www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 839-844

www.thepharmajournal.com
Received: 08-04-2022
Accepted: 17-06-2022

G Narayana Swamy
Ph.D., Department of Horticulture, KVK Nellore, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India

D Tirupal
Scientist, Department of Horticulture, KVK, Periyavaram, Dr. YSR Horticultural University, Andhra Pradesh, India

Manisha
Ph.D., Scholar, Division of Vegetable Crops ICAR-IARI-IIHR Outreach Campus ICAR-IIHR, Bengaluru, Karnataka, India

M Pradeep
Assistant Professor, Department of Pathology, SV Agri., College, ANGRAU, Andhra Pradesh, India

B Vijayasree
Scientist, Department of Home Science, KVK, Periyavaram, Dr. YSR Horticultural University, Andhra Pradesh, India

Corresponding Author:
G Narayana Swamy
Ph.D., Department of Horticulture, KVK Nellore, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India

Integrated nematode management in vegetables: Review article

G Narayana Swamy, D Thirupal, Manisha, M Pradeep and B Vijayasree

Abstract
Vegetable production around the world is being increasingly hampered by the un favourable soil and environmental conditions that include abiotic constraints, as well as biotic ones as soil-borne pests and diseases. Among them Root knot nematode *Meloidogyne* spp. is one of the most important yield limiting constraints in vegetable crops causing an estimated yield loss of 5–43% in the tropics and subtropics. The concept of Integrated Nematode Management (INM) gaining momentum for management of Root knot nematodes compared to individual approach. INM is not isolated approach from Integrated Pest Management (IPM), rather a component of it. INM is pragmatic approach; it includes Cultural methods, Physical methods, Bio management methods and Chemical methods.

Keywords: INM, Root knot nematodes, *Meloidogyne* spp. Bio management

1. Introduction

Root knot nematodes are severe damaging pests in Vegetable crops. In overall Plant-parasitic nematodes cause 21.3 per cent crop losses amounting to Rs. 102,039.79 million (1.58 billion USD) annually in different crops. In India in Horticultural crops monetary loss due to nematodes is Rs. 50,224.98 million with yield loss 23.03 per cent annually (Kumar *et al*., 2020) [22]. In Vegetable crops due to plant parasitic nematodes monetary losses amounting to Rs.14461.22 million with 19.6 per cent yield losses In Protected cultivation, an overall average annual yield loss in major horticultural crops due to nematodes goes up to 60% (Kumar *et al*., 2020) [22]. Root-knot nematodes are obligate sedentary endo parasites, that induce the formation of giant cells in the roots, from which the nematode feed to complete its life cycle (Baldacci-Cresp *et al.*, 2015) [4]. The availability of water and nutrients to the plant decreases while the giant cells are located close to the root systems xylem and phloem. As the giant cells are located close to the xylem and phloem, availability of water and nutrients to the plant decreases (Siddiqui *et al.*, 2014) [36]. Hence, for managing Root knot nematodes, Integrated Nematode Management (INM) is better approach. Biological management of Root knot nematodes main aims to manipulate the parasites, predators and pathogens of nematodes in the rhizosphere in order to control the plant parasitic nematodes.

2. Major Nematode species infecting vegetable crops

Every vegetable grown is known to be attacked by either of 4 common species of Root knot nematodes (*Meloidogyne incognita, M. arenaria, M. javanica, M. hapla)*. These four species are worldwide distributed and have a wide host range that includes vegetable crops (Greco & Esmenjaud, 2004) [9]. *M. incognita, M. javanica, M. arenaria* are widely distributed in tropical & sub-tropical warm temperate regions of the world, *M. arenaria* is less frequent and *M. hapla* occurs in temperate climate i.e., temperature -15º c to -27º c. Root knot nematode (RKN), identified as serious crop pest worldwide are obligatory sedentary endoparasites of plant roots' vascular tissues in eggplant (Caillaud *et al*., 2008).

2.1 Different races in Root knot nematodes

Root knot nematodes races are known to occur in four prominent species of the root knot nematodes such as *M. incognita, M. javanica, M. arenaria and M. hapla*. Sasser (1952) [30] first reports the host range variations in four major *Meloidogyne* species. Taylor and Sasser, (1978) [31] used the term 'race' to *Meloidogyne* populations.

Table 1: Races (Root knot nematodes) in India

Occurrence of race	Species	Reference
4 races (race 1, 2, 3 and 4)	*M. incognita*	Sharma and Gill 1992 [33]; Khan 1997 [18]
3 races (race 1, 2 (pepper race) and 3 (groundnut race)	*M. javanica*	Sharma *et al*. 1995 [34]; Khan *et al*. 2003 [16]
1 race (race 2)	*M. arenaria*	Khan *et al*. 1993 [19]; Kumar *et al*. 2008 [21]
race 5 and 6	*M. incognita*	Khan *et al*. (2014) [17]
3 new races	*M. javanica*	

In *M. incognita*, out of four races, race 1 is widely prevalent in India and race 2, 3 and 4 are reported to present in selected parts of the country. Similarly, the races of *M. javanica* and *M. arenaria* distribution in different parts the country.

2.2 Symptomology

Formation of Giant Galls in roots are the most characteristic symptom shown by plants infected by the most important *Meloidogyne* species. The size of galls is variable depending on quantity of inoculum and plant species. Low nematode density produces individual or scattered galls induced by one or few females and an egg mass, related to individual females, can be observed on the root surface. As density of nematodes increases, galls develop closer to each other and roots become deformed, their size increase considerably. In this case, only few egg masses can be seen on the root surface, as the majority of them are inside the root. Plant species affects gall size, ranked from more to less discrete galls: Alliaceae, Cruciferae, Asteraceae, Chenopodiaceae, Apiaceae, Fabaceae, Cucurbitaceae and Solanaceae (Ornat. C and Sorribas F). Symptoms in the aboveground depend on disease severity, they can range from no symptoms, when initial population density is lower than the tolerance limit, to dead plants, at higher population densities. Damping-off can occur when seeds are planted in heavily infested soils. Nutrient and water absorption is affected in plants with severely galled roots. As a consequence, plant growth is retarded, leaves show nutrient deficiency, wilt, yellowing and necrosis, flowering can be reduced or flowers become dry, in addition, the number of fruits is reduced or fruit size does not attain marketable standards (Ornat. C and Sorribas F.)

3. Integrated Nematode Management (INM)

3.1 Objectives of Integrated Nematode management (INM)

1. To minimize environmental and health hazards.
2. Utilization of several compatible measures.
3. To maximize natural environmental resistance to plant parasitic nematodes.
4. To minimize the use of drastic control measures and also to minimize the input costs.
5. To increase reliance on location specific and resource compatible management strategy.

3.2 Main components of Integrated Nematode Management

3.2.1 Cultural methods: Main principles behind cultural practices are (i) Prevention of new area from pest infestations i.e., prevention of infested soil, crop residues, vegetative propagules, human activities and irrigation water. (ii) Reduction of secondary soil inoculum once nematode is infested**.**

1. **Summer ploughing:** 2 or 3 deep summer ploughings during the hot summer months (May-June) expose the nematodes and infected tissue to solar heat and dehydration. This method reduces the root knot nematode population densities, weeds, soil borne pathogenic fungi and bacteria. This practice has been found effective to manage root-knot nematodes (Jain and Bhatti, 1987) [11]. In brinjal, fallowing and summer ploughing during hot summer months significantly reduce the M. incognita (Singh, 2013) [38]. According to Jain and Gupta (1990) [12] normal (10 cm) and deep ploughing (20 cm) during the month of June followed by a fallow period of about two months recorded significant reduction of root-knot nematode population ranging between 78.2 to 92.3%, respectively at the time of transplanting of tomato.
2. **Crop rotation:** Certain cropping sequences, including non-preferred hosts like sesame, mustard, wheat, maize, etc. are found to suppress the nematode population in vegetable crops. The key principal involved in this method is starvation and interruption in their life cycle. Rotation of non-host crops such as Velvet bean (Mucuna) mustard, garlic, onion and cereals at least for 2 to 3 years in a suitable cropping system helps in minimizing inoculum level of the nematodes. Siddiqui and Alam (2001) [35] evidenced that, the cropping sequences of sorghum-wheat-horse gram-turnip and fallow cauliflower-sorghum-coriander were found to have a maximum suppressive effect on root knot nematode *M. incognita* and reniform nematode *R. reniformis.*
3. **Antagonistic Crop (Bio fumigation):** Crops like asparagus (*Asparagus officinalis*), mustard, and African marigold as antagonistic crops in susceptible main crop helps in suppression of root knot nematode population. Growing African marigold (*Tagetes erecta* or *Tagetes patula*) with susceptible crop helps in suppressing root knot nematode population by releasing nematotoxic compounds polyterthienyl (α-terthienyl) through root exudates respectively. Incorporation of *Brassica* spp. such as Indian mustard (*Brassica juncea*) and rapeseed (*B. napus*) as green manures into the soil limits the reproduction of nematodes. After decomposition, they release volatile compound like isothiocyanates produced from glucosinolates, which are highly toxic to root knot nematodes. This process generally termed as bio-fumigation.
4. **Cover crops:** Green manures suppress the nematode population by releasing nematotoxic compounds after decomposition (Chitwood and David 2002) [5]. In general, crops such as Crotalaria, castor bean, velvet bean, jack bean, sorghum-sudan, castor, grasses and cereals have been successfully utilized as cover crops for root knot nematode management (Hackney and Dickerson 1975; Viaene *et al*. 2006) [10, 43].
5. **Trap crops:** Trap crops are highly susceptible crops normally grown in root knot nematode infested fields. These crops which allow invasion by root knot nematodes, but do not support their development E.g. *Crotalaria spectabilis*.
6. **Destructions of crop residues:** Burning of infected plant debris helps in reducing inoculum densities. Removal of weeds such as *Chenopodium album*, *Solanum nigrum*, *Tithonia rotundifolia* and other unknown weeds are known to be associated with vegetable crops act as

alternate hosts for root knot nematodes for the perpetuation of life cycle. (Khan *et al.*, 2014) [17].

7. **Applications of organic amendments:** Organic amendments with C: N ratios between 12 and 20 were highly suitable to exhibit high nematicidal activity and even to avoid phytotoxicity on crops. Plant products such as Neem (leaf, seed kernel, seed powders, seed extracts, oil, sawdust, and oilcake) has been extensively used against control of root knot nematodes including other major plant parasitic nematodes. Nematicidal action is due to release of chemical compounds from neem such as salanin, azadirachtin, nimbin, thionemone and various flavonoids.
8. **Host plant resistance:** Host plant resistance is one of the best environment safe approach for Root knot nematode management. In Nematology, resistance is the ability of a plant to suppress development or reproduction of nematodes (Roberts, 2002). Resistance sources in Solanaceous and other vegetables furnished in below table.

Table 1: Host plant resistance in Tomato

Parasite	Host resistance	References
Meloidogyne incognita	Hisar Lalit, HN 2, PNR 7, IIHR 2614 and IIHR 2868	Sujatha R. *et al.*, (2017) [40]
	Advanced line- H-88-78-1 and Hisar Lalit, Motelle and Mogeor	Yerasu Suresh Reddy *et al.*, (2018) [24].
	LA2819, LA2820, LA2822, CGN14387 and LA1221	Ali *et al.* (2015) [2]
	Bridget40, Galilea, and Irma	Seid *et al.* (2017) [31]
	Mahy 80, JK Kajal and Hybrid green, Mahy 112 and Mahy Ruby.	Akhter and Khan (2018) [1]
	Red Rock	Faraj and Qadir (2018) [8]
	Samrudhi F1 (*S. lycopersicum*) rootstock., *S. aethiopicum*, *S. macrocarpon* and Mongal F1 (*S. lycopersicum*)	Okorley *et al.* (2018) [27]
	Hybrid-HN2 × CLN 2123A	Sundharaiya and Karuthamani (2018) [41]
	MS-113, CLN-2366C, E-9111, E-9113, E-9321, PAU Sel. 2-1, PAU-951 and Punjab Swarna	Kaur *et al.* (2019) [15]
	EC- 617047, EC- 620394 and EC- 620427	Nihal *et al.* (2019) [26]
Meloidogyne javanica	Assila, Eden, Galilea, Tisey, CLN-2366A, CLN-2366B and CLN-2366C	Seid *et al.* (2017) [31]

Table 2: Host Plant resistance in Chilli and Capsicum

Crop	Parasite	Host resistance	Ref
C. chacoense	*Meloidogyne incognita*	528-8, 529-8, 46-530/7, 530-8, 213-8	Naresh *et al.*, 2019 [24]
C. chinense		PA-353, PA-398, PA-426, 201-26, 547-7, 56-547/7	
C. frutescens		586-12, 28-201, Santanka XS, White Kandhar	
C. annuum		PI322719, PI201234, CM 334, Pusa Jwala, Carolina Cayenne, PM687, PM217, PR205, PM702	
Capsicum (Bell pepper)		Charleston Hot', 'Carolina Wonder', 'Charleston Belle', 'Mississippi Nemaheart' and 'Carolina Cayenne'	Kokalis-Burelle *et al.*, 2009 [20]

Table 3: Host plant resistance in Egg plant and Potato

Crop	Parasite	Host resistance	Ref.
Brinjal	*Meloidogyne incognita*	*Solanum sisymbrifolium Solanum torvum Solanum aethiopicum*	Di Vito *et al.*, 1992 [7].
		Gachhabaigan, Azadkranti,Kantabaigen, Athagara Local, Kamaghara local, Solanum indicum, PBR 129-5, ARU-1, BB1-3, BB 45-C, BB-49, KS-224, Utkal madhuri, BR-112, LB-13, LB-25, LB-28, LB-30, LB-44, LB-55	Nayak D K
Potato	Potato cyst nematode	Kufri Swarna, Kufri Neelima, Kufri Sahyadri *Solanum demissum, S acule, S,Chacoense*	www.cpri.in

Table 4: Host plant resistance in other Vegetables

Crop Name	*Host resistance*	Reference
Okra	Abelmoschus moschatus (two genotypes *viz.* IC-14O970-A, IC-203863) and Abelmoschus angulosus genotypes (IC-	Manjunatha T., *et al.*, 2017 [23]
Bottle gourd	PSPL, Hoe-505, Samrat, Bogh-2	
Other Cucurbits	*Cucumis anguria, C. ficifolius, C. longipes, C. metuliferus, C. eptadactylu*	Dhall R.K. 2016 [6].

3.2.2 Biological control
Biological management of Root knot nematodes main aims to manipulate the parasites, predators and pathogens of nematodes in the rhizosphere in order to control the plant parasitic nematodes.

3.2.2.1 Biological control -Antagonists
Antagonists are colonizing in the soil and remain active (inoculation strategy). Effective biological antagonists are generally belonging to the 1. Fungi and 2. Bacteria group. These antagonists feed or parasitize the nematodes or release secondary metabolites which are having nematicidal activity.

3.2.2.2 Fungal antagonists
This group categorized into three groups based on their mode of action. The detailed information furnished in below

3.2.2.3 Nematode trapping fungi
Fungal antagonists *viz., Arthrobotrys spp. and Monacrosporium* spp. are trap nematodes in constricting rings and adhesive nets respectively. Their predation mechanism involves the association between a lectin secreted by the fungus and a carbohydrate secreted by the nematode cuticle. However, their predation is specific to certain nematode species and restricted availability of these antagonists in soil

limits their potential use. (Manjunatha T. *et al.*, 2017) [23]

3.3 Egg parasites
Paecilomyces lilacinus 1% W. P. *and Pochonia chlamydosporia* 1% W. P. are effective bionematicides. *P. lilacinus* and *P. chlamydosporia* are the potential fungal antagonists successfully control by parasitizing eggs and females of root knot nematode. (IIHR, Bengaluru)

3.4 Toxin producing fungi
Aspergillus spp. (*Aspergillus niger, Aspergillus fumigates, Aspergillus terreus*), *Trichoderma* spp. (*Trichoderma viride, Trichoderma harzianum*) *Rhizoctonia bataticola*, *Alternaria alternata*, *Aspergillus flavus, Penicillium chrysogenum*, produce toxin which act as antagonists against plant parasitic nematodes. Most prominently the filamentous fungi, *Trichoderma harzianum1% W. P. & Trichoderma viride* 1.5% *W. P* strains commercially used for the management of root knot nematodes infesting vegetable crops and the effective bio-fungicides. (IIHR, Bengaluru).

3.4.1 Bacterial antagonists
This group categorized in to two major groups *viz*., Nematode parasites (*Pasteuria penetrans*) and Nematode antagonistic rhizobacteria (Plant growth promoting rhizobacteria).

3.4.2 *Pasteuria penetrans:* It is obligate parasite produces adhesive endospore which inhibits reproduction activity in the root knot nematode.

3.4.3 Nematode antagonistic rhizobacteria: Plant Growth Promoting Rhizobacteria (PGPR) having four multiple mode of actions such as i. competition ii. Antibiosis iii. plant growth promotion and iv. induction of systemic resistance against, plant parasitic nematodes including root knot nematodes, fungal and bacterial pathogens infecting a wide range of host plant species. *Pseudomonas fluorescens* 1% W. P. an effective bio bactericide and also has nematicidal properties. Strains *of P. fluorescens* which produce an antibiotic DAPG (2, 4-diacetylphloroglucinol) is responsible for high nematicidal action. Hence strains producing antibiotic DAPG have been widely used for the control of root knot nematodes infecting vegetables as well as other crops. Other Promising nematode antagonists in PGPR is *Bacillus* spp. *Bacillus* spp. (*Bacillus subtilis, B pumilus*) are also most promising antagonist which produce secondary toxic metabolites to suppress the population of root knot nematodes.

3.5 Mode of Application Bio agents
3.5.1 Method of seed treatment with bio-agents
Formulation can be used as a seed treatment or seed dressing agent. Dosage – 15 to 20 grams of formulation /kg of seed.

1. **Method of substrate treatment with bio-agents:** Formulation can be used for treatment of coco-peat (substrate) in which seedlings are grown under shade net or protected conditions. Dosage – 5 – 10g of formulation/kg of coco-peat (substrate)
2. **Enrichment process:** One ton of Neem cake/ Vermicompost/ well decomposed FYM has to be enriched by mixing with 2 kg each of Pseudomonas fluorescens + Trichoderma harzianum + Paecilomyces lilacinus formulation under shade. It has to be covered with mulch and optimum moisture of 25 - 30% has to be maintained for a period of 15 -21 days.
3. **Seed treatment:** 15 to 20 g of formulation /kg of seed.
4. **Nursery treatment:** For transplanted vegetable crops such as tomato, brinjal and chilli, nursery beds treated with antagonists (*Trichoderma harzianum*, *Paecilomyces lilacinus* or *Pseudomonas fluorescens*) @ 50g/m^2 area.
5. **Substrate treatment:** 5 to 10 g of formulation/kg of coco-peat (substrate). iii. Preparation of beds: Bio-pesticides enriched FYM@ 5kg/sq.m + bio-pesticides enriched neemcake @ 250g/sq.m or bio-pesticides enriched vermicompost @ 1kg have to be mixed in top 12 cm of soil in the beds.
6. **Spraying, drenching/drip irrigation:** Formulation sprayed on the plants, applied through drip / by drenching at regular intervals at a dosage of 5g/ lit.

As reference source from technical bulletin (Manjunath *et al.*, 2017) [23] and field experiments at IIHR Varanasi, application of Organic manures i.e., combined application of FYM @ 10 t/ha + poultry manure @ 2.5 t/ha + bio-fertilizers (Rhizobium and Phosphate Solubilizing Bacteria) effectively reduced root knot incidence along with other plant parasitic nematodes at organic farm at ICAR-IIVR, Varanasi. Integrated application of both the antagonists *Pseudomonas fluorescens* and fungal bio-gent, *Trichoderma harzianum* (Seed treatment (10g/kg seed and soil application of 10kg /ha with 1.5 ton FYM) effectively reduced root knot incidence in bitter gourd. Seed treatment with *Pseudomonas fluorescens* 1% W.P. (2 x 10^8 cfu) @ 20g/kg seed and application of 5 tons of FYM enriched with 2.5 kg of each *Paecilomyces lilacinus* (2 x 10^6 cfu/g) + *Pseudomonas fluorescens* (2 x 10^8 cfu/g) have been found highly effective for reducing the root knot nematode *M. incognita* disease by increasing in marketable yield in okra.In Brinjal, root knot nematode incidence has been effectively reduced through integrated approaches such as application of neem cake (1.5 t/ha) before 10 days of transplanting of seedlings + soil application of 10 kg/ha (talc-based formulation of antagonists *Pseudomonas fluorescens* + *Trichoderma harzianum*) enriched with farm yard manure 1.5 t/ha (FYM) at the time of transplanting. In chilli, combined application of talc based formulations such as *Trichoderma viride* (30g/10 m^2), *Pochonia chlamydosporia* (20g/10 m^2) and neem cake (0.15 kg/10 m^2) showed greater plant growth with a significant reduction of root knot nematode (*M. incognita*).

3.6 Physical Methods
3.6.1 Steam sterilization: Generally used in Protected cultivation.

3.6.2 Soil solarization: It is a method of heating moist soil by covering it with 100 gauge Linear Low-Density Polyethylene (LLDPE) clear films were efficient to manage root knot nematode incidence.

3.6.2.1 Principle of Soil Solarization
1 Accumulation of heat due to transmission of short-wave solar radiation and prevents loss of long wave radiation in solarized soil. (2) increase in temperature due to greenhouse effect; (3) soil moisture helps in solarization process by conducting heat energy; (4) increase in microbial and physico-chemical reactions in the soil resulting in to accumulations of gases, some being toxic pathogens and

others acting as a nutrient source or induce resistance to subsequent crop and (5) prolonged exposure to higher temperature resulting in increased mortality of nematodes and also making them susceptible to antagonists. Jain and Gupta (1996) [13] reported that, solarization during May to June months reduced 78% of *M. javanica* soil nematode population. In nursery, soil solarization with clear and black LLDPE (Linear Low-Density Polyethylene) mulch reduced 92.5 and 87.4% of soil population of M. javanica respectively (Jain and Gupta 1997) [14]. Soil solarization through 100 gauze (25 µm) LLDPE clear plastic film for 15 days during May month reduced the root knot disease and weeds by 66% and 93% respectively (Walia *et al*. 2016) [44].

3.7 Chemical Control

Carbofuran 1kg a.i./ha (33 kg/ha) or Apply Nimitz (Fluensulfone 2% G) @ 1 g/plant before planting or Apply Velumprime (Fluopyram 35%EC) @ 0.3 to 0.5 ml per plant before planting.

3.8 Field experiments- Integrated Nematodes management

Shanti *et al*. (2005) [32] reported in Tomato, 56.50 per cent yield was increased and 65.30 per cent reduction of Root knot nematode (*M. incognita*) population in soil, with Solarization of nursery bed + resistant tomato variety (Hisar Lalit) transplanted to main field.

In Chilli 70 per cent Root knot nematode (*M. incognita*) population was reduced in soil and 117 per cent yield was increased over control through, three deep summer ploughings at 15 days interval + neem cake at 20 t/ha + seed treatment (6 g/kg seed) + soil application with a talc formulation of fungal biological control agents (*Pochonia chlamydosporia* (2×107 cfu/g) at 12 kg/ha and Trichoderma viride (2.8×106 cfu/g) at 12 kg ha (Singh *et al*. 2012) [37].

In Brinjal 89.9 per cent Root knot nematode (*M. incognita*) population was reduced in soil and 69.6 per cent yield was increased over control through, Combined application of neem cake (1.5 t/ha) before 10 days of transplanting + soil application of 10 kg/ha talc-based formulation of antagonists Pseudomonas fluorescens + Trichoderma harzianum enriched with farm yard manure 1.5 t/ha (Singh 2013) [38].

In Okra 82.40 per cent Root knot nematode (*M. incognita*) population was reduced in soil and 71 per cent yield was increased over control through, Seed treatment with *Pseudomonas fluorescens* 1% W.P. (2 × 108 cfu) @ 20g/kg seed + application of 5 tons of FYM enriched with 2.5 kg of each *Paecilomyces lilacinus* (2 x 106 cfu/g) and Pseudomonas fluorescens (2 x 108 cfu/g) (Singh *et al*. 2014) [39]

Rao *et al.*, (2104) [29] revealed in Carrot crop, 82.40 per cent Root knot nematode (*M. incognita*) population was reduced in soil and 71 per cent yield was increased over control through, Seed treatment with Bacillus subtilis IIHR BS-2 at 10 ml kg/seed+ soil application of 2 tons/ ha of vermicompost enriched with 5 litres of B. subtilis IIHR BS-2.

4. Conclusion

According to the issues summarized in this review, Integrated nematode management, can generally be considered as the best option for nematode management. Availability of Resistant sources basically cost effective and environmentally benign. However, unlike the use of nematicides that is not dependent on biological specificity of action among nematodes, natural host resistance can be applied only after an investigation of the specificity of the resistance traits and their targets among the wide variety of nematode species and subspecies. Physical methods and cultural methods are pre precautionary measures for management of Root knot nematode (*M. incognita)* in Vegetables. Bio management is effective antagonists in management of Root knot nematodes.

5. References

1. Akhter G, Khan TA. Response of brinjal (*Solanum melongena* L.) varieties for resistance against root-knot nematode, *Meloidogyne incognita* race-1. The Journal of Phytopharmacology. 2018;7(3):222-224.
2. Ali AHH, Hasnin NM, Mahmoud AMA, Kesba HH. Evaluation of Some Tomato Genotypes to *Meloidogyne incognita* Resistance. American-Eurasian Journal of Agricultural and Environmental Sciences. 2015;15(7):1402-1410.
3. Anonymous IIHR, Bengaluru Commercialization of Technologies.
4. Baldicci-Cresp F. *et al*. Maturation of nematode-induced galls in Medicago truncatula is related to water status and primary metabolism modifications. Plant Science. 2015;232:77-85.
5. Chitwood David J. Phytochemical based strategies for nematode control. Annu Rev Phytopathol. 2002;40:221-249.
6. Dhall RK. Breeding for Biotic Stresses Resistance in Vegetable Crops: A Review Research & Reviews: Journal of Crop Science and Technology. 2016;4(1):1-16.
7. Di Vito M, Saccardo F, Zaccheo G. Response of lines of Capsicum spp. to italian populations of four species of Meloidogyne. Nematol. Mediterr. 1991, 19.1.
8. Faraj NM, Qadir RA. Evaluation of four tomato genotypes resistance to root-knot nematode. Kurdistan Journal of Applied Research. 2018;3(1):53-57.
9. Greco N, Esmenjaud D. Management strategies for nematode control in Europe. In: R. Cook & D. J. Hunt (Eds.), Nematology Monographs & Perpectives. Proceedings of the Fourth International Congress of Nematology Spain: Tenerife. The Nederlands: Brill, Leiden. 2004, 33-43.
10. Hackney RW, Dickerson OJ. Marigold, castor bean and chrysanthemum as controls of *Meloidogyne incognita* and Pratylenchus alleni. J Nematol. 1975;7:84-90.
11. Jain RK, Bhatti DS. Population development of rootknot nematode (*Meloidogyne javanica*) and tomato yield as influenced by summer ploughings. Tropical Pest Manage. 1987;33:122-125.
12. Jain RK, Gupta DC. Integrated management of root knot nematode infecting tomato and okra. Indian J Nematol. 1990;20:14-18.
13. Jain RK, Gupta DC. Integrated management of root knot nematode (*Meloidogyne incognita*) through summer ploughing and nematicide in okra. Indian J Nematol. 1996;26:121-122.
14. Jain RK and Gupta DC (1997) Solarization as nursery bed treatment in the management of root knot nematode (*Meloidogyne javanica*) infecting tomato. Indian J Nematol 27: 261-263.
15. Kaur SG, Dhaliwal MS, Cheema DS, Jindal SK and Gaikwad AK. Screening of tomato (*Solanum lycopersicum* L.) germplasm for root-knot nematode resistance using conventional and molecular marker

techniques. Indian J Nematol. 2014;44:56-61.
16. Khan B, Khan AA, Khan MR. Pathogenic variability among isolates of *Meloidogyne javanica* on Capsicum annum. J Nematol. 2003;35:430-432.
17. Khan MR, Jain RK, Ghule TM, Pal S. Root knot Nematodes in India-a comprehensive monograph. All India Coordinated Research Project on Plant Parasitic nematodes with Integrated approach for their Control, Indian Agricultural Research Institute, New Delhi. 2014, pp 1-78.
18. Khan MW. The four major species of root knot nematodes -current status and management approaches. Indian Phytopath. 1997;50:445–457.
19. Khan MW, Ashraf SS, Ansari NA, Khan AA. Incidence and intensity of root-knot on vegetables and identity of species/races of root-knot nematodes in some hilly districts of Uttar Pradesh, India. Indian J Nematol. 1993;23:95-100.
20. Kokalis-Burelle N, Bausher MG, Rosskopf EN. Greenhouse evaluation of Capsicum rootstocks for management *of Meloidogyne incognita* on grafted bell pepper. Nematropica. 2009. 39:121-132
21. Kumar A, Jain RK, Bajaj HK. Occurrence and identification of populations of root-knot nematodes (*Meloidogyne spp.*) from Haryana State. Indian J Nematol. 2008;38:141-145.
22. Kumar V, Matiyar Rahaman Khan, Walia RK. Crop Loss Estimations due to Plant-Parasitic Nematodes in Major Crops in India. Natl. Acad. Sci. Lett. 2020, 1-5.
23. Manjunatha T, Gowda Rai AB, Singh B. Root Knot Nematode: A Threat to Vegetable Production and its Management. IIVR Technical Bulletin No. 76, IIVR, Varanasi, 2017, 32.
24. Naresh P, Kumari Meenu, Acharya GC, Anand Reddy C. Lakshmana Reddy DC. Genetics and molecular markers for resistance to major soil borne pathogens in chilli (*Capsicum annuum* L.). 2019;19(1):101-105.
25. Nayak DK, Pandey R. Screening and evaluation of brinjal varieties /cultivars against root-knot nematode, *Meloidogyne incognita*. International Journal of Advanced Research. 2015;3:476 -479.
26. Nihal R, Guleria KS, Snehalatha N, Pavan T. Evaluation of tomato germplasms for resistance against root knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood race 2. Journal of Entomology and Zoology Studies. 2019;7(1):630-633.
27. Okorley BA, Agyeman C, Amissah N, Nyaku ST. Screening selected solanum plants as potential rootstocks for the management of root-knot nematodes (*Meloidogyne incognita*). International Journal of Agronomy. 2018;1(2018):1-9
28. Ornat C, Sorribas FJ. (n.d.). Integrated Management of Root knot nematodes in Mediterranean Horticultural Crops. Integrated Management and Biocontrol of Vegetable and Grain crops Nematodes, 295-319.
29. Rao MS, Kamalnath M, Umamaheshwari, Rajanikanth R, Prabu P, Priti K. Bacillus subtilis IIHR BS-2 enriched vermicompost controls root knot nematode and soft rot disease complex in carrot. Scientia Horticulturae, 2017;218:56-62.
30. Sasser JN. Identification of root-knot nematodes (*Meloidogyne* spp.) by host reaction. Pl Dis. Reptr 1952;36:84-86.
31. Seid A, Fininsa C, Mekete TM, Decraemer W, Wesemael WML. Resistance screening of breeding lines and commercial tomato cultivars for *Meloidogyne incognita and M. javanica* populations (Nematoda) from Ethiopia. Euphytica. 2017;213(4):97.
32. Shanti Sivakumar A, Devarajan. Management of root knot nematode, *Meloidogyne incognita* in tomato by soil solarization and resistant varieties. Indian J Nematol 2005;39:243-244.
33. Sharma HK, Gill JS. Prevalence of races in root-knot nematode, *Meloidogyne incognita* in India. Indian J Nematol. 1992;22:43-49.
34. Sharma SB, Smith DH, McDonald D. Host races of Meloidogyne javanica, with preliminary evidence that the 'Groundnut race' is widely distributed in India. Int Arachis Newsl. 1995;15:45-46.
35. Siddiqui MA, Alam MM. Integrated management of the root-knot and reniform nematodes with cropping sequences and ploughing. Arch Phytopathol Plant Protect. 2001;33:415-430.
36. Siddiqui Y, *et al*. Histopathological changes induced by *Meloidogyne incognita* in some ornamental plants. Crop Protection, 2014;65:216-220.
37. Singh S. Integrated approach for the management of the root-knot nematode, *Meloidogyne incognita*, on eggplant under field conditions. Nematology. 2013;15:747-757.
38. Singh S, Singh RK. Development of an integrated approach for managing root-knot disease on chili (*Capsicum annum* L.) under field conditions. Russian J Nematol. 2012;20:65-73.
39. Singh S, Singh B, Singh AP. Integrated management of root-knot disease of okra caused by root-knot nematode, *Meloidogyne incognita*. Indian J Nematol. 2014;44:172-178.
40. Sujatha R, Irene VP, Manivannan N, Sivam KM. Screening of Tomato Genotypes for Root Knot Nematode (Meloidogyne incognita Kofoid and White Chit wood). Int. J. Curr. Microbiol. App. Sci. 2017;6(3):1525-1533.
41. Sundharaiya K, Karuthamani M. Evaluation of tomato hybrids for resistance to root knot nematode (*Meloidogyne incognita*). International Journal of Agricultural Sciences. 2018;14(1):76-84.
42. Taylor AL, Sasser JN. Biology, identification and control of root-knot nematodes (*Meloidogyne* species). Raleigh. 1978.
43. Viaene N, Coyne DL, Kerry BR. Biological and cultural management. In: Plant nematology. Perry RN, Moens M (ed) CABI publishing USA, 2006, 346-369.
44. Walia RK, Kumar V, Kumar P. Major nematode problems and technologies generated for their management. Project coordinating cell, ICAR-IARI, New Delhi. 2016;110012:1-34.