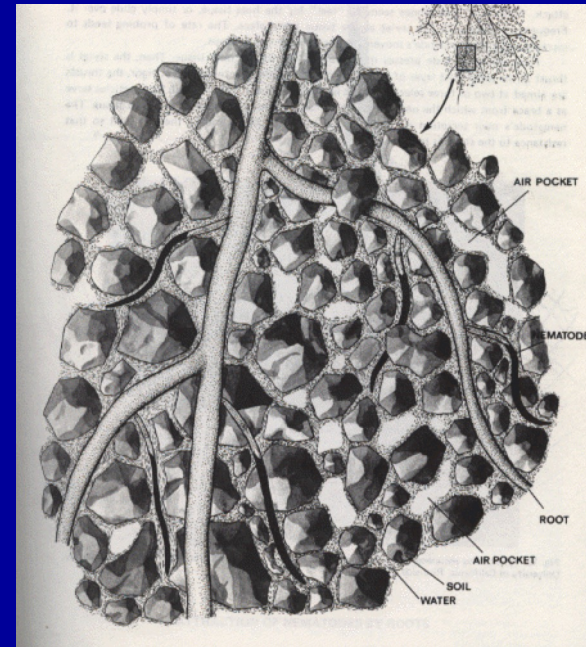


**NEM 204: CULTURAL METHODS -  
ARE WE DOING SOMETHING NEW?**

Principles of Nematology (Gerald Thorne, 1961):

"It is fitting that a few words of commendation be given to the officials of the Shell Chemical Corporation and The Dow Chemical Company for their foresight in pioneering the field of soil fumigation. Their efficient, generous, cooperative, and persistent campaigns have carried the science of soil fumigation into almost every country. Those of us who had spent many years attempting to control nematodes by crop-rotation and cultural methods, often with futile, discouraging results, now realized the satisfaction of recommending D-D and EBD for the control of nematodes on certain moderate- and high-priced crops."



**SHOULD WE  
EXPECT  
SOMETHING ELSE  
TO WORK AS  
WELL AS A  
FUMIGANT?**

**FUMIGANTS MOVE  
THEMSELVES  
THROUGH SOIL**

**WHAT MAKES A  
FUMIGANT WORK,  
ALSO MAKES IT A  
VOC**

**NON-FUMIGANTS  
NEED TO BE  
MOVED WITH  
WATER OR  
TILLAGE**

**ARE WE REINVENTING THE WHEEL?  
OR DO WE KNOW SOMETHING THAT GERALD THORNE  
DIDN'T?**

**BETTER UNDERSTANDING OF SOIL HEALTH**

**NEW TACTICS FOR CROP ROTATION**

**IMPROVEMENTS IN DIAGNOSTIC TECHNIQUES**

**MOLECULAR METHODS TO ID SPECIES**

**VARIETY SELECTION WITH COMPUTER DATABASES**

**ADVANCES IN USE OF RESISTANT VARIETIES /**

**BIOFUMIGATION / TRAP CROPPING**

**BETTER UNDERSTANDING OF NEMATODE BIOLOGY**

**EFFECTS OF TEMPERATURE**

**ON NEMATODE REPRODUCTION**

**ONLINE SOIL TEMPERATURE DATA FROM**

**CIMIS WEATHER STATIONS (DATE OF**

**PLANTING)**

**HOW TO USE DEGREE DAYS TO PREDICT**

**POPULATION INCREASES (DATE OF HARVEST)**

**RENEWED INTEREST IN SOIL AMENDMENTS /**

**NATURAL PRODUCTS**

**CULTURAL PRACTICES:**

**CROP ROTATION**

**RESISTANT VARIETIES**

**COVER CROPS**

**FALLOWING**

**DATE OF PLANTING & HARVEST**

**FLOODING**

**BIOFUMIGATION**

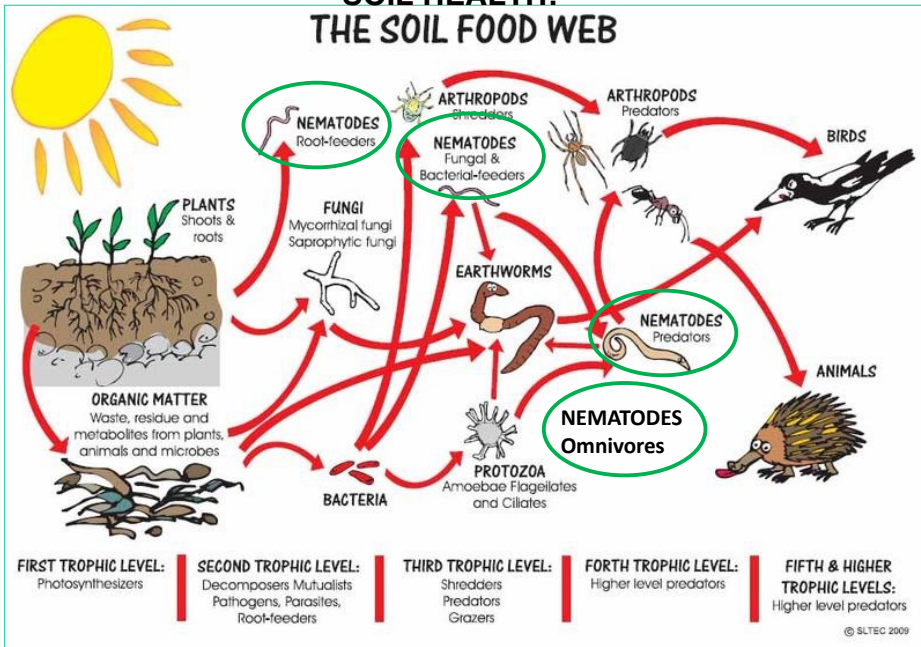
**TRAP CROPS**

**REMOVING PLANTS WITH SYMPTOMS**

**WEED CONTROL (NEMABASE)**

**SOIL AMENDMENTS**

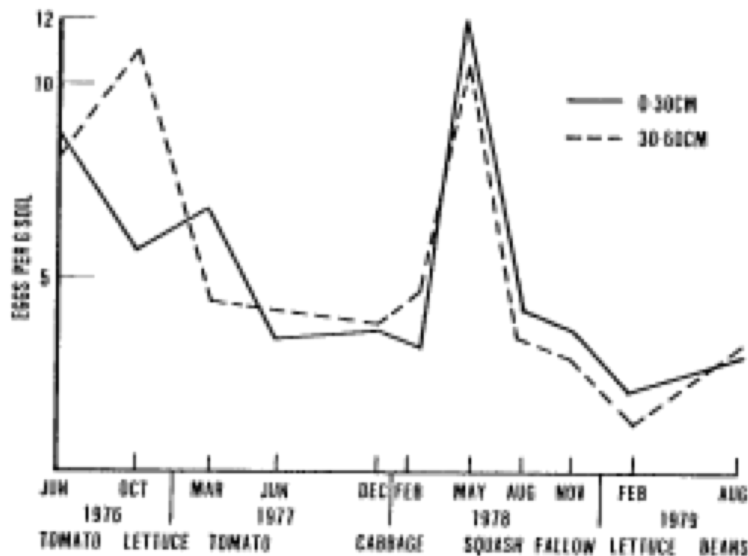
## SOIL HEALTH: THE SOIL FOOD WEB



## CROP ROTATION FOR NEMATODE MANAGEMENT: BASIC INFORMATION NEEDED:

**NEMATODES PRESENT IN FIELD**  
**HOST RANGE OF SPECIES PRESENT**  
**EXPECTED RATE OF POPULATION INCREASE**  
**EXPECTED RATE OF POPULATION DECLINE**  
**POSSIBLE CROPS**  
**AVAILABILITY OF RESISTANT VARIETIES**  
**GROWING SEASON (TIME OF PLANTING)**  
**NEMATODE DAMAGE THRESHOLD**  
**IMPORTANCE OF WEEDS**

## EFFECT OF CROP ROTATION ON POPULATION DENSITY OF SUGARBEET CYST NEMATODE:



## CROP ROTATION

	FIRST YEAR		SECOND YEAR		THIRD YEAR	
	FALL/ WINTER	SPRING/ SUMMER	FALL/ WINTER	SPRING/ SUMMER	FALL/ WINTER	SPRING/ SUMMER
SECTION A	Weed Free Fallow	Nematode Resistant Tomatoes	Other Crops	Other Crops	Weed Free Fallow	Weed Free Fallow
SECTION B	Other Crops	Weed Free Fallow	Weed Free Fallow	Nematode Resistant Tomatoes	Weed Free Fallow	Other Crops
SECTION C	Weed Free Fallow	Other Crops (with soil amended to reduce damage)	Weed Free Fallow	Weed Free Fallow	Other Crops	Nematode Resistant Tomatoes

## USE OF RESISTANT & TOLERANT VARIETIES:

**Immune** - plants do not allow nematode attack, including initial root invasion.

**Resistant or nonhost** - plants may be invaded by nematodes and may show damage, but chemical or physical unsuitability of the plant will prevent population increases.

**Susceptible** - plants allow normal nematode reproduction and may or may not tolerate nematode attack.

**Tolerant host** - plants are able to withstand nematode attack.

**Intolerant host** - plants are more likely damaged by nematode attack.

## STONE FRUIT AND NUT ROOTSTOCKS

ROOTSTOCK	Root Knot						
	Northern <i>Meloidogyne hapla</i>	Southern <i>Meloidogyne incognita</i>	Javanese <i>Meloidogyne javanica</i>	Peanut <i>Meloidogyne arenaria</i>	Lesion <i>Pratylenchus vulnus</i>	Ring <i>Criconebella xenoplax</i>	Dagger <i>Xiphinema americanum</i>
Lovell	SUSCEPTIBLE, TOLERANT				SUSCEPTIBLE		
Nemaguard	NONHOST	NONHOST	NONHOST	NONHOST	INTOLERANT		
Marianna 2624	NONHOST	NONHOST	NONHOST	NONHOST			
Myrobalan 29C	NONHOST	NONHOST	NONHOST	NONHOST			

## WALNUT ROOTSTOCKS

WALNUT ROOTSTOCK	Root Knot				Lesion <i>Pratylenchus vulnus</i>	Ring <i>Criconebella xenoplax</i>
	Northern <i>Meloidogyne hapla</i>	Southern <i>Meloidogyne incognita</i>	Javanese <i>Meloidogyne javanica</i>	Peanut <i>Meloidogyne arenaria</i>		
English					SUSCEPTIBLE	
Black	SUSCEPTIBLE, TOLERANT				INTOLERANT	
Paradox Hybrid	SUSCEPTIBLE, TOLERANT					

## The replant problems...

- **Replant disease (RD)** Microbe-induced growth suppression; incidence nearly universal in *Prunus* after *Prunus*, but severity varies greatly
- **Plant-parasitic nematodes** (ring, lesion, root knot), approx. 35% of almond and fresh stone fruit acreage, 60% of cling peach acreage infested (McKenry)
- **Aggressive pathogens, pests** (*Phytophthora*, *Armillaria*, *Verticillium*, Ten-Lined June Beetle) –localized, not managed completely by fumigation
- **Abiotic factors** (physical, chemical conditions related to previous production)



Ring nematode



Lesion nematode

Key nematode parasites on *Prunus*

Healthy tree      RD-affected tree  
Symptoms of replant disease on almond

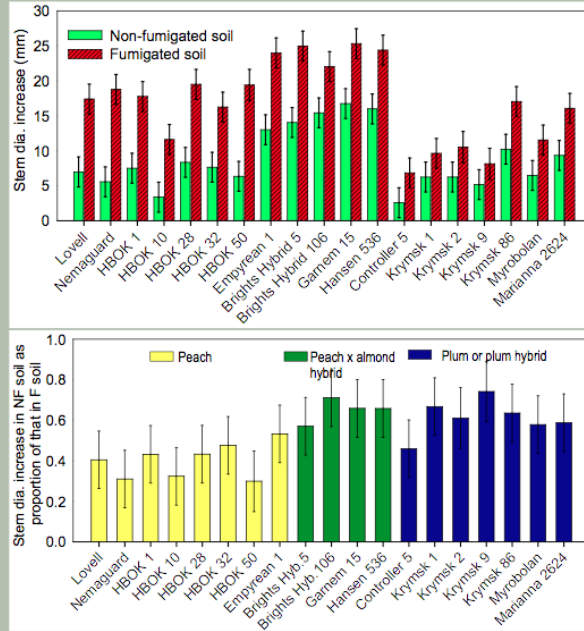
Greg Browne (USDA, UC Davis)




**2010-2011  
Evaluations of  
rootstock  
resistance to  
PRD complex**



**Greg Browne  
(USDA,  
UC Davis)**



**Foundation Plant Services** 

HOME GRAPE PRUNUS PISTACHIO STRAWBERRY ROSE SWEET POTATO VARIETY ID VIRUS DIAGNOSTICS RESOURCES ABOUT FPS

**FPS News**  
Exciting Greenhouse Progress!  
Construction of the phase 1 greenhouse to hold FPS's core grapevine collection has been completed, and plants have been moved in!

**About FPS**  
Faculty & Staff  
New Customers  
Directions  
Contact Information  
[Shigano\\_smalino\\_and@fps.ucdavis.edu](mailto:Shigano_smalino_and@fps.ucdavis.edu)  
530.752.3500 Phone  
530.752.2132 Fax  
Hours of Operation:  
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Questions or Comments? E-mail: [Webmaster@fps.ucdavis.edu](mailto:Webmaster@fps.ucdavis.edu) / [Privacy & Accessibility](#) Copyright 2024 The Regents of the University of California, Davis campus. All rights reserved.

<https://fps.ucdavis.edu/index.cfm>

## Grape Rootstocks

	Lesion	Root knot*	Dagger (X.i.)	Ring	Pin	Citrus
Dogridge	S	R	S	S	S?	MR
Ramsey	R?	R	R	S	S?	S
1613C	S	MR	R	S	S?	S
Harmony	S	R	S	S	S?	S
Freedom	S	R	R	S	S?	S
Scwarzm	S	S	R	S	S?	S
K51-32	R?	MR	R	S	S?	S
Teleki 5C	S	MR	S	S	S?	S
O39-16	S	S	R	S	S?	S

\* not *M. arenaria*

**Breeding program:**

**O39-16** – Released in 1991 by H. P. Olmo

**RS-3, RS-9** – Released in 2003 by D. Ramming and M. V. McKenry

**UCDGRN1, UCDGRN2, UCDGRN3, UCDGRN4, UCDGRN5** – Released in 2008 by

**M. A. Walker (H. Ferris)**

**USDA 10-17A, USDA 10-23B, USDA 6-19B** – Released by USDA

**Nematodes:**

**Cx** – *Criconemoides xenoplax* (ring)

**Pv** – *Pratylenchus vulnus* (lesion)

**Ts** – *Tylenchulus semipenetrans* (citrus)

**Xi** – *Xiphinema index* (dagger, transmits grapevine fanleaf virus)

**Xa** – *Xiphinema americanum* (dagger, transmits virus)

**Mi** – *Meloidogyne incognita* Race 3 (southern or cotton root-knot)

**Ma** – *Meloidogyne arenaria* virulent on Harmony rootstock (peanut root-knot)

**Mia** – *Meloidogyne incognita* virulent on Harmony rootstock (southern root-knot)

**Mj** – *Meloidogyne javanica* (Javanese root-knot)

**Mc** – *Meloidogyne chitwoodi* (Columbia root-knot)

**Resistance level:**

**R** – Resistant

**MR** – Moderately Resistant


**S** – Susceptible



## Grape Rootstock Resistance Breeding Programs:

Rootstock	Cx	Pv	Ts	Xi	Xa	Mi	Ma	Mih	Mj	Mc
O39-16	S	S	S	R						
RS-3	MR	R	MR	S		R	R	R	R	MR
RS-9	MR	R	MR	S		R	R	R	R	
UCDGRN1	R	R	R	R		R	R	R		
UCDGRN2	MR	MR	MS	R		R	R	R		
UCDGRN3	MS	MR	MS	R		R	R	R		
UCDGRN4	MR	MR	MR	R		R	R	R		
UCDGRN5	MS	MS	R	R		R	R	R		
USDA 10-17A	MS	R	R	R		MR			R	MR
USDA 10-23B	MR	R	R	R		R			R	R
USDA 6-19B	MR	R	R	MR	R	R			R	MR

## New Rootstock Summary

	Citrus Nematode	Ring Nematode	Phylloxera Nodosities	Rooting Depth
 GRN-1	R	R	HR	D
GRN-2	MS	S	HR	S
GRN-3	R	S	R	M
GRN-4	R	MS	R	M
GRN-5	R	MR	MS	D

## GRN Parentages

- GRN-1 = 8909-05 *rupestris* x *rotundifolia* 'Cowart'
- GRN-2 = 9363-16 (*rufotomentosa* x (Dog Ridge x Riparia Gloire)) x Riparia Gloire
- GRN-3 = 9365-43 (*rufotomentosa* x (Dog Ridge x Riparia Gloire)) x *champinii* c9038
- GRN-4 = 9365-85 (*rufotomentosa* x (Dog Ridge x Riparia Gloire)) x *champinii* c9038
- GRN-5 = 9407-14 (Ramsey x Riparia Gloire) x *champinii* c9021

### Root-Knot Nematode Resistant Varieties:

Tomatoes - yes

Sweet potatoes - yes

Potatoes - no

Carrots - under development

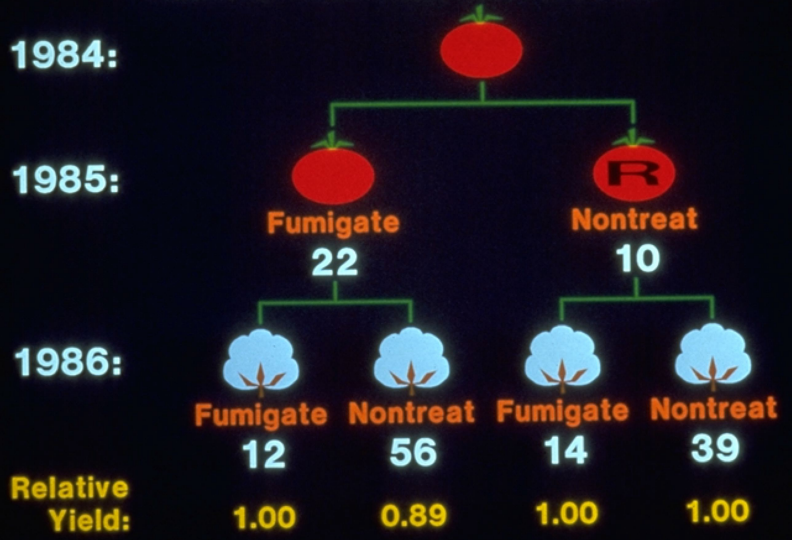
Cole Crops - no

Beans - yes and under development

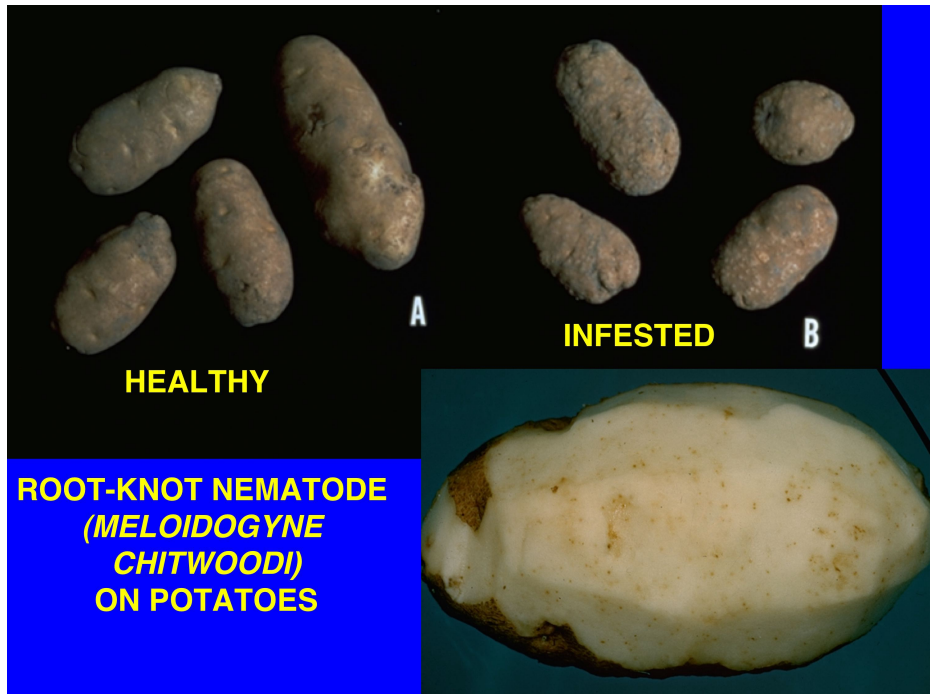
Sugarbeets - yes

Potential problems if other nematodes such as stubby root or needle are present in same field

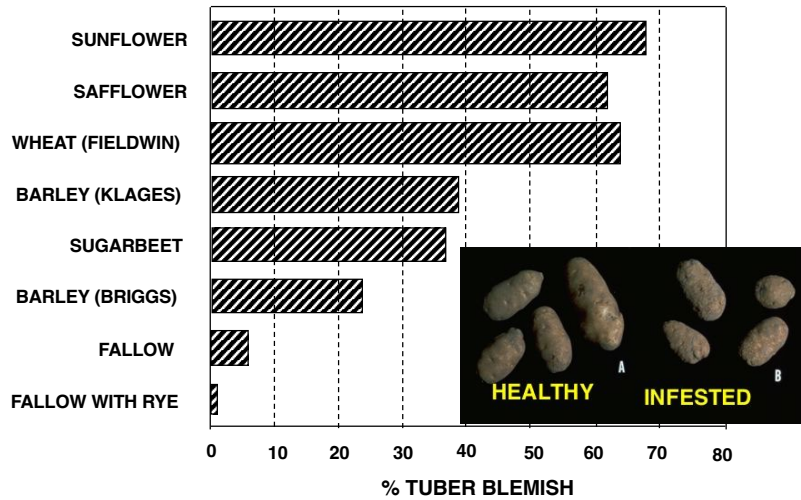
# TOMATO-COTTON ROTATION



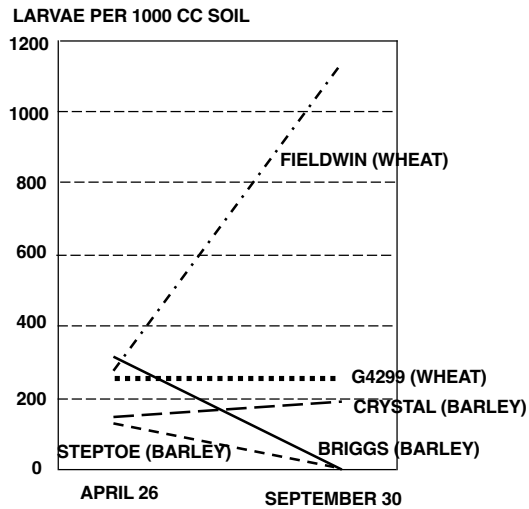
# California Potato Production Areas



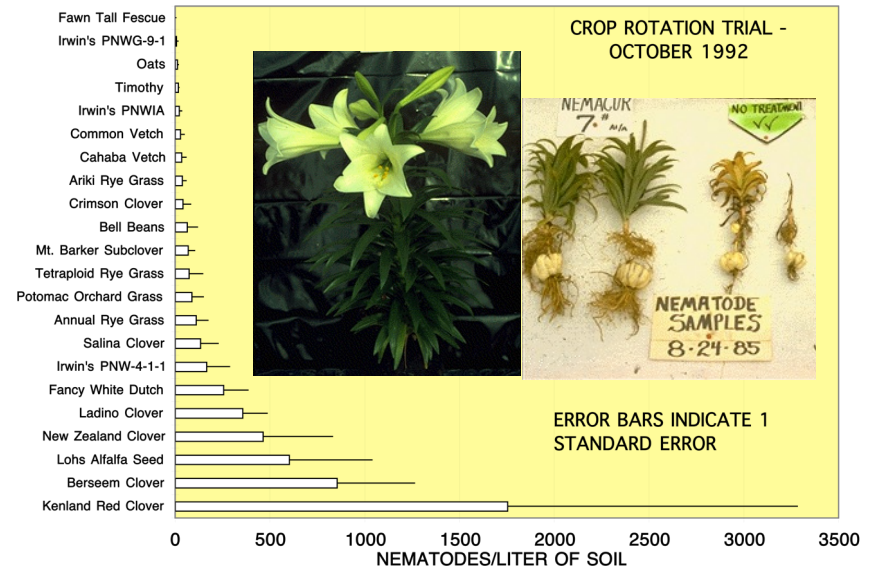
### EFFECT OF PRECEEDING CROP ROTATION ON NEMATODE TUBER BLEMISH IN POTATOES



### POTATO CROPPING SYSTEM IN TULELAKE: COLUMBIA ROOT-KNOT NEMATODE ON WHEAT AND BARLEY



### LESION NEMATODE (PRATYLENCHUS PENETRANS) ON EASTER LILY





**FALLOW**

**NO CROP - NO WEEDS - NEMATODES STARVE  
EFFECTIVENESS - EXCELLENT  
COST - ??**

	<b>RATE OF DECLINE/ YEAR</b>	<b>YEARS OF FALLOW</b>
<b>ROOT-KNOT</b>	85 %	0.25 - 2
<b>SUGAR BEET CYST</b>	25-50 %	4 - 8
<b>STEM AND BULB DAGGER (X. INDEX)</b>		4
		10

????

**LESION  
CITRUS  
STUBBY ROOT  
FOLIAR**

**RING  
DAGGER  
NEEDLE  
SHEATH**

**DRY VS WET, SOIL DISTURBANCE, COST OF WEED  
CONTROL**

**TO SELECT A ROTATION CROP OR A COVER CROP  
YOU NEED TO KNOW WHICH SPECIES YOU HAVE**

SUMMARY OF HOST-NEMATODE RESPONSES ON COVER CROPS:

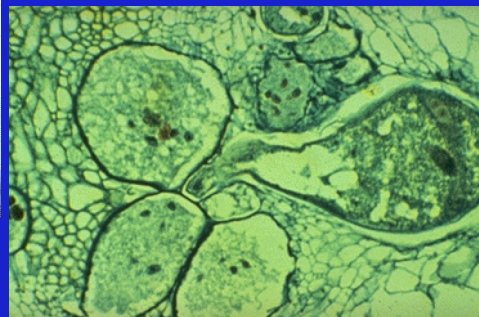
	Root Knot			
	Northern <i>Meloidogyne hapla</i>	Southern <i>Meloidogyne incognita</i>	Javanese <i>Meloidogyne javanica</i>	Peanut <i>Meloidogyne arenaria</i>
Marigold	Host	Host	Host, Trap	Crop Non Host
Sudan, SS-222	Poor Host	Good Host	Host	Host
Barley, Columbia	Host	Poor Host	Good Host	Host
Cahaba White Vetch	Good Host	Poor Host	Host, Trap Crop	Host
Salina Sweet Clover	Host	Poor Host	Poor Host	Nonhost
Moapa Alfalfa Coker 916	Susceptible	Poor Host	Poor Host	Nonhost
Wheat				
Nova II Vetch	+	-	-	-
Blando Brome Grass	Host	Nonhost		

DATA SUMMARY BY M.V. MCKENRY, 1991

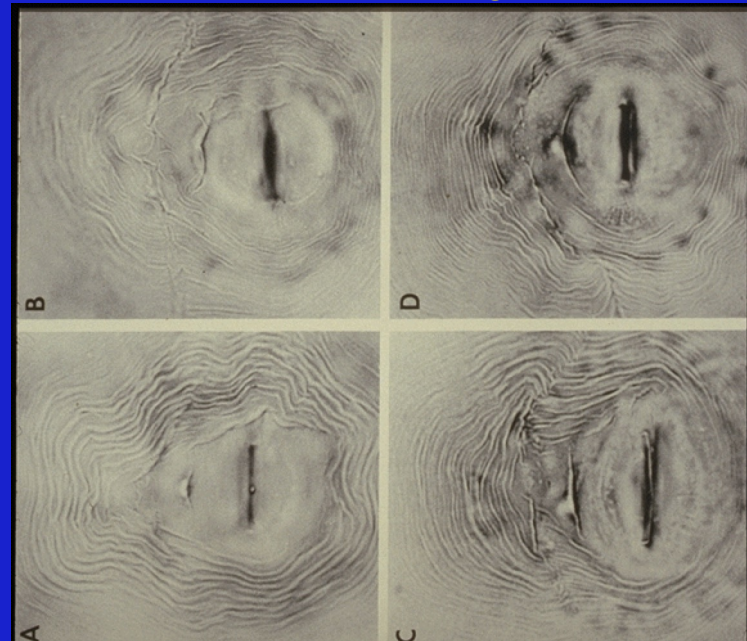
+ = PROBABLE HOST, - = PROBABLE NONHOST, BASED  
ON DATA FROM GEORGIA AND S. CAROLINA



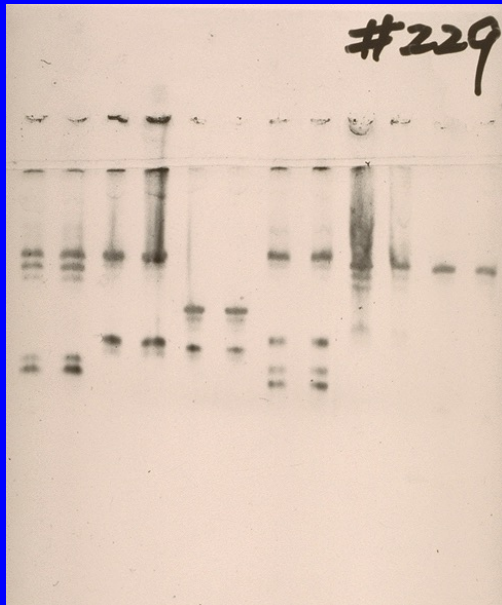
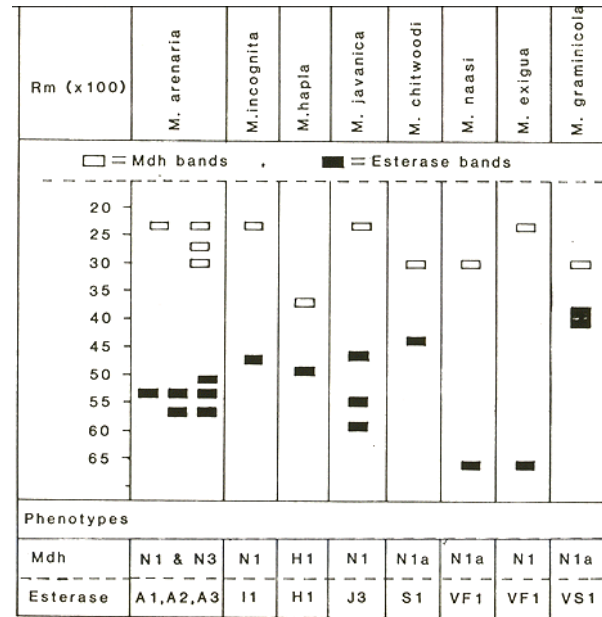
**ROOT-KNOT NEMATODE  
SPECIES ID**



**PERINEAL PATTERNS**



## ISOZYME ELECTROPHORESIS



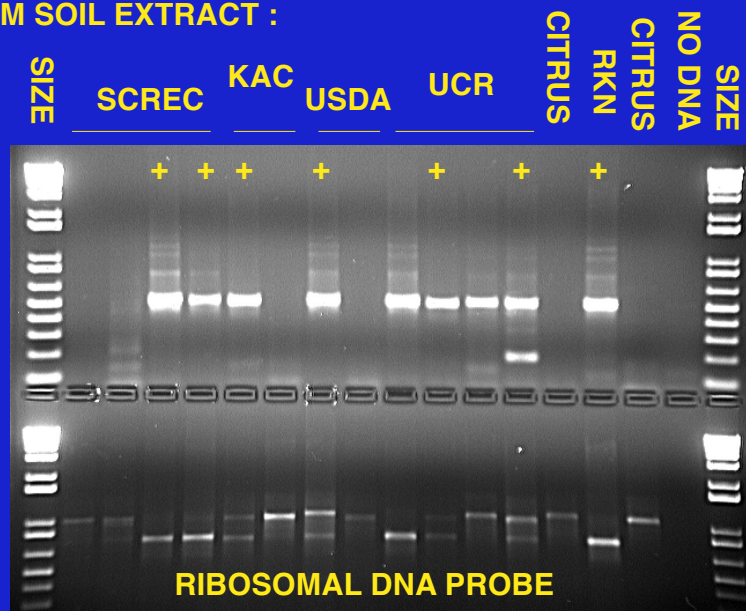
## MOLECULAR AND BIOCHEMICAL TECHNIQUES TO IDENTIFY ROOT-KNOT NEMATODE

V. WILLIAMSON, J. QIU, B. WESTERDAHL



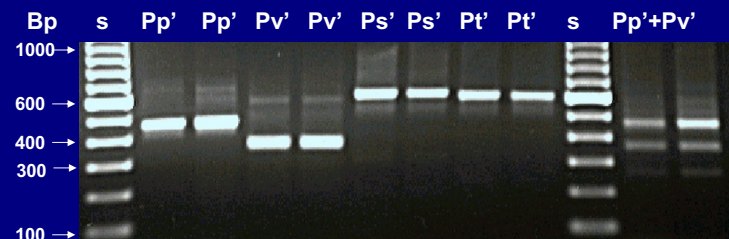


**MOLECULAR TECHNIQUES TO ID ROOT-KNOT NEMATODE FROM SOIL EXTRACT :**



**Identification of Lesion Nematode to Species:**  
 Presence or absence of sperm in the spermatheca.  
 Presence or absence of males in the sample.

**Multiplex PCR with mixture of DNA from 4 species of lesion nematodes (*P. penetrans*, *P. vulnus*, *P. scribneri* and *P. thornei*)**



**Cover / Rotation Crops**

	Lesion	Root knot	Dagger	Ring	Citrus	Pin
Sudan	N	H	N	N	N	?
Barley	N	H-	N	H	N	?
Cahaba Vetch	H	H-	N	H	N	?
Alfalfa	N	H-	H	H	N	?

**THE EFFECTS OF TEMPERATURE ON NEMATODE BIOLOGY**

**TIME OF PLANTING:**      **MINIMUM FOR INFEC-TION**      **REPRO- DUCTI ON**      **OPTIMUM FOR ACTIVITY**

**ROOT KNOT  
 MELOIDOGYNE SP.**

*M. CHITWOODI*      45F      45F      68-77F  
 (COLUMBIA)      (6C)      (6C)      (20-25C)

*M. HAPLA*      54F      54F      77-86F  
 (NORTHERN)      (12C)      (12C)      (25-30C)

*M. INCOGNITA*      65F      50F      76-90F  
 (SOUTHERN)      (18C)      (10C)      (25-32C)

**SUGARBEET CYST  
 HETERODERA**

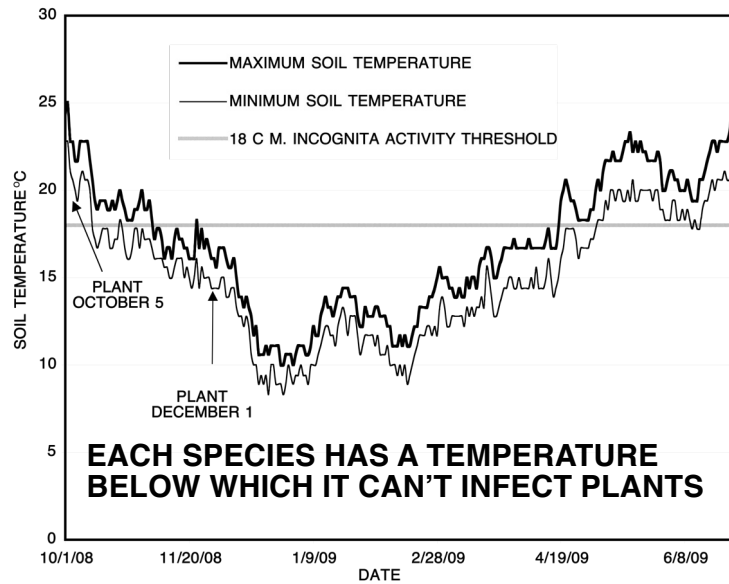
*SCHACHTII*      50F      46F      70-81F  
 (10C)      (8C)      (21-27C)

**NEEDLE LONGIDORUS AFRICANUS**

DAMAGE TO LETTUCE SEEDLINGS IS MINIMAL AT SOIL TEMPERATURES LESS THAN 22C (72F)



## DELAYED PLANTING CAN REDUCE DAMAGE



## MINIATURE DATA LOGGERS



## NOT FOOLPROOF



## USING DEGREE DAYS TO PREDICT POPULATION INCREASES (DATE OF HARVEST)

$$\text{DEGREE DAYS (OR HEAT UNITS)} = \frac{\text{DAILY HIGH} + \text{DAILY LOW}}{2} - \text{DEVELOPMENTAL THRESHOLD (OR BASE)}$$

## NEMATODE DEGREE DAYS PER GENERATION:

### ROOT KNOT (*MELOIDOGYNE* SP.)

*M. INCOGNITA* 600 DD, BASE 10C

*M. CHITWOODI* 600 DD, BASE 5-6C

### SUGARBEET CYST

*HETERODERA SCHACHTII* (450 DD, BASE 8C)

### Calculate Nematode Degree Days (clockwise)

**Calculate any degree-days**

Thresholds  
 Fahrenheit  Celsius

Enter lower: 5  
 Enter upper (optional):  
 Method of calculation: Single sine  
 Upper cutoff method (optional): Horizontal or none

Calculate Clear

Select from stations in which California county?

Sierra  
 Siskiyou  
 Solano  
 Sonoma  
 Stanislaus  Include active stations only

Set time period for running model  
 Start date: May 15 2009  
 End date: October 15 2009

Choose File: no file selected

Text file (comma or tab delimited) format

See also nearby counties: Del Norte, Humboldt, Siskiyou County (map)

Siakiyou County (map)

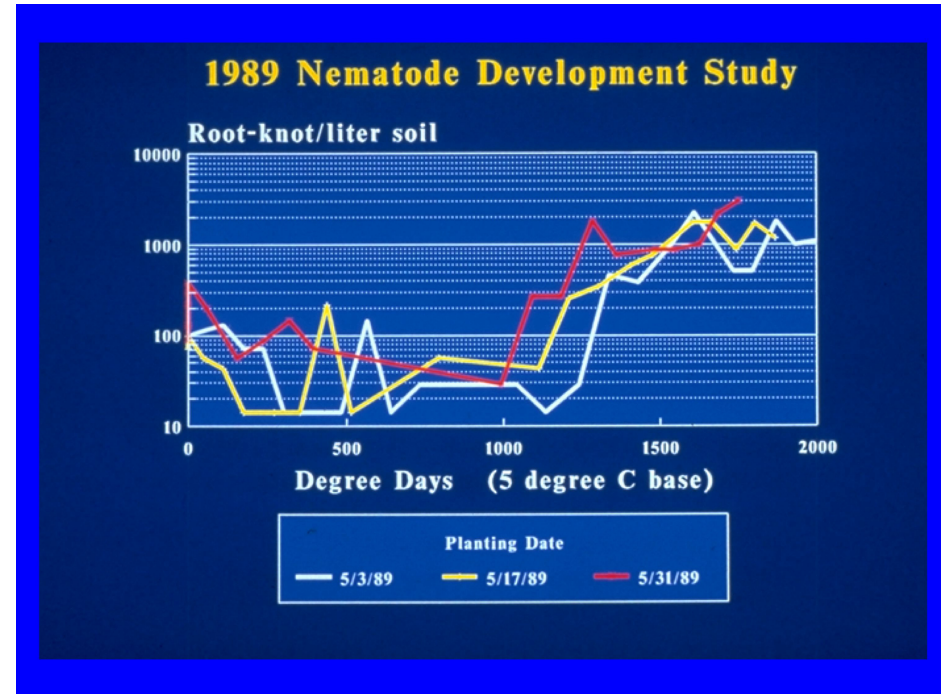
FRTJONES.C (NCDC #3182, Fort Jones Ranger Station) 19 mc  
 MTHEBRON.C (NCDC #5941, Mount Hebron Ranger Station) 19 mc  
 TULELAKE.C (NCDC #9053, Tulelake) 19 mc  
 TULELK2A (CIMIS #91, Tulelake PS) 19 mc  
 YREKA.C (NCDC #9866, Yreka) 19 mc

Date	Soil temperatures (°C)		Degree-days	
	Min	Max	Daily	Accumulated
May 15 2009	10.6	12.8	6.70	6.70
May 16 2009	11.7	13.9	7.80	14.50
May 17 2009	12.8	15.0	8.90	23.40
May 18 2009	13.9	17.2	10.55	33.95
May 19 2009	15.0	16.7	10.85	44.80
May 20 2009	13.9	15.6	9.75	54.55
May 21 2009	13.9	15.6	9.75	64.30
May 22 2009	14.4	16.1	10.25	74.55
May 23 2009	14.4	16.7	10.55	85.10
May 24 2009	15.0	17.2	11.10	96.20
May 25 2009	14.4	18.1	11.55	107.75

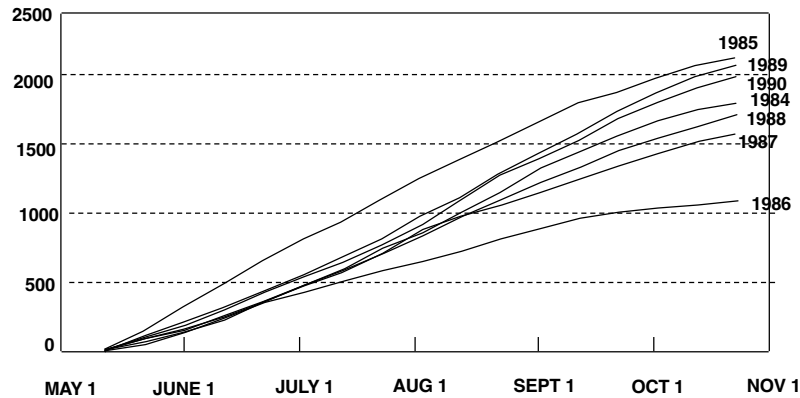
Temperature variable:  Air temperature,  Soil temperature

Select output:  Formatted report,  Comma-delimited data file

Calculate Clear



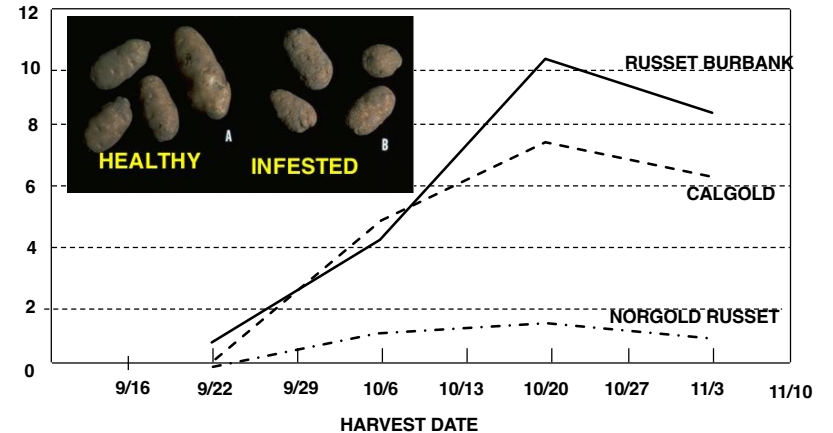
### NEMATODE DEGREE DAYS FROM MAY 10 (5 DEGREE C BASE)



### EARLY HARVEST AND VARIETY SELECTION CAN REDUCE DAMAGE

#### 1987 POTATO DATE OF HARVEST STUDY

#### NEMATODE TUBER BLEMISH (%)





**FLOODING TO CONTROL ROOT-KNOT NEMATODE:  
1928 - 1930 - SACRAMENTO-SAN JOAQUIN  
DELTA**

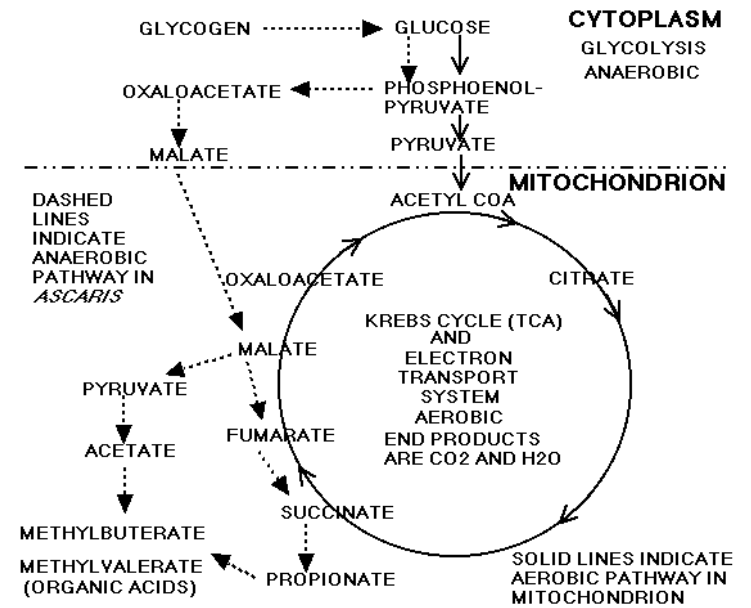
**HETERODERA MARIONI (12-22 MONTHS)**

**1969 - 1971 - TULELAKE/KLAMATH BASIN,  
MELOIDOGYNE NAASI, BARLEY ROOT-KNOT  
(2 YEARS)**

**1989 - 1991 - TULELAKE/KLAMATH BASIN,  
M. CHITWOODI, COLUMBIA ROOT-KNOT  
(6 MONTHS)**

**RESULTS: CONTROL ALMOST AS GOOD AS  
FALLOW**

**FLOODING: AEROBIC VS ANAEROBIC METABOLISM**



**BIOFUMIGATION**

**EVALUATION OF BROCCOLI RESIDUE FOR  
SUGARBEET CYST NEMATODE CONTROL  
BRASSICACEAE PRODUCE GLUCOSINOLATES  
BROCCOLI DEGRADATION RELEASES  
ISOTHIOCYANATES  
METAM SODIUM IS A SYNTHETIC ISOTHIOCYANATE**



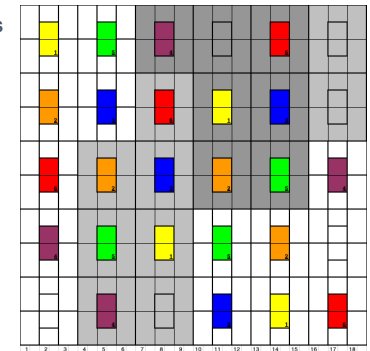
**BROCCOLI BIOFUMIGATION TRIAL  
RANDOMIZED COMPLETE BLOCK  
4 REPS PER TREATMENT  
HARVESTED PLOTS 10 FEET LONG X 30 INCHES  
WIDE (COLORED AREAS)**

**HARVEST MATURE BROCCOLI  
MECHANICALLY MOW AND CHOP STALKS**

- STAKE OUT 6 TREATMENTS:**
- YELLOW** NONE (CHOPPED BROCCOLI WILL BE MOVED TO 2X TREATMENT)
  - ORANGE** 1X BROCCOLI RESIDUE
  - BLUE** 2X BROCCOLI RESIDUE
  - PURPLE** 1X BROCCOLI RESIDUE WITH TARP
  - GREEN** 1X BROCCOLI WITH 1X TELONE (9 GPA)
  - RED** 1X BROCCOLI WITH 2X TELONE (18 GPA)

**MOVE STALKS FROM YELLOW TO BLUE  
TILL FIELD  
MAKE BEDS  
INJECT TELONE INTO GREEN AND RED PLOTS  
TARP PURPLE PLOTS FOR 2 WEEKS  
REMOVE TARPS AND PLANT BROCCOLI**

**2 WEEKS TOTAL BETWEEN CROPS  
(GROWER STANDARD PRACTICE)**

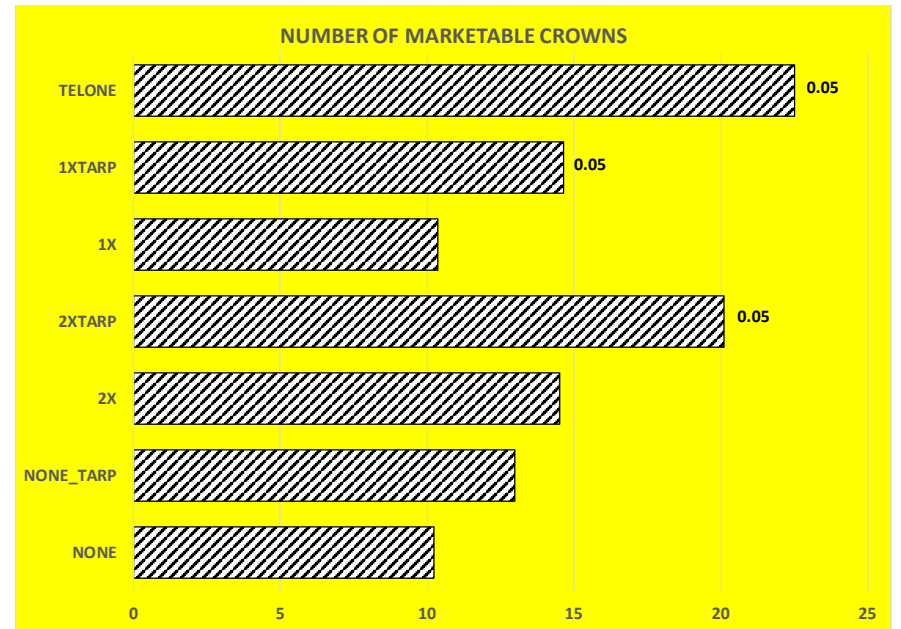
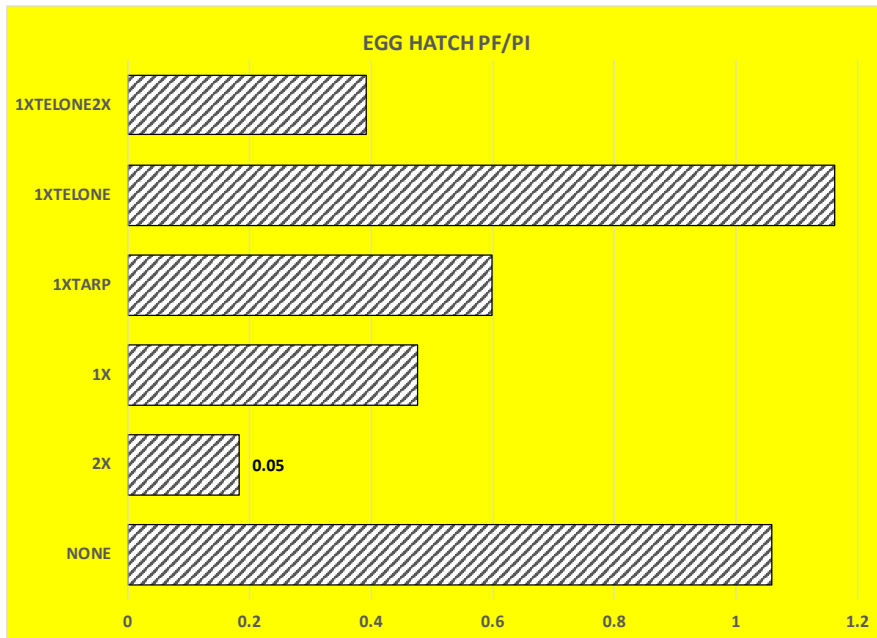
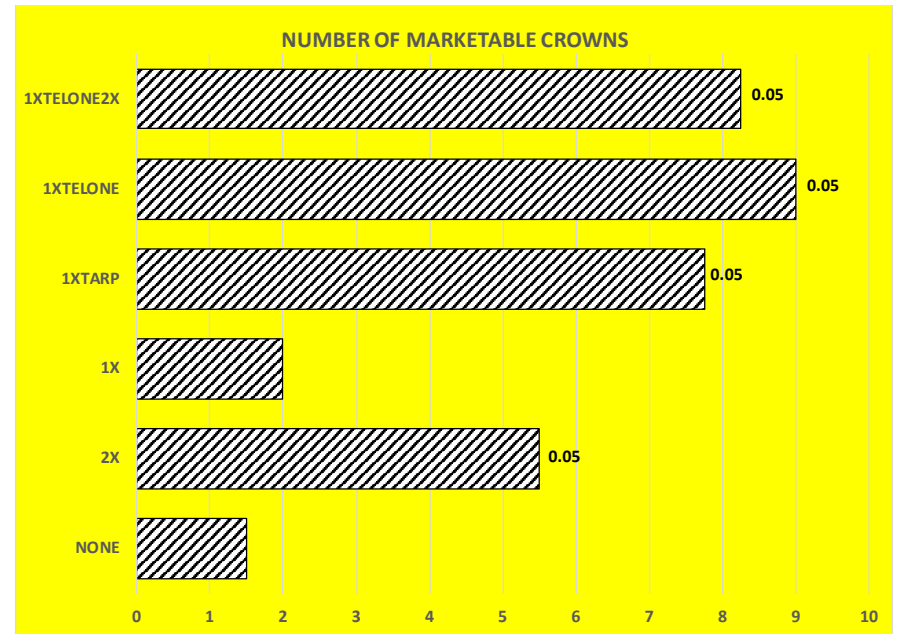


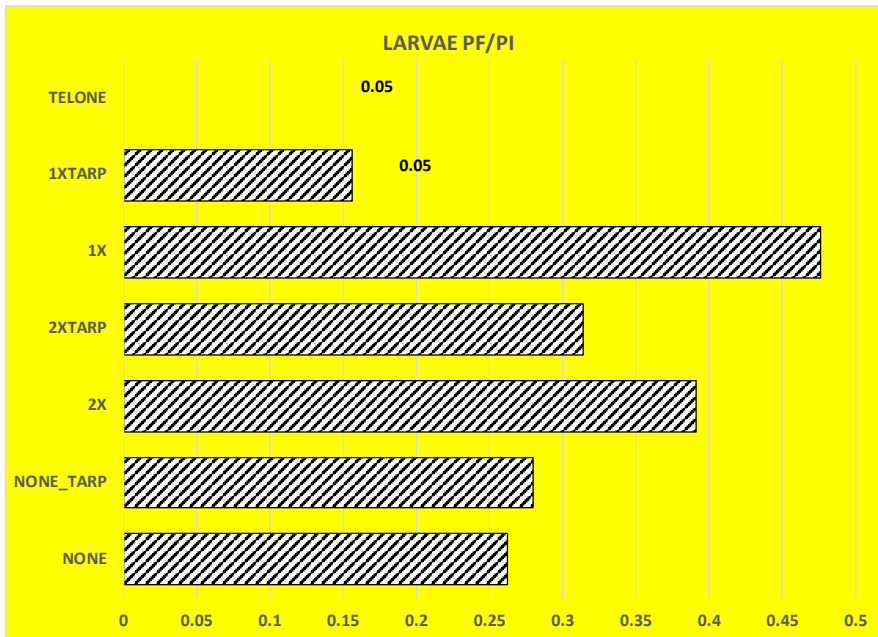




**BROCCOLI  
MOWED  
AND  
CHOPPED**

**FIELD  
TILLED,  
BEDDED,  
AND  
TARPED**





**TRAP CROPPING FOR SEDENTARY ENDOPARASITIC NEMATODES (ROOT KNOT AND CYST):**

**JUVENILE ENTERS ROOT AND BEGINS FEEDING  
IMMATURE FEMALE NO LONGER ABLE TO MOVE  
DESTROY CROP BEFORE FEMALE LAYS EGGS  
PLANT COMMERCIAL CROP**



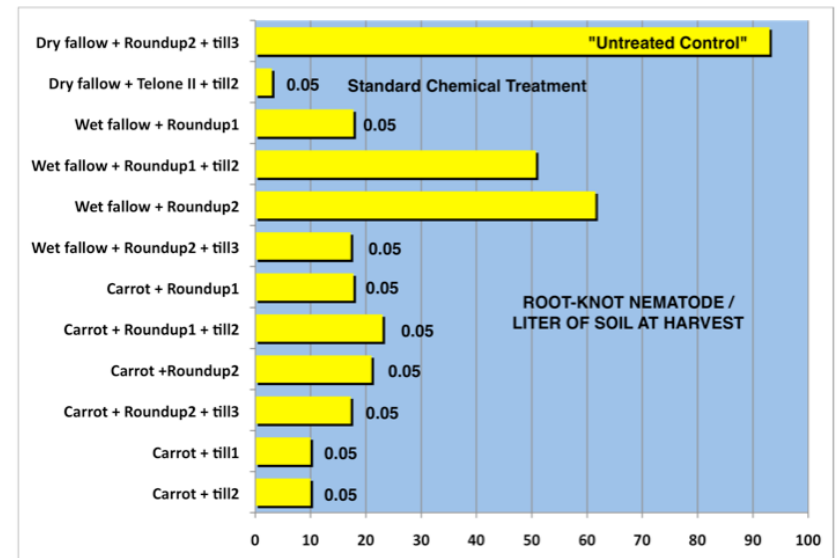
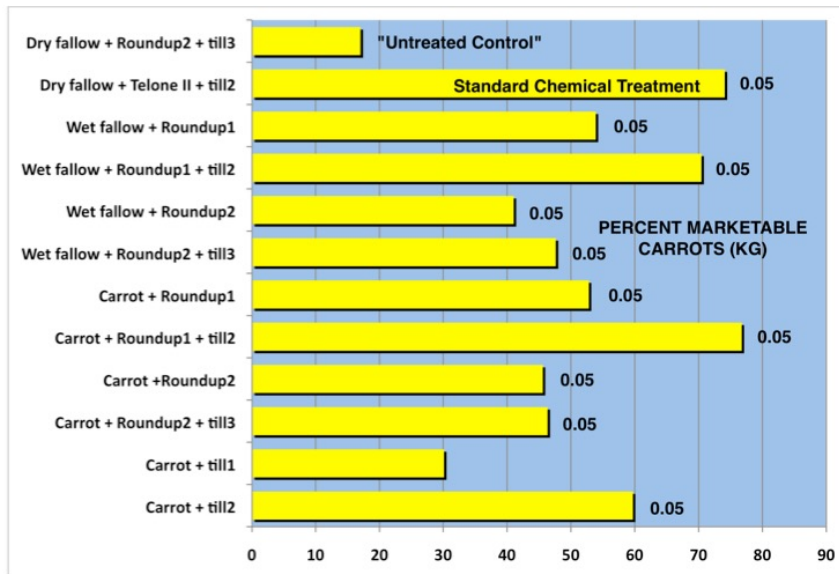
B. A. JAFFEE

**SOUTH COAST RESEARCH AND EXTENSION CENTER  
TRAP CROP TRIAL  
5 REPLICATES  
RANDOMIZED COMPLETE BLOCK DESIGN  
EACH REP - 1 ROW WIDE  
20 FEET LONG (6 METERS)**

**Treatments (Numbers Indicate Weeks After Carrot Germination)**

Dry fallow + Roundup2 + till3
Dry fallow + Telone II + till2
Wet fallow + Roundup1
Wet fallow + Roundup1 + till2
Wet fallow + Roundup2
Wet fallow + Roundup2 + till3
Carrot + Roundup1
Carrot + Roundup1 + till2
Carrot + Roundup2
Carrot + Roundup2 + till3
Carrot + till1
Carrot + till2





**POSSIBLE MODES OF ACTION OF SOIL AMENDMENTS / NATURAL PRODUCTS:**

- ADDITION OF BENEFICIAL MICROBIALS
- STIMULATION OF NEMATOPHAGOUS FUNGI
- COMPETITION FOR ROOT SURFACE
- REDUCE STRESS ON NEMATODE INFESTED PLANTS (VIA IMPROVED SOIL STRUCTURE, SOIL WATER RETENTION, PLANT NUTRITION)
- PRODUCE NEMATOCIDAL BREAKDOWN PRODUCTS



**ASD (Anaerobic Soil Disinfestation)**

Spreading rice bran – broadcast with manure spreader

Incorporate  
Irrigate  
Tarp (2 months)

Carol Shennan  
UC Santa Cruz