Management of Plant-parasitic Nematodes

(with the emphasis on the practices in Thailand)

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Module 1: Vegetables: from Seed to Harvest

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Principles of Plant-parasitic Nematode Management

1. **Before planting, to reduce initial nematode population**

   "Very Important"

- **Solarization, soil steaming, hot water, fallow, flooding**

- **Pre-planting nematicides such as 1.3-Dichloropropene, metham sodium, dazomet**

- **Growing marigold, or crotalaria**

2. During planting, to reduce rate of population increase

- Post plant nematicides such as systemic nematicides (oxamyl, femamiphos, carbofuran)

- Biological control such as using fungi *Paecilomyces*, the bacteria (*Pasturia penetrans*)

Before Planting

Solarization

- Using the polyethylene sheets to cover the moist soil

- Strong sunlight can kill nematodes and other soil microorganisms

- Strong sunlight can change the physical, biochemical and, biological properties of soil

Increasing and enhancing the availability of nitrogen in soil

Solarization

- Soil clods need to be broken up
- Cover the soil with clear plastic tarp and bury the edges of the plastic
- Cover the soil for 4-6 weeks
- Disinfected zone is usually 6-8 inches deep
- Work best in the summer months

Soil steaming

- Hot vapor is released into the soil through the pipes built about 20-40 cm beneath the soil surface

- However, expensive and not suitable for low valued crops

Hot Water

- Applicable to control nematodes in bulbs or ginger rhizome or in other planting materials

- Most nematode metabolisms cease at the temperature of 50 C

- Hot water (at too high temperatures) may cause negative effects or stop the spout germination

- In ginger rhizomes, hot water at 50 C for 30 minutes can kill nematodes in ginger rhizomes without causing negative effects to ginger.

Hot water treatment

50 C for 30 minutes

Fallow

- Nematodes need plants (hosts) for food to survive

- Without plants, nematodes starve and die

- However, a 6 month fallow is needed (at least). Eradication of weeds (voluntary plants) in soil is also important because a lot of weeds are hosts of nematodes

- Fallow is effectively used to control nematode juveniles, but not to nematode eggs and cysts.

Some of Thai weeds that are hosts of root-knot nematodes

Red flame ivy
Hemigraphis alternata
ACANTHACEAE

Prickly chaff-flower
Achyranthes aspera L.
AMARANTHACEAE

Little iron weed
Vernonia cinerea (L.) Less.
COMPOSITAE

Nut grass, Coco grass
Cyperus rotundus L.
CYPERACEAE

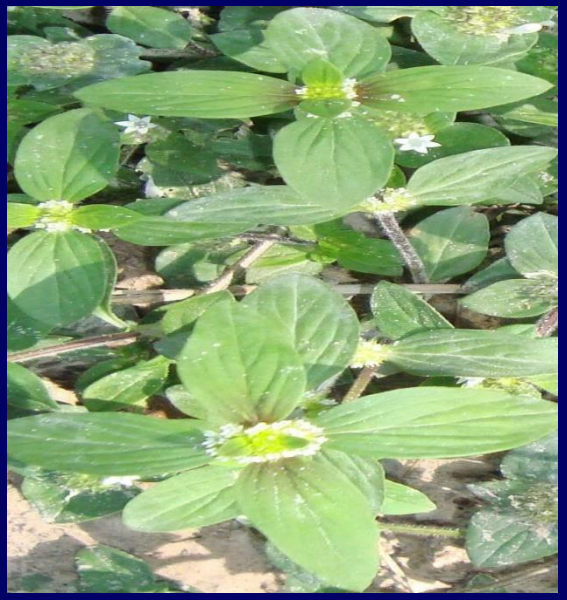
Some of Thai weeds that are hosts of root-knot nematodes

Giant sensitive plant
Mimosa invisa Mart.
var. *inermis* Adelb.

LEGUMINOSAE-
MIMOSOIDEAE

Common garden purslane
Portulaca oleracea L.

PORTULACACEAE



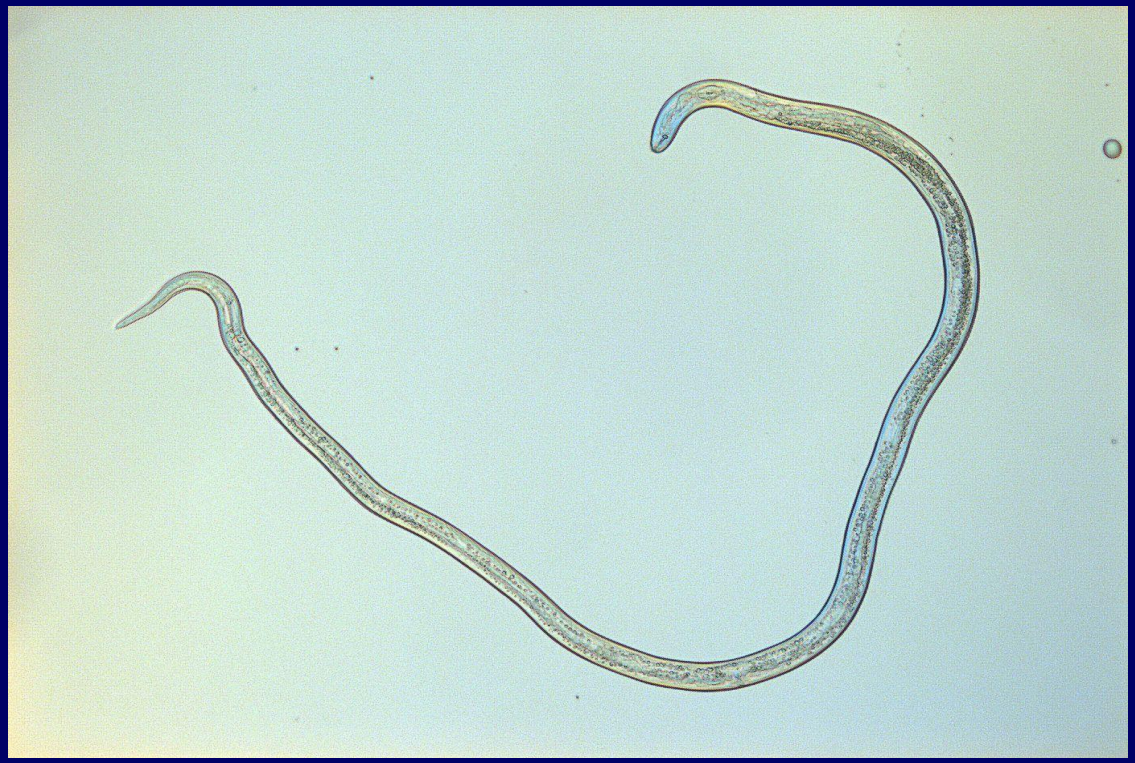
Kradum bai lek
Borreria laevis (Lamk.)

RUBIACEAE

Flooding

- Normally, nematodes do not attack plants in flooded areas
- Low oxygen in flooded soil
- However, 12-22 months of flooding is needed. Not cost-effective and a lot of water is needed.
- The nematode *Hirschmanniella oryzae* can survive in flooded areas or in the water for long times.

Rice Nematode *Hirschmanniella oryzae* can live in the water or in flooded areas for long time



Before Planting

- Pre-planting nematicides such as 1.3-Dichloropropene, metham sodium, dazomet

Preplant nematicides

Common Names	Chemical Group	LD50	Year	Trade Names	Formulation	Distributor
1.3-Dichloro propene	Halogenated hydrocarbon	150	1956	Telone II Telobe EC	Liquid Liquid	Dow Agro Sciences
Metham Sodium	Methyl isothiocyanate liberator	77-220	1951	Vapam, Vapam HL	Liquid	AmVac Chemical
Dazomet	Methyl isothiocyanate liberator	77-220	1897	Basamid	Microgranule	BASF

The application of pre-plant nematicides
Such as 1.3-Dichloropropene, metham sodium, dazomet

Preplanting nematicides

- **Disadvantages**
  - Dangerous, highly toxic, easily vaporized
  - Need polyethylene sheets, costly
  - Not good for big planting areas, costly

- **Advantages**
  - Highly effective
  - Even better than using post plant nematicides because pre-planting nematicides preclude nematode infection into the plants

Using Marigold or crotalaria

Marigold

- Marigold (*Tagetes* spp.) produces the chemical alpha-tertienyl

-The chemical property is to kill nematodes

Crotalaria

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ภาพปอเทืองอายุ 20 วัน ในแปลงเกษตรกรที่เข้าร่วมโครงการ

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Crotalaria

ภาพเกษตรกรผู้เข้าร่วมโครงการกับแปลงปลูกปอเทือง

ภาพปอเทืองที่อายุประมาณ 30 วัน บนแปลงเกษตรกรผู้ปลูกพริก

เกษตรกรทำการไถกลบปอเทืองลงในแปลงที่อายุ 45 วัน

The Benefits of Planting Crotalaria

1. Crotalaria is a poor host of nematodes. Therefore, nematode population in soil is reduced when crotalaria is planted.

2. Fixing nitrogen from the air to the soil (getting free nitrogen)

3. Increasing organic matter in the soil (more soil nutrients and good soil texture)

During planting

- Post plant nematicides such as systemic nematicides (oxamyl, femamiphos, carbofuran)

- Biological control such as using fungi *Paecilomyces*, the bacteria (*Pasturia penetrans*)

Postplant Nematicides

Common Names	Chemical Group	LD50	Year	Trade Names	Formulation	Distributors
fenamiphos	Organophosphorus	6	1967	Nemacur 15G Nemacaur 3	Microgranule Liquid	Bayer CropScience
cadusafos	Organophosphorus	37	1982	Rugby 200 CS Rugby 10G	Liquid Microgranules	FMC Corporation
ethoprophos	Organophophorus	62	1966	Mocap 10G Mocap EC	Microgranules Liquid	Bayer CropScience
fosthiazate	Organophosphorus	73	1992	Nemathorin 10G	Microgranules	Syngenta
aldicarb	Oxime carbamate	0.93	1965	Temik 10G Temik 15G	Microgranule Microgranule	Bayer Crop Science
oxamyl	Oxime carbamate	3.1	1974	Vydate 10G Vydate L	Microgranule Liquid	Du pont
carbofuran	Carbamate	8	1965	Furadan 15G Furadan 4F	Microgranule Liquid	FMC Corporation

Examples of Nematicides Made from Natural Products

Common Names	Distributor	Raw Products	Active Ingredients	Control
DragonFire	Poulenger USA	Sesame seed oil Sesame seed meal	Aldehydes, ketones, linolenic acids	Nematodes in grasses
Neo-trol	Bramic Industries Australia	Sesame stalk	Aldehydes, ketones, linolenic acids	Nematodes in grasses
Crop-Guard	IIlovo Sugar South Africa	Woody biomass	2-Fufuraldehyde	-
Clandosan 618	Igene Biotechnology USA	Crabs and shrimp shells	Chitin and Urea (increasing microorganisms to kill nematodes)	-
Ditera	Valent BioSciences USA	*Myrothecium verrucaria*	The extract derived from fermented bacteria	Approved by EPA in 1997
Neem Nemate	Several companies from India	Neem	Azadirachtin	-

Post plant nematicides

Advantages

- Highly effective but less than “preplant nematicides”
- The only way to kill nematodes inside plant tissues

Disadvantages

- Toxic residues in plants
- Expensive
- Most of them are banned, not available in the market

During planting:

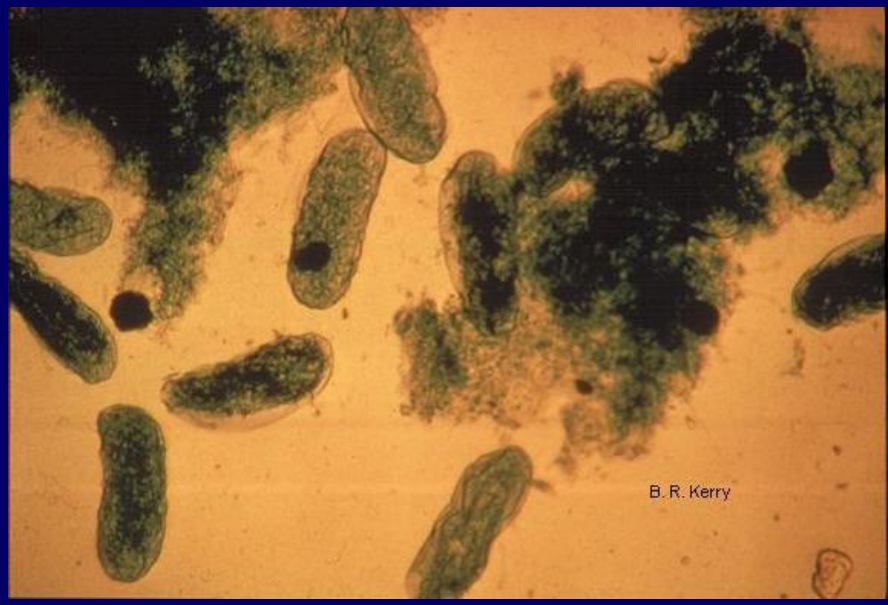
- Biological control such as using fungi and bacteria

The fungi Dactylaria haptotyla **produce adhesive knobs to catch nematodes**

The fungi Arthrobotrys anchonin **produce constricting rings to catch nematodes**

The fungi *Paecilomyces lilacinus* attack nematode eggs

The fungi *Verticillium chlamydosporium* eat eggs of root-knot nematodes



The bacteria *Pasteuria penetrans* attack nematode cuticles

Biological Control of Nematodes by Fungi or Bacteria

Advantages

- Help reduce the application of toxic chemicals
- Less dangerous to human and environment (if used wisely)

Disadvantages

- Less stable and less effective in nature as compared to the laboratory

- The fungi *Paecilomyces lilacinus* attack human lungs

- High diversity of fungi and varied effectiveness between isolates

Case Studies of Nematode Control In Thailand

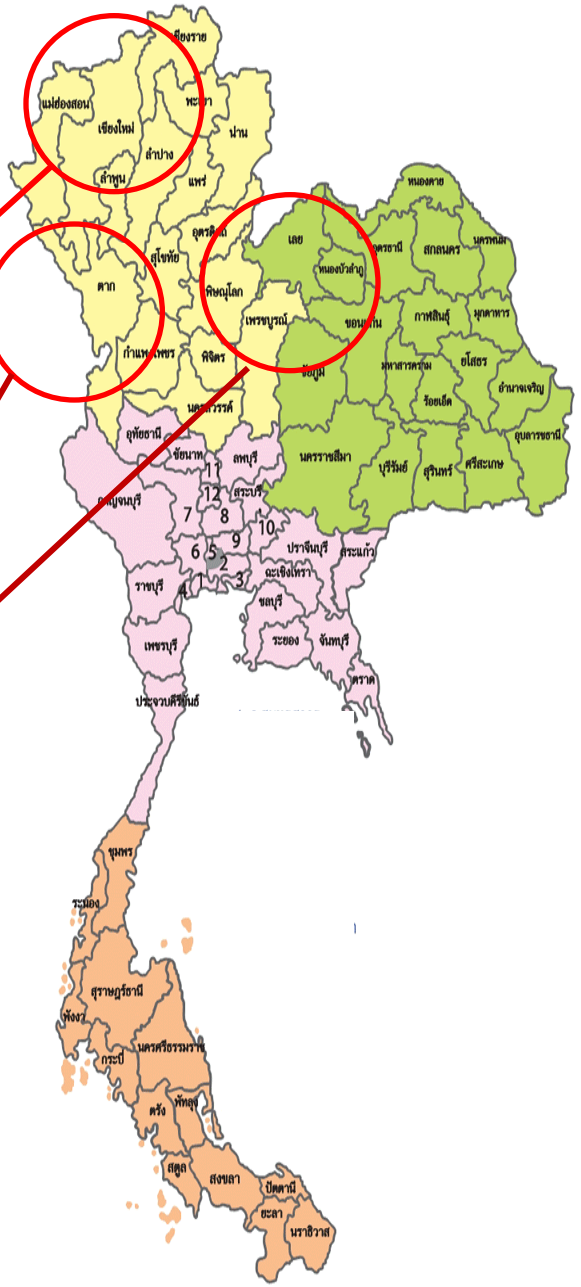
Potato in Thailand

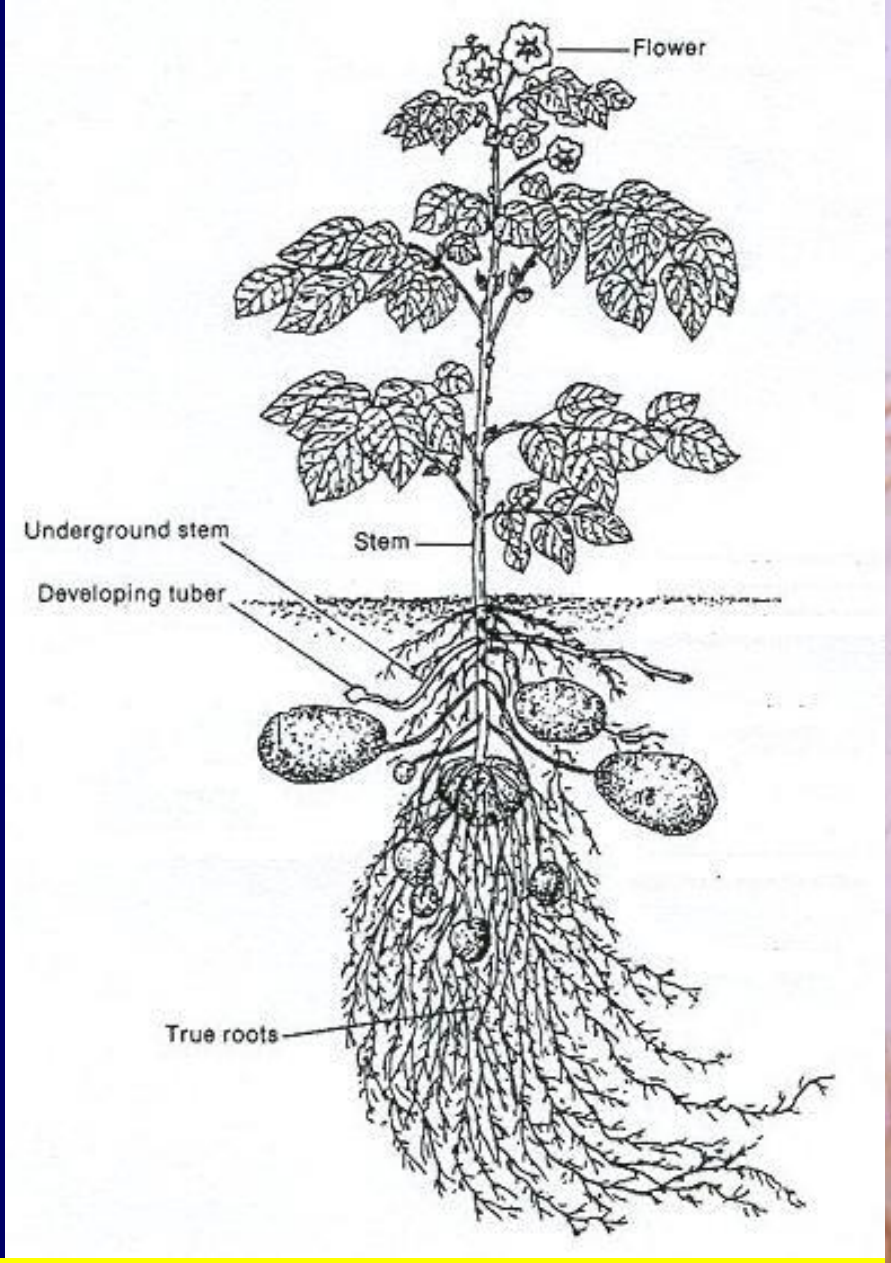
- **Growing areas: 6,217.28 hectares (in 2014)**
- **Production: 98,464 tons (in 2014)**

Mostly after rice
(few nematode problems)

Mostly after chili, tobacco, tomato, vegetables (Solanaceae)

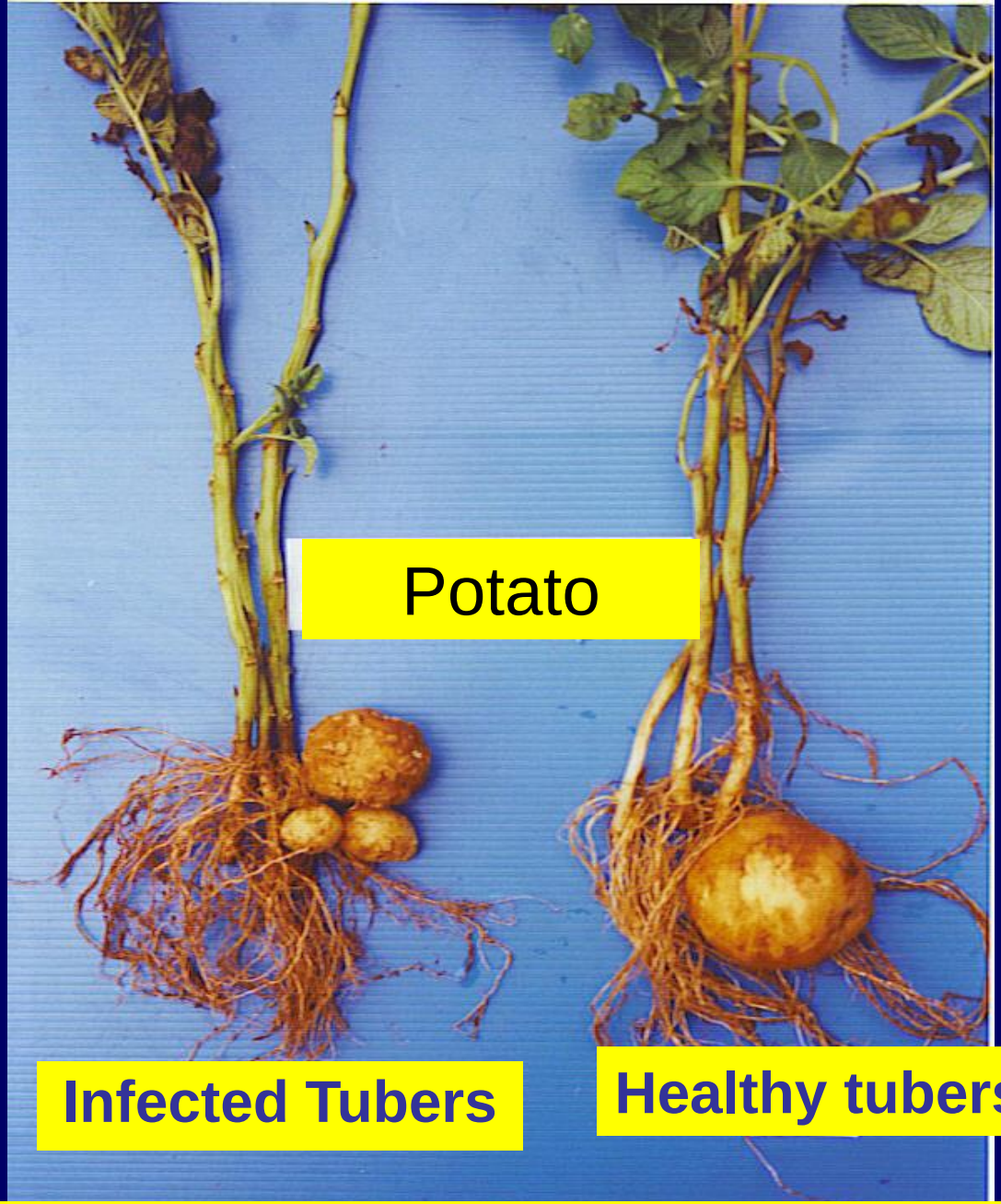
(Serious nematode problems)





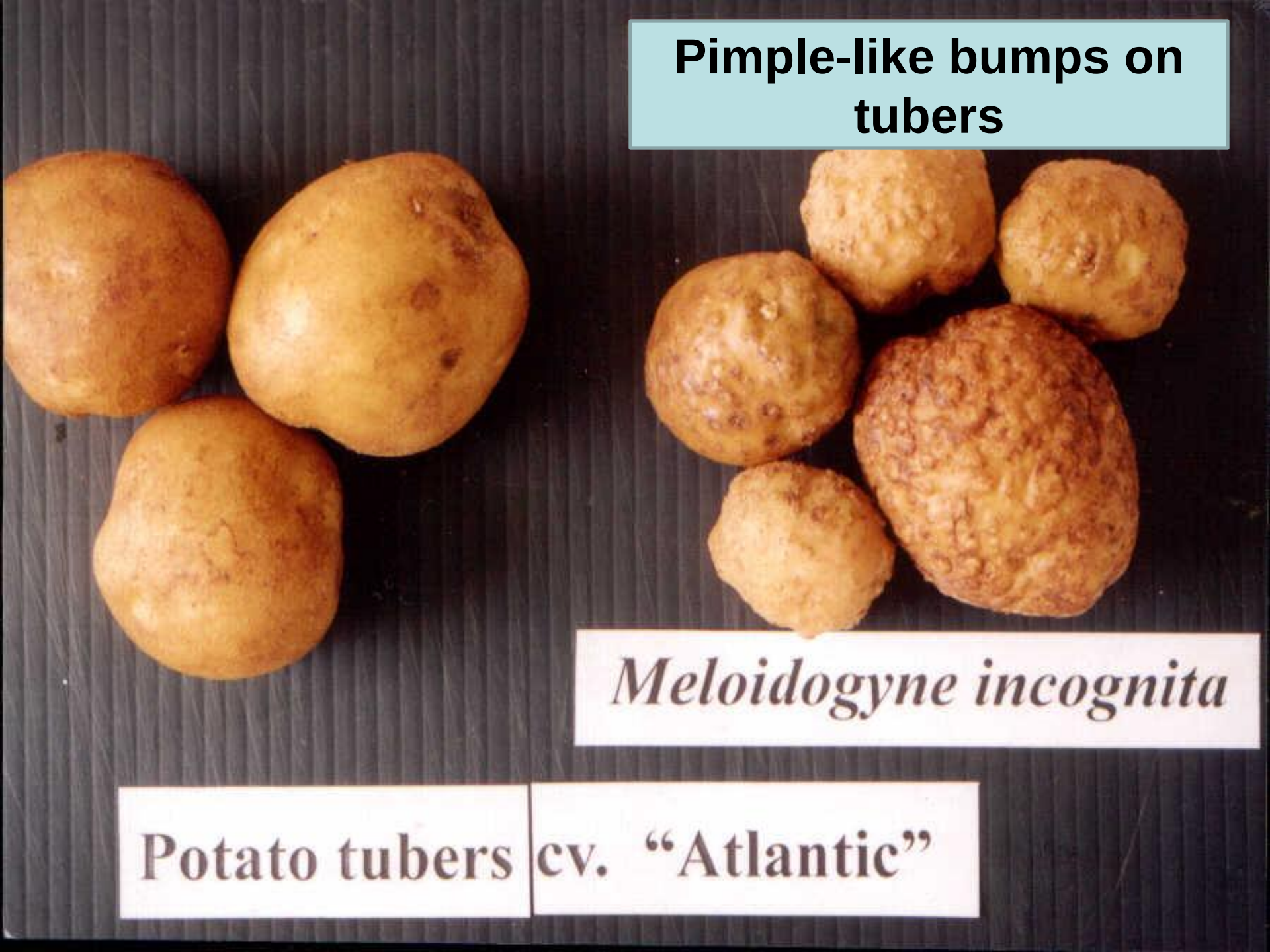
Nematodes firstly attack to roots then to tubers (50-60 days later)

Egg masses deposited on roots at early stage of infection

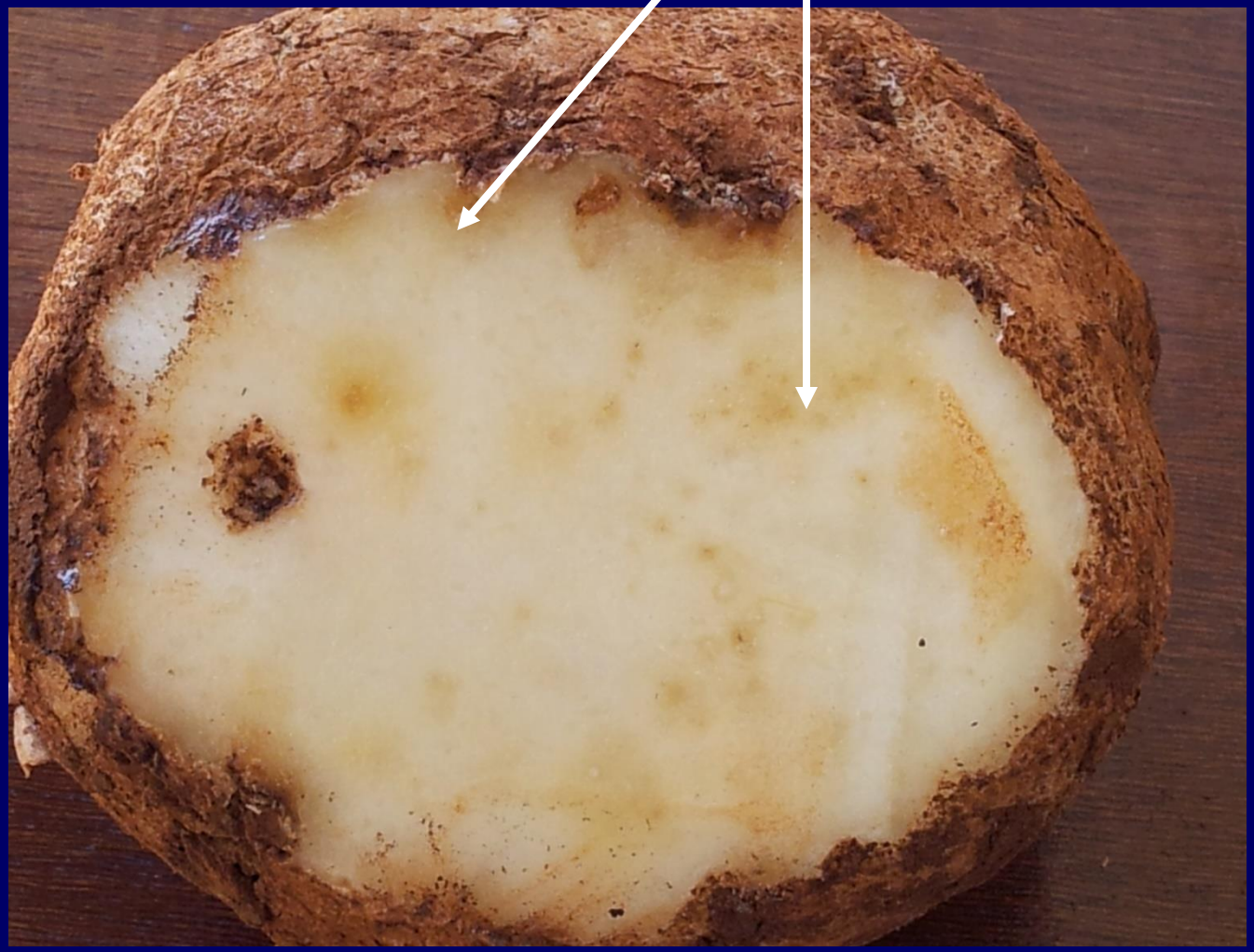


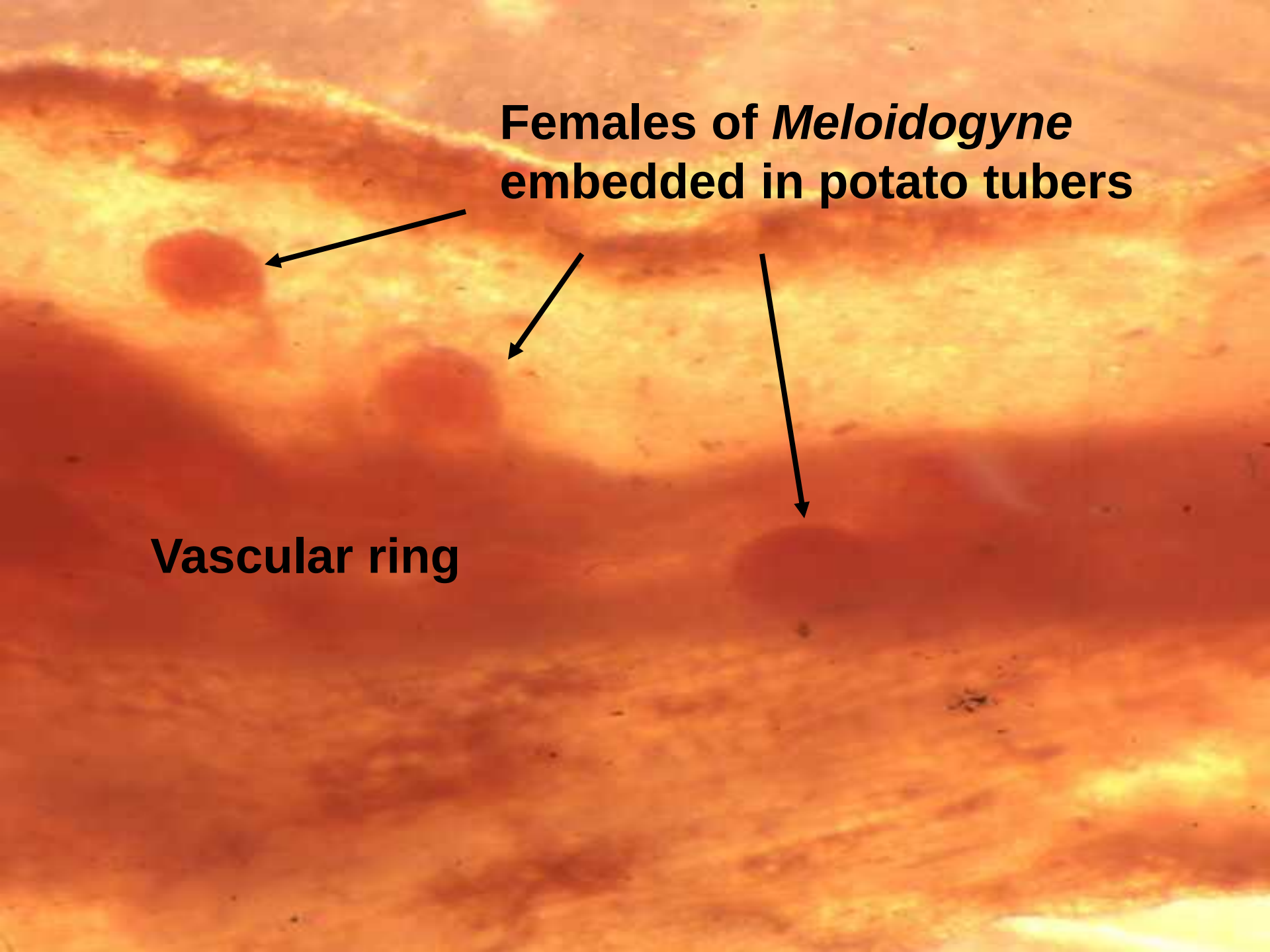
Nematode infection = low numbers of tubers
low quality tubers (small & off graded)


Potatoes infected by *Meloidogyne*
(warty potatoes)
are rejected by the factory


Pimple-like bumps on tubers
Meloidogyne incognita
Potato tubers
cv. "Atlantic"

Brown spots (nematode females)




Females of *Meloidogyne* embedded in potato tubers
Vascular ring

Control Measures

- Rotating potato with maize, crotalaria, marigold

- Changing new planting areas

- Using carbofuran or oxamyl

- **Avoid growing potato on waterlogged soil or poorly-drained soil (more nematode infestation)**

Chili in Thailand

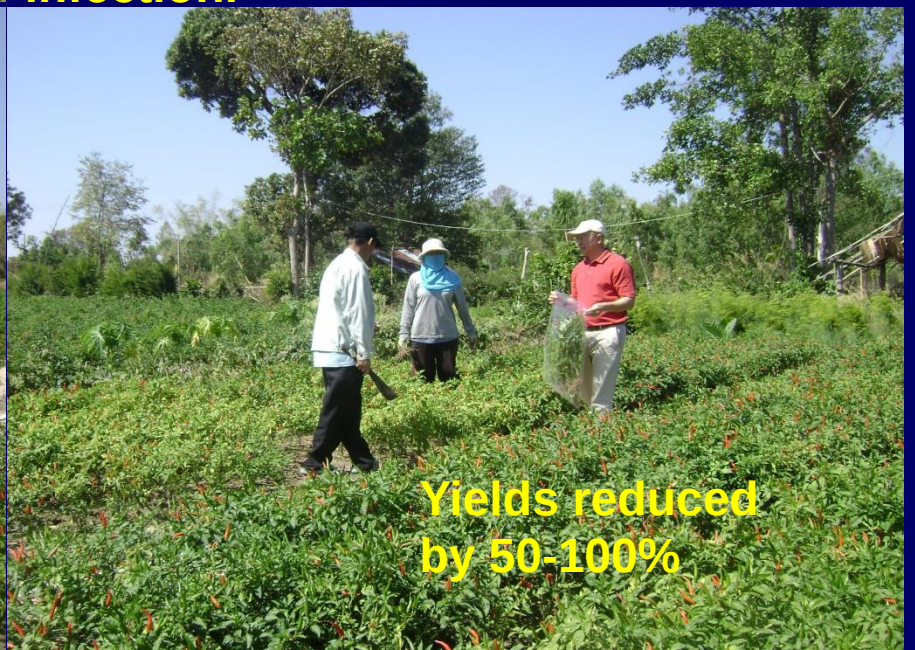
- Planted all over the country
- For fresh and dried consumption in Thailand
- Nematode problem:

  in the Northeastern Thailand

Wilt symptoms under water
High temperature stresses

Yellow patches
of stunted chili

Infestations will gradually radiate outward from an initial point of infection.



Yields reduced
by 50-100%

Numerous galls observed
Often roots rotten and decayed
(non functional anymore)

Meloidogyne **usually found associated with the fungi** ***Fusarium oxysporum***
(Wilt disease)

- Almost all chili growers in Thailand face root-galling problems
- The problem is due to growing chili (same varieties) in the same growing areas for for than three years

- The growers buy (unclean) chili seedlings from local seedling producers

Nematode Problem in Chili in Thailand

Sri Saket province

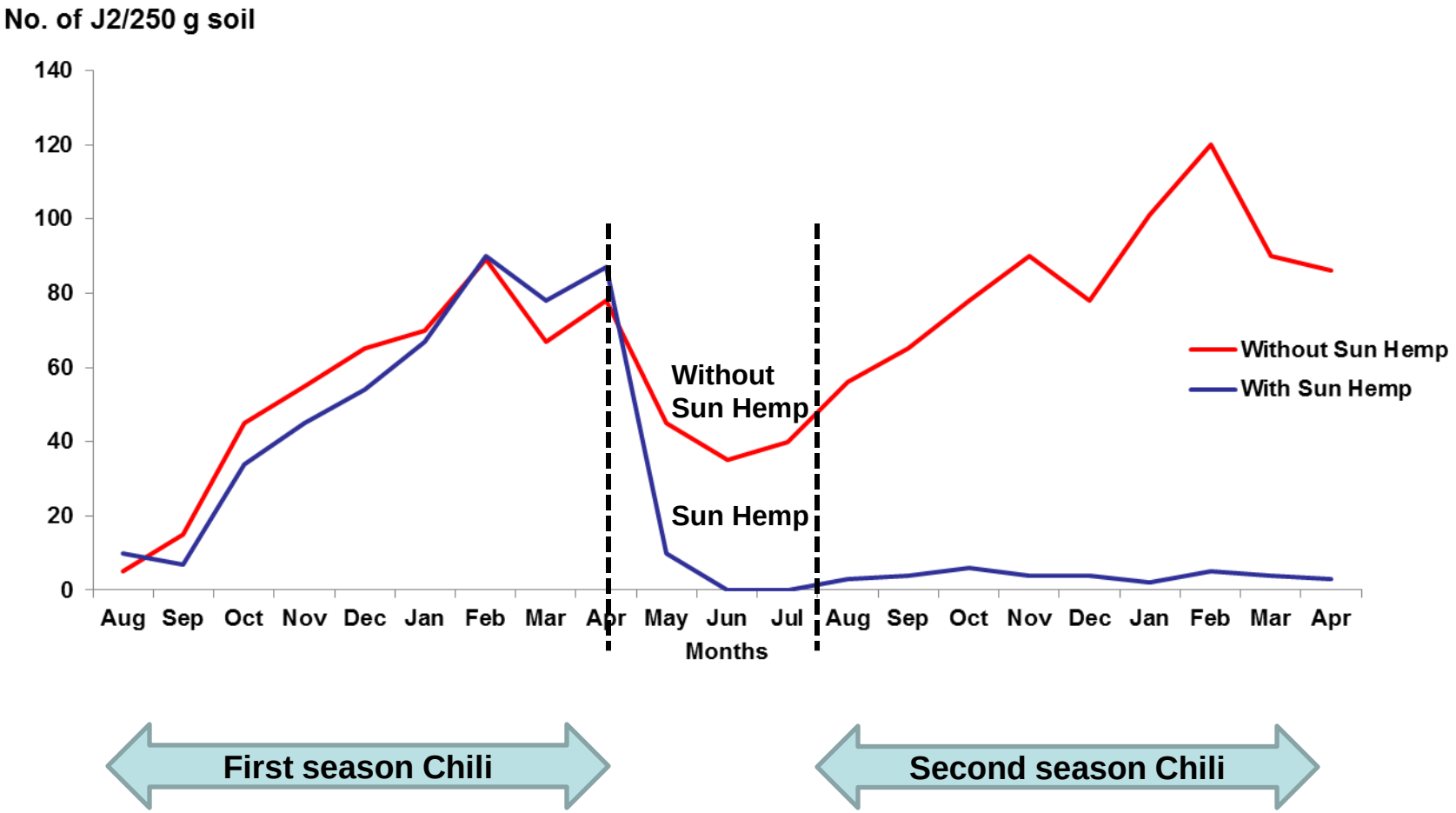
Ubon Ratchathani province - serious problem

Soil texture: Sandy soil

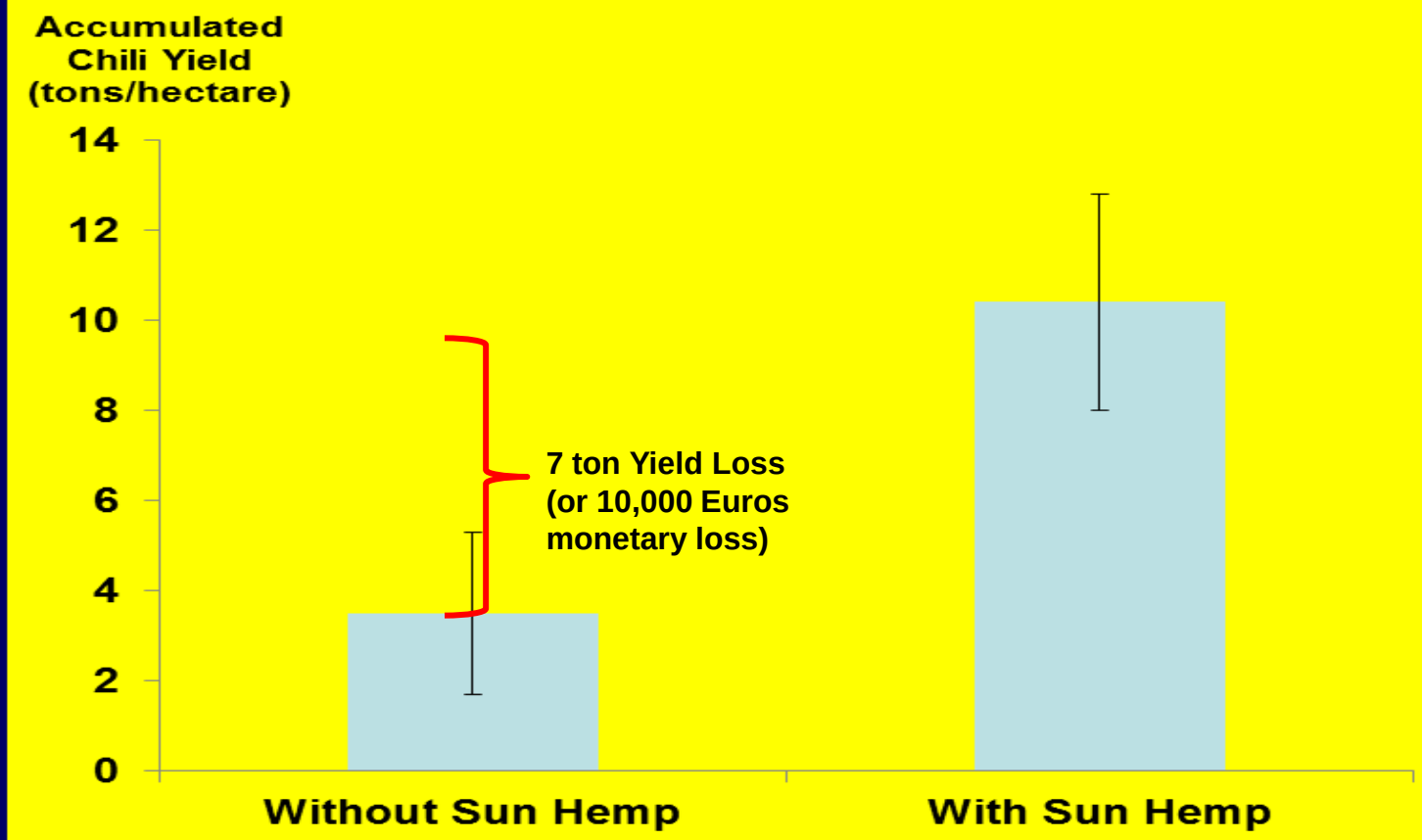
Sandy loam soil

!!!! Growing chili on the same areas for more than 5 years

Effects of Sun Hemp (*Crotalaria juncea*) on population of root-knot nematodes in chili



Chili Yield (Second Season)



Sun Hemp (*Crotalaria juncea*)

- **Incorporate into the soil 45 days after planting**
- **Suppress *Meloidogyne* population**
- **Help increase nutrients and organic matters in soil**
- **Increase yields of the second season chili by 2-3 times as compared to the non-incorporated**



Mode of action: Sun Hemp (*Crotalaria juncea*)

- **Non host or poor host**
- **Produce toxic compounds against nematodes**
- **Enhance nematode-trapping fungi in soil**
- **Also behave as green manure**



Points of Consideration

- Best nematode control = preventive

  Once nematodes in plants, it is difficult to rid them off and plant yields have already been affected

- Nematode infestation is usually in water-logged areas (alternate wet and dry fields)

- High soil moisture content = usually big problem

50% of cassavas in the field of 1 hectare showed these symptoms

Stunted, wilting (mostly one side of the canopy), droopy leaves

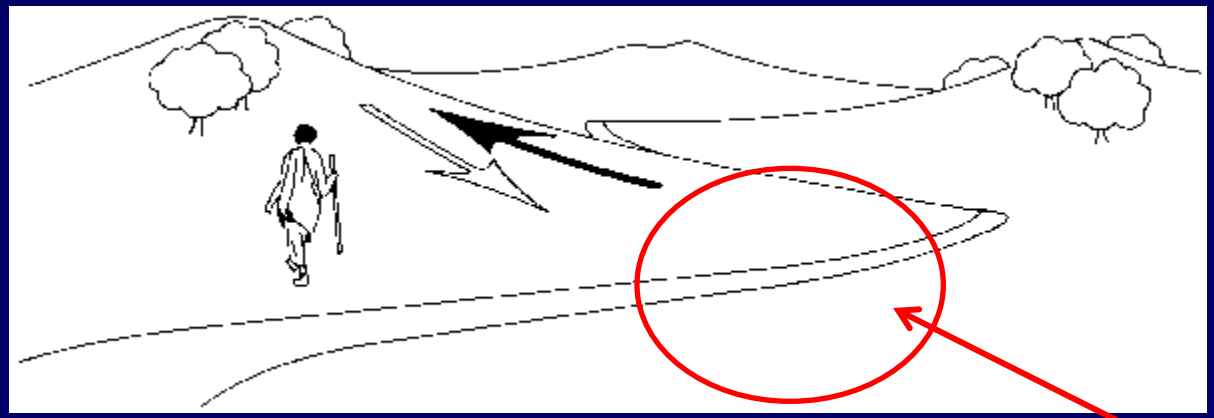
Drip irrigation

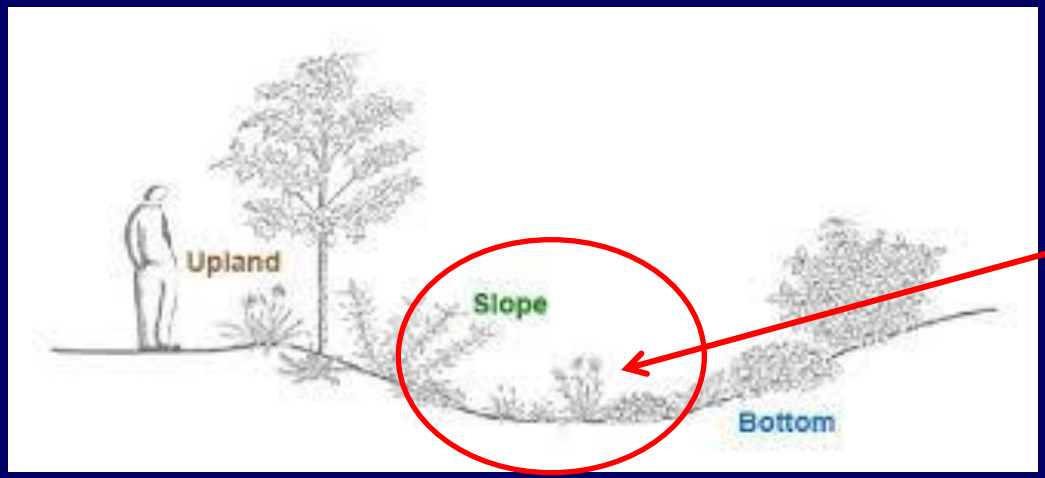
Wet conditions cause more nematode problems

Nematode resistance screening trial on tomato

Plots with high soil moisture as they were close to the irrigation furrows

Nematode problem is usually high in foothill





- Water in soil increases nematode activity

- Water running from uphill helps flush down nematodes to the base of the hill


Moist area
High infestation
Dry area
Less infestation

Meloidogyne enterolobii
Yang & Eisenback, 1983

- **Recently discovered in Thailand (Jindapunnapat *et al*., 2012)**

- **A tropical or subtropical species reported in Brazil, Venezuela, China, Cuba, Vietnam, USA etc.**

- **Ability to reproduce on *Mi-1* gene carrying tomatoes**

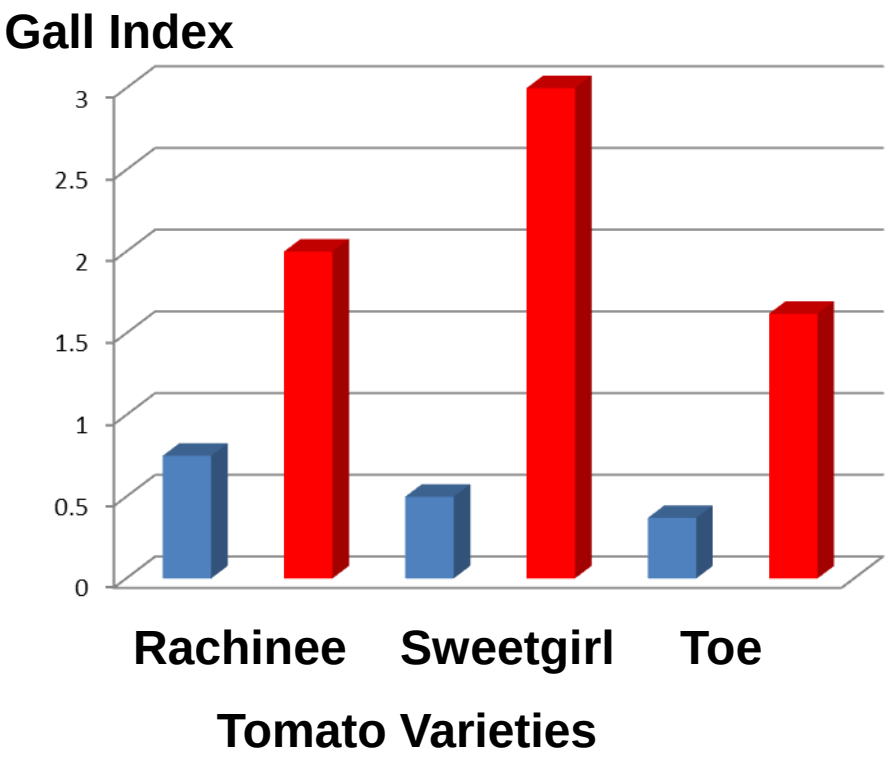
Infected guava trees

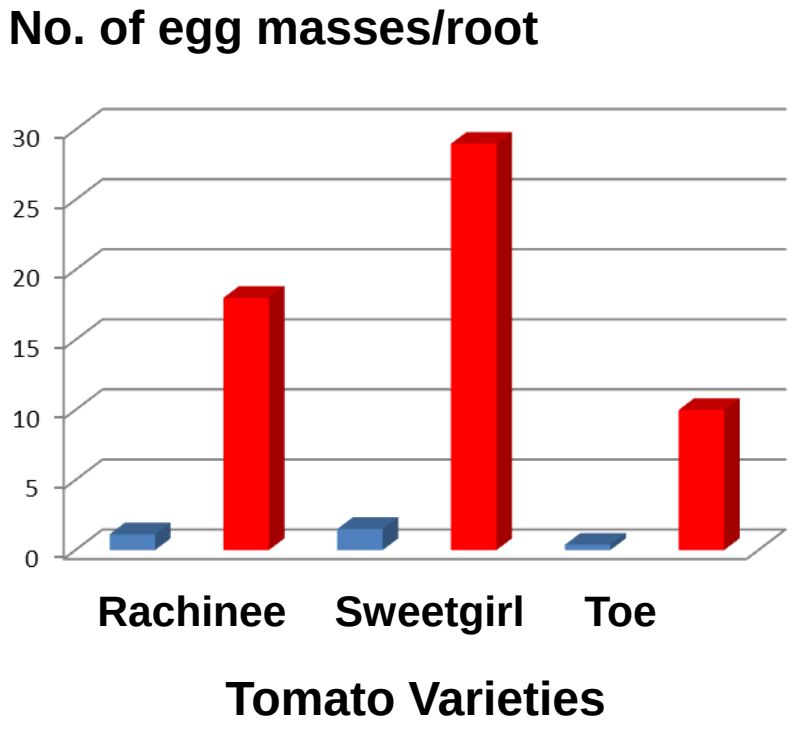
Stunted & not responsive to fertilizers

Rotten roots (severe case!!!)

Conspicuous galls

M. enterolobii is more virulent than *M. incognita* on three different commercial tomato varieties





M. enterolobii

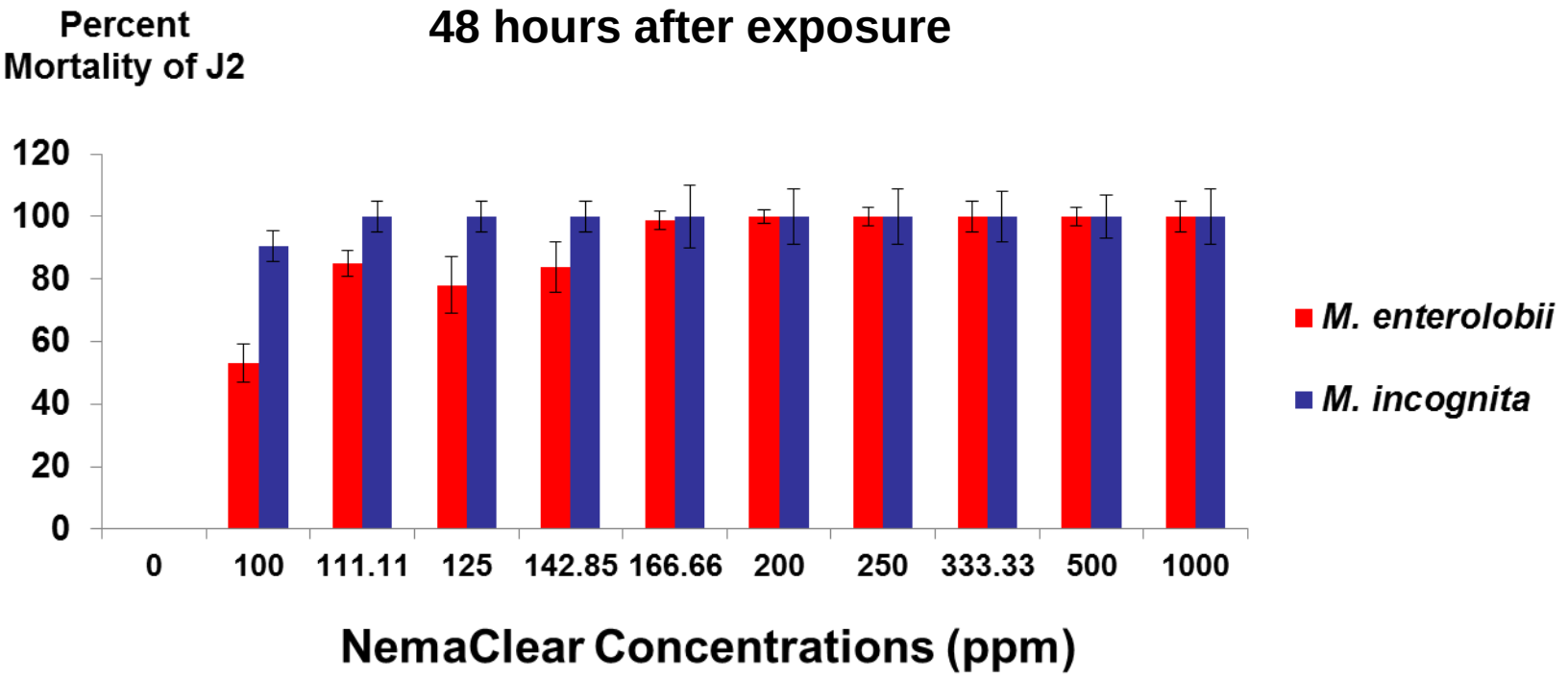
M. incognita

Chanakarn, 2015

M. incognita

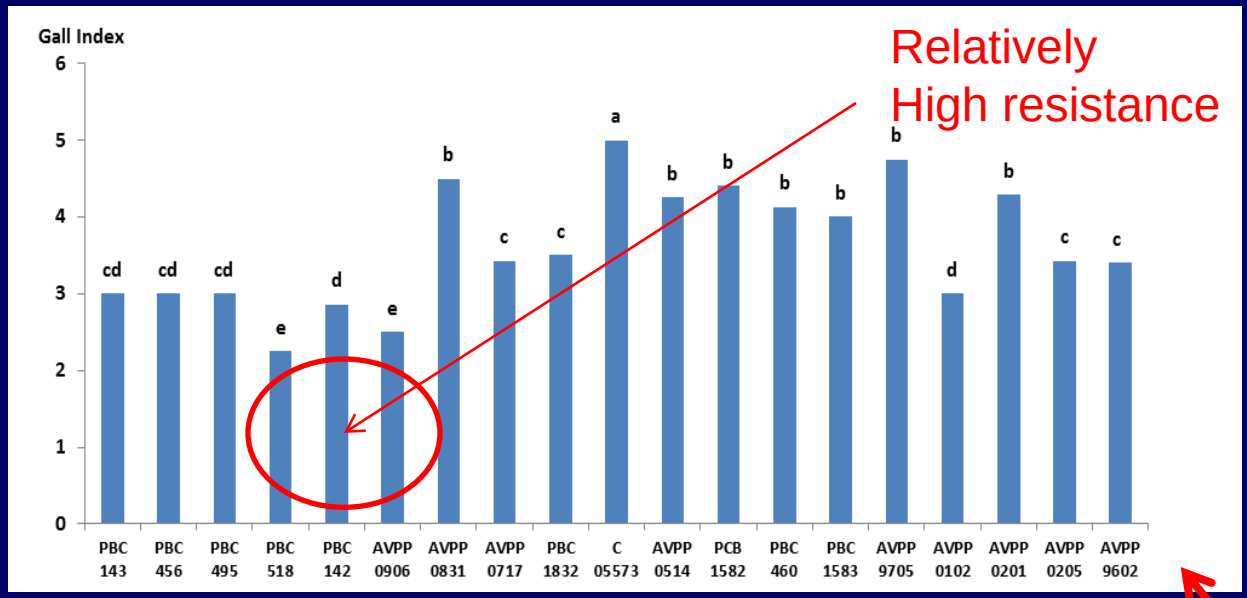
M. enterolobii

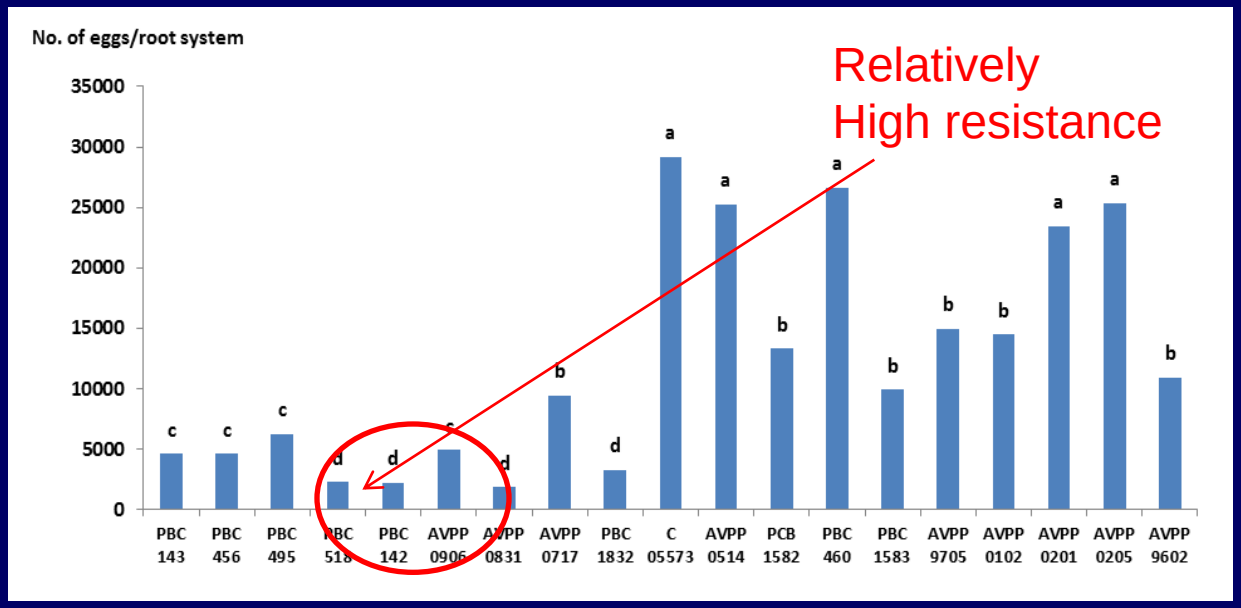
M. enterolobii is more resistant than *M. incognita* to the Chemical NemaClear (Arcis:Altos Group)



Nathawut, 2015

A study on resistance screening of pepper lines against *M. enterolobii* in the greenhouse in Thailand





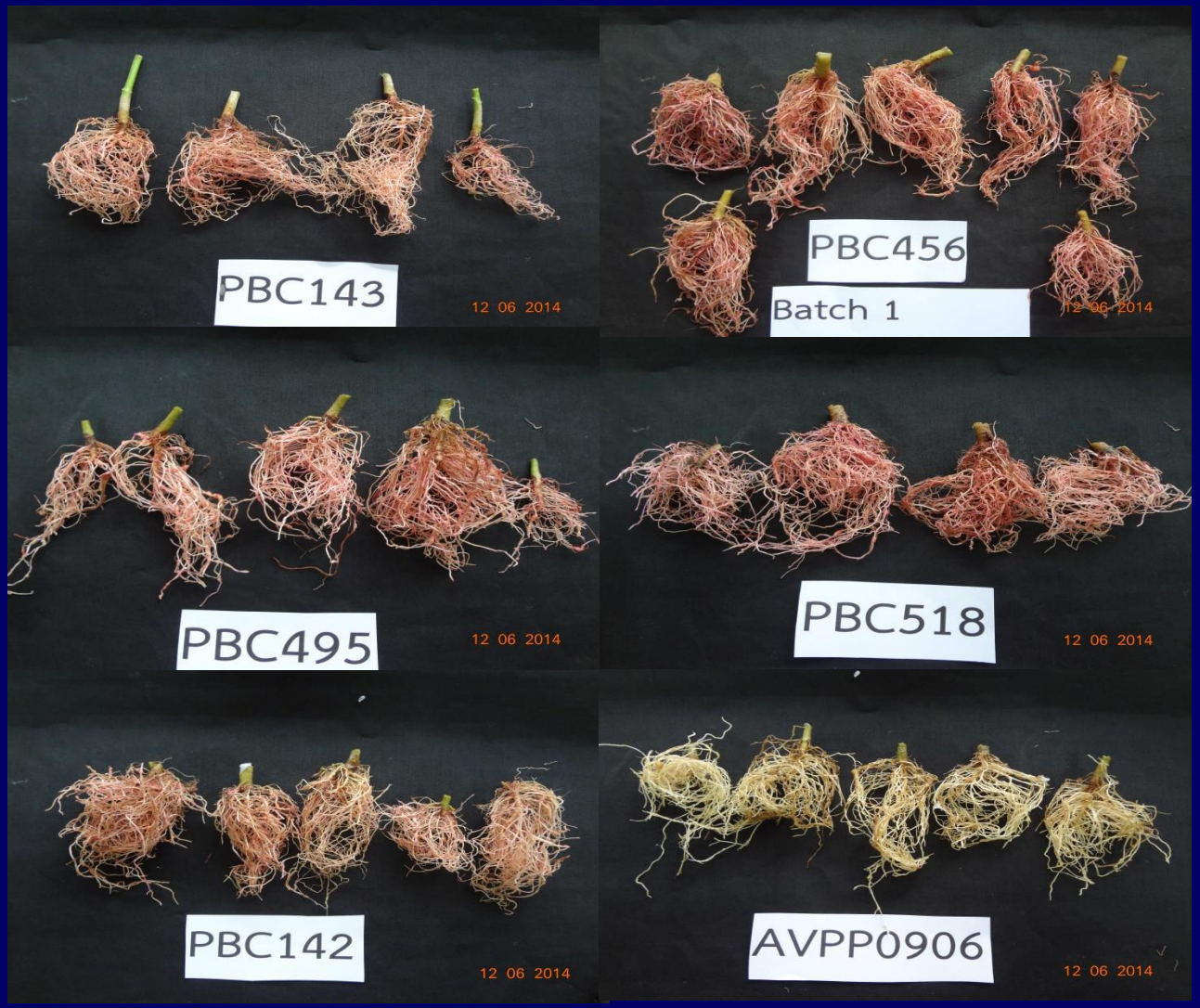
AVRDC Pepper lines

+1000 J2 *M. enterolobii*

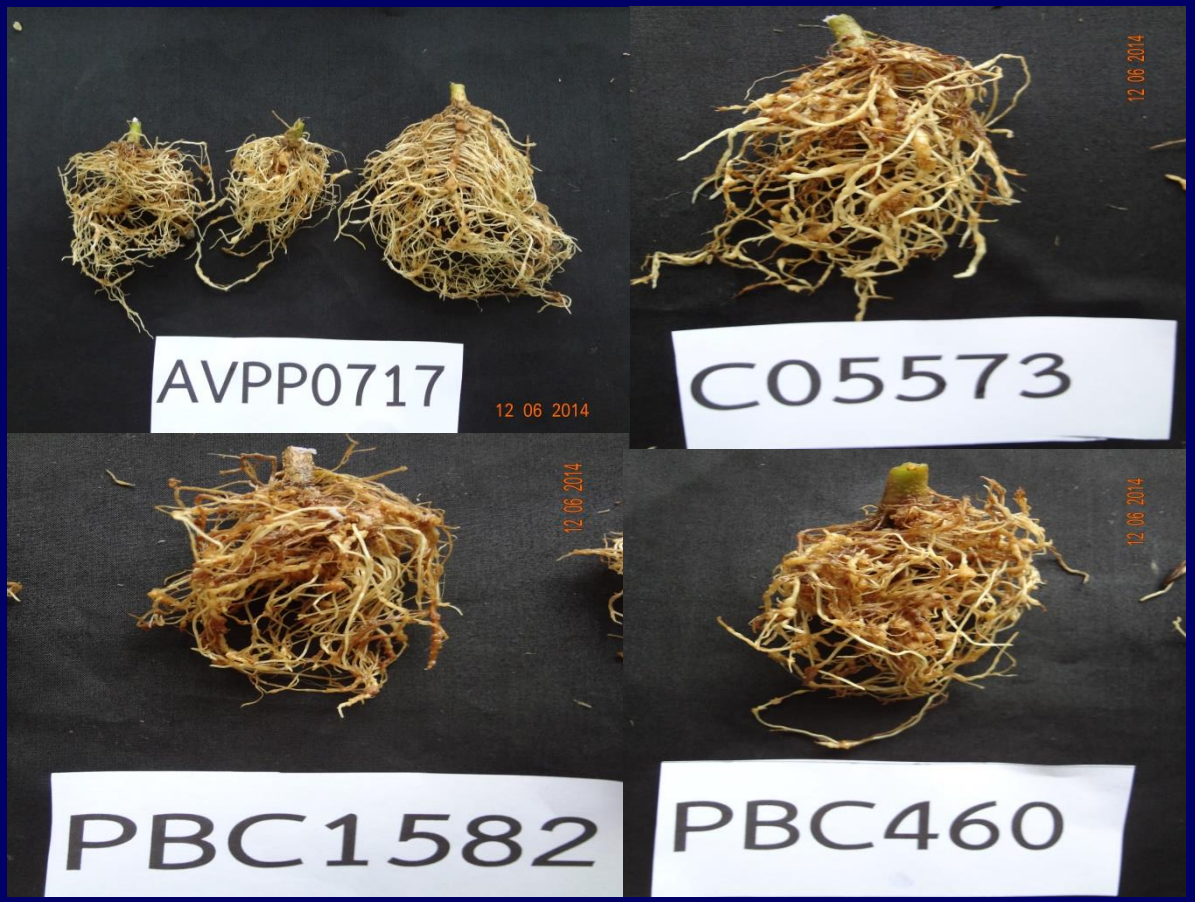
Table 2: **Host status of different pepper lines for *M. enterolobii***

Pepper Lines	Gall Index	Egg Production	Shoot Weights of plants infected with nematodes as compared to non-infected	Root Weights of plants infected with nematodes as compared to non-infected	Status (Most Likely)
PBC143	XXX	XX	Same	Increased	R
PBC456	XXX	XX	Increased	Increased	R
PBC495	XXX	XX	Same	Same	R
PBC518	XX	X	Increased	Increased	R (high)
PBC142	XXX	X	Same	Same	R (high)
AVPP0906	XX	XX	Decreased	Same	R
AVPP0831	XXXXX	X	Decreased	Increased	R
AVPP0717	XXXX	XXX	Decreased	Same	S
PBC1832	XXXX	X	Same	Same	R
C 05573	XXXXXX	XXXXXXX	Same	Increased	S (high)
AVPP0514	XXXXX	XXXXXX	Same	Same	T
PBC1582	XXXXX	XXX	Same	Increased	S
PBC460	XXXXX	XXXXXX	Decreased	Same	S
PBC1583	XXXXX	XXX	Same	Same	T
AVPP9705	XXXXX	XXX	Increased	Increased	S
AVPP0102	XXX	XXX	Decreased	Same	S
AVPP0201	XXXXX	XXXXXX	Same	Same	T
AVPP0205	XXXX	XXXXXX	Decreased	Same	S
AVPP9602	XXXX	XXX	Decreased	Decreased	S

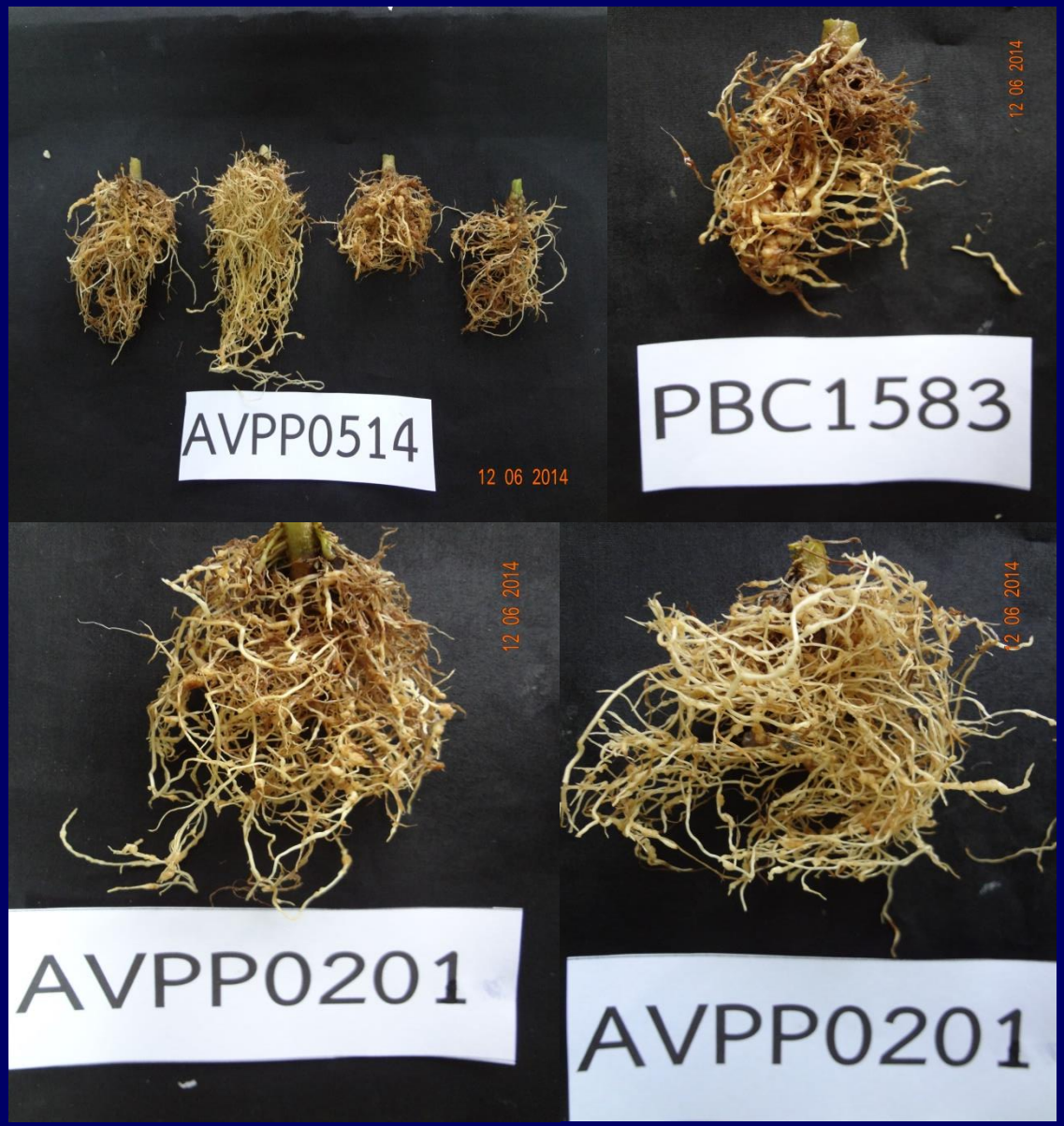
The number of "X" indicates the extent of gall and egg production
R= Resistance, S = Susceptibility, T = Tolerance



Relatively Resistant Pepper LInes



Relatively Susceptible Pepper LInes



Relatively Tolerance Pepper LInes

Thank you very much