# Resistance to Root-knot Nematodes in Tomato

**Root-knot Nematode Life cycle**
***Mi-1* gene**
**Markers for *Mi-1***
**Resistance-breaking nematodes**
**Other sources of resistance**

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**Tomato Breeders Roundtable**

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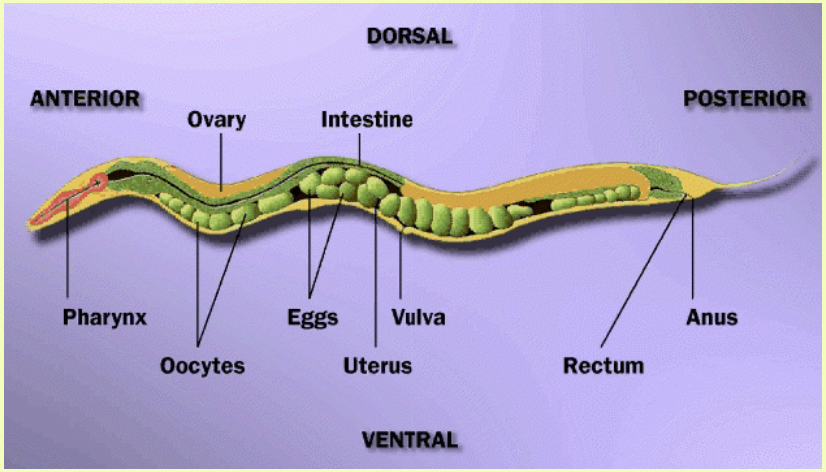
# Phylum Nematoda

**One of the largest phyla in the kingdom Animalia**

**<u>Kingdom</u>: Animalia**

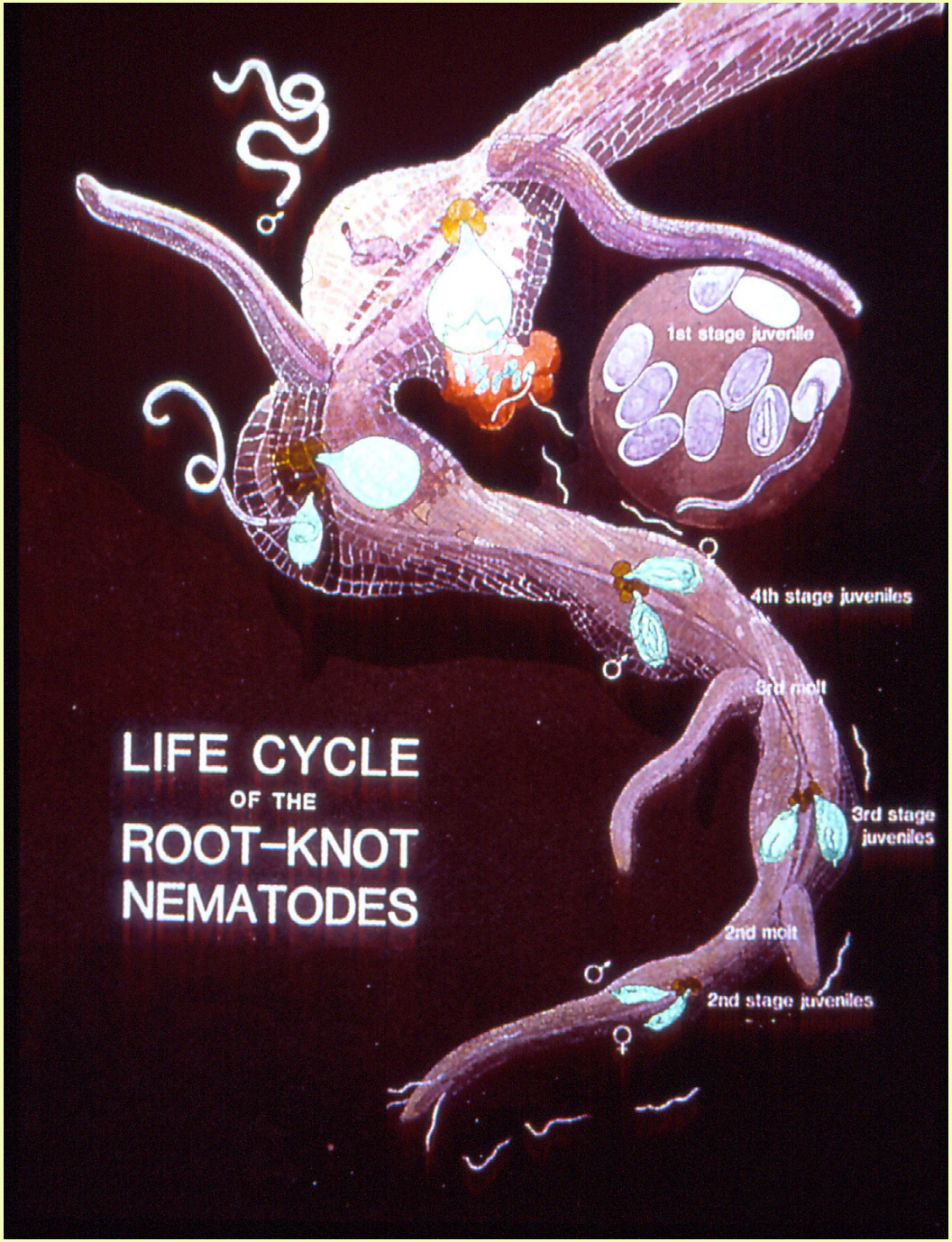



**<u>Microbe</u>: a very small living organism**


www.mactode.com

# LIFE CYCLE OF ROOT-KNOT NEMATODES

- Juvenile nematodes penetrate the root and enter the vascular cylinder.
- Nematode manipulates the host cells to become "giant cells."
- Giant cells are used by the sedentary nematodes for feeding.
- Nematodes molt and lay eggs, which hatch and infect new roots.



# Nematode resistance in tomato is mediated by a single dominant gene, *Mi-1*



**Resistance:** failure to allow reproduction of the nematode (e.g., few or no eggs). Galling is not a great indicator!

# The nematode resistance gene *Mi*

## (aka *Mi-1*)

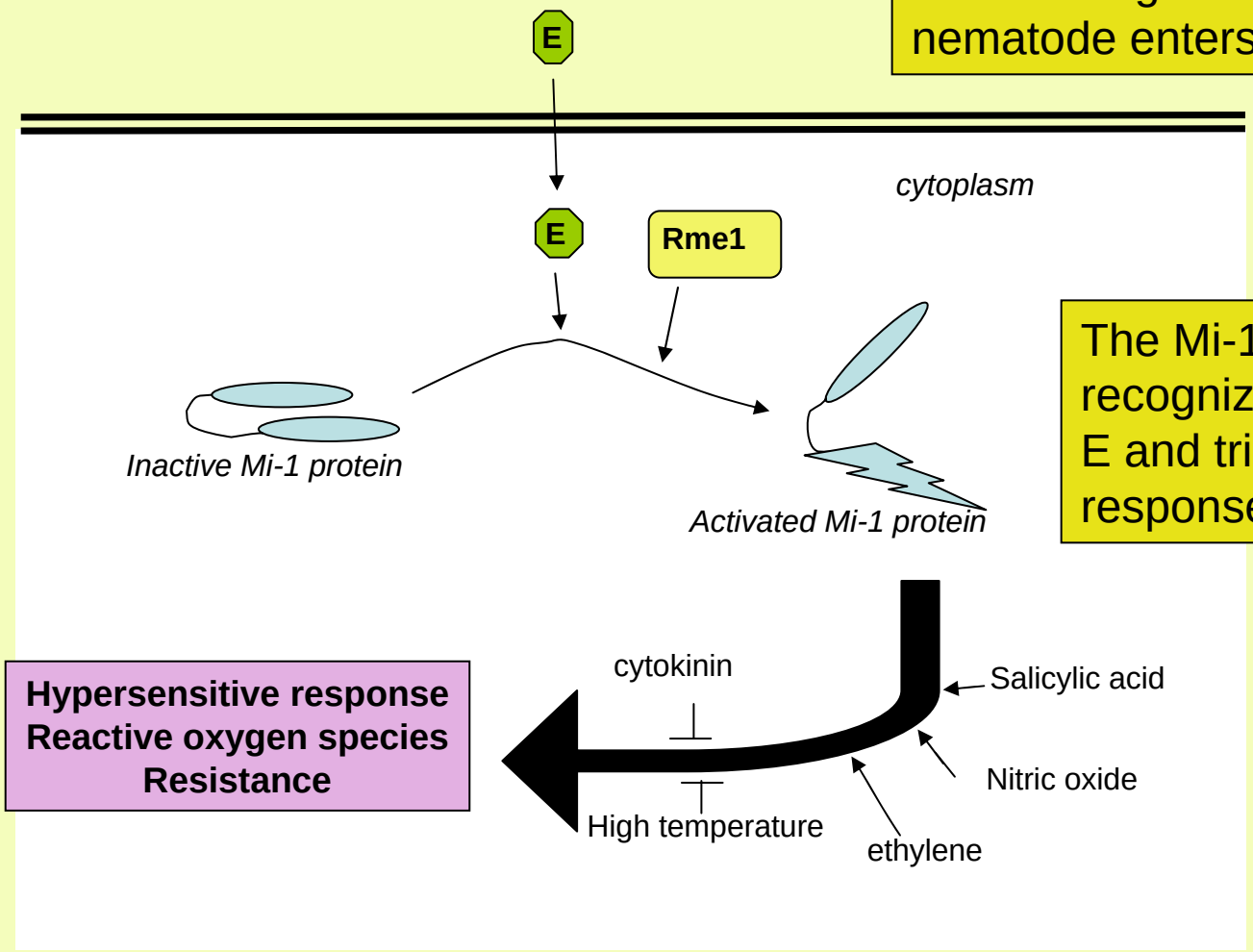
**A single, dominant resistance gene that confers effective resistance against several species of root-knot nematode (*M. incognita, M. javanica, M. arenaria,* but not *M. hapla or M. enterolobii* or …..).**

***Mi-1* also confers resistance against some isolates of potato aphid and white flies.**

***Mi-1* was introgressed into tomato from the wild species *Solanum peruvianum* using embryo rescue (Paul Smith, ~1940).**

# Model for the role of *Mi-1* in the signaling of nematode resistance

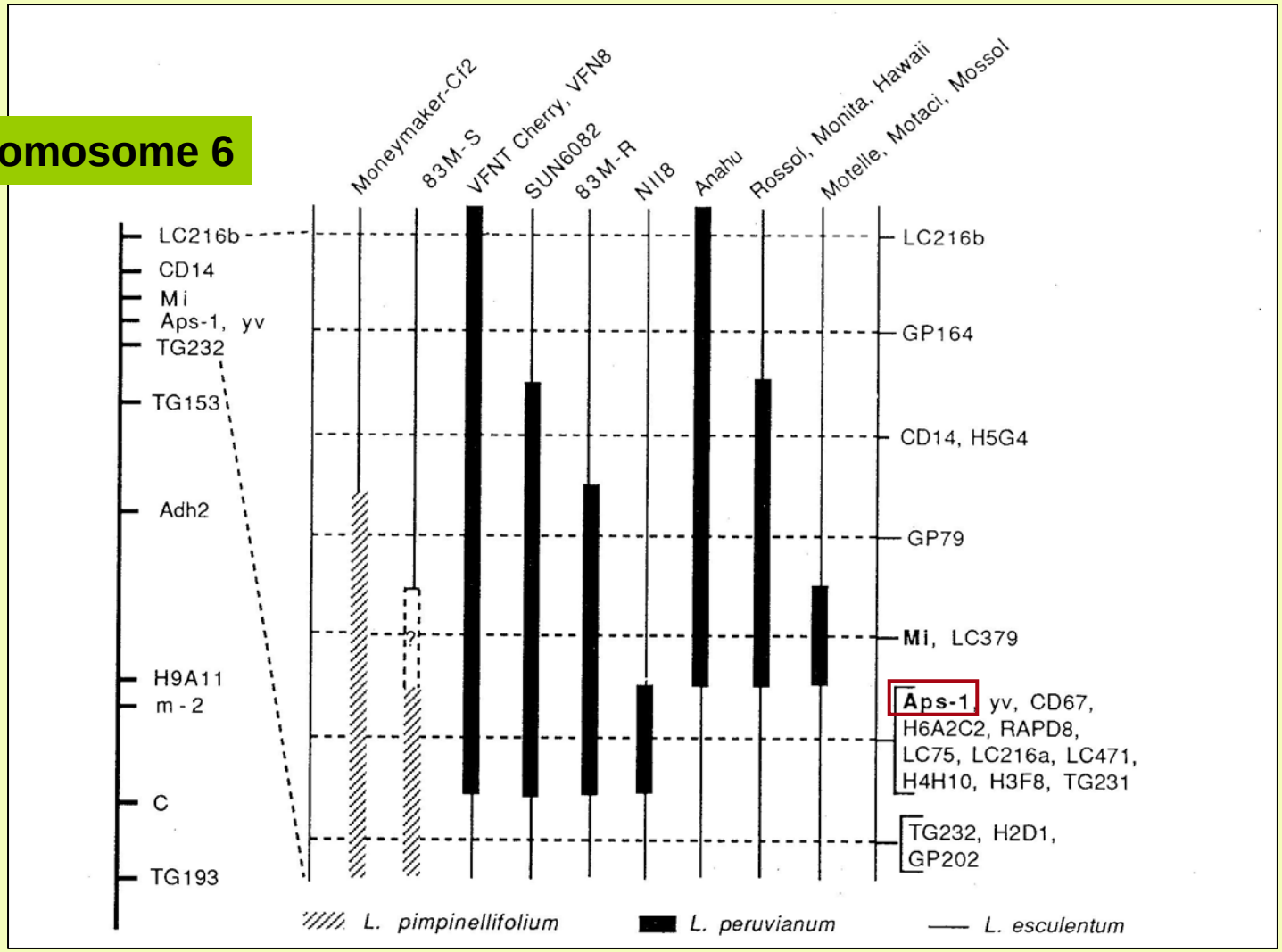
Elicitor (E), product of the avirulence gene from the nematode enters plant cell




The Mi-1 gene product recognizes the presence of E and triggers a defense response

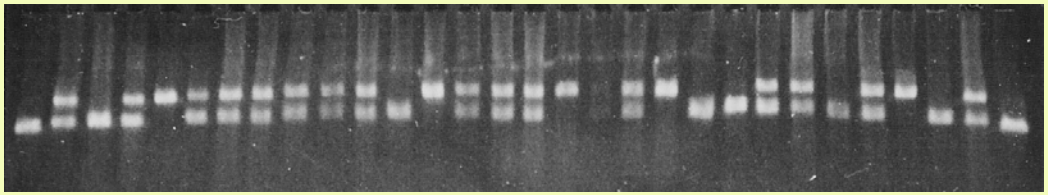
# Developing molecular markers for the Mi region has been challenging due to the complex structure of the region and the high variability in introgressed regions

**Chromosome 6**

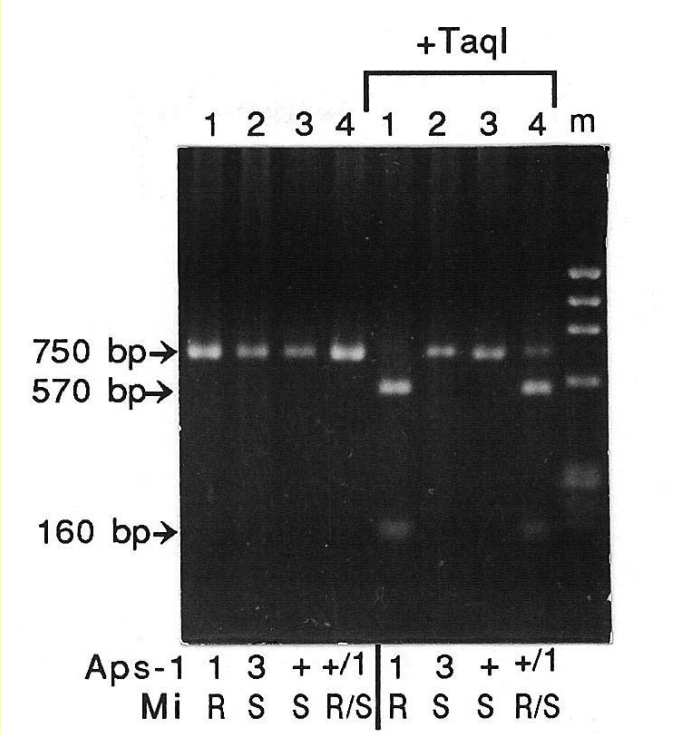



Ho et al., Plant J. 2:971

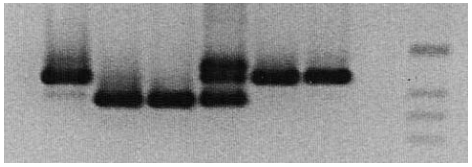
## PCR/CAPS marker Rex-1 is useful to follow incorporation of *Mi-1*



Williamson et al., TAG 87:757

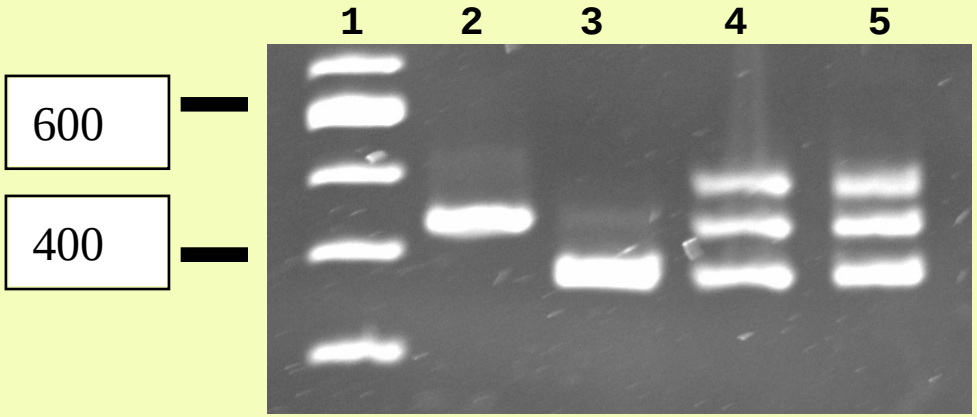


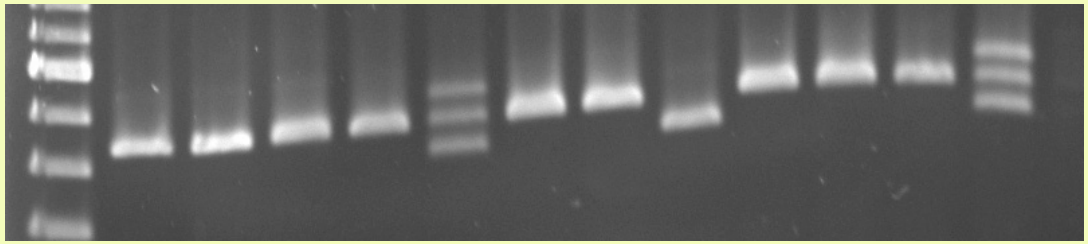

## Mi-1 PCR marker VMi1 reveals a size polymorphism so does not need to be cut with restriction enzyme.



**For both Rex-1 and VMi1 heterozygotes can be easily distinguished.**

**Both of Rex-1 and VMi1 can give "false positives" when the short arm of chromosome 6 is introgressed from *S. peruvianum* or other wild species.**



**Mi23 is a co-dominant SCAR marker for detection of the *Mi-1* locus for resistance to root-knot nematode in tomato germplasm that is useful for some sources of begamovirus resistance (Maxwell)**

**Seah et al., TGC 57:37**

***Mi-1 i*s widely deployed in processing tomato in California**

**Highly effective in preventing/reducing nematode damage.**

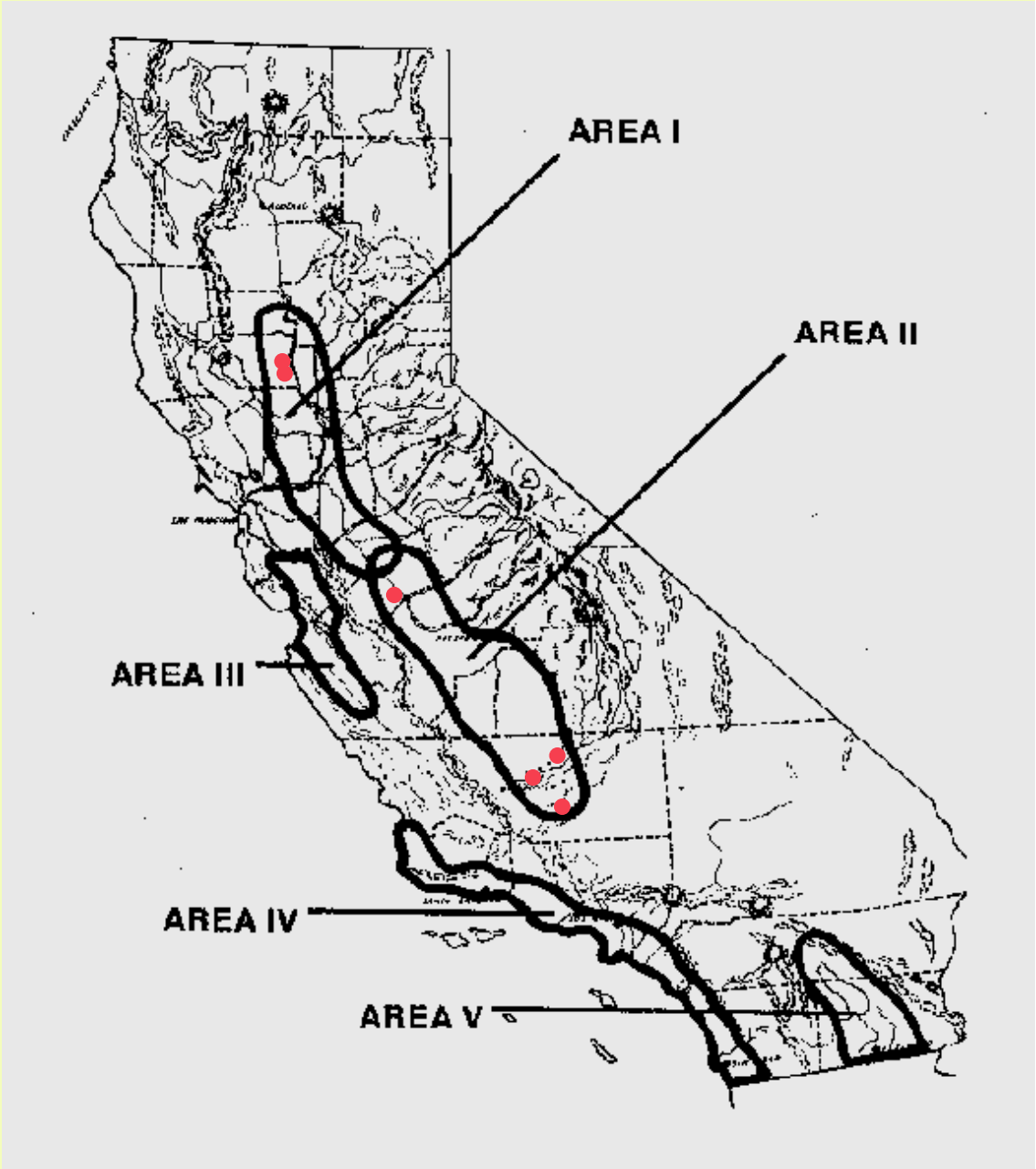
# Problems with *Mi-1*:

**Doesn't work at high soil temperatures (>30º C)**

**Linkage drag: association of resistance with undesirable traits.**

**Virulent isolates of RKN exist and can be selected.**

**Resistance-breaking nematodes have been found in several processing tomato production regions in California**




•= locations where RBNs were obtained

# California Field Isolates of Mi-virulent root-knot nematodes are not all the same

## Virulent field isolates

| Isolate | Species | Reproduces on pepper |
|---|---|---|
| W-1 | *M. inc.* | +++ |
| Y-1 | *M. jav.* | nd |
| Y-2 | *M. jav.* | nd |
| Y-3 | *M. inc* | ++ |
| Y-4 | *M. jav.* | + |
| Y-5 | *M. inc.* | nd |
| LB-1 | *M. inc.* | 0 |
| K1 | *M. inc.* | nd |
| K-3 | *M. ??* | nd |

## Avirulent isolates

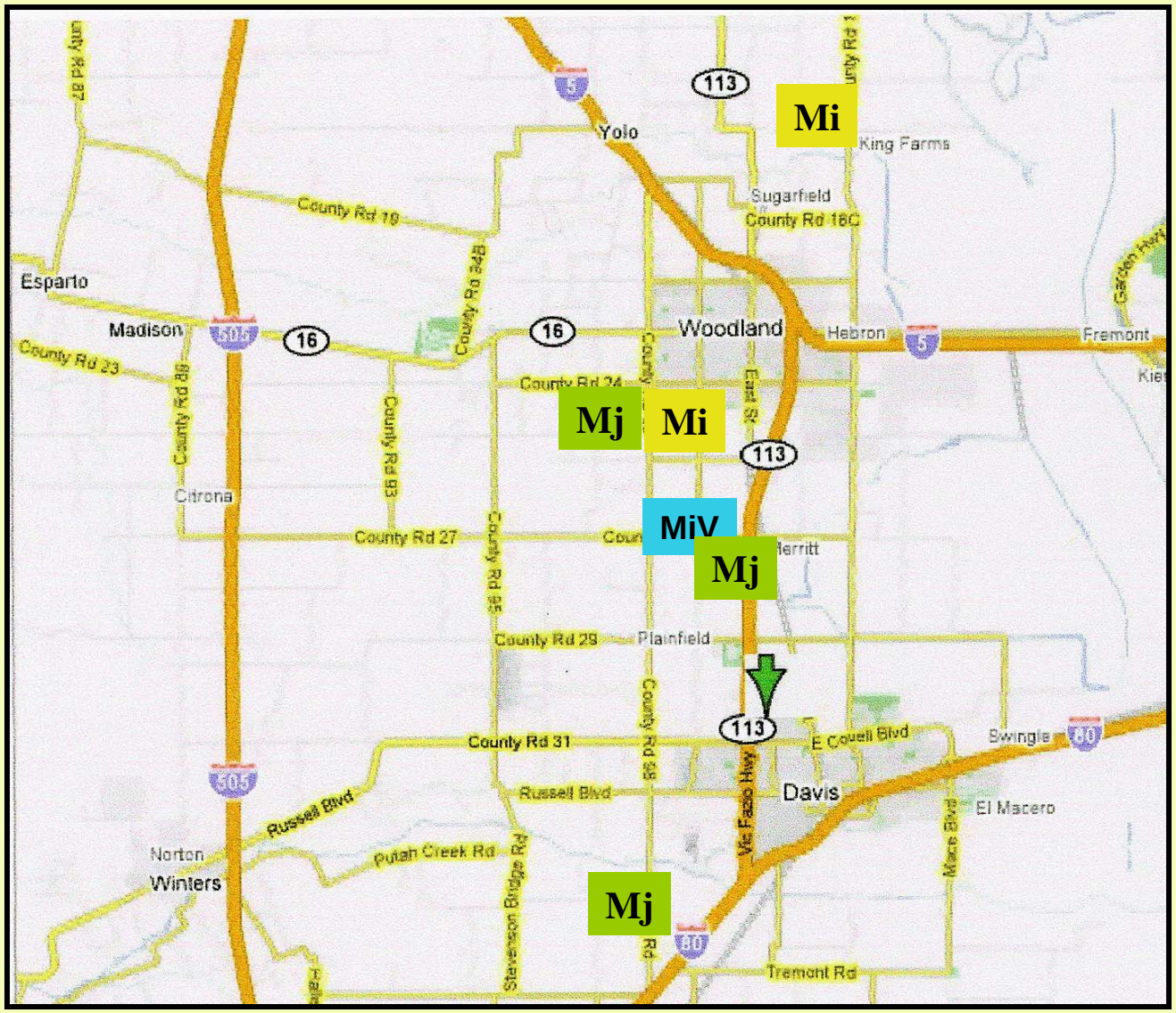
| Isolate | Species | Reproduces on pepper |
|---|---|---|
| VW6 | *M. inc.* | nd |
| Mi-BEL | *M. inc.* | nd |
| Mi-HarC | *M. inc.* | ++ |
| VW4 | *M. jav.* | nd |

**At least two species:**
***M. incognita* and *M. javanica***

***there are differences in ability of isolates to reproduce on pepper.**

**Molecular marker differences within species, but no marker so far can identify all virulent isolates.**

# Locations in Yolo Co. where RBNs were found




**Resistance breaking RKN isolates likely evolved independently. However, it is likely that there is some spread by agriculture activity.**

# Other sources of nematode resistance

**Table 1** Root-knot nematode resistance genes in *Lycopersicon* spp.[a]

| Gene | Source[b] | Properties | Genetics |
|---|---|---|---|
| *Mi* (*Mi-1*) | *L. peruvianum* PI128657 | Resistance to several species of RKN; resistance lost at >30°C | Mapped to short arm of chromosome 6; cloned |
| *Mi-2* | PI270435-2R2 | Resistant to *M. incognita* at 32°C | Not linked to *Mi* or *Mi-3*; linked to *Mi-8* |
| *Mi-3* | PI126443-1MH | Resistance to *Mi*-virulent *M. incognita* 557R | Mapped to short arm of chromosome 12; linked to *Mi-5* |
| *Mi-4* | LA1708-1 | Resistant to *M. javanica* and *M. incognita* at 32°C | — |
| *Mi-5* | PI126443-1MH | Resistant at 32°C to *M. incognita* and *M. javanica* | Linked to *Mi-3* on chromosome 12 |
| *Mi-6* | P1270435-3MH | Resistant to *M. incognita* at 32°C | Linked to *Mi-7* |
| *Mi-7* | PI270435-3MH | Resistant to *Mi*-virulent *M. incognita* 557R at 25°C | Linked to *Mi-6* |
| *Mi-8* | PI270435-2R2 | Resistant to *Mi*-virulent *M. incognita* 557R at 25°C | Linked to *Mi-2*. |

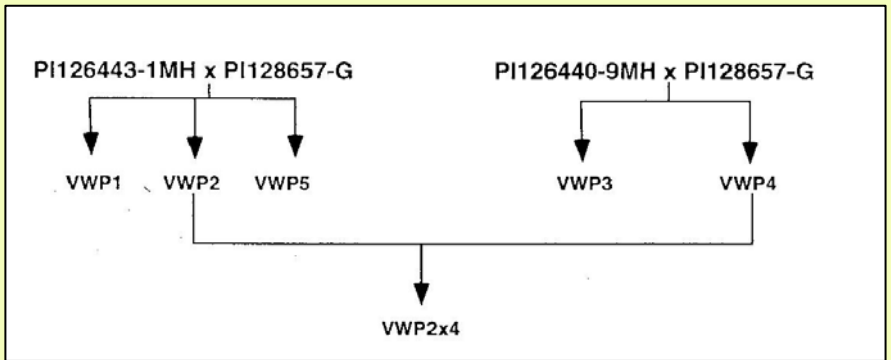
Williamson, An. Rev. Phytopathology 36:277

# From: Yaghoobi et al., TAG 91:457

**Table 1** Screening *L. peruvianum* for nematode resistance

| Plants | Source[b] | Response to root-knot nematodes[a] | |
|---|---|---|---|
| | | Strain VW4 | Strain 557R |
| Accessions | | | |
| LA98 | 1 | S, S, S | S, S |
| LA103 | 1 | R, S, S | S, S, S |
| LA110 | 1 | R, R, R, | S, R, S |
| LA1537 | 1 | — | S, S, S |
| LA2157 | 1 | R, R, R | S, S, S |
| PI126448 | 2 | R, R | R, S, R |
| PI128653 | 2 | R, R | R, R |
| PI199380 | 2 | R, R | S, R |
| Clones | | | |
| PI128657-G | 2 | R, R | S |
| PI128657-3R4 | 3 | R, R, R | S, S, S |
| PI270435-3MH | 3 | R, R, R | R, R, R |
| PI270435-2R2 | 3 | R, R, R | R, R, R |
| VWP2 | 4 | R, R | R, R |
| VWP3 | 4 | R, R | S, S |
| VWP4 | 4 | R, R | S |
| VWP5 | 4 | R, R | R, R, R |

Mi-3 lines




Lines segregating for Mi-3

# *Mi-3 Gene*

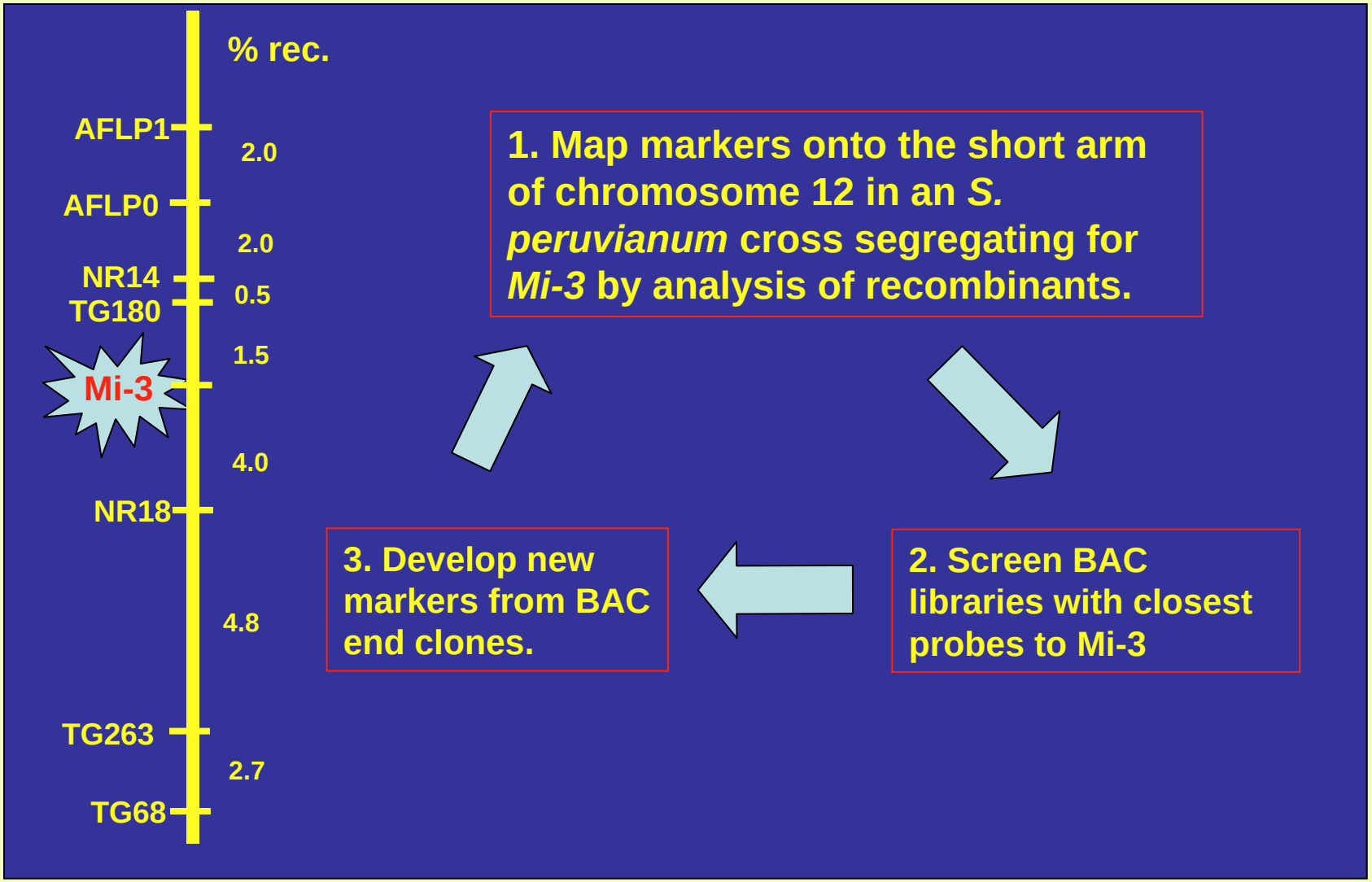
**A dominant, or partially dominant gene that maps to the short arm of chromosome 12 in some accessions of *L. peruvianum* (*S. corneliomulleri*)**

**Confers resistance against *Mi-1*-virulent nematode strains.**

**Confers resistance at 32°C where *Mi-1* is not effective.**

**Resistance is characterized by a hypersensitive response, but some giant cell and nematode development occurs.**

# Mapping Mi-3 and identification of DNA markers




Yaghoobi et al., MGG 274:60

# Attempts to transfer Mi-3 to cultivated tomato using a bridging line (MSK93)

MSK93 is a complex hybrid of *L. esculentum* and *L. peruvianum*. Possible 'bridging species'? It was orignally designed to be easily transformed (Maarten Koornneef Plant Sci. 45:201-208)

<u>MSK93 can cross to Le</u>

VFNT x MSK93

↓

Seeds!

<u>MSK93 can cross to Lp</u>

MSK93 x VWP2

↓

Seeds!

Plant VW118 (NR14$^{+}$)

↓ **Self**

Seeds!

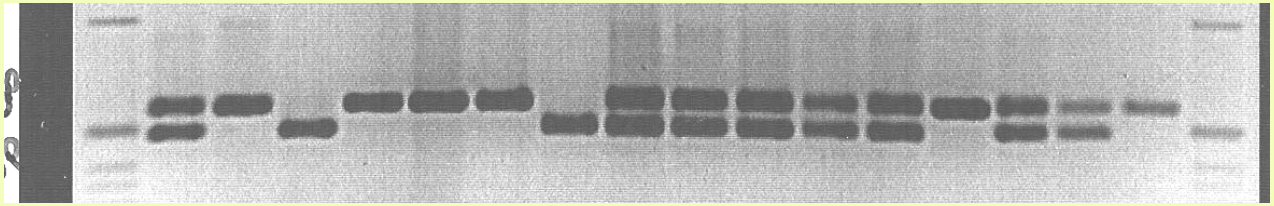
VW118-1, -2, -3

MSK93
Complex hybrid
(mi-3/mi-3)

V118-2

V118-11

## VW118 progeny are segregating for the *Mi-3* allele of VN22R



VW118 progeny are resistant or partially resistant to Mi-virulent nematode strains W-1 and 557R. However, the resistance level does not correlate with Mi-3 marker.

Progeny plant VW118-2 was homozygous for Mi-3 marker and had good resistance to both nematode strains.

VFNT X VW118-2

⇩

ONE PLANT (VW131)

VW131 has Mi-3 marker VN22R, but is:
*Not resistant at high temp after infection with VW4.
*Not resistant to 557R.

Are two doses of *Mi-3* needed?
Is there other resistance that is segregating and will work in tomato?

Of six selfed progeny of VW131, only one has partial resistance to Strain W-1.

# Summary

***Mi-1*** **is widely utilized and effective.**
**Molecular markers are available, but should be used with caution.**

**Mi-virulent isolates of *M. incognita* and *M. javanica* are being noted more widely. Species of root-knot nematode against which *Mi-1* is not effective may be more widespread than previously known.**

**No new resistance sources are yet ready (as far as I know). We have not been successful in introgressing new sources of resistance.**

**No cultivated sources of resistance to *M. hapla* or *M. mayaguensis* (*enterolobii*) are available.**

**Funding: USDA, California Tomato Research Institute**