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Plant- Nematode Interaction

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SUMMARY

Nematodes are abundant, diverse and obligate parasite which cannot survive without host and they obtain there nutrition from the cytoplasm of living plant cells. Whilst most nematodes are free living, about 7% (>4100 species) of the characterised nematodes belong to the plant parasitic nematode (PPN) group. PPNs are agricultural pests that cause significant crop damage and pose a threat to the food security in the world and it estimates a crop loss up to $US 125 billion globally per annum. This is due to the diversion of host nutrients to PPNs and interference with transport processes, as well as physical damage caused during feeding or migration, which can also result in secondary infections.

INTRODUCTION

Plant parasitic nematodes can be divided into broad groups- a majority of which attack roots and other below ground plant parts and a few which attack above ground plant parts such as stems, leaves, buds, inflorescence etc. According to parasitism:

Ectoparasites- These nematodes live freely in the soil and move closely or on the root surface, feed intermittently on the epidermis and root hairs near the root tip.

Migratory ectoparasites: spend their entire life cycle free in the soil. When the roots are disturbed the detach themselves. (e.g.) *Criconemoides* spp. *Paratylenchus* spp. and *Trichodorus* spp., etc.

Sedentary ectoparasites : attachment of nematode to the root system is permanent. (e.g.) *Hemicycliophora arenaria* and *Cacopaurus pestis* etc.

Endoparasites- spend much of their lives inside roots and major portion of the nematode body found inside the plant tissue. They may also be migratory or sedentary endoparasites.

Migratory endoparasites- move through the root, causing massive cellular necrosis. (e.g.) *Hirschmanniella* spp., *Pratylenchus* spp., and *Radopholus similis* etc

Sedentary endoparasites- completely embedded in the root- initial stages of development but later become sessile after entering into root tissue. (e.g.) *Heterodera* spp. and *Meloidogyne* spp.

Sedentary endoparasites of the family *Heteroderidae* and *Meloidogynidae* that cause the most economic damage worldwide.

Semi-endoparasites – the anterior part of nematode , head and neck being permanently fixed in the cortex and the posterior part extents free in soil. (e.g) *Rotylenchulus reniformis and Tylenchulus semipenetrans.*

These PPNs have evolved a highly specialised feeding structure, termed the stylet, to feed on plant tissues, and often display complex life-stages to suit their environment.

How the Nematode Cause Disturbance

Penetration- initial disturbance to the plant occurs when the nematode arrives at the plant surface. Chemosensory signals- important for nematode attraction to host roots and also for the identification of appropriate sites for penetration of host and initiation of feeding. Consequently some cells may be punctured by the nematode's stylet in the early stages of infection causing some superficial damage. The stylet may also be used in a rasping action in the same way that some nematodes remove tissues from the gut wall of the host thereby causing extensive lesion. *Trichodorus viruliferous* , for example, rasp the epidermis and hypodermis of the host root causing a superficial but characteristic browning. The nematode, having selected a cell or an area on the root, its activities become more purposeful, the stylet is thrust rapidly backwards and forwards through the cell wall and the first major disturbance occurs.

Feeding- Feeding may be confined to the epidermal cells with the nematode moving from cell to cell. Such activity may cause only superficial damage to the plant, although it may lay the plant open to secondary bacterial and fungal infections. During feeding, the stylet is inserted through the cell wall without piercing the plasma membrane, which becomes invaginated around the stylet. Consequently some cells are punctured by the nematode's stylet in the early stage of infection causing some superficial damage. The nematode withdraws nutrients from the the parasitized cell through a minute hole created in the plasma membrane of the stylet orifice. Secretion from the oesophageal glands released through the stylet contain the biochemical trigger(s) for giant cell and syncytium development as well as substances important for the initial penetration and migration. During feeding- feeding tube , associated with the stylet, is found in the cytoplasm of the host feeding cell. A new tube is formed each time the nematode reinserts its stylet into a feeding cell, result in numerous feeding tubes in giant cells or syncytia. In giant cell- endomembrane system rearranges to produce a compact membrane system around the feeding tube- function in transporting nutrients to the feeding tube for withdrawal by the parasites. Digestive juices secreted from dorsal oesophageal glands are injected into the host plant cell by means of the stylet. During feeding a distinct zone develop around the feeding site in the host cell. There are two feeding phases:

Injection phase or Salivation Phase :During this phase, the flow of salivary juices into host cell occurs due to contraction of lateral muscle of the median bulb.

Ingestion Phase : During this phase rhythmical contraction of the posterior part of the oesophagus associated with the median bulb occurs. The nematode is thought to be preparing for salivation and, in some cases, fluid has been observed moving towards the stylet before it is pumped into cell contents before ingestion. The introduction of secretions into the host cell during salivation probably contributes to extra oral digestion prior to ingestion. The duration of salivation is the longest phase of the feeding process, The cell contents are drawn up the stylet by the pumping of the oesophagus, and the stylet is then withdrawn. Some species posses longer stylets and can feed on plant tissues deeper than the epidermis. These have a more complex relationship with the plant, including gall formation via increases in the number and size of cells as well as causing necrosis (cell death). The simplest type of feeding is seen in *Aphelenchus avenae* which feeds on fungi, after the fungal wall is penetrated the contents of the cell are sucked out, there is no injection of secretions. Similarly, the fungus-feeding nematode, *Ditylenchus destructor*, injects digestive substances into the host over a short period to the longer period of ingestion. Secretions flow from the dorsal gland through the lumen of the spear and into the fungus cell following penetration by the spear. Ingestion of cellular contents begins with rhythmic pulsations of the cardia and adjacent portions of the intestine. Doncaster (1966) describes ingestion by the same nematode as involving pulsation of the posterior pharynx assisted by occasional pumping of the median bulb. Disturbance caused by mechanical damage during penetration and feeding there is the additional influence of saliva, secretions or enzymes.

Role of Nematode Secretions- enzymes break down cell walls and degrade the cell contents and as a result, toxic metabolites are formed usually by the plant which may damage the protoplasts of the host's cells, or change the osmotic relations of the cells and the permeability of the cell walls. Growth promoting substances resembling those produced by plants may be introduced into the host. The host may not be just a passive substrate on which nematodes secretion act, instead, nematode may have developed systems for directing the host's metabolism or for initiating physiological process without the direct injection of an enzyme. For example, *D. dipsaci* , possesses a large amount of pectinase. Cell wall modifying enzymes (endoglucanases, pectolyticenzymes, cellulase, polygalacturonas, xylanases and expansins) break down cell walls and degrade the cell contents and may result in damage of the protoplasts of the host cell. suggests that the secretion of proteolytic enzymes by nematodes into plants releases IAA and gibberellins which are bound to proteins. Amino acids that initiate gall formation may be discharged, a process involving the production of growth-promoting substances by the plant. The nematodes secrete substances into the plant that can initiate the kinds of physiological changes that is recognised as symptoms of disease, and that such changes as hyperplasia and increased metabolism can occur at the posterior end of nematodes and should not put too much emphasis on the secretion of enzymes and growth substances via the stylet. Fluorescent antibody techniques have shown that antigenic material exudes from the excretory pores and, to a lesser extent, from the stylet of larvae and adults of *Meloidogyne javanica*. The gelatinous matrix exuded from the adult female also has antigenic properties.

Migration Through Tissue : Nematodes move through the tissue feeding on cells as they go and leaving tunnels and cavities behind them. Some species disturb only a few cells during feeding or penetration and it result only in death of the cells. And also there are series of species that cause such mechanical damage to varying degrees. Some species of nematodes disturb only a few cells during feeding or penetration and this results in death of cells only. Internal feeding, unlike surface feeding, stimulated gall production (Clark, 1967). *Xiphinema* and *Longidorus*, damage the plant by penetrating and feeding on cells with the stylet. *Nacobbus serendipiticus,* larvae feed either on the surface of the root or enter the root to feed. *Telotylenchus loofi* feed on root hairs, rootlets, main roots and the root cap are all attacked and has no specific region for feeding. *Trichodorus christie* sometimes penetrate to half a body length as they force apart the loosely adhering cells at the root cap. Some nematodes completely enter the root and once inside migrate through the tissue either inter or intracellulary, e.g.- *Helicotylenchus multicinctus. Radopholus simils,* forms tunnels and cavities by lysis of cells as the nematodes progress through the root cortex (Blake, 1966). *Trichodorus christiei* sometimes penetrate to half a body length as they force apart the loosely adhering cells at the root cap. There are nematodes that completely enter the root and once inside migrate through the tissues either inter-or intracellularly. *Helicotylenchus multicinctus* , for example, may migrate for distances upto 75 cm from the pseudostem of bananas (Strich Harari et al., 1966). Large numbers of *Pratylenchus* spp. can occur in roots, without causing any appreciable reduction in rate of growth of the plant, is probably because the nematodes feed on cortical cells and leave the vascular tissues undamaged. In nematodes like *Heterodera* and *Meloidogyne,* migration through the cortex, and feeding on syncytial cells of the stele, cause two kinds of disturbance. In potato roots, for example, second stage larvae of *Heterodera rostochiensis* cause necrosis by travelling a certain distance through the cortex. As a result the growth rate of roots is reduced. Shortly after penetration, the larvae become sedentary and induce changes in the vascular bundle to form syncytia or giant cells.

Tissue Changes Resulting Due to Nematode Feeding in Plants, Fall into 3 Categories-
Destructive Changes: cell die or are severely damage or separate from each other due to nematode feeding.
Adaptive Changes: host tissue may adapt to nematode by enlarging and increasing there metabolic activities.
Neoplastic Changes: cells undergo new growth and multiplication.

Host Tissue Degradation by Enzymatic Action of the Pathogen

Nematode produce pectinase and other cellulytic enzymes. Middle lamella when macerated by the pectinase enzymes is degraded to pectic acid. Pectic acid when combine with the Al or Mn present in the plant to form gels block the xylem vessel. Polyphenol oxidase enzyme secreted by the pathogen acts upon the phenol produce by the plants producing melanin pigments that get deposited on the walls of xylem vessel causing browning of xylem walls. Melanin pigment when mixed with the gels from the gum that also block the xylem vessel. Cellulytic enzymes produce by the nematode particularly α cellulase react within the host tissue near xylem vessel producing gum or gel and sometimes results in hyperplastic by increasing the level of IAA resulting in blocking of the xylem vessel.

CONCLUSION

As a result of the identification of several gene receptors involved in immunity against PPNs, researcher have gradually begun to understand how plants recognize and respond to nematode infection at the molecular level. As nematodes are obligate pathogens of number of plant species, they cause multiple symptoms and dramatic changes in the morphology and physiology of the plant system. Several nematode genes involved in parasitism has been identified and how their pathogenic action processes towards the utilization of nematode derivable plant genes for creating new forms of plant resistance. Thus, vital challenges for future research in the field of plant and nematode interactions has to be carried out to clarify the molecular bases of individual immune responses of plants to understand the interactions of these components and signaling pathways in PPN immunity.

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