Special Issue on Wider Adoption of IPM: A Way Forward for Success to Farmers
Volume 3, Issue 1 - 2021, Pg. No. 17-25

Short Article

Peer Reviewed Journal

# Good Agricultural Practices for Nematode Management in Horticultural Crops

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## I N F O

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**How to cite this article:**
Kranti KKVVS, Supriya P, Keshari N et al. Good Agricultural Practices for Nematode Management in Horticultural Crops. *Int J Agric Env Sustain* 2021; 3(1): 17-25.

Date of Submission: 2021-05-12
Date of Acceptance: 2021-06-01

## I N T R O D U C T I O N

Nematodes are now-a-days considered and gaining importance as the major soil borne pests of most rhizospheres, including vegetables, fruits, ornamentals, medicinal, aromatic, plantation, species and condiments and several other field crops. The importance of plant parasitic nematodes can no longer be underrated although the damage they cause is rarely visible to naked eyes. Because of their short life cycle and very high rates of reproduction, nematodes build up high population densities very fast in vegetables, potatoes, sugar beets, tobacco etc. or in perennial fruit crops such as citrus, grapes, bananas, pineapples etc. The population remains constant as there is no possibility of crop rotation. Plant parasitic nematodes are microscopic in size (length 0.5-1.5 mm; diameter 30-50 µm), inhabit in soil and damage the root system, as a result the superficial inspection of the crop from outside does not immediately disclose the adverse effects on the growth of the plant and hence its damage is most often underestimated.

Crop rotation, antagonistic crops, resistant varieties, cultural practices and application of nematicides are the common methods that are followed by the farmers that knowingly or unknowingly suppress the nematode populations. But the nematodes like root knot nematode, reniform nematode, lesion nematode, etc., multiply rapidly in tropical and subtropical climates and cause decline in the plant vigor and yield due to their polyphagous feeding and wide host range. They not only debilitate the plant health but also lead to quality losses of market value root vegetables like carrot, sugar beet, spinach, turmeric, ginger and mushrooms (Nagesh et al., 2005). The quality of planting material including the rhizomes, tubers, transplants samplings and cuttings of various crops like tuberose, gladiolus, carnations, banana, solanaceous vegetables, patchouli, geranium acid lime etc. raised in nematode infested fields/ soil is not only poor but also such plants are pre disposed to other soil borne pathogens. With increasing awareness of harmful effects of synthetic chemicals on human health and environment,

the immediate need for nematode management through sustainable, ecofriendly and effective means is anticipated. For getting the good yields and quality, the maintenance of crop health is very important. Hence, it very necessary to develop long term strategies to minimize the pest and disease occurrence. This can be achieved by enhancing the natural control mechanism i.e., by growing the healthy plants. These strategies include: i) use of disease and pest resistant crops; ii) crop rotations with pastures; iii) skillful use of agrochemicals to control weeds, diseases, pests; iv) application of pests and disease forecasting techniques; v) use of certified seeds and planting materials; vi) field sanitation; vii) use of the biological organism as biocontrol agents.

Root knot nematodes, cyst nematodes and root lesion nematodes are considered as major limiting factors for vegetable cultivation. Major drawback is the lack of awareness among the farmers about the nematode damage that causes to crops and the non-availability of the region wise specific suitable package of practices to front line workers like extension officers and agricultural officers for the management of these nematodes. These are the major hindrances for protecting the cultivated crops from these nematodes. The most effective approach of management is chemical approach but very high doses are required which neither meet the cost benefit ratio nor they are economical and environmentally safe. Hence the nematode population should always be kept below economic threshold level. The young seedlings are highly susceptible to attack by nematodes while the older plant achieve some degree of tolerance. Keeping in view of farmers suitability, the good agricultural practices should be followed for management of these nematodes.

## Losses Caused by Plant Parasitic Nematodes

As discussed earlier, plant parasitic nematodes feed on roots and few aerial parts. The losses are influenced by pathogenicity of species of nematodes and also depend on the degree of susceptibility of the crop, variety and environmental factors. On the world basis the Society of nematologists estimated the losses caused by nematodes in different crops i.e., on an average they cause 12.3% loss.

And it was quite alarming to state that vegetables and fruits suffer more percent of damage as compared to other crops. Few crops and loss percent are listed in Table 1.

## Historical Aspects

The first report of plant parasitic nematode in horticultural crops was reported in India in 1933 by Ayyar on vegetable crops from the southern part of the country. Then in 1961 Jones detected the presence of the potato cyst nematode, *Globodera rostochiensis* in Nilgiris, which was of great importance.

This discovery triggered the nematological research in India. Then in 1961, Siddiqui reported the presence of the citrus nematode, *Tylenchulus semipenetrans* from Uttar Pradesh for the first time in India.

Another important plant parasite was burrowing nematode, Radopholus similis reported by Nair et al., in 1966. The International Meloidogyne project (IMP) was operated 1975 to 1984 with its headquarters in North Carolina State University, USA and its collaborating centers were located in many developing countries of the tropics and subtropics.

The major nematode pests, their nature and magnitude of the important nematode diseases of horticultural crops that includes vegetables, fruits, medicinal plants ornamentals and flower crops are reviewed in this chapter.

**Table 1.The Estimated Losses in India due to Economically Important Plant Parasitic Nematodes to Various Horticultural Crops (Jain Et Al. 2007)**

| Crop | Nematodes affecting the crop | Yield loss (%) | Monetary loss (Rs. in millions) |
|---|---|---|---|
| Banana | *Meloidogyne incognita, M. javanica, radopholus similis, Heterodera oryzicola* | 12.3 | 2960.00 |
| Brinjal | *Meloidogyne incognita* | 16.67 | 1400.30 |
| Carrot | *Meloidogyne incognita* | 10.00 | 290.00 |
| Chili | *Meloidogyne incognita* | 12.85 | 210.00 |
| Citrus | *Tylenchulus semipenetrans* | 12.60 | 945.00 |
| Cowpea | *Meloidogyne incognita, Rotylenchulus reniformis* | 27.30 | 32.00 |
| Cucurbits | *Meloidogyne incognita* | 18.20 | 547.50 |
| Ginger | *Meloidogyne incognita, Pratylenchus spp.* | 14.50 | 90.00 |
| Okra | *Meloidogyne incognita* | 14.10 | 480.00 |
| Pomegranate | *Meloidogyne incognita* | 17.30 | 270.00 |
| Tomato | *Meloidogyne incognita* | 27.20 | 2204.00 |

## Major Nematode Pests of Horticultural Crops

### Root Knot Nematode Species (Meloidogyne Spp.)

The root knot nematode, *M. incognita* is a serious problem on various fruits like grapevine pineapple, papaya, passion fruit, banana, guava, etc. Whereas, *M. indica* and *M. javanica* causes damage to citrus plants and reported from Andhra Pradesh (Mani, 1986). Root knot nematodes infect more than 3000 plant species (Abad et al., 2003). Vegetables harbor large number of nematodes but among them root knot nematode is most damaging one because most of the vegetables are vulnerable to this nematode attack. Coming to the distribution aspects, root knot nematodes are distributed worldwide and they are more prevalent in tropical and subtropical climatic zones (Sikora and Fernandez, 2005).

The four main species that cause economic damage to fruits and vegetables are *M. incognita Kofoid* & White, *M. javanica* Treub, *M. arenaria* Ned and *M. hapla* Chitwood. The first three species are found in tropical and subtropical conditions while the last *M. hapla* is found only in temperate conditions and at higher altitudes in tropics (Hunt and Handoo, 2009). *M. incognita* is most frequently and commonly observed species in India followed by *M. javanica* and *M. arenaria* in vegetables. All these species produce the below ground symptoms popularly known as 'root gall' and 'knotted roots' that can be easily visualized by naked eyes.

Different species produce different size and shape of galls and this depends on the host and the species of the nematodes involved. For example, the nematodes produce large number of galls on cucumber and small size galls in chilli, tomato, etc. M. hapla produces the small size galls as compared to *M. incognita* and *M. javanica*. In case of heavy infections large size galls, secondary galls, multiple galls are produced. Besides galling, the forking of taproots in carrots, tubercule on potato tubers is also noticed. Above ground symptoms exhibit general mineral deficiency, wilting, yellowing, stunting, chlorosis, premature shedding of leaves, etc.

**Figure 1**

Cucumber roots infested heavily with root knot nematodes in polyhouses (Figure 1).

**Figure 2**

Heavy infestation by root knot nematode in tomato in polyhouse Figure 2.

**Figure 3.Root Knot Infested Potato Tuber**

**Figure 4.Forking and Galling Caused by Root Knot Nematodes in Carrot**

The root knot nematodes also play an important role in breakdown of resistance by interacting with Ralstonia solanacearum causing the 'Pseudomonas wilt' in solanceous crops like tomato, brinjal, potato, etc. Root knot nematodes are polyphagous in nature. It has high reproduction potential and is gifted with different and unique mechanism of survival strategy through laying the eggs in gelatinous matrix which is highly protective in nature. Under intensive

crop cultivation systems, it is very difficult to manage these nematodes.

Another species of the root knot nematode, M enterolobii has recently become a threat to guava production worldwide and in India too, leading to destruction of guava orchards (Poornima et al., 2017). It is capable of inducing severe root galling and plant decline. It is considered to be particularly aggressive as it has a high reproduction rate, induces large galls and a very wide host range. Due to its endoparasitc nature, it can be easily transmitted from nurseries to nematode-free orchards through plant root material, soil and growing media.

**Figure 5.Guava Root Infested with Root Knot Nematode, M. Enterolobii and wilt Causing Fungi, Fusarium Spp.**

**Figure 6.M. Enterolobii Infested Guava Trees with Sparse Flowering, Stunted Growth, Yellowing and Bronzing of Leaves**

**Figure 7.Formation of Minute Galls on Roots**

**Figure 8.Root Knot Nematode Predisposed Wilt in Pomegranate**

## Good Agricultural Practices for Root Knot Nematodes in Horticultural Crops

Cultural practices are proved to be the most effective and economic means of managing of insect pests and diseases including the plant parasitic nematodes especially under protected cultivation.

Two to three summer ploughings (20 cm deep) during the summer months of May-June at an interval of 15 days exposed the nematodes, weeds, pathogens and hibernating stages of insect pests. Soil solarization through trapping with 100-gauge (25 microns thickness) LLDPE clear plastic film for about two to three weeks during May-June was found to be best for the management of Root Knot Nematodes (RKN) and weeds especially in polyhouses where root knot nematode susceptible crops like cucumber, tomato, etc. are undertaken.

Rubbing with bajra husk in RKN infested nursery 7 kg/ $m^2$ a week prior to seeding is best for the management of root knot nematode.

Intercropping with antagonistic plants like marigold (Tagetes spp.) reduces the soil population of many soil borne nematodes especially, the root knot nematodes. Marigold suppresses the nematode population by releasing the bioactive compounds known as α-therthienyl and this phenomenon is called as allelopathy. Incorporation of antagonistic crops in cropping systems either as intercrop or alternative crops should be taken into consideration wherever feasible.

Crop rotation with resistant varieties or non-host crops like mustard, sesame; maize, wheat, etc. will avoid the damage of nematodes and are useful to bring down root knot nematode population below the damage threshold levels.

Application of organic manure like farm yard manure/ vermicompost at about 18 to 20 t/ha reduces the population as they release the toxic substances, enhance crop tolerance and encourage soil microbial antagonistics. For example, application of poultry manure @ 2-3 t/ha 15 days prior to sowing helps in management of disease complex caused by

thee root knot nematodes and wilt causing fungi and also helps in getting more number of transplantable seedlings.

Plant resistant varieties plays a very important role in integrated pest management but there is scarcity of the resistant varieties of vegetable crops and are very few in number and many of them are not available to the farmer that are suitable to their respective agroclimatic conditions. One good option was recommended for the farmers of middle Gujarat zone III for management of root knot nematodes was growing of root knot resistant variety Anand vegetable cowpea-1 in kharif and tomato variety Hisar Lalit in rabi for three years.

**Biological Control Aspects:** Despite its several limitations the biological control aspects of root knot nematode is cost effective and ecofriendly method. The three main bioagents Paecilomyces lilacinus (Khan & Goswami, 2002), Pseudomonas fluorescens and Pasteuria penetrans has been used widely as promising biocontrol agents.

Oilseed cakes of castor (Ricinnus communis), Mahua (Madhuca indica), Mustard (Brassica campestris), Neem (Azadiracta indica), Karanj (Pongamia glabra), Undi (Calophylum inophyllum) etc. have been widely used for management of root knot nematode infecting vegetables and pulses (Goswami and Swarup, 1971; Khan et al., 1979) and also soil borne fungi viz., root rot, etc. (Sharma and Bedi, 1988). Combinations of oilseed cakes and nematicides in reduced dose have also been demonstrated to perform better than when either of them was used alone in reducing nematode population (Bhattacharya and Goswami, 1987; Goswami and Mishra 1994). Application of neem cake / mustard cake @ 300-400 kg/ ha at sowing was also found effective.

**Use of Fungi:** Lhode in 1874 from Germany first time reported that fungus Harposporium anguillulae for the control of sugar beet nematode Heterodera schachtii. The nematophagus fungi are conveniently classified as 1) Predaceous or trapping fungi; 2) Endozoic or endoparasitic fungi; 3) toxic and egg parasitic or opportunistic fungi. The last group of fungi is saprophytic in nature that are commercially viable and easily culturable on the artificial media. They either produce the toxin or colonize the reproductive structures of nematodes like Heterodera, Globodera, Meloidogyne species because their sedentary stages are more vulnerable to invasion while the former types mainly kill the infective second stage larvae of same nematodes. Toxins are produced by Aspergillus spp. while the example of egg parasitic and opportunistic fungi are Paecilomyces, Cladosporium, Trichoderma and Verticillium. Like application of Purpureocillium lilacinum (= Paecilomyces lilacinus) 20 kg/ ha + castor cake @ 2 t/ ha in root zone at six-month intervals to manage root knot nematode has given higher fruit yield. The fruit yield of okra increased by the application of P. lilacinum @ 2.5 kg/ha in 2.5 t FYM to manage M. incognita.

For the effective management of M. enterolobii, 1 tonne of FYM /biocompost cis enriched with each 1-2 kg of Pseudomonas fluorescens/Trichoderma viride / T. harzianum or Paecilomyces lilacinus, kept for 2-3 weeks under shade with weekly turnings to maintain enough moisture for multiplication and applied @ 500 g/pit around the rhizosphere region. This may be repeated every six months.

## Potato Cyst Nematodes (Globodera Rostochiensis and G. Pallida)

The golden nematode of potato has been reported from many countries of the world. In India, the Potato Cyst Nematode (PCN) is known since 1961 when F.G Jones detected this nematode from the field of Vijayanagaram state farm in Ootacamund of Nilgiri Hills in Tamil Nadu, after the Government of Tamil Nadu has imposed the Destructive Pest Act in 1919 in 1971 to contain the nematode in Nilgiri Hills. This has also been reported in Kerala and Karnataka. This nematode is popularly known as golden nematode and nematode has a very long and interacting history of causing commercial losses as well as failure of the potato cultivation in the European countries as it causes losses of 9 % of global potato amounting to about 40 million tons (Krishna Prasad, 1995). The cyst nematode pathotypes $RO_1$ and $RO_2$ of G. rostochiensis and $Pa_2$ and $Pa_3$ of G. pallida are known to be prevalent in India.

**Figure 9.Overview of Potato Field Infested with Globodera Rostochiensis**

**Figure 10.Small Cysts on the Potato Root Hairs**

**Figure 11.Cyst Females Adhering on the Root Surface**

The symptoms of heavy infestation are considerable wilting during the midday, stunting and yellowing of the plants. This leads to poor root development and poor growth of plant. The fecundity of cyst nematodes is 500 eggs and the eggs hatch when the temperature is around 15°C and stimulus is received by the roots. The second stage juveniles emerging from the roots enter the roots and take up the position near the vascular system, feed and undergo a series of changes. The females remain sedentary, swell and erupt out of the root to which they remain attached by thin neck and the white females turn golden orange and brown. The females on roots can be seen with naked eyes and the life cycle completes in 38-48 days. The eggs in the cysts are spread through soil particles adhering to tubers, gunny bags, farm implements, workers feet, etc. However, the irrigation water as well the rain water running down the hill slopes carry the cyst nematodes from the infested fields to the uninfected fields.

## Good Agricultural Practices for Cyst Nematodes

In India, as the regulatory method, there is quarantine Act against the cyst nematodes of potato (G. rostochiensis) in Nilgiris. The infested seed material of potato is not allowed to be transported from Nilgiris to other parts of India for seed purpose. The potato seeds free of cyst nematodes can be produced commercially by seed certification and this is one of the best option. Also, the G. rostochiensis can be eliminated by selecting the nematode free planting material.

Best option for the management is growing non host solanaceous crops like cauliflower, cabbage, turnip, carrots garlic, beet root, radish, etc.

One of the most useful rotations is potato-cabbage-carrot as it is most commonly practiced by the farmers of Nilgiris hills.

Avoiding the growing of potato year after year and green manuring with lupin also serves as one of the best option

Seed treatment with P. fluorescens @ 20 g/kg seeds and its soil application @ 2.5 kg/ha for the management of G. rostochiensis is highly effective.

## Burrowing Nematode (Radopholus Similis)

*R. similis* commonly known as burrowing nematode causes serious diseases of black pepper which is popularly known as 'pepper yellows' in Indonesia, 'spreading decline' in Florida and 'slow wilt' in India. Many economical important crops like citrus, betelvine, banana, coconut, black pepper, arecanut, ginger, etc. that are commonly cultivated in coastal parts are the serious hosts of this nematode. This nematode is a major pest and causes serious problems in southern states like Karnataka, Andhra Pradesh, Tamil Nadu and Kerala, (Parvatha Reddy & Singh, 1980). Due to the indiscriminate movement of planting material of banana, ginger, and turmeric rhizomes to other states, recently it has spread to states like, Orissa, north east state like Manipur, Maharashtra, Madhya Pradesh, Himachal Pradesh and Gujarat.

Burrowing nematode infested banana plants show the 'toppling disease' at bearing stage, that results in premature defoliation, poor plant vigor and finally reduce the bunch size and fruit weight. Below ground symptoms exhibit as development of lesions, subsequent rotting, and the decaying of the tender roots, due to interaction and involvement of other soil microorganisms. In southern states, the coconut plants that are attacked by R. similis show general decline symptoms like yellowing, stunting and smalling of the leaves and button shedding which results in poor yields.

In black pepper, slow growth of vines, yellowing of leaves followed by severe die back and death of vines are the common symptoms. The roots of coffee, arecanut, betelvine are seriously attacked and develop characteristic lesions, root decay and rotting. Burrowing nematode is the migratory endoparasite of root on the succulent tissue of feeder roots. Due to their intracellular movement, the nematode destroys the cells and forms burrows or cavities inside the roots. All the developmental stages are capable of feeding roots. Eggs are laid in root tissues and newly hatched juveniles start feeding and develop inside the roots. As they are complete root migratory endoparasites, total life cycle is completed within the roots and takes about 20-25 days. Only the banana race of R. similis is prevalent in India.

## Good Agricultural Practices for Management of Burrowing Nematodes

As this nematode is endoparasitic in nature, the management is quite difficult. The preventive measures like planting materials and seedlings should be free from the nematodes. Any appearance of the discoloration on the rhizome should be removed and treated with bordeux mixture or nematicides. Hot water treatment with rhizomes at 50-55°C for 20-25 minutes is one the pf best option to get rid of burrowing nematodes.

The coconut seedlings, areca nut, black pepper should be raised from nematode free nursery bed.

The sun drying of banana rhizomes and planting after it, is also an effective method to reduce nematode problems.

Other curative measures like application of neem cake at 400 g/plant two times, once at planting and second dose after 4 months increase the bunch weight and the banana yield.

The susceptible crops should be avoided as intercrops. For eg. intercropping with Crotolaria juncea reduces R. similis population. Bioagent applications like P. lilacinus, G. fasciculatum, Pasteuria penetrans has given the promising results against R. similis. Few resistant or tolerant varieties has been listed in the Table 2.

**Table 2.Resistant or Tolerant Varieties**

| S. No. | Crop | Varieties |
|---|---|---|
| 1. | Banana | Kadali, Pedalimoongil, Kunnan, Pey kunnan, Pisang Seriby (Sunderraju & Koshy, 1988) |
| 2. | Arecanut | VTL-11×VTL-17 (resistant) (Sunderraju & Koshy, 1988), Tolerant: Indonesia-6 (VTL-11); Mahuva-B, Andaman-5 (VTL-29e) |
| 3. | Coconut | Kenthali, Klappawangi, Hybrid Java Giant (JG×Kulashekaram dwarf yellow (KDY), KDY×JG, Java Tall × Malayan yellow drawf, San ramon× Gangabondan (Sosamma et al.,1980) |

## Citrus Nematode (Tylenchulus Semipentrans)

T. Semipentrans commonly called as the citrus nematode is a sedentary semi endoparasite and is found in all the areas of the country where citrus is cultivated and it is recognized as economically important pest of citrus. It is one of the causal organisms of causing the slow decline of citrus; this causes the general reduction of tree growth, lack of vigor, yellowing of foliage and small size of fruits. The symptoms that are caused by this nematode are often destructive and that are non-descriptive and difficult to diagnose. It is often unnoticed in seedlings in nursery which caused widespread distribution. The female nematodes and their gelatinous matrix containing eggs that are adhered to the soil particles gave the roots a characteristic 'dirty appearance' which is not easily washed off. The most serious effects of the nematode are visualized on the plant growth and yield of the citrus and usually encountered when new seedlings are planted in the same orchard. This condition is known as 'citrus replant problem'. If the growth of the young tree is very slow and fruiting is delayed then the condition of the infested tree is known as 'slow decline' which implies deteoration of citrus trees hence produces smaller and fewer fruits in the beginning stages.

The extent of this decline in mature trees is related to their vigor, tolerance to nematode and to the degree of infection. As it feeds on the surface layers of roots, this leads to discoloration and necrosis. A young female that penetrates into deep root tissues, establishes a feeding site around the head. This site compromises of 16 cortical cells and it is known as 'nurse cells'. The posterior part of mature female body remains outside and the eggs are laid in gelatinous matrix outside the host tissue. The life cycle of this nematode is completed within the 6-8 weeks under optimum temperature at 25 to 31C.

### Good Agricultural Practices for Management of Citrus Nematode

The seedlings raised in the nurseries should be free from nematode infection. Also the orchard should not be taken up at the previously infested citrus field. Hence it should be either avoided or fumigated to kill any nematode population in soil.

The run off water should be prevented from the adjacent citrus orchards. The use of clean equipment or implements for carrying out the cultural practices should be used because movement of any soil particles from one place to another in orchard may disseminate the citrus nematode. Also, it becomes very difficult to eliminate the nematodes once they are established in orchards, hence the regular monitoring is very essential for preventing the nematodes to reach above the damage threshold level (500/ g of feeding root) and not damaging to the crop but at high population rate (4000/ g root) causes the devastating damage to orchards which leads to tremendous loss to the farmers (Nickle, 1991).

As curative measures, the application of oil cakes of neem, groundnut, mahua at 1 kg/ plant can reduce this nematode population. The application of neem cake at 1 kg/ plant along with carbofuran 3 G (Furadan) 1.0 kg ai/ ha is also proved to be effective (Parvatha Reddy et al., 1996).

As a sanitation measure to reduce the soil population, the farmers should remove the old feeder roots before the start of growth flush followed by application of FYM.

## Reniform Nematode (Rotylenchulus Reniformis)

The adult female of R. reniformis is an obligatory, sedentary semi endoparasite of a wide range of fiber, oilseed, fruits and plantation crops. The name 'reniform' was derived from the kidney shaped mature females. It has distributed worldwide and is gaining importance as national pest of crops. In western parts of India, this nematode has been associated with many vegetable crops, banana, tube rose, tea, pulses, betelvine, fruits etc.

The symptom of this crop is too nonspecific on the above ground and below ground. It feeds on the cortical tissue, phloem and pericycles which leads to formation of necrosis on roots of few crops. Typically the symptoms appear as discoloration of roots leading to malformation, shedding of leaves and formation of malformed seeds. In addition to causing the direct damage to plant roots, the nematodes in concert with other pathogens like Verticillium spp., Fusarium spp., Rhizoctonia solani, Sclerotium rolfsi, etc. and develops the disease complexes. Gaur and Perry, 1991 reported that the nematode is capable of surviving in air dried soils and this type of unique adoption is due to retention of moulted cuticles of previous stages.

The survival loss of this nematode is inversely related to the rate of moisture loss in soil. Therefore, the alternate drying and wetting of field soil leads to sharp decrease of population density of nematodes in soil. The young females are the only infective stages and after infection in the roots the young females becomes sedentary by orienting themselves perpendicularly to the longitudinal axis of the roots keeping the remaining posterior part outside the roots. After the successful establishment of feeding sites, it forms into the kidney shaped females, with posterior portion protruding outside the roots. After invasion, egg laying starts within 7-10 days and eggs are laid into gelatinous matrix which is secreted by six specialized cells located around vagina. Each egg masses contains around 30-200 eggs and the total life cycle is completed within three to four weeks which is highly dependent upon temperature and host suitability.

## Good Agricultural Practices for Reniform Nematode Management

Crop rotation with non-hosts crops like sugarcane, mustard, maize, marigold and growing the susceptible crops in winter seasons.

Organic amendments like application of organic manures like FYM, oilcakes like neem, mustard, karanj etc., have been found to be promising.

Two to three summer ploughings during the hot months are also promising.

Irrigation between ploughings result in alternate drying and wetting which stimulates exsheathment of young females of R. reniformis.

## Lesion Nematodes (Pratylenchus Spp.)

Pratylenchus spp. are the migratory endoparasites of roots. The root lesion nematode name is derived from the discolored patches or lesions that are developed in roots. The host range including the crops like wheat, maize, cotton, karanj, potato, banana, tea, vegetables, ornamentals and fruits. Some nematode species like *P. Thornei* in wheat, soybean, chickpea, sunflower, *P. zeae* in maize, *P. indicus* in rice, *P. loosi* in tea, *P. coffeae* in banana, *P. pratensis* and *P. vulnus* in temperate fruits are serious problems.

The above ground symptoms are nonspecific in nature and this nematode usually infect in roots, tubers, rhizomes, etc. Having penetrated into roots they multiply in large numbers. All the stages of this nematode are infective and the attacked plant root exhibit dark red brown lesions caused by necrosis of the invaded cells. The lesions formed on roots initially appear as small, elongated water-soaked spots which gradually changes to brown and to black. This leads to loss of primary roots, decaying of roots, reduced size of blossoms and shrinking of grains are associated symptoms of this nematodes. This nematode acts as predisposing agents to several soil borne fungi and bacteria which also lead to rotting and decay of roots affecting the normal functioning of infested roots.

## Good Agricultural Practices for Management of Lesion Nematodes

Summer ploughings reduces the nematode populations and growing of antagonistic crops like marigold (Tagetes patula), hot water treatment of bulbs, corms and fleshy roots can kill the dormant nematodes inside the root.

### Future Prospects

Considering the magnitude of damage caused by the important plant parasitic nematodes, it can be concluded that they can be no longer be ignored and the greater emphasis should be on the research that constitutes mainly on the development of the resistant varieties and ecofriendly technologies as there is increasing concern on the nematicide residue problems. Good agricultural practices with the emphasis on the cultural methods, tolerant hosts and biological agents is now being practiced and popularized in wider perspective. The aspects that needs to be emphasized in future to attain the sustainable nematode management are extensive dissemination of the diagnostic and advisory services centers trough electronic media for the farmers, data base for region or the crop specific nematode management practices, search for the novel and potent green molecules of biological origin for nematode control as a curative control, development of location specific crop rotation and intercropping crops for nematode management, to standardize the protocols for mass production, application methods at required doses and finally organizing the workshops to frontline agricultural workers, to sensitize about the nematodes and its damage.

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