Plant Diseases Caused by Nematodes

By

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36th International Vegetable Training Course

Module 1: Vegetables: from Seed to Harvest

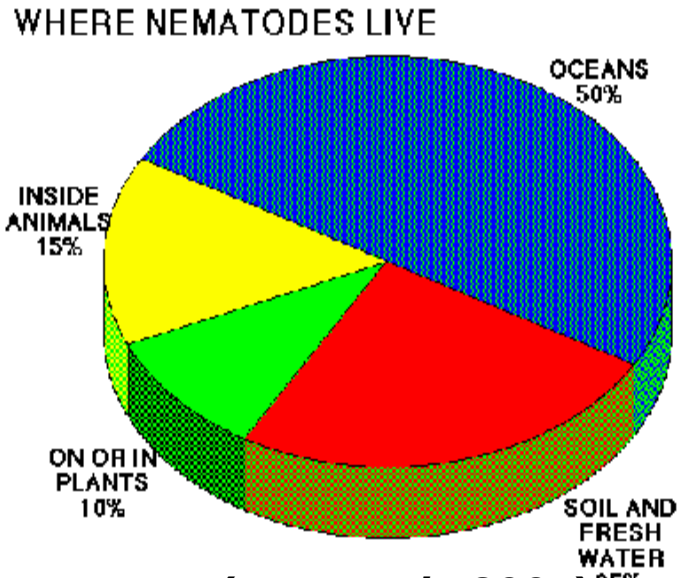
Monday 30 October 2017

Nematodes

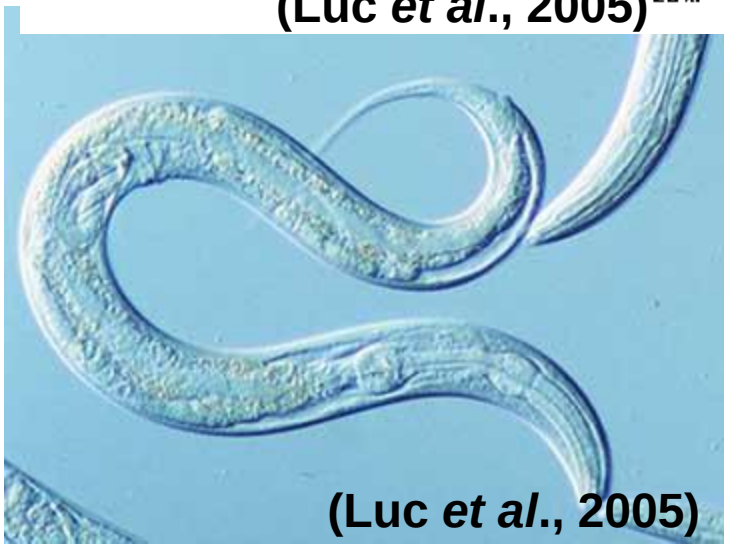
- Kingdom Animalia

- Worm like in appearance but distinct taxonomically from true worms

- Most of nematodes live freely in fresh or salt waters, in soil, feeding on microorganisms or microscopic plants and animals



(Luc *et al*., 2005)



(Luc *et al*., 2005)

Nematodes

- **Some nematodes attack humans and animals, causing diseases**

(SON, 2012)

(SON, 2012)

(SON, 2012)

Some nematodes are known to feed on living plants (receiving food with spears or stylets), causing diseases

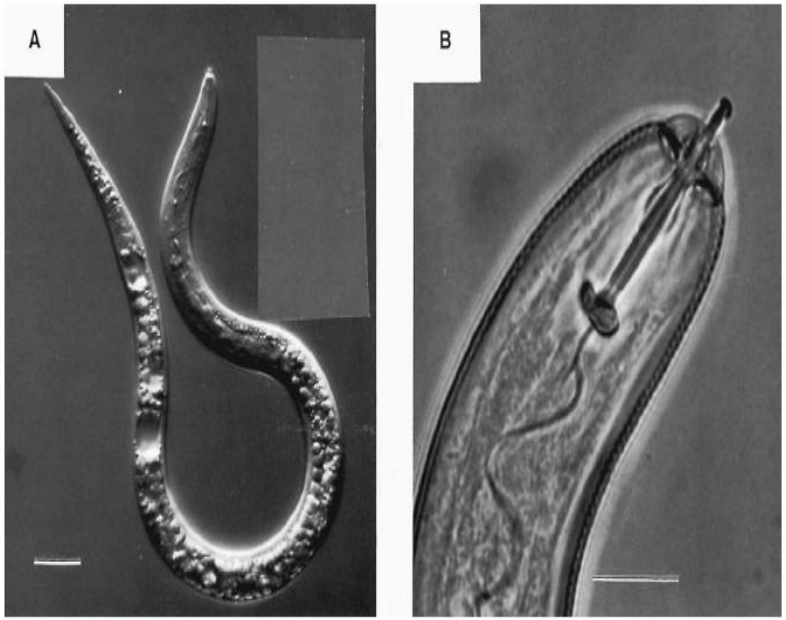
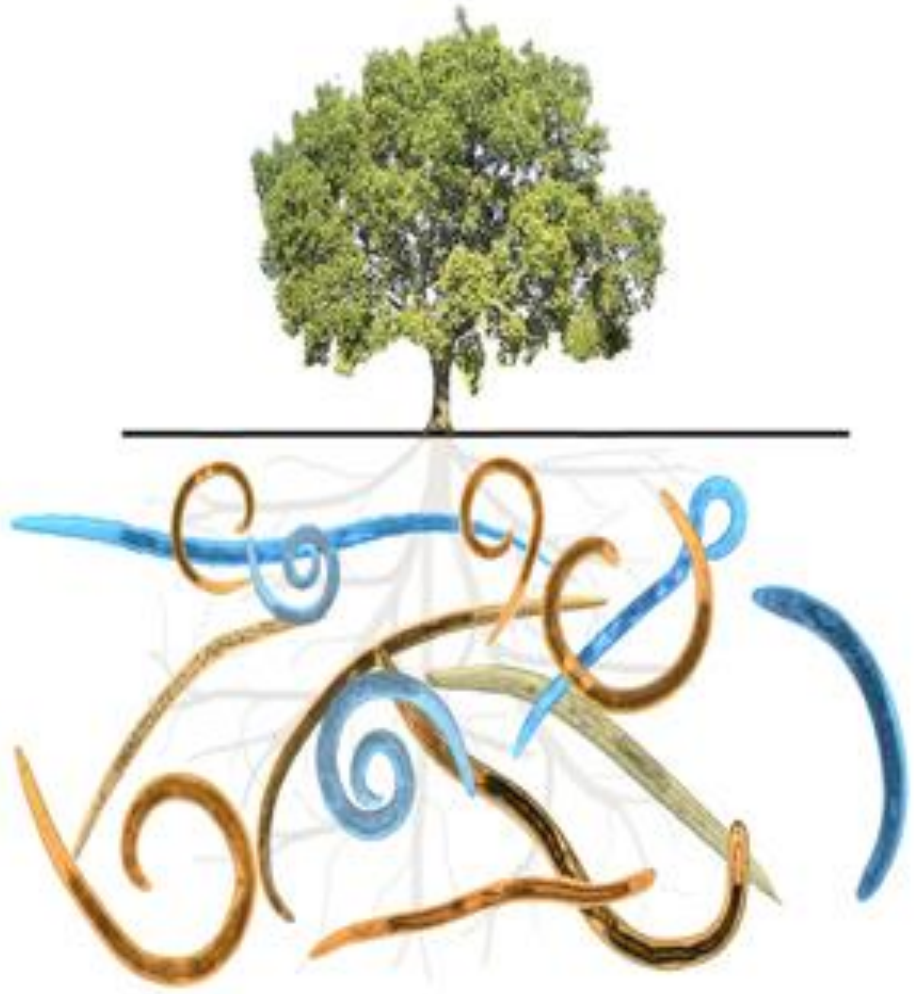


FIGURE 15-1 (A) Typical plant parasitic nematode. (B) Close-up of the head of a plant parasitic nematode showing the spear or stylet. Scale bars: 10 µm. [From McClure and von Mende (1987), *Phytopathology 77, 1463–1469.*]

(Agrios, 2005)

(Coyne *et al*, 2009)



(Gheysen and Jones, 2006)

(SON, 2012)

Nematodes

- **The annual worldwide losses caused by nematodes on life-sustaining crops (all grains, legumes, banana. cassava, coconut, potato, sugar beet, sugarcane, sweet potato, and yam)**

Estimated to be about 11%

Nematodes

- **The annual worldwide losses caused by nematodes on most other economically important crops (vegetables, fruits, and other nonedible field crops)**

Estimated to be about 14%

Nematodes

- **Total worldwide losses**

(life sustaining crops + most other economically important crops)

$80 billion annually

Characteristics of Plant Pathologenic Nematodes

Morphology:

- **Small (300-1000 microns), some up to 4 millimeters long and 15-35 microns wide**

- **Invisible by naked eye**

- **Easily observed under microscope**

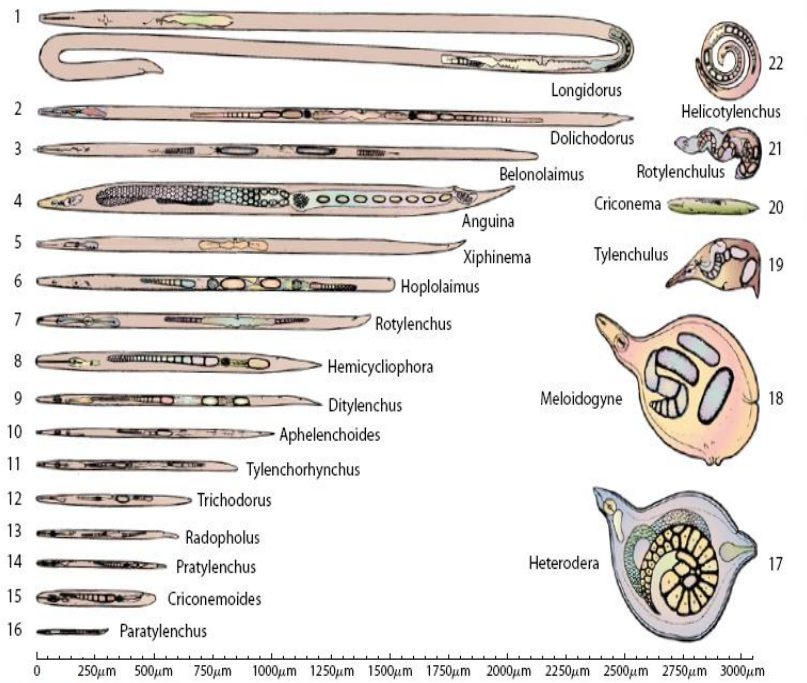


FIGURE 15-3 Morphology and related sizes of some of the most important plant parasitic nematodes.

(Agrios, 2005)

Characteristics of Plant Pathologenic Nematodes

Morphology:

- Eel shaped and round in cross section
- Smooth, unsegmented bodies
- Without legs or other appendages
- Females of some species – swollen at maturity and have pear shaped or spheroid bodies

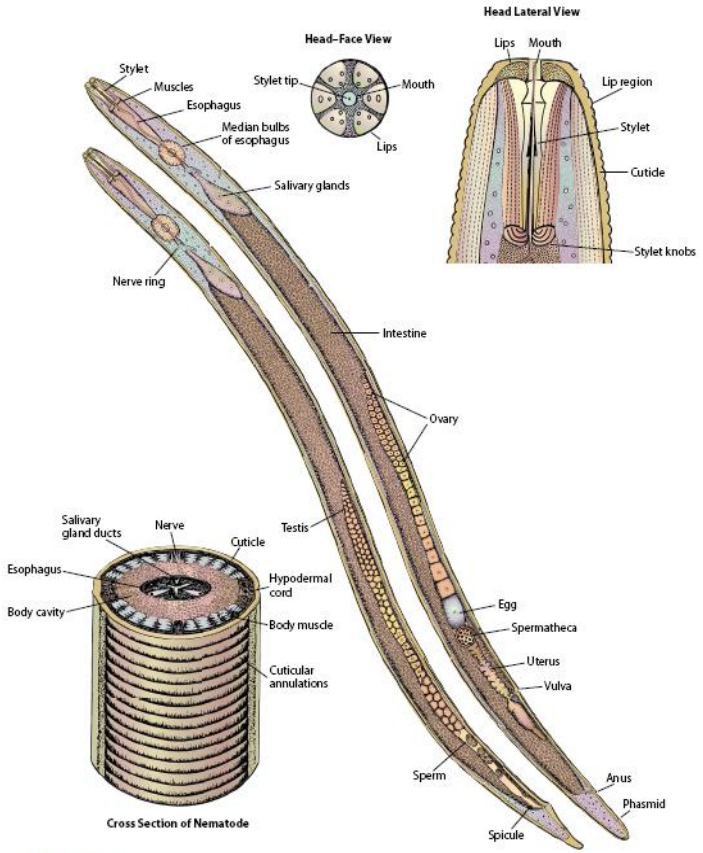


FIGURE 15-2 Morphology and main characteristics of typical male and female plant parasitic nematodes.

(Agrios, 2005)

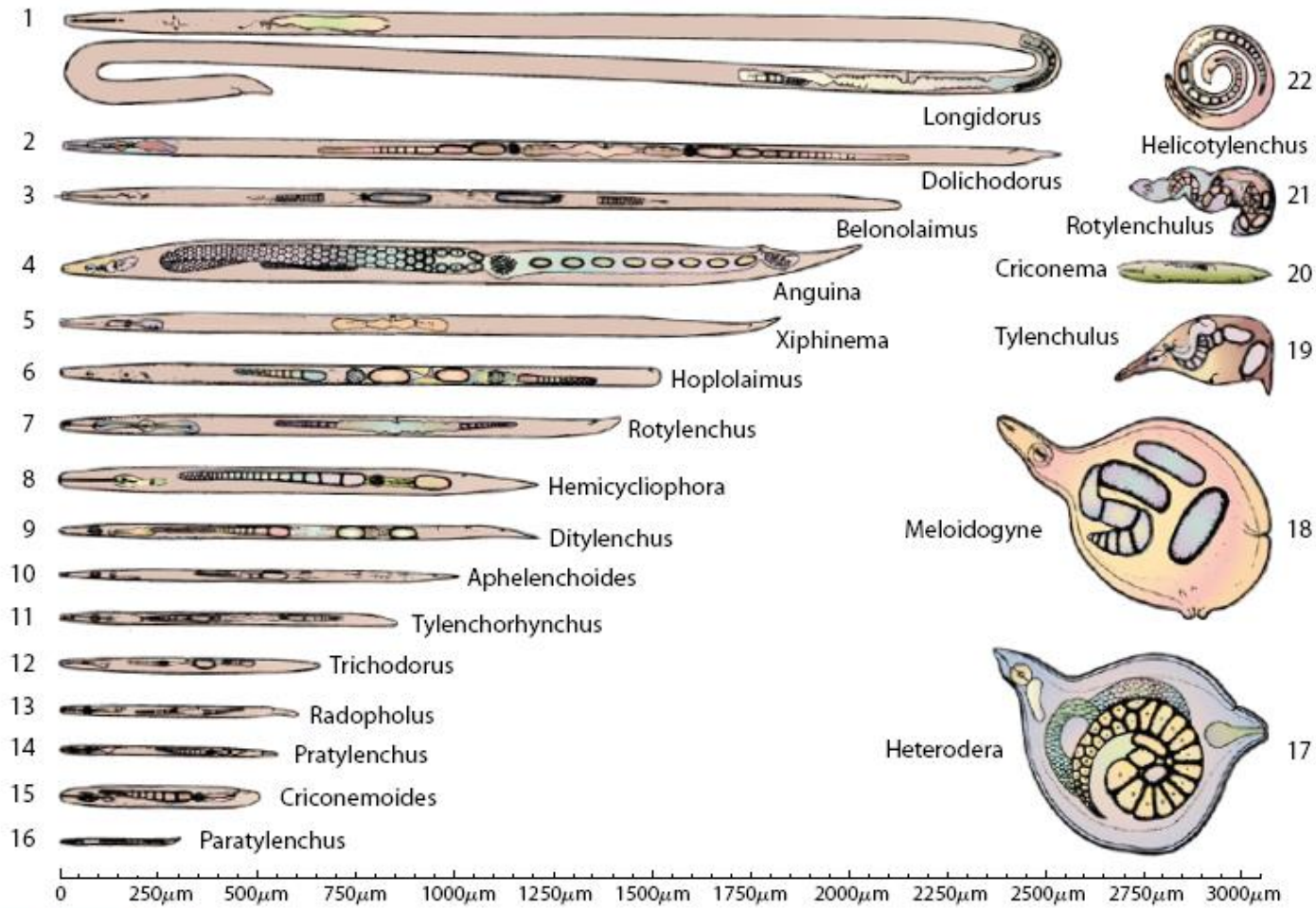


FIGURE 15-3 Morphology and related sizes of some of the most important plant parasitic nematodes.

(Agrios, 2005)

Characteristics of Plant Pathologenic Nematodes

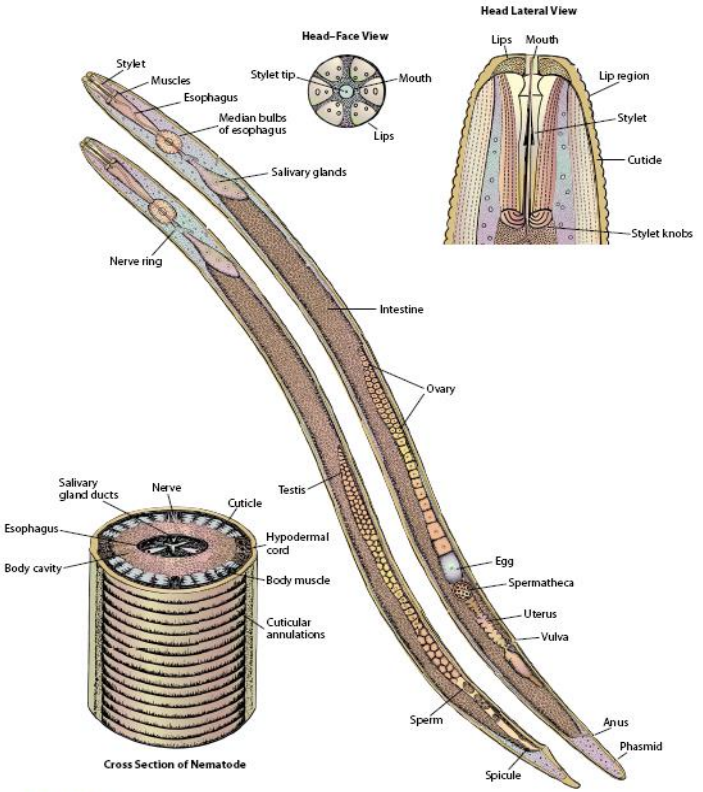
Anatomy:

-Nematodes body: more or less transparent

- Body covered by colorless cuticle

-Cuticle usually marked by striations or other markings

- Cuticle molts when a nematode goes through the successive juvenile stages



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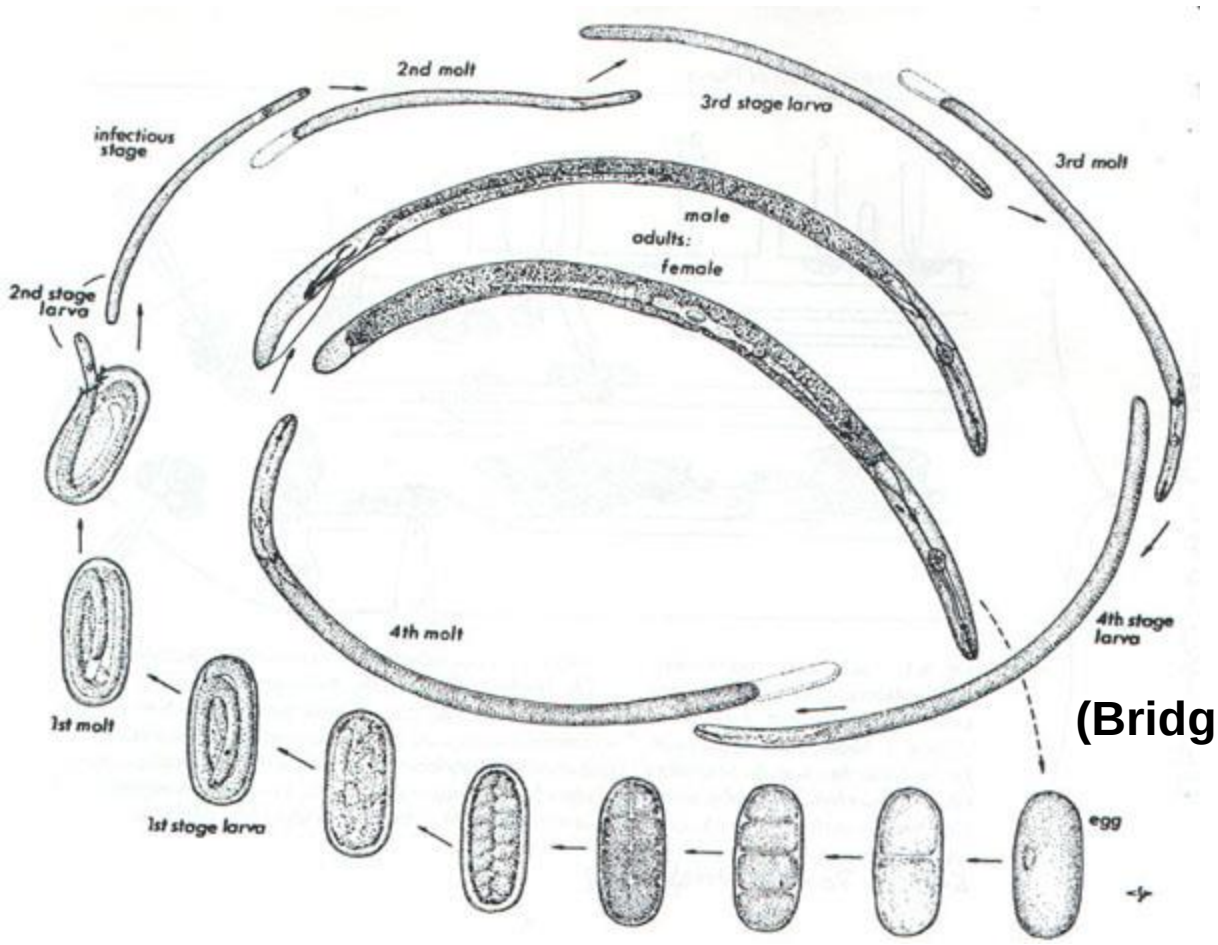
(Agrios, 2005)



(Bridge *et al*., 2005)

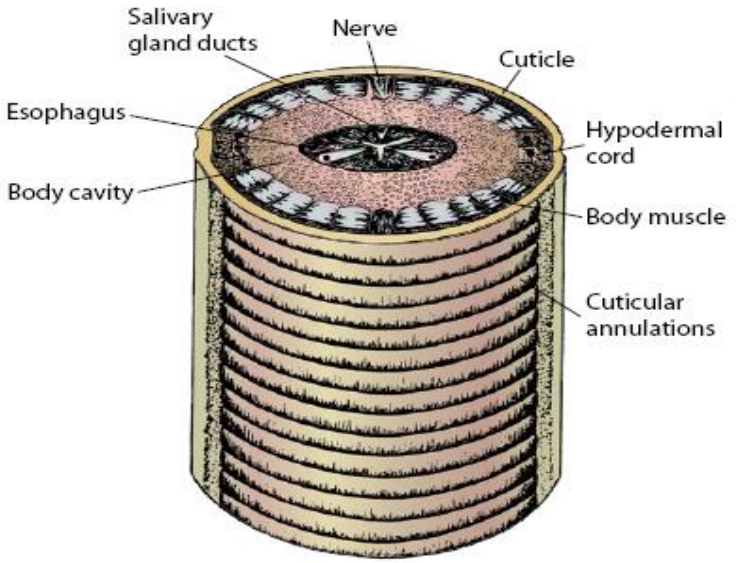
Cuticle molts when a nematode goes through the successive juvenile stages

Characteristics of Plant Pathologenic Nematodes

Anatomy:

- Cuticle produced by hypodermis (section consisting of living cells, extending into the body cavity as four chords, and separating four bands of longitudinal muscles)

- The muscles help nematode move



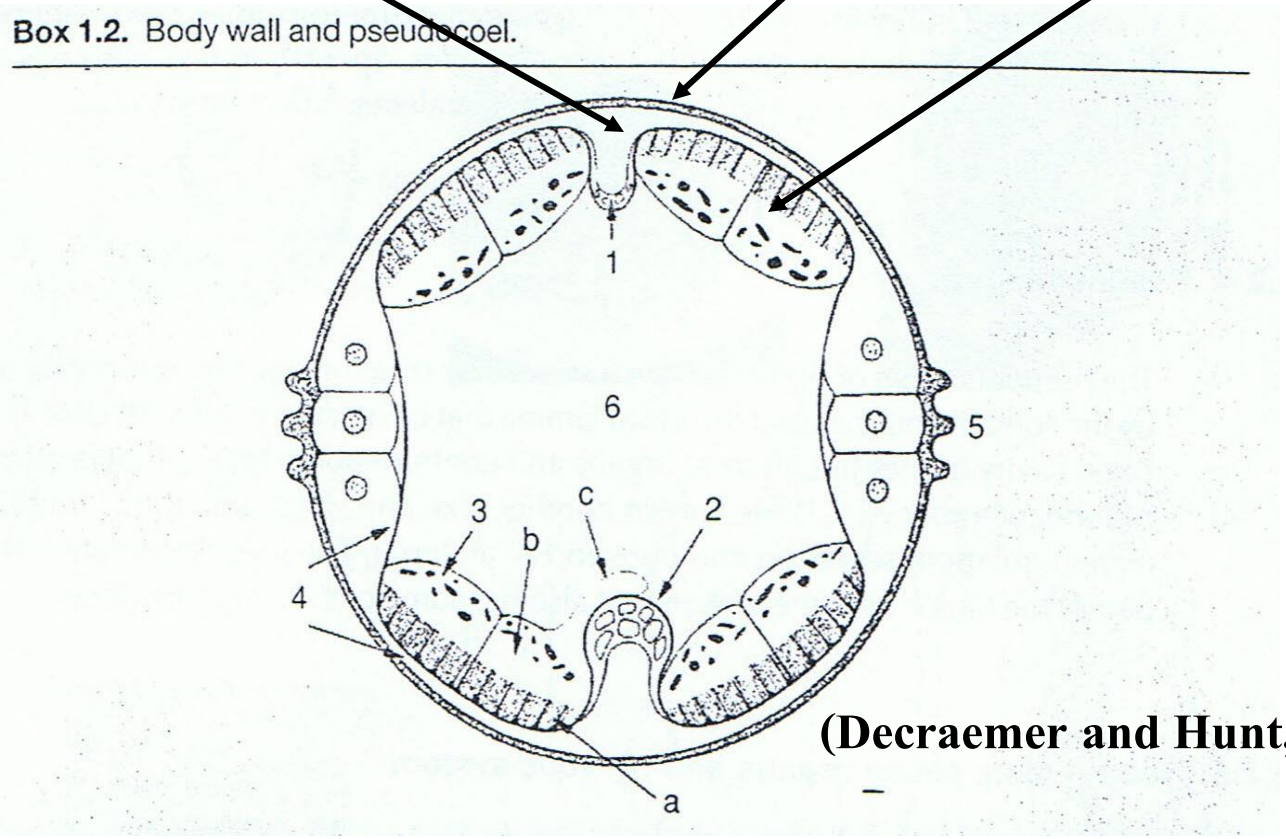
Cross Section of Nematode

(Agrios, 2005)

Hypodermis

Cuticle

Muscles



(Decraemer and Hunt, 2006)

Hypodermis cell = one cell or more than one cell

Hypodermis – divided into 4 parts (dorsal, ventral, two lateral chords)

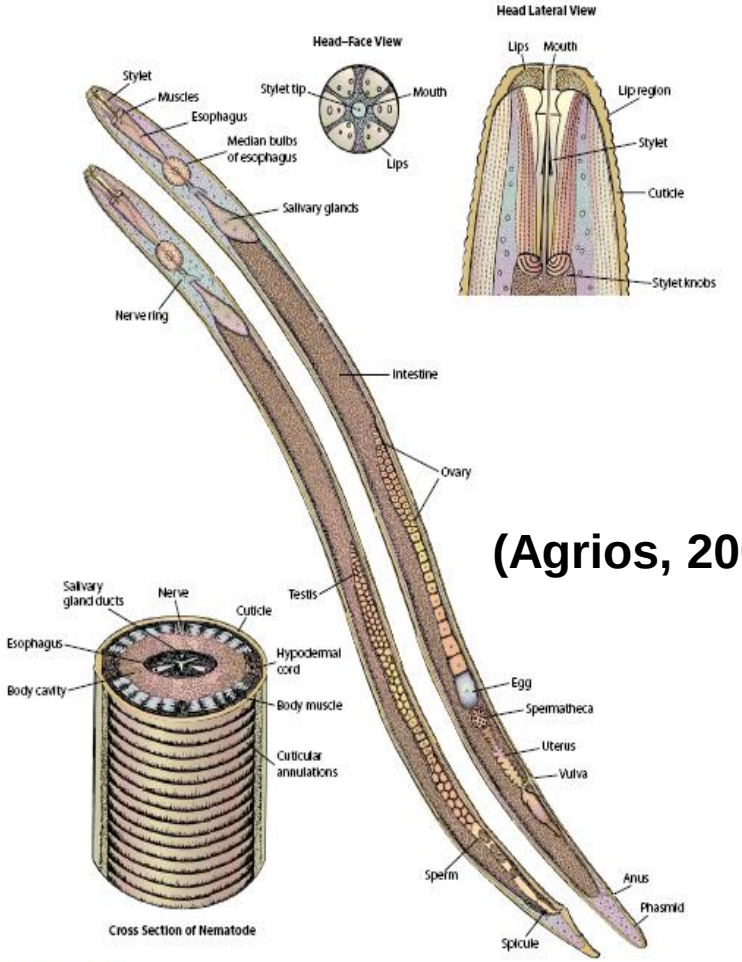
Characteristics of Plant Pathologenic Nematodes

Anatomy:

- Nematode body cavity: fluid through which circulation and respiration take place

- Digestive system – hollow tube extending from mouth through esophagus, intestine, rectum, and anus.

- Lips, usually six in number, surround the mouth



(Agrios, 2005)

FIGURE 15-2 Morphology and main characteristics of typical male and female plant parasitic nematodes.

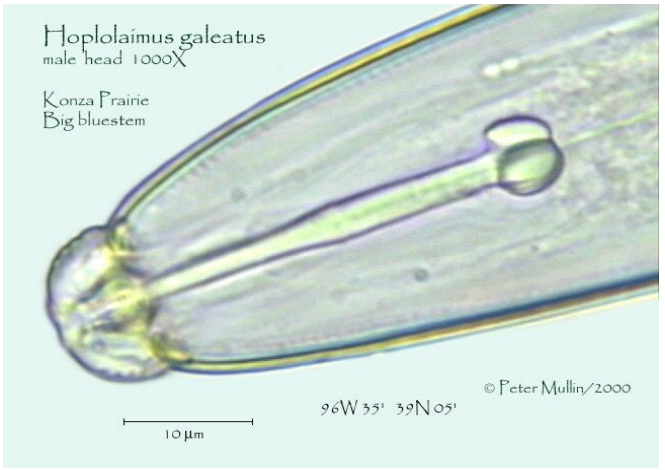
Characteristics of Plant Pathologenic Nematodes

Anatomy:

- Most plant parasitic nematodes have a hollow stylet or spear

- Few have a solid modified spear

- Spears used for puncturing holes in plant cells through which to withdraw nutrients from the cells



(Muller, 2000)

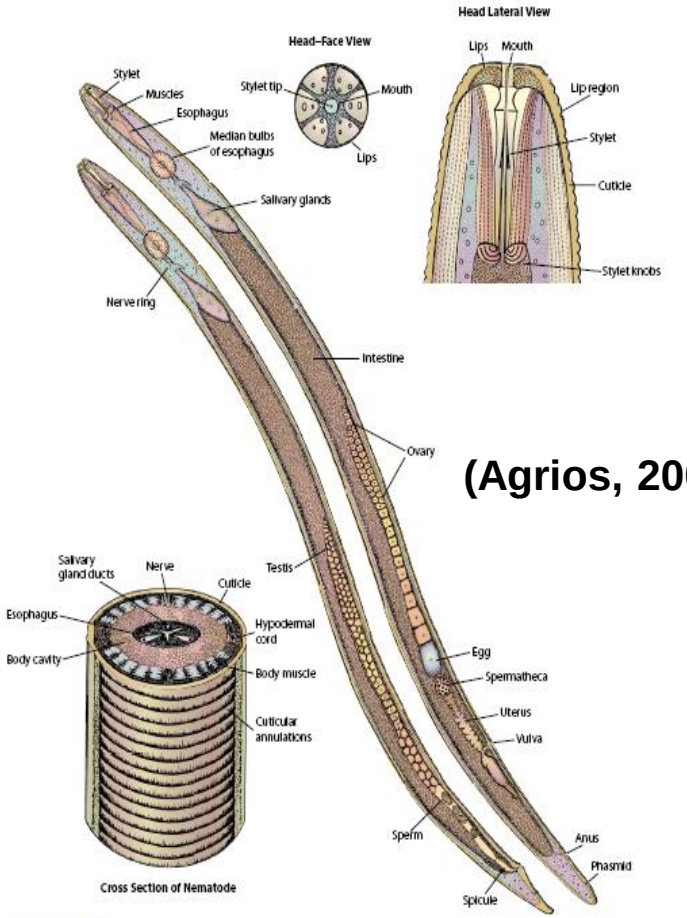
Characteristics of Plant Pathologenic Nematodes

Anatomy:

- Reproductive system: well developed

- Females have one or two ovaries, followed by an oviduct and uterus terminating in a vulva

- Males have a testis, seminal vesicle and a terminus (in a common opening with the intestine)



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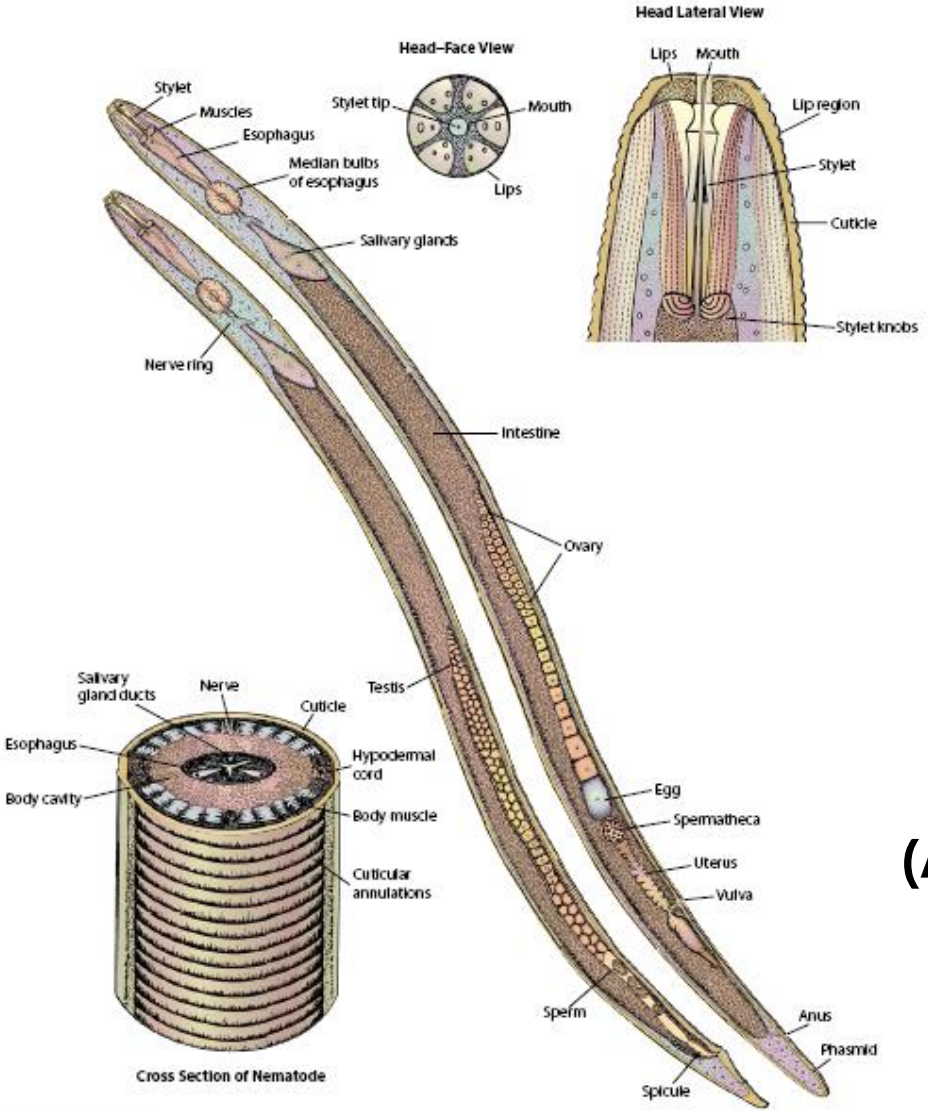


FIGURE 15-2 Morphology and main characteristics of typical male and female plant parasitic nematodes.

(Agrios, 2005)

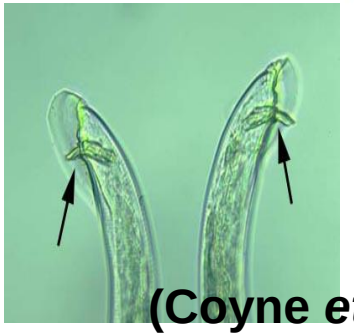
Characteristics of Plant Pathologenic Nematodes

Anatomy:

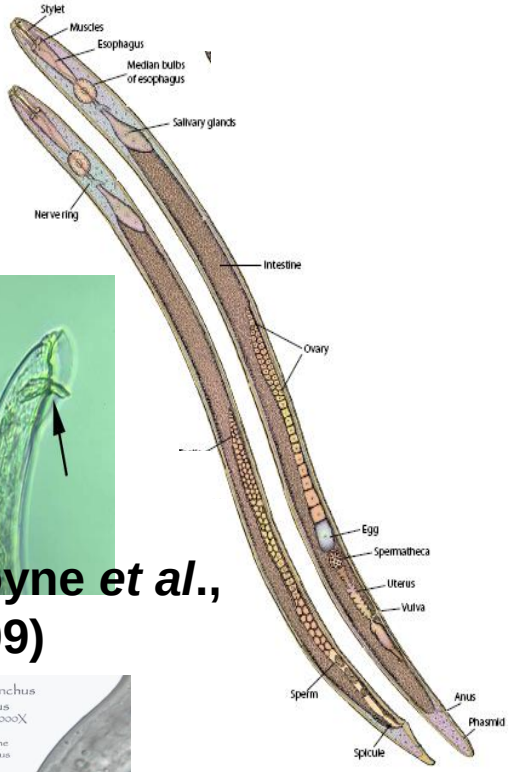
-Males have a pair of protrusible, copulatory spicules

-Reproduction of plant parasitic nematodes is through eggs either sexually or non sexually (parthenogenetically)

- Many nematode species lack males



(Coyne *et al*., 2009)



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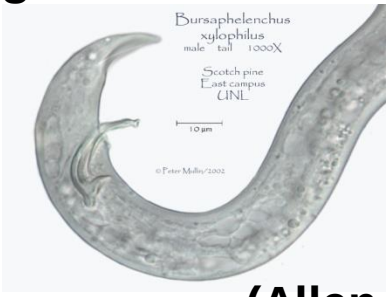


(Allen, 1975)

Characteristics of Plant Pathologenic Nematodes

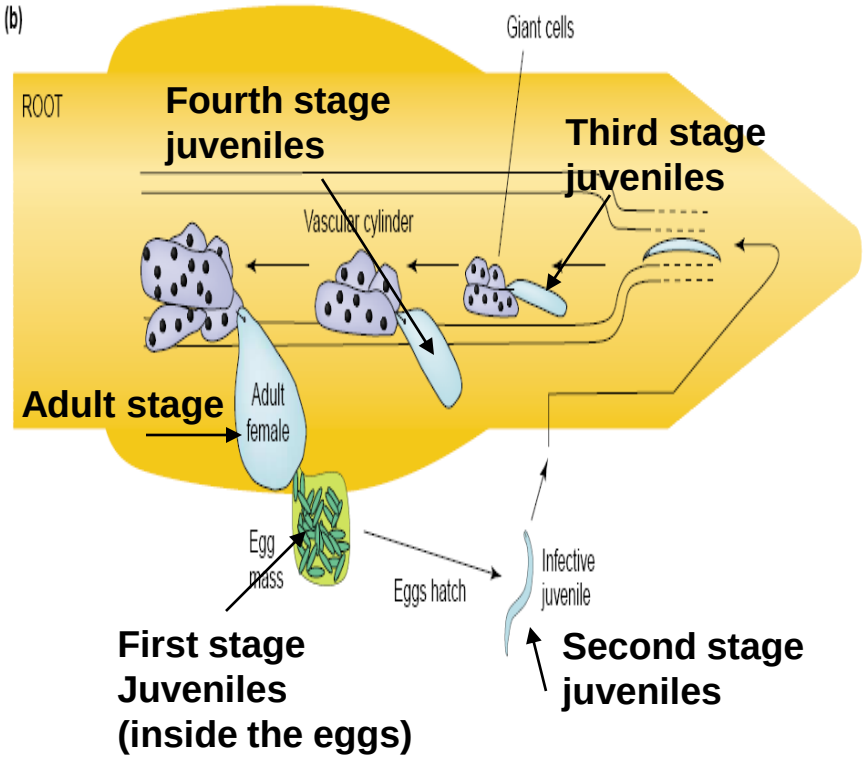
Life cycles:

- Quite similar

- Eggs hatch into juveniles (usually with their structures and appearances similar to the adults)

-Juveniles grow in size, each stage terminated by a molt

- All nematodes have four juvenile stages



(Williamson and Gleason, 2003)

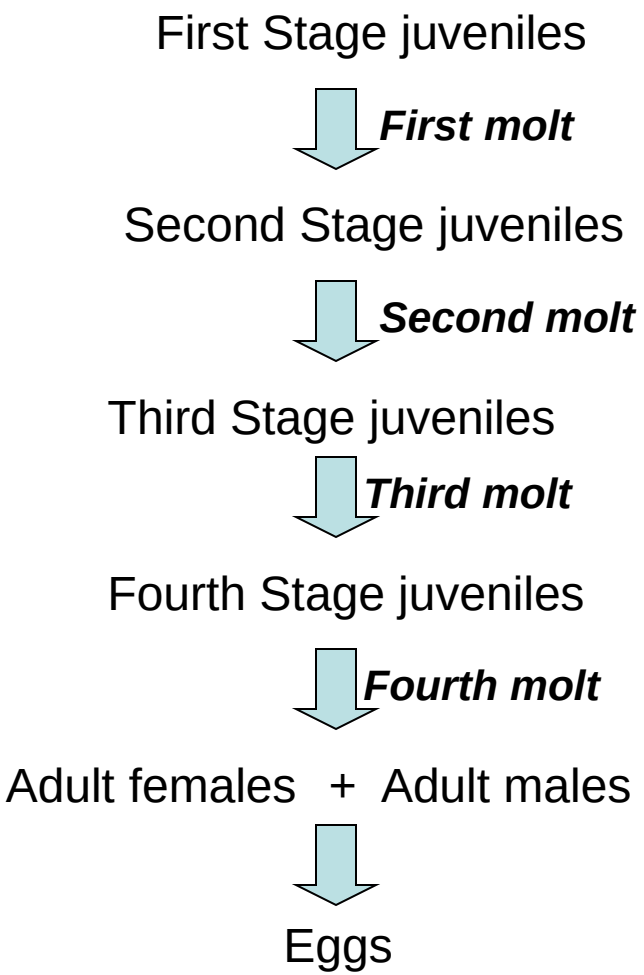
Characteristics of Plant Pathologenic Nematodes

Life cycles:

- **After the final molt, the nematodes differentiate into males and females**

- **Females produce fertile eggs, either after mating with males or in the absence of males, parthenogenetically**

- **A life cycle (egg to egg) – usually 2-4 weeks under optimum environment (temperature)**



Characteristics of Plant Pathologenic Nematodes

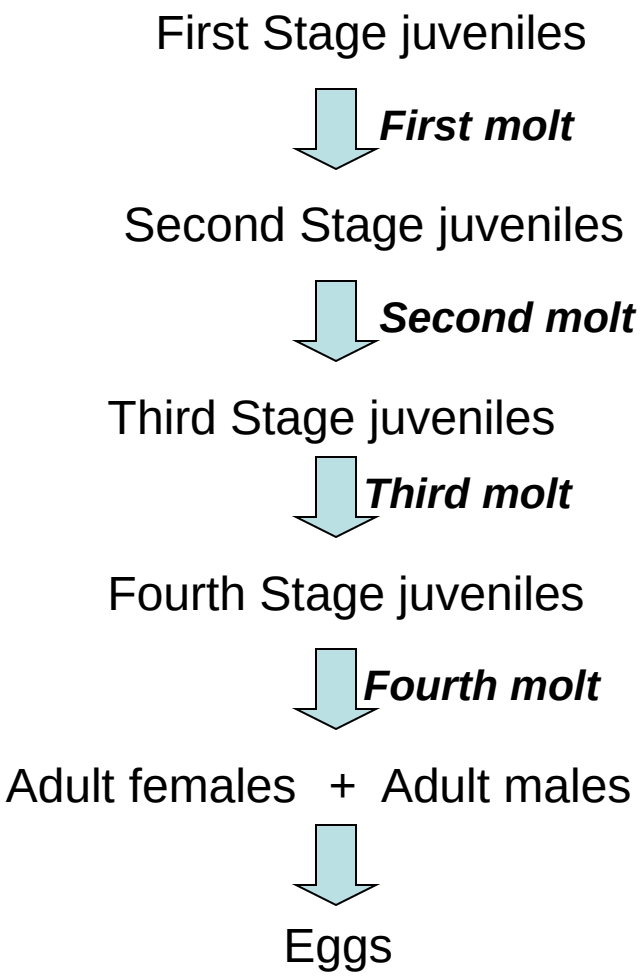
Life cycles:

- Life cycle takes longer in cooler temperatures

- Energy stored in the eggs and in the first and second stage juveniles are important for nematode survival and infection

- In the absence of plants, juveniles may die in a few months

-However, some nematodes may enter quiescent stages (drying up) or eggs may remain dormant



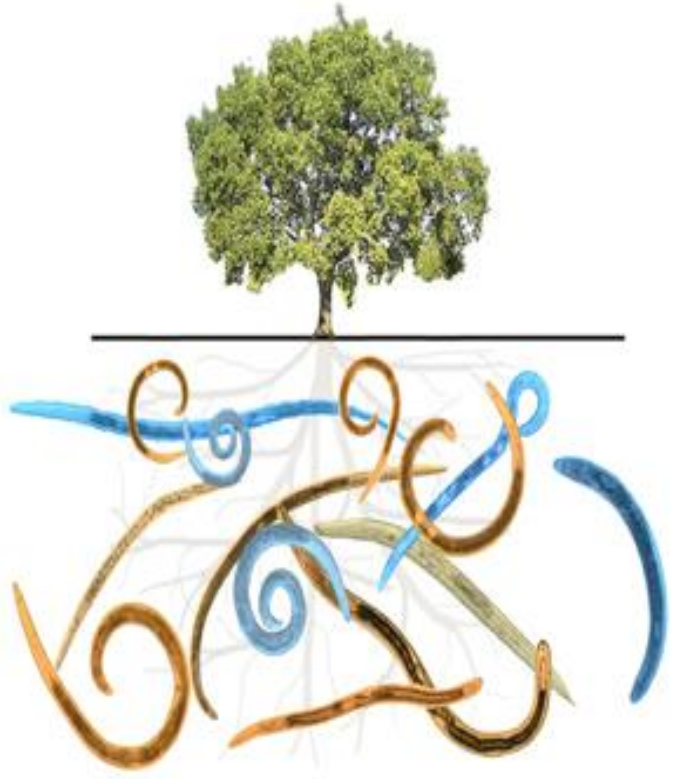
Characteristics of Plant Pathogenic Nematodes

Ecology and spread:

-**Soil temperature, moisture, and aeration affect nematode survival and movement in soil**

- Nematode – great abundance in the top 15-30 cm of soil

- Nematode distribution in cultivated soil: Irregular and is greatest in or around plant root zones



(Sikora *et al*., 2005)

Characteristics of Plant Pathologenic Nematodes

Ecology and spread:

- However, nematodes can sometimes be found at considerable depths (150 cm or more)

- Nematodes in greater concentrations in the root zones due to

  - Availability of Food Supply
  - Attraction of nematodes by substances released by plant roots

Characteristics of Plant Pathologenic Nematodes

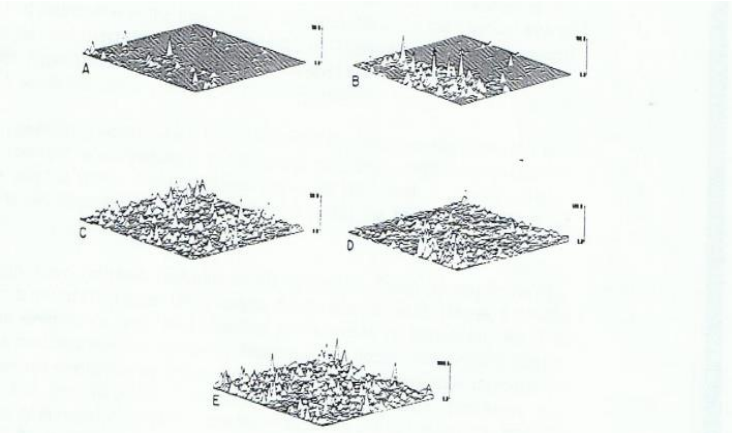
Ecology and spread:

-After hatching, nematode juveniles spread through the soil by their own power

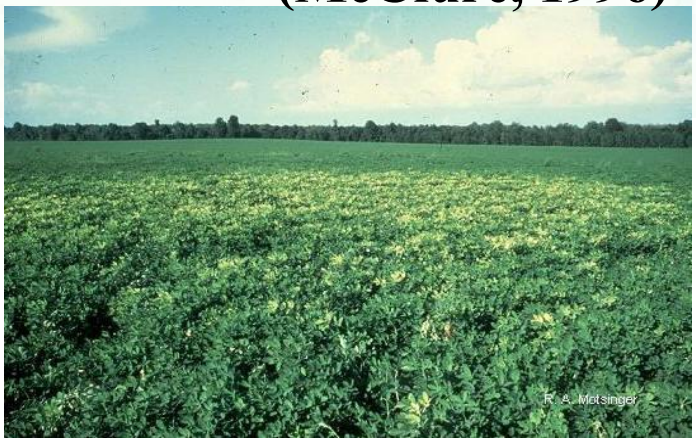
- Nematodes can travel a few meters per season by their own power

- Nematodes move faster in the soil pores lined with a thin film of water (a few micrometers thick)

- Nematode movement is low in waterlogged soil



(McClure, 1996)



Patches of yellowing "Hot spot" in peanut field infested with *Meloidogyne hapla*

Characteristics of Plant Pathologenic Nematodes

Ecology and spread:

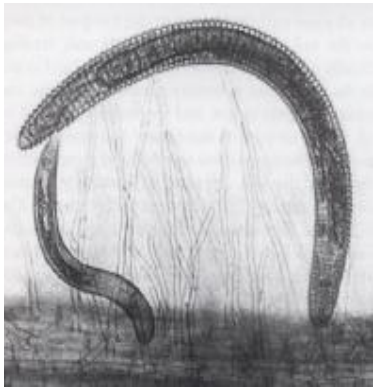
- Nematodes spread faster by farm equipments, irrigation, flood or drainage water, animal feet, birds, dust storms etc.

- Nematode spreads in a long distance by farm produce and nursery plants.

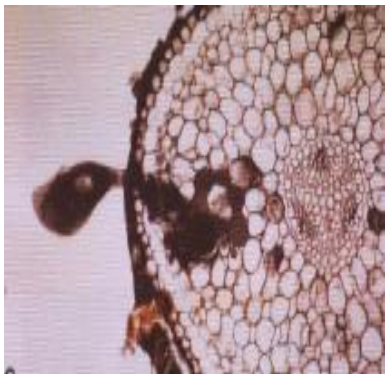
- Nematodes which attack above-ground plant portions can be splashed to other plants by falling raining, overhead watering

Nematode Classification

***Ectoparasites**

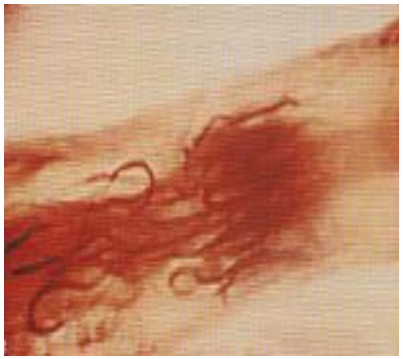


Migratory Ectoparasites (Sikora *et al*., 2005)

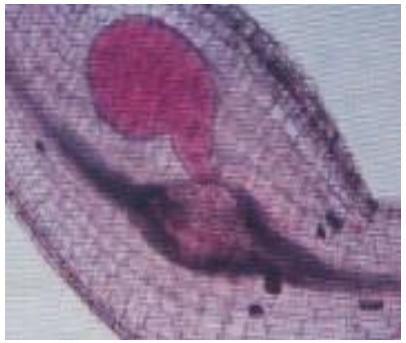


Sedentary Ectoparasites (Sikora *et al*., 2005)

***Endoparasites**



Migratory Endoparasites (Sikora *et al*., 2005)



Sedentary Endoparasites: (Sikora *et al*., 2005)

Some nematodes – Ectoparasites during part of their lives
Endoparasites during parts of their lives

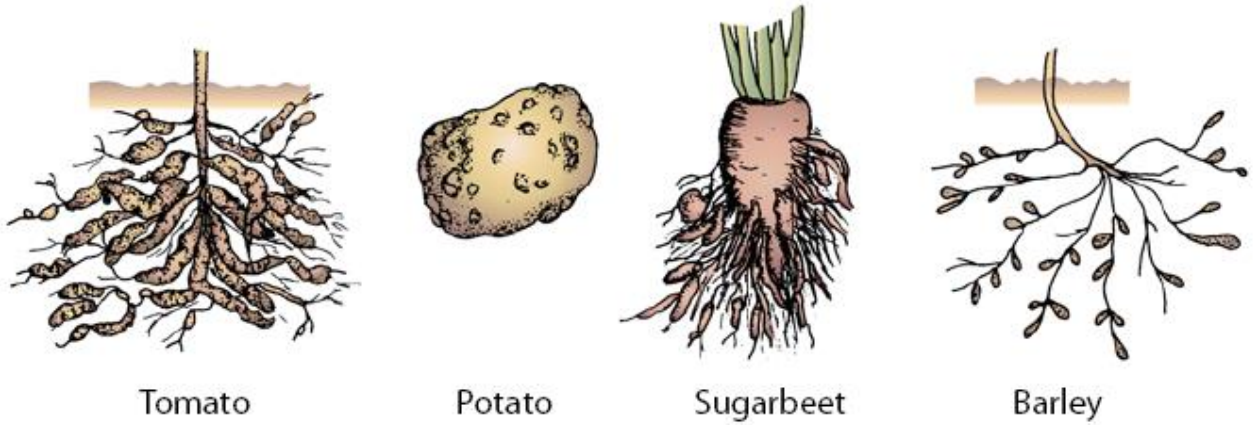
Symptoms Caused by Nematodes attacking plant roots

- Symptoms

  - On roots

  - On the aboveground parts of plants

Root Symptoms

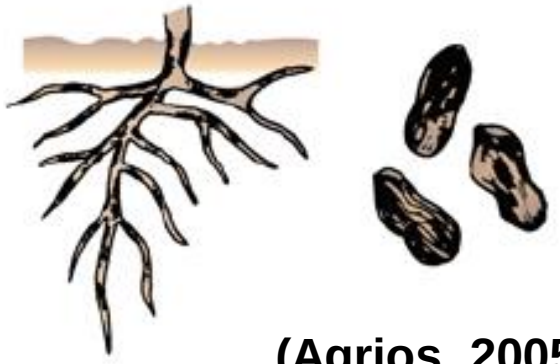


Root Knot (*Meloidogyne*)

(Agrios, 2005)

Root knots or galls

Root Symptoms



(Agrios, 2005)

(Agrios, 2005)

Root Lesion

Stem and Bulb Nematode (*Ditylenchus*)

(Agrios, 2005)

rotting

(especially when nematode infection is accompanied by plant pathogenic, or saprophytic bacteria and fungi)

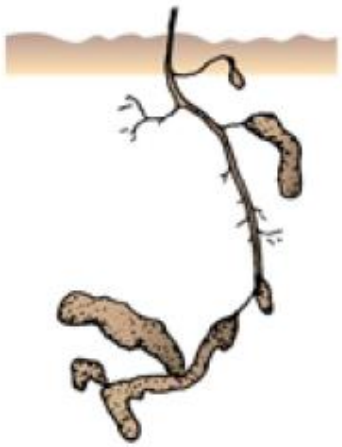
Corn

Stubby Root
(*Paratrichodorus*)

(Agrios, 2005)

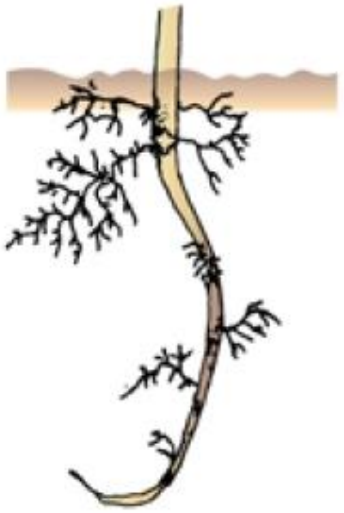
Injured root tips

Raspberry



Rose

Dagger Nematode
(*Xiphinema*)

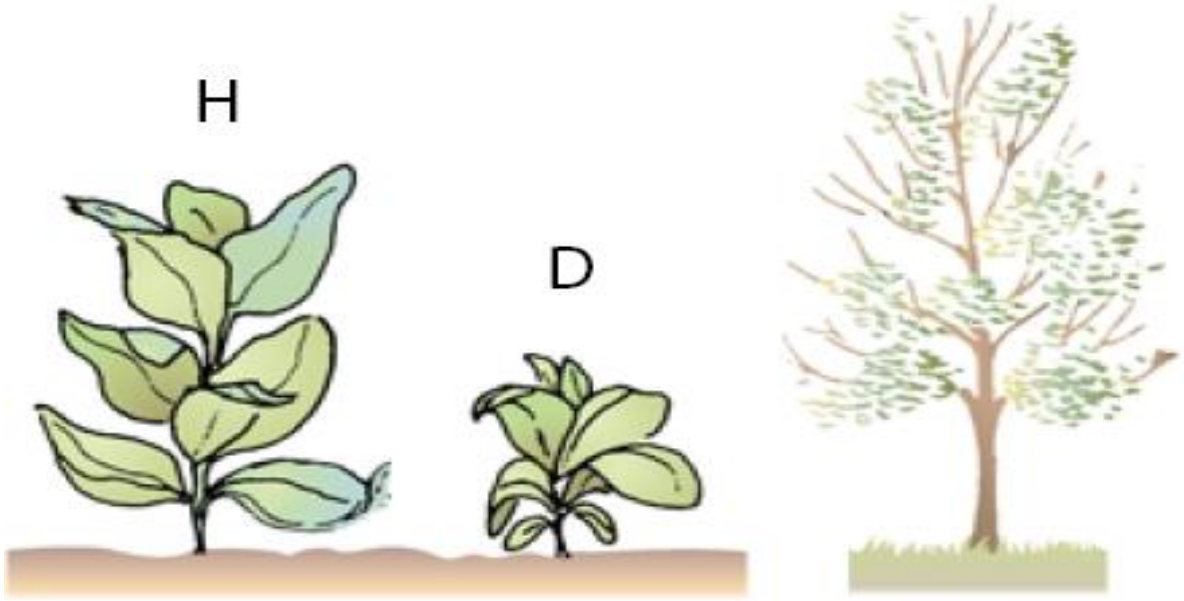


Bean

Sting Nematode
(*Belonolaeimus*)

(Agrios, 2005)

Excessive root branching



(Agrios, 2005)

Aboveground symptoms of root infection by nematodes

Symptoms caused by nematodes invading the aboveground portions of plants

- **Galls**
- **Necrotic lesions and rots**
- **Twisting or distortion of leaves and stems**
- **Abnormal development of floral parts**
- **Seed galls (in case of cereals or grasses)**

(Agrios, 2005)

Wheat Seed galls

Seed-Gall Nematode (*Anguina*)

Chrysanthemum Foliar Nematode
(*Aphelenchoides*)

(Agrios, 2005)

Necrotic lesions

(Agrios, 2005)

Interrelationships between nematodes and other plant pathogens

- **Nematodes can assist in developing more disease severity by co-operating with other soil microorganisms**

- **Several nematode –fungus disease complexes have been known**

Interrelationships between nematodes and other plant pathogens

- **Disease incidence and severity of *Fusarium* wilt of several plants increase when the plants are also infected with root-knot, lesion, sting, reniform, burrowing or stunt nematodes**

- **Other cases: *Verticillium* wilt, *Pythium* dampling off, *Rhizoctonia* and *Phytophthora* root rots, and etc.**

Interrelationships between nematodes and other plant pathogens

- **Potato early dying symptom: *Verticillium dahliae* alone may cause wilt and die**
- **If lesion nematode, *Pratylenchus penetrans* (even small population) are present, the disease is activated and causes early wilt and death**
- **Plant varieties ordinarily resistant to fungi apparently become infected (susceptible!!!) after previous infection by nematodes**

Interrelationships between nematodes and other plant pathogens

- **For nematode-bacteria disease interaction (complexes)**

  Root-knot nematodes, *Meloidogyne* spp. and *Ralstonia solanacaerum*

  "Bacterial wilt of tobacco"

Interrelationships between nematodes and other plant pathogens

- **Nematode-bacteria disease interaction (complexes)**

Root-knot nematodes, *Meloidogyne* spp. and *Clavibacter michiganense* subsp. *insidiosum*

"Bacterial wilt of alfalfa"

Interrelationships between nematodes and other plant pathogens

- **Nematode-bacteria disease interaction (complexes)**

  Root-knot nematodes, *Meloidogyne* spp. and *Pseudomonas marginata*

  “Bacterial scab of gladiolus”

Interrelationships between nematodes and other plant pathogens

- **Nematode-bacteria disease interaction (complexes)**

In most cases, the mechanism is

“Nematodes provide bacteria with an infection court and assist bacterial infection by wounding the host”

Interrelationships between nematodes and other plant pathogens

- **Nematode-bacteria disease interaction (complexes)**

  In case of the ring nematode, *Criconemella xenoplax,* and the bacterium *Pseudomonas syringae* pv. *syringae* in plum trees

The mechanism is

"The ring nematodes change the physiology of the trees and result in more extensive cankers"

Interrelationships between nematodes and other plant pathogens

- **Nematode-bacteria interaction (complex!!!)**

  Seed-gall nematode, *Anguina*, and the bacterium, *Clavibacter toxicus,*

  (Nematode works as the vector of the bacteria and causes distortion and prevention of normal formation of grass seed heads)

  ***Clavibacter toxicus* also produce corynetoxins**

  (causing lethal neurological convulsion in domestic animals)

Interrelationships between nematodes and other plant pathogens

- **Nematode-virus interaction (complex!!!)**

  ***Grapevine fanleaf virus**

  ***Tomato ringspot virus**

  ***Raspberry ringspot virus**

  ***Tobacco rattle virus**

  ***Pea early browning virus**

  Transmitted by the following nematodes

  ***Xiphinema**

  ***Longidorus**

  ***Paralongidorus**

  ***Trichodorus**

  ***Paratrichodorus**

Interrelationships between nematodes and other plant pathogens

- **Nematode-virus interaction (complex!!!)**

***Nematodes can be a potent virus vector after feeding on virus-infected plants for 1 hr to 4 days**

***Then the nematodes can carry viruses in their bodies for 2-4 months (some even longer!!!!)**

***All nematode stages: juveniles and adult can transmit viruses**

Root-knot Nematodes

-**Scientific Name: *Meloidogyne* spp.**

-**Occur throughout the world, especially hot or warm climate**

-**Attacking more than 2,000 plant species (almost all cultivated plants)**

-**The nematodes devitalize root tips and cause root swellings**

- Nutrients are therefore deprived

FIGURE 15-9 Galls and other symptoms caused by the root-knot nematode on tomato (A), carrots (B), potato (C), peanuts (D), yam (F), and a dogwood tree (G). (E) Healthy yams. [Photographs courtesy of (A, C, and D) D. W. Dickson, (B) D. Ormrod, W.C.P.D., (E and F) D. Coyne, IITA, Nigeria, and (G) E. L. Barnard.]

(Agrios, 2005)

Root-knot Nematodes

- **The nematode disfigures and reduce market value of crops**

- **Seedlings may die or sustain heavy losses**

Root-knot Nematodes

- **Male and female are easily distinguished morphologically**

-Male is worm like
(1.2-1.5 mm long by 0.030-0.036 mm in diameter)

-Female is pear-shaped
(0.4-1.3 mm long by 0.27-0.75 mm in diameter)

Root-knot Nematodes

- **Life cycle**

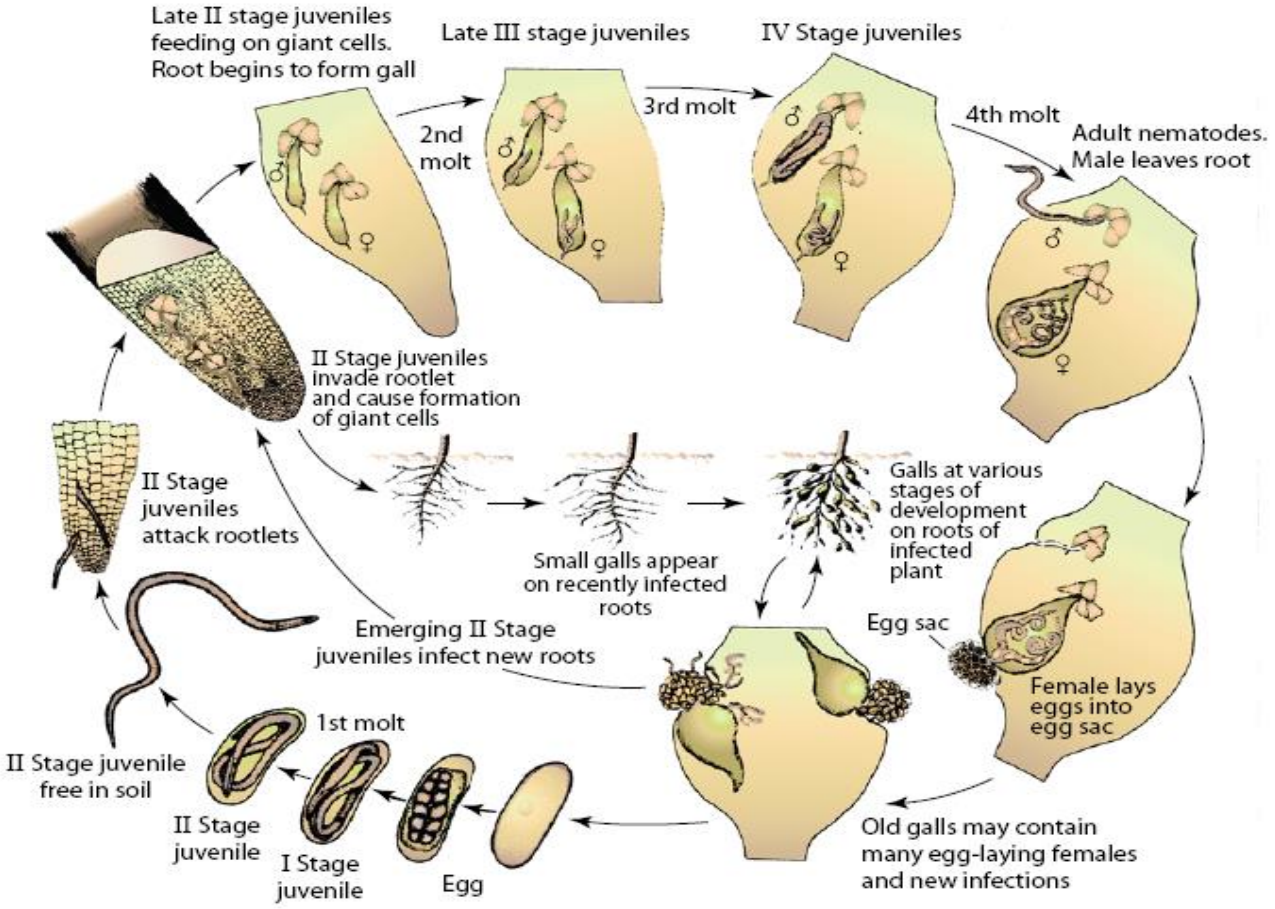


FIGURE 15-11 Disease cycle of root knot caused by nematodes of the genus *Meloidogyne*.

(Agrios, 2005)

Root-knot Nematodes

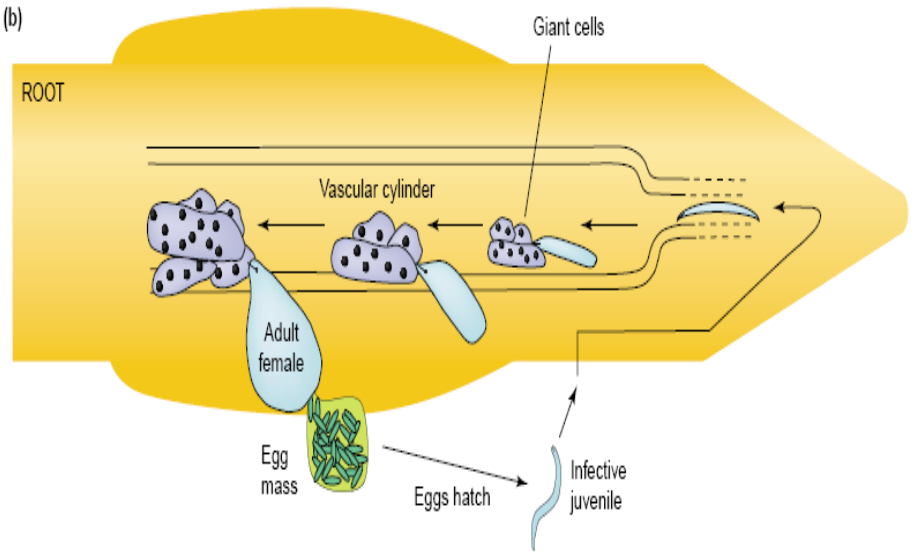
- Giant cells attract nutrients from surrounding cells

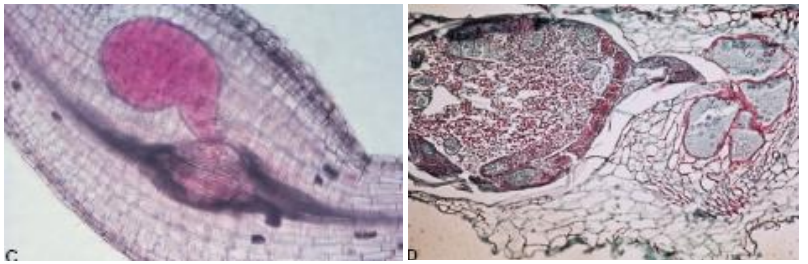
-Giant cells also serve as feeder cells for nematodes

-Root galls or swellings

due to 1) Excessive enlargement and division of all types of cells surrounding the giant cells

2) Enlargement of the nematodes





(Williamson and Gleason, 2003)

Root-knot Nematodes

- **Disease complex between root-knot nematodes and fungi increases disease severity**

-Galls – comprised of weakened tissues, hypertrophied, undifferentiated cells

Easy to be attacked by fungi!!!

***Fusarium*, *Rhizoctonia*, *Pythium* grow and reproduce much faster in the galls than in other areas of the roots**

Root-knot Nematodes

- **Control:**

***Greenhouse plants; Steam sterilization or soil fumigation**

***Crops in the field; Soil fumigation good for one season!!!**

***Resistant varieties**

***Cultural practices: crop rotation, fallow, soil solarization, etc.**

Root-knot Nematodes

- **Control:**

Biological control:** **The bacteria *Pasturia penetrans
The fungus *Trichoderma harzianum*
The fungus *Dactylella oviparasitica*
Mycorrhiza *Gigaspora* and *Glomus*

- Essential oil of some spices
- Some chemicals that can induce plant resistance

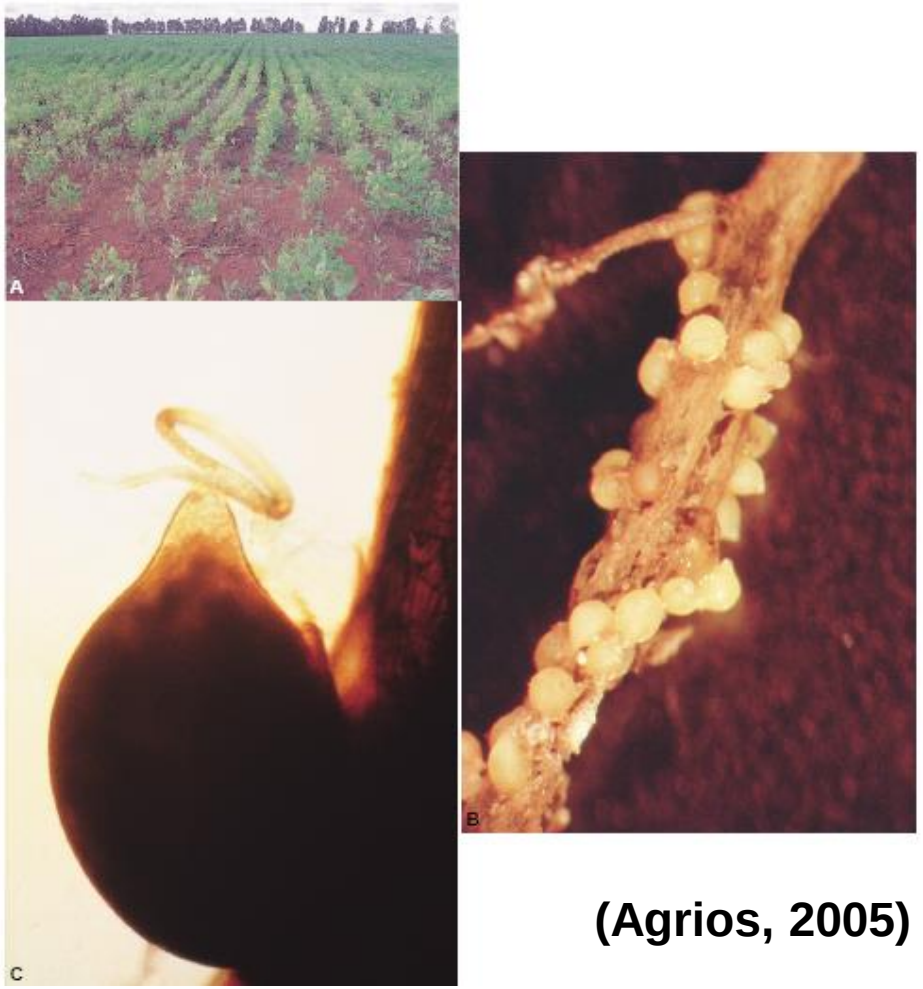
Amino-butyric acid, other amino acids

Cyst Nematodes: *Heterodera* and *Globodera*

- Causing diseases in the temperate region of the world

-Some cyst nematodes attack a few plant species and are present in a limited geographic areas

-Some attack a large number of plants and distribute world wide



(Agrios, 2005)

Cyst Nematodes:

Cyst Nematodes: *Heterodera* and *Globodera*

- ***Globodera rostochiensis*. (Golden Nematodes)**

- Important pest of potato (mostly), also found in tomato, eggplant.

-***Heterodera avenae*** **on cereal**

-***H. glycines*** **on soybean**

-***H. schachtii*** **on sugar beet, spinach, and crucifer**

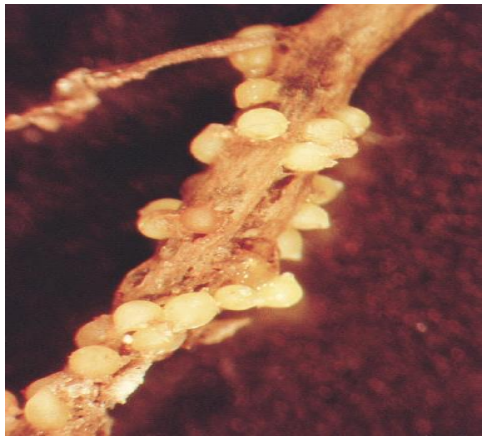
- ***H. tabacum*** **on tobacco**

-***H. trifolii*** **on clover**

Cyst Nematodes: *Heterodera* and *Globodera*

- Diagnostic feature of cyst nematodes

*Presence of cysts on the roots
*Proliferation of roots
*Production of shallow, bushy root system



(Agrios, 2005)

Soybean Cyst Nematodes: *Heterodera glycines*

- **Found in northeastern Asia, Japan, and Java, in most soybean producing states of USA, Columbia, Brazil**

-**Spread slowly to new areas**

-**Also found in other legumes, such as common bean, forage legumes**

- **Damage ranged between 30-75%**

Soybean Cyst Nematodes: *Heterodera glycines*

- **Symptoms:**

  - **Yellow leaves and fall off early**

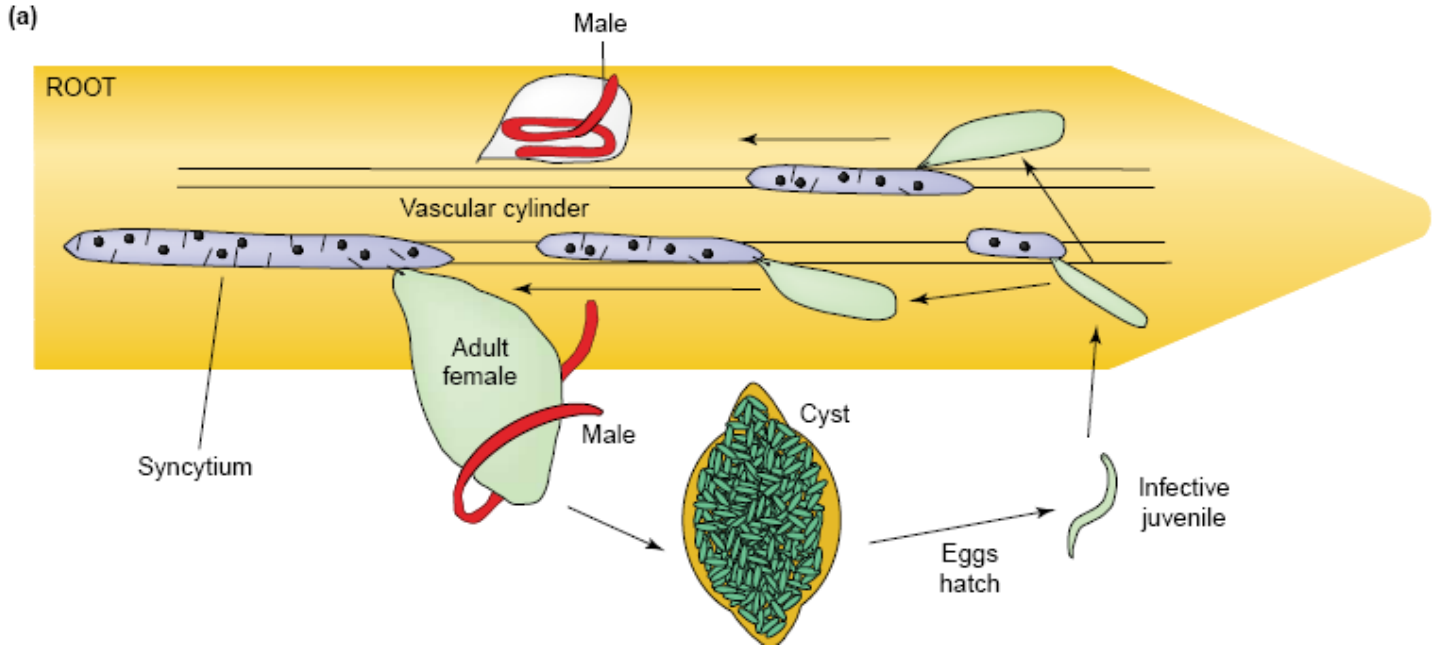
  - **Bearing a few flowers and small seeds**

  - **Chlorotic leaves and dwarfed plants**

  - **Fewer bacterial nodules**

  - **Presence of female nematodes, mature cysts attached on soybean roots**

Life cycle of cyst nematodes



(Williamson and Gleason, 2003)

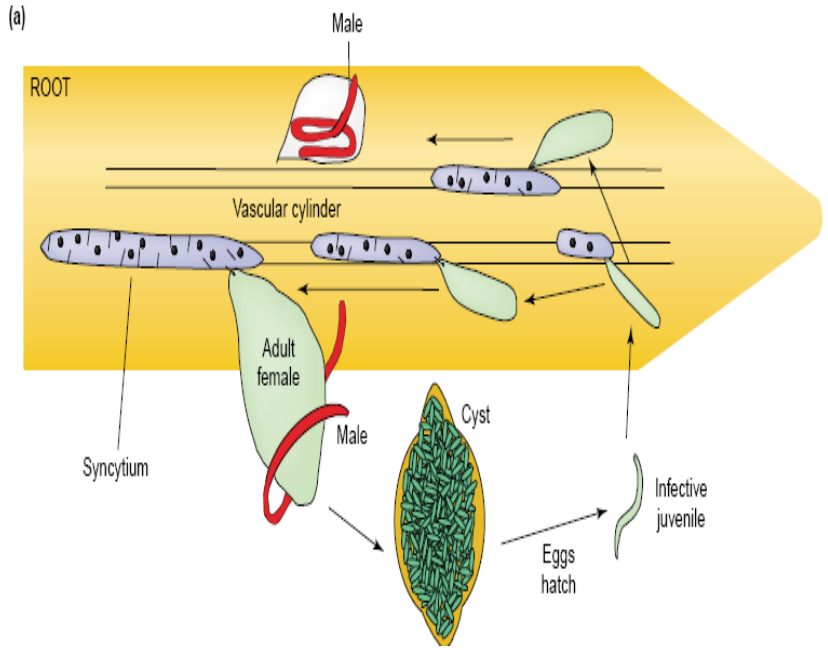
Soybean Cyst Nematodes: *Heterodera glycines*

- ***Heterodera glycines***

***Nematodes overwinter as eggs in brown cysts**

***When temperature is appropriate in the spring, juveniles hatch**

***Life cycle is generally similar to other cyst nematodes**



(Williamson and Gleason, 2003)

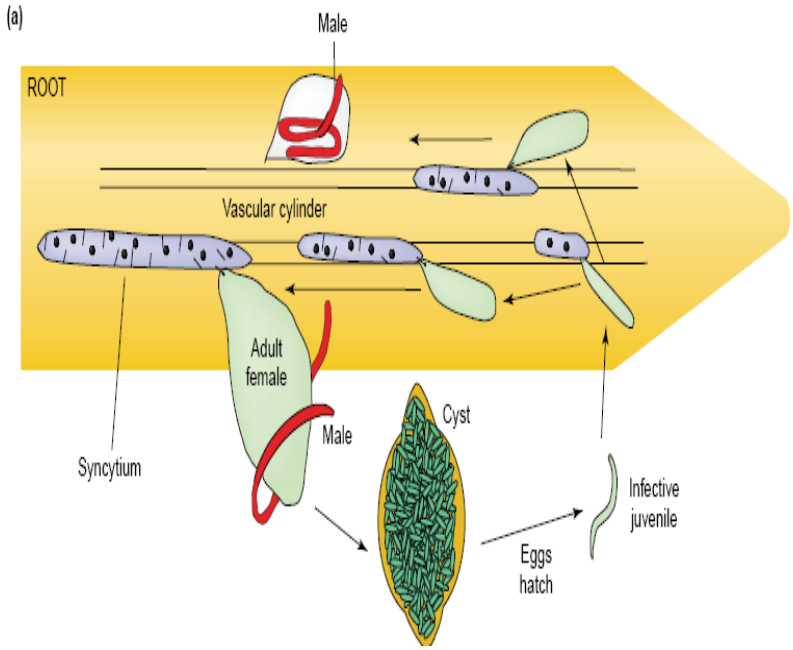
Soybean Cyst Nematodes: *Heterodera glycines*

- ***Heterodera glycines***

***Nematodes develop the feeding cells called "syncytia"**

***Syncytia inhibite secondary growth of phloem and xylem, reducing drastically conducive elements**

***Poor growth and yield, especially under stressed moisture conditions**



(Williamson and Gleason, 2003)

Soybean Cyst Nematodes: *Heterodera glycines*

- Control:

***Soil fumigation of the field**

***Soil treatment with nonfumigant nematicides**

***However, those treatments cannot completely the nematodes from the soil**

***Nematode population will build up later on**

Potato Cyst Nematodes
Globodera rostochiensis and *G. pallida*

- **Golden nematodes**
- **Attack potato, tomato, eggplant, other solanaceous crops**
- **Occur in many parts of the world and cause Severe losses**

Potato Cyst Nematodes
Globodera rostochiensis and *G. pallida*

- **Difficult to completely eradicate (eggs survive in cysts in soil over 20 years)**
- **Symptoms: potato grows poorly, small and yellowish green leaves, wilt and die**
- **Infected potato: fewer and smaller tubers**
- **Cysts on the roots are visible by eyes**

FIGURE 15-15 (A) Females (white) and cysts (brown) of the potato golden nematode. (B) White cysts feeding on potato roots. [Photographs courtesy of USDA.]

(Agrios, 2005)

Lesion Nematodes: *Pratylenchus*

- **Occurs in all parts of the world**

-**Wide host range**

-**Reducing or inhibit root development by forming local lesions on young roots**

-**In potato, synergism between *Pratylenchus* and *Verticillium dahliae* "potato early dying syndrome"**

Reduced yields and premature death

Lesion Nematodes: *Pratylenchus*

- **Symptoms:**

  ***Stunted, chlorotic (similar to mineral deficiencies or drought)**

  ***Roots show at first small, water-soaked lesions**

  ***Then turning brown to almost black**

FIGURE 15-17 Damage in fields of young corn plants (A) and cotton plants (B), on root of tobacco plant (C), and on peanut pods caused by the lesion nematode *Pratylenchus* sp. [Photographs courtesy of (A) G. Tylka, (C) University of Georgia, and (D) D. W. Dickson.]

(Agrios, 2005)

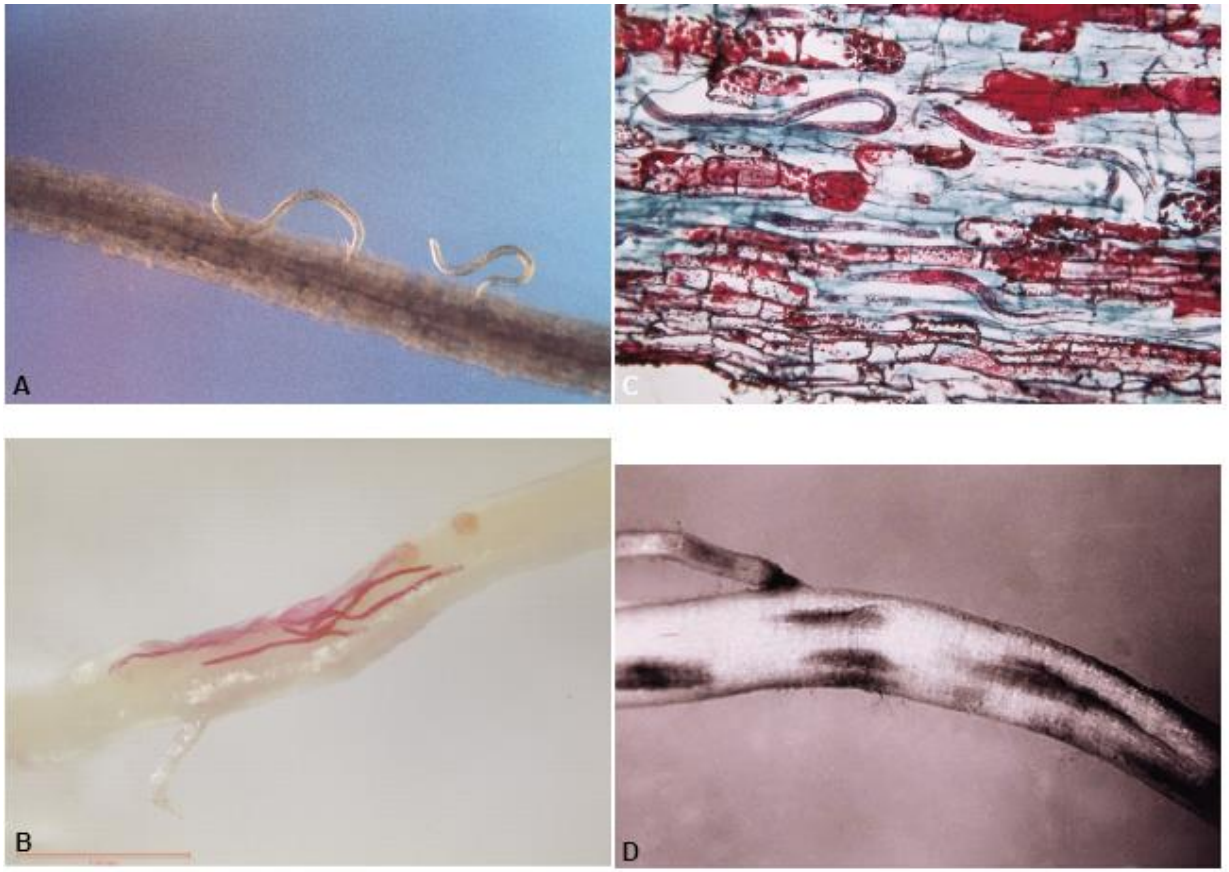


FIGURE 15-18 (A) Two *Pratylenchus* nematodes penetrating on corn root. (B) Nematodes within a tomato root iniciating a lesion. (C) Numerous *Pratylenchus* nematodes within a short segment of a root killing plant cells and leading to the formation of a lesion. (D) External appearance of lesions on young root infected with Pratylenchus nematodes. [Photographs courtesy of (A) D. Chitwood, USDA, (B) W. T. Crow and A. Hixon, (C) R. A. Rohde. (D) J. W. Townsend]

(Agrios, 2005)

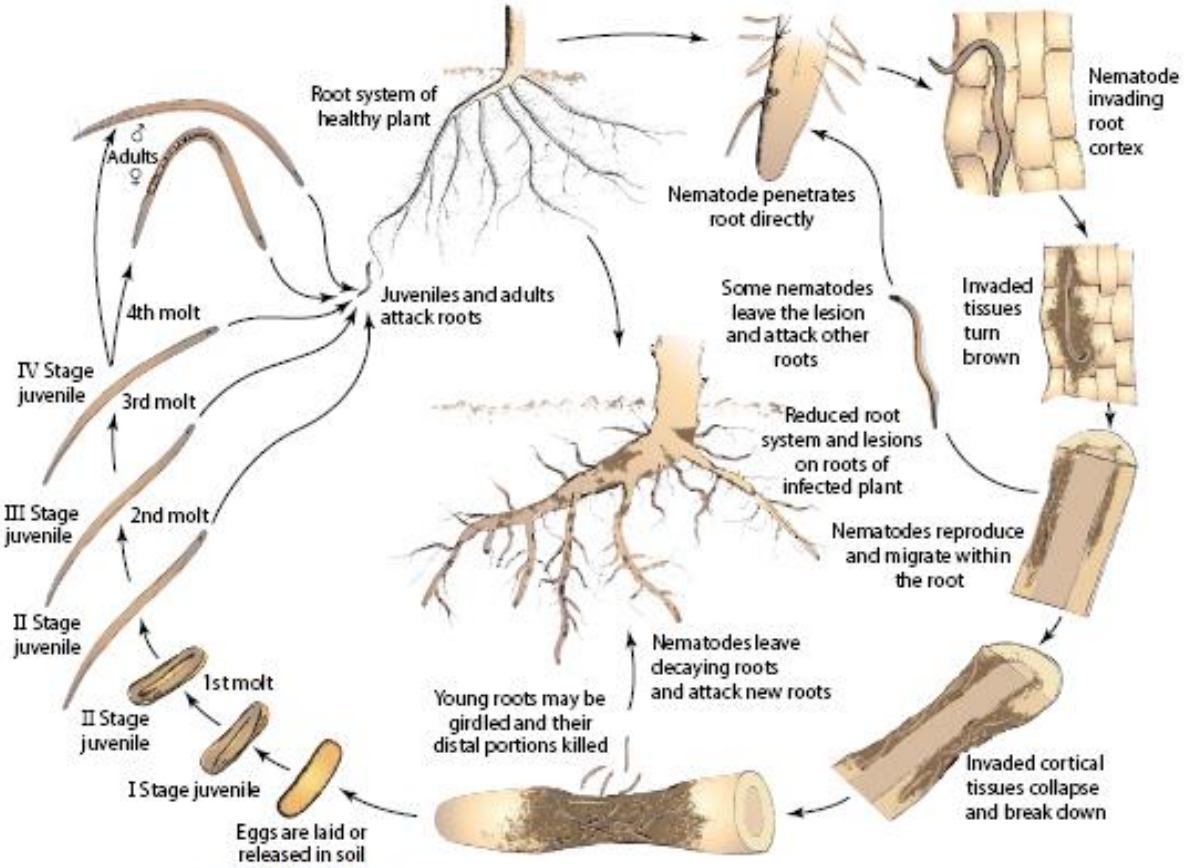


FIGURE 15-19 Disease cycle of the lesion nematode *Pratylenchus* sp.

(Agrios, 2005)

Lesion Nematodes: *Pratylenchus*

- **Controls:**

  *** Overall or row treatment of nematicides**

  *** Good control, but cannot completely eradicate nematodes**

  *** Summer fallow, exposing nematodes with sun light**

Burrowing Nematodes: *Radopholus*

- **Widely distributed in tropical and subtropical regions and in the greenhouse in Europe**

- ***Radopholus similis* - Most important in banana (Banana rot, blackhead toppling disease, or decline of banana)**

- ***R. citrophilus* – spreading decline in citrus**

Burrowing Nematodes: *Radopholus*

- **Symptoms:**

Similar to those by *Pratylenchus

Premature defoliation, small fruits and leaves, banana toppling

Radopholus similis

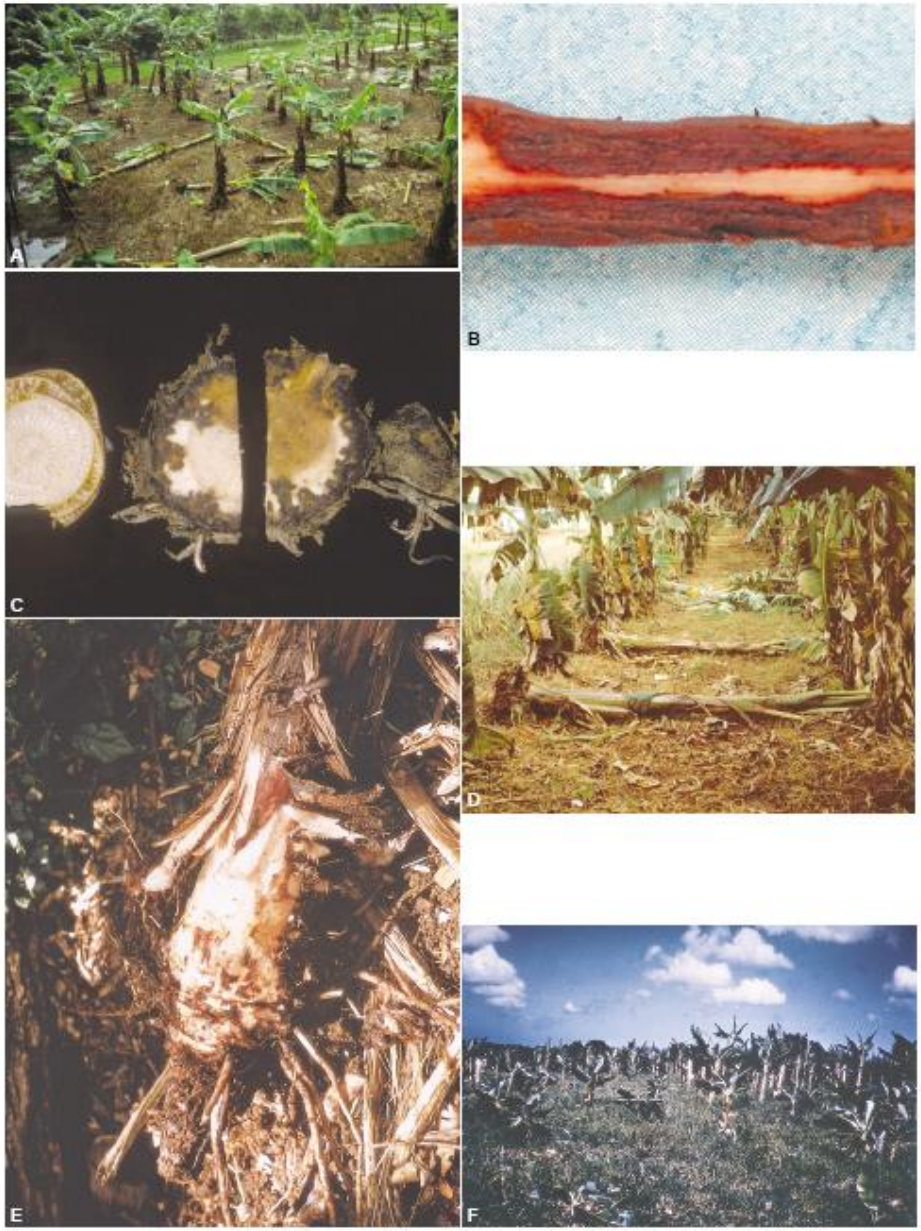


FIGURE 15-21 Symptoms of banana plants infected with the burrowing nematode *Radopholus similis*. (A and D) Most banana plants are stunted and several toppled over because roots are destroyed and provide poor anchoring. Root lesions (B) enlarge and increase destroying the root system (C) and part of the pseudostem (E). Decline has set in in this field as a result of heavy infestation with burrowing nematodes. [Photographs courtesy of (A and B) D. Coyne, IITA, Nigeria, (C and D) D. H. Thurston, and (E and F) University of Florida.]

(Agrios, 2005)

***R. citrophilus* –**
spreading decline in citrus

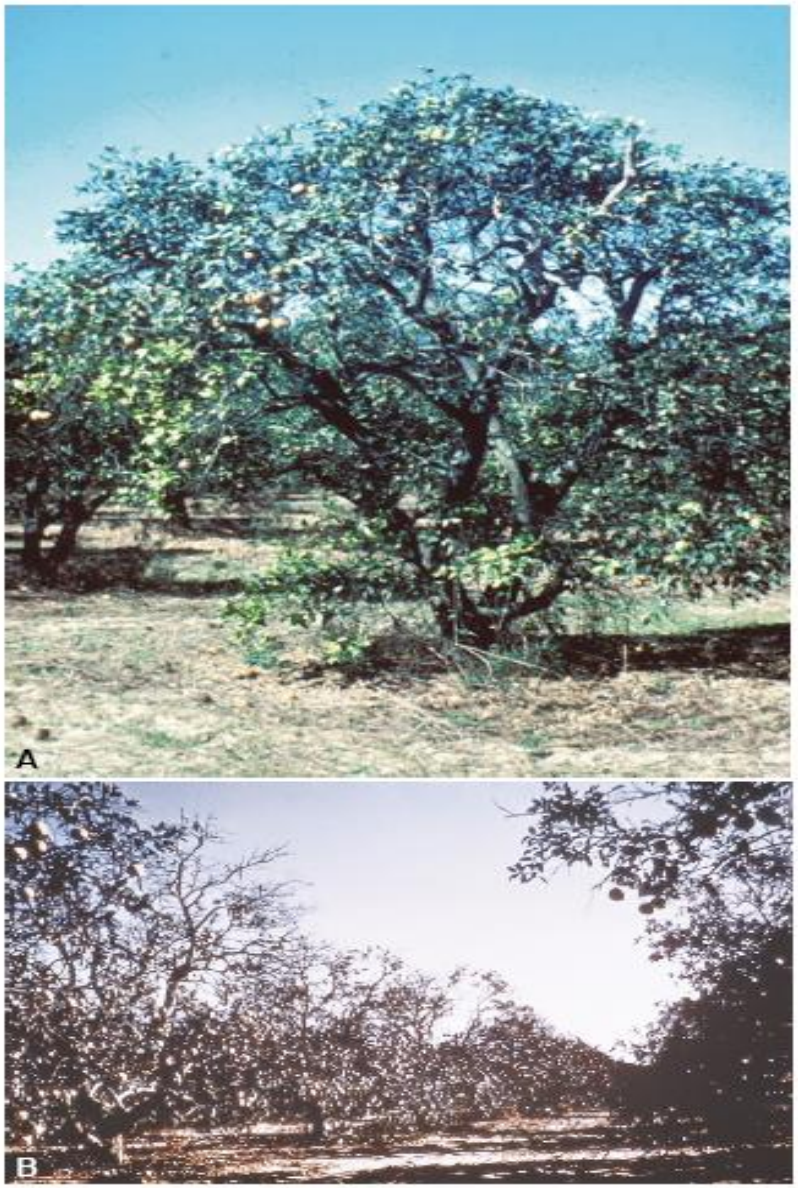
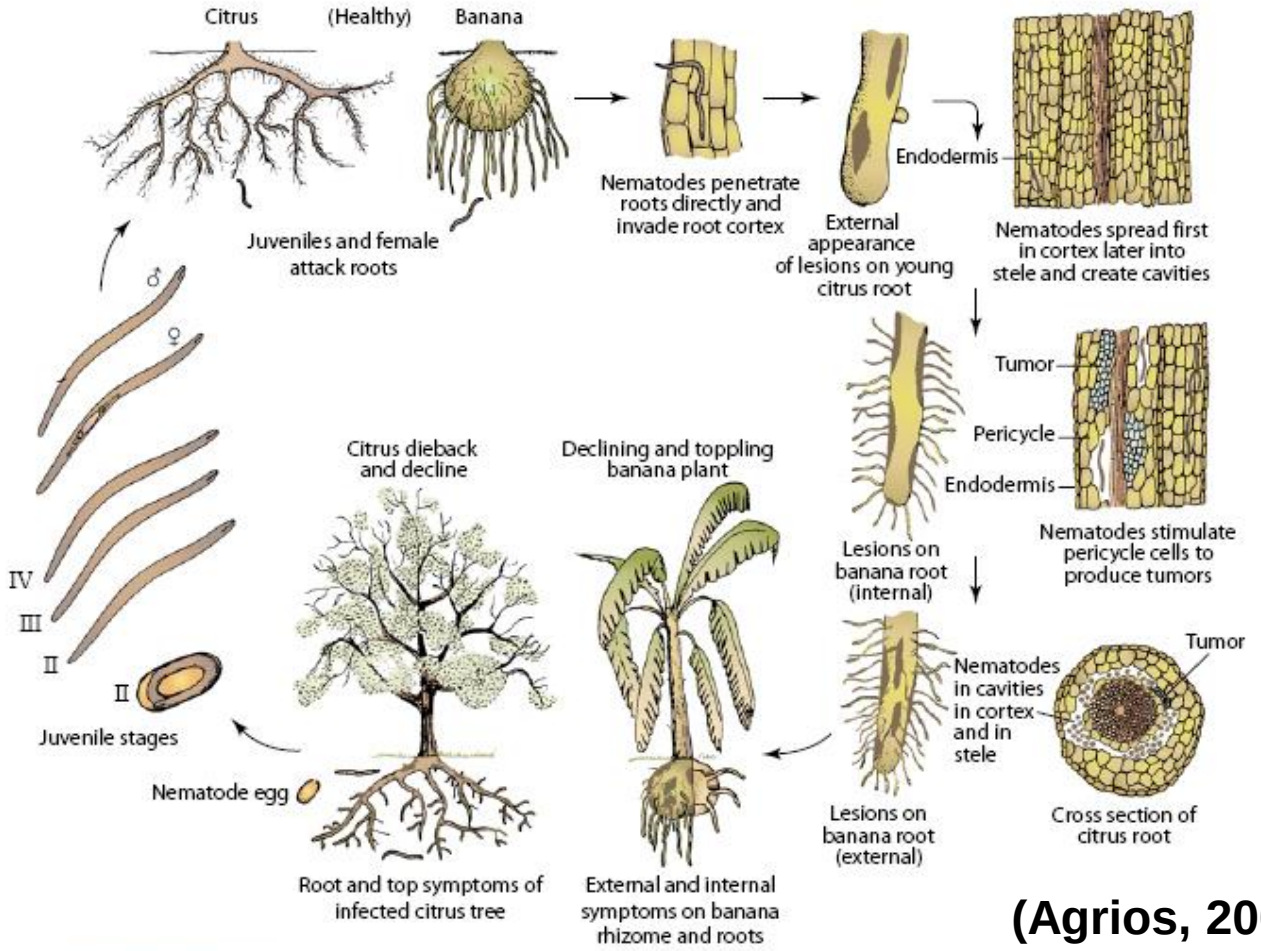


FIGURE 15-22 (A) Declining citrus tree due to infection with the citrus-burrowing nematode *Radopholus citrophilus*. (B) A whole row of rapidly declining citrus trees due to infection by the burrowing nematode. [Photographs courtesy of University of Florida.]

(Agrios, 2005)



(Agrios, 2005)

FIGURE 15-23 Disease cycle of the burrowing nematode *Radopholus* sp. in banana and citrus.

Life cycle of the burrowing nematode *Radopholus* sp.

Burrowing Nematodes: *Radopholus*

- **Control:**

***Nematode-free plantlets**

***Dipping banana sets in hot water (55 C for 20 minutes)**

***Dipping nursery trees in hot water (50 C for 10 minutes) (For citrus trees)**

*** Using tolerant or resistant rootstocks (For citrus tress)**