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Root-Knot Nematode (*Meloidogyne* spp.) Symptoms, Biology and their Management

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Root-knot Nematodes are plant-parasitic nematodes from the genus *Meloidogyne*. They exist in soil in areas with hot climates or short winters. About 2000 plants worldwide are susceptible to infection by root-knot nematodes and they cause approximately 5% of global crop loss. Root-knot nematode larvae infect plant roots, causing the development of root-knot galls that drain the plant's photosynthate and nutrients. Infection of young plants may be lethal, while infection of mature plants causes decreased yield

Fig: Root-Knot Nematode (*Meloidogyne* spp.)

Root-knot nematodes (*Meloidogyne* spp.) are one of the three most economically damaging genera of plant-parasitic nematodes on horticultural and field crops. Root-knot nematodes are distributed worldwide, and are obligate parasites of the roots of thousands of plant species, including monocotyledonous and dicotyledonous, herbaceous and woody plants. The genus includes more than 90 species, with some species having several races. Four *Meloidogyne* species (*M. javanica, M. arenaria, M. incognita, and M. hapla*) are major pests worldwide, with another seven being important on a local basis.

Symptoms and signs

Below ground Symptoms: Root-knot nematode symptoms on plant roots are dramatic. As a result of nematode feeding, large galls or "knots" can form throughout the root system of infected plants. Severe infections result in reduced yields on numerous crops and can also affect consumer acceptance of several plants, including vegetables. The degree of root galling generally depends on three factors: nematode population density, *Meloidogyne* species and "race," and host plant species and even cultivar. As the density of nematodes increases in a particular field, the number of galls per plant also will increase. Large numbers of nematodes stabbing roots in close proximity also will result in larger galls. *Meloidogyne hapla* (the northern root-knot nematode) produces galls less than half the size of those produced by *M. incognita* (the southern root-knot nematode) on the same plant hosts. Carrots typically undergo severe forking with galling predominantly found on lateral roots. Root-knot nematode galls on lettuce are beadlike. On grasses and onions, galls are usually small and barely noticeable, often no more than slight swellings. Depending upon the crop affected and the severity of infection, these symptoms can often result in significant economic losses to growers.

Above Ground Symptoms: While the most diagnostic root-knot nematode damage occurs below ground, numerous symptoms can also be observed above ground. Severely affected plants will often wilt readily. Because galled roots have only limited ability to absorb and transport water and nutrients to the rest of the plant, severely infected plants may wilt even in the presence of sufficient soil moisture, especially during the afternoon. Plants also may exhibit nutrient deficiency symptoms because of their reduced ability to absorb and transport nutrients from the soil. Additional fertilization will not generally result in remediation of root-knot nematode-induced chlorosis. Stunting is frequently observed on host crops grown in root-knot nematode-infested fields, and crop yields are reduced.

Pathogen Biology

Root-knot nematodes were first reported in 1855 by Berkeley, who observed them causing damage on cucumbers. Until Chitwood's work in 1949, which defined 4 species and one subspecies (*M. incognita acrita*) within the genus *Meloidogyne*, the root-knot nematodes were all considered the same species, *Heterodera radicola*. From this description, Chitwood obtained the name we currently use for the root-knot nematodes.

The name *Meloidogyne* is of Greek origin, meaning "apple-shaped female." Approximately 100 species of *Meloidogyne* have been described. The most widespread and economically important species are *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. chitwoodi* and *M. graminicola*. Root-knot nematodes are primarily tropical to sub-tropical organisms, however *M. hapla* and *M. chitwoodi* are well adapted to temperate climates.

Like all plant-parasitic nematodes, root-knot nematodes possess a stylet for injecting secretions as well as ingesting nutrients from host plant cells. Nematodes have no internal skeletal framework, and their "skin" or cuticle acts against internal turgor pressure to maintain body shape and aid locomotion.

Unlike most other plant-parasitic nematodes, root-knot nematode females are globose and sedentary at maturity. They range in length from 400 to 1000 µm. The root-knot nematode feeding site is actually a group of cells known as "giant-cells". When a nematode initially penetrates a plant cell with its stylet, it injects secretary proteins that stimulate changes within the parasitized cells.

The female nematode enlarges, its posterior region may break the epidermis of the root, and the eggs are deposited into a gelatinous egg mass. Mature root-knot females (pearly white in color) can be observed without magnification. Second-stage juveniles (J2) and males can only be observed with the aid of a microscope. Generally, females of root-knot nematodes have a globose body, with a short "neck," containing their stylet, metacarpus and esophageal gland cells.

Disease Cycle

Root-knot nematodes begin their lives as eggs that rapidly develop into J1 (first-stage juvenile) nematodes. The J1 stage resides entirely inside the translucent egg case, where it molts into a J2 nematode. The motile J2 stage is the only stage that can initiate infections. J2s attack growing root tips and enter roots intercellularly, behind the root cap (Figure 21). They move to the area of cell elongation where they initiate a feeding site by injecting esophageal gland secretions into root cells. These nematode secretions cause dramatic physiological changes in the parasitized cells, transforming them into giant-cells.

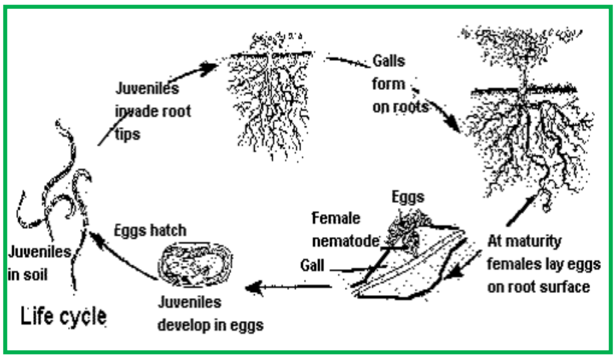

Fig. - Life Cycle of Root-knot Nematode (*Meloidogyne* spp.)

Disease Management

Cultural Controls: The use of cultural control methods to manage root-knot nematodes is the most environmentally sustainable and potentially most successful method for limiting root-knot nematode damage. However, because root-knot nematodes have very large host ranges, cultural control methods require careful planning. Vegetable fields infested with *M. hapla* can potentially be planted to a nonhost crop such as corn, but the grower's short-term economic return could be diminished. If the grower can identify an alternative nonhost crop with high economic return, crop rotation can be very successful.

Another cultural control strategy is the use of cover crops. Cover crops can be grown outside of the normal agricultural growing season, and some are antagonistic to nematodes. Cover crops such as sudangrass and marigolds actually produce chemicals that are toxic to nematodes. Other techniques, including flooding and solarization of fields, have controlled nematodes, but only in warm climates and when a particular field can be removed from cultivation for long periods during the treatment.

Plant Resistance: In certain crops, root-knot nematodes are effectively controlled by resistance genes. In tomato, genetic resistance to root-knot nematodes is conferred by the Mi gene which was obtained from *Lycopersicon peruvianum*, a wild relative of the common tomato. Many other resistance genes have also been identified that are effective against species of *Meloidogyne*. These include the Mi2 through Mi8 genes (all from *Lycopersicon*) and the Me and N genes from pepper. When resistance genes are transferred into susceptible germplasm, the genetically altered plants become resistant to infection by certain species of root-knot nematode.

Biological Control: Control measures employing organisms antagonistic to root-knot nematodes have been attempted by many researchers. The most commonly used biological control agents are fungi and bacteria. There are many kinds of nematophagous fungi use mycelial traps or sticky spores to capture nematodes, for example, *Arthrobotrys* spp. and *Monacrosporium* spp. other fungi parasitize eggs and root-knot nematode females, e.g., *Pochonia chlamydosporia* and *Paecilomyces lilacinus*. The major bacterial antagonists are *Pasteuria penetrans* and species of *Bacillus*. Endospores of *P. penetrans* attach to the cuticle of a juvenile nematode, produce penetration structures that enter the nematode, and slowly consume it. A number of commercial products based on biocontrol agents are available for the management of root-knot and other nematodes.

Chemical Control: Root-knot nematodes are very difficult to manage because they are soil-borne pathogens with a wide host range. Because root-knot nematodes live in the soil, chemical control requires applications of large amounts of chemicals with specialized equipment. Fumigants (such as 1,3-dichloropropene, methyl bromide and dazomet) are commonly applied as preplant treatments to reduce nematode numbers, but they must thoroughly penetrate large soil volumes to be effective. Some fumigants volatilize very quickly, so treated soil must have a cover or tarp to maintain the fumigant in the soil long enough to be effective. The phasing out of methyl bromide (an efficient fumigant) has intensified the search for alternatives that can be used by farmers.

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