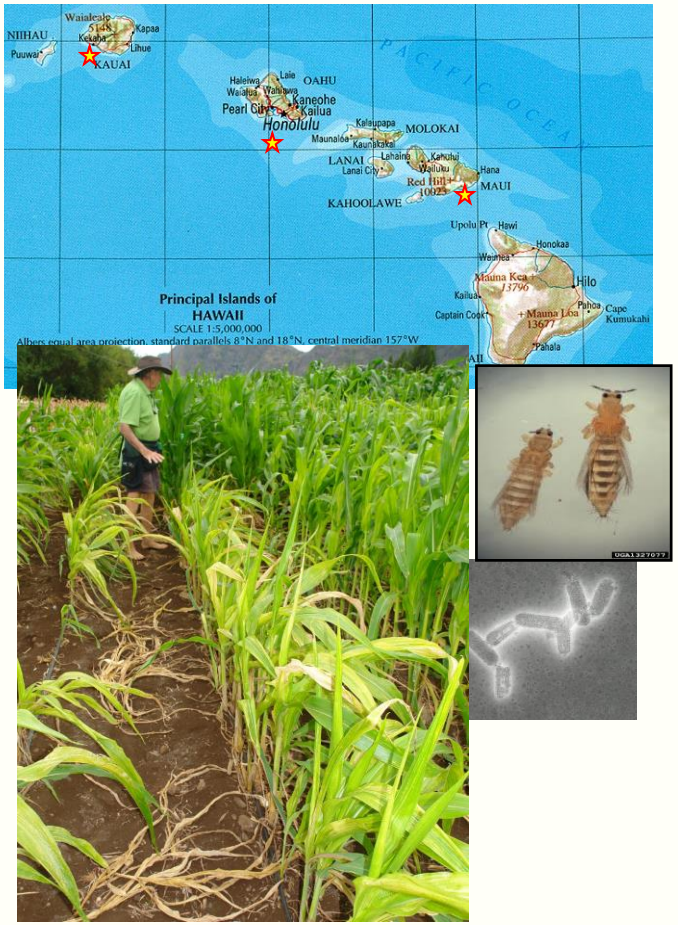


MCMV + Potyvirus = MLN

- Plants inoculated with MCMV, MDMV or WSMV alone had mosaic symptoms.
- The plants inoculated with one virus were smaller than healthy plants (not shown).
- Plants inoculated with MCMV *plus* MDMV or WSMV were much more severely affected than plants with one virus. (Compare 3 left pots to 2 right pots.)

MCMV emergence in Hawaii

- Kauai-seed companies germplasm development since ‘70s.
- MCMV identified in 1990
- Thrips present in fields and could transmit MCMV.
- Several other potential vectors present, and +MCMV. These did not transmit.
- Now present in Oahu and Maui.
- Synergistic interaction with *Maize mosaic virus.*



Jiang et al. 1992. Crop Prot. 11:248-254.

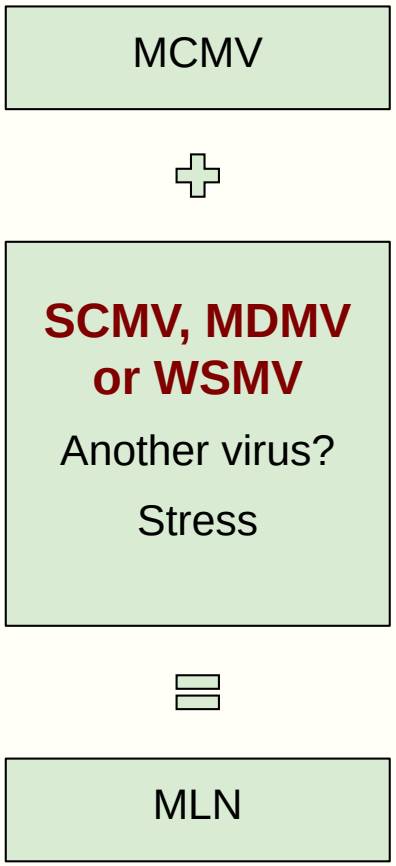
MCMV Transmission

- Transmitted for up to six days after acquisition by beetles: *Oulema melanopa* (flea beetle), *Chaetocnema pulicaria* (corn flea beetle), *Systena frontalis* and *Diabrotica sp.*
- In Hawaii, maize thrips (*Frankiniella williamsi*) transmitted MCMV for up to 6 days after 1-3 days of feeding on infected plants.
- Seed transmitted at about 1/2500 seed collected from infected plants. Transmission rates varied among seed lots.
- Soil/water transmission is known for Tombusviridae. Ben Lockhart has found soil transmission for MCMV.

Nault, et al. 1978. Phytopath. 68:1071-1074.
Jiang et al. 1992. Crop Protect. 11:248-254.
Jensen et al. 1991. Plant Dis.75:497-498.
Nyasani et al. 2012. Entomol. Exp. Appl.142:236-246.
Jensen et al. 1991. Plant Dis.75:497-498.
Phillips et al. 1982. Plant Dis. 66:376-379.
Cabanas et al. 2013. J. Econ. Ent. 106: 16-24.

MLN Control in the U.S. Cornbelt

- *MLN is an occasional and local problem. Found mostly in the Republican River Valley.*
- Crop rotation: In the 70's, two year moratoriums were imposed on growing maize. This reduced insect populations, and increased future yields.
- Living with MCMV: Last serious outbreak in Kansas was 1988, but MCMV is still present in up to 20% of fields. Commercial hybrids are strongly resistant to potyviruses and are likely tolerant of MCMV.
- Winter: Prevents 'continuous corn' and reduces vector populations. Maize thrips not present.



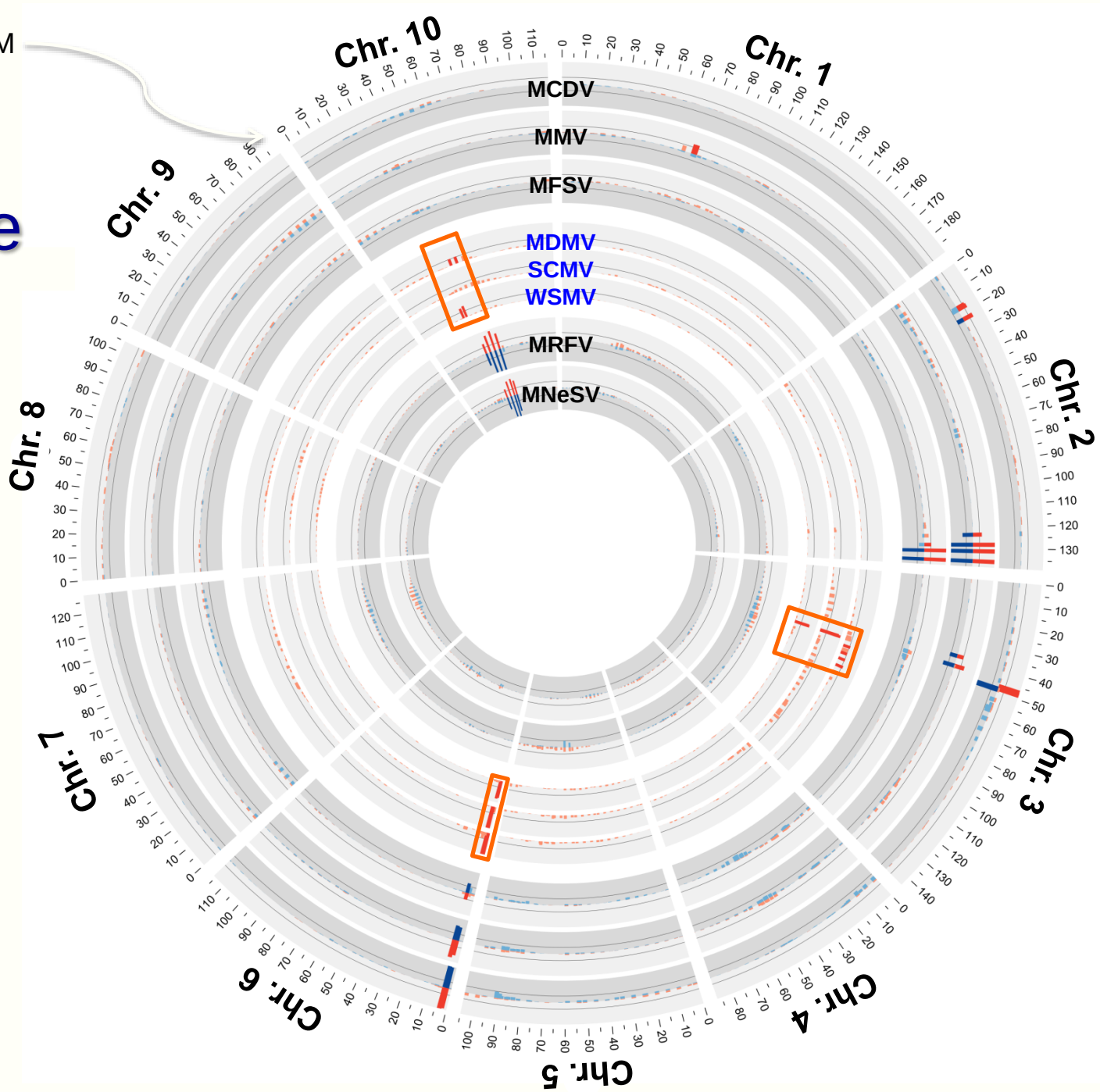
MLN Control in Hawaii

- Problem on several islands, different crops use different approaches.
- Abiotic stresses and *Maize mosaic virus* plus MCMV produce MLN.
- *Seed production fields:*
  - Intensive insect control regimes—weekly or more frequent spray protocols for thrips.
  - Industry imposed maize-free periods of two months
  - Active and intensive roguing of symptomatic plants.
- *Sweet corn fields:*
  - MMV resistance; MCMV tolerance/resistance.
  - Crop rotations, spray programs, etc.

Long Term Control – Virus Resistance

- Strong resistance identified in maize germplasm for most viruses investigated.
- Resistance genes or major QTL identified and mapped for 9-10 viruses.
- Minor QTL are identified for most viruses.
- For *Perigrinus maidis* (MSpV and MMV vector), some vector resistance identified.
- *Maize virus resistance genes are not yet cloned.*
- *Maize tolerance to MCMV is known, but strong resistance to MCMV has not yet been characterized.*

QTLs for virus resistance in maize



MCMV Tolerance in Maize

- Jim Brewbaker, University of Hawaii, has investigated MCMV resistance in maize.
- In replicated plots found 46% were highly tolerant of MCMV (1-2.5 on a 1-9 scale), 23% highly susceptible (5-9) and 31% intermediate.
- Many Latin American landraces are are tolerant or highly tolerant of MCMV. Although gains can be made in 3-4 cycles of selection, genetic control is not well understood.
- Segregating populations based on Hi27 (highly tolerant) indicate a locus on chromosome 7 near A2 is important for tolerance.
- HiS3, a synthetic population based on inbred lines, that segregates for tolerance.
- *Virus can be isolated from most of these lines after inoculation.*
- Very few of the resistant/tolerant lines have white kernels.

MCMV Tolerant Materials

Inbred	Origin	Source	Inbred	Origin	Source
Hi27	Hawaii	Colombia	1416-1	NCSt	
Hi28	Hawaii	Cuba	1487-2	NCSt	
Hi30	Hawaii	Cuba	CIMA21	CIMMYT	
Hi34	Hawaii	Antigua	CM103	India	
Hi39	Hawaii	Hybrid	CML52	CIMMYT	
Hi40	Hawaii	Hybrid	CML69	CIMMYT	
Hi41	Hawaii	Hybrid	CML223	CIMMYT	
Hi42	Hawaii	Suwan 1	Fla2AT116	Florida	
Hi44	Hawaii	Suwan 1	KS23-5	Hawaii	KS23 Thai
Hi45	Hawaii	Hybrid	KS23-6	Hawaii	KS23 Thai
Hi48	Hawaii	CM116	MP68-616	Miss.	
Hi49	Hawaii	CM201	NC300	NCSt	
Hi52	Hawaii	Fla2BT106	NC358	NCSt	
Hi54	Hawaii	ICAL221	OH7B	Ohio	
Hi55	Hawaii	ICAL224	TZi17	IITA	Kim
Hi58	Hawaii	Ki14 Thai			
Hi66	Hawaii	TZi4			
Hi68	Hawaii	TZi23			

Jim Brewbaker's list of tolerant inbreds.

These develop very few symptoms, but do contain the virus.

The Peruvian Cooperative Corn Program identified a number of 'resistant' inbreds and populations, but the nature of the resistance isn't known.

Some remaining questions

- Role for potyvirus and/or MSV resistance in disease control?
- Germplasm responses to different MCMV isolates.
- Will tolerance work? Alone and in the presence of a second virus or stress.
- Potential for other control measures.
- Potential for vector resistance and/or stress resistance in reducing disease.

Thanks!