# National Symposium

## Nematode: A Friend and Foe of Agri-Horticultural Crops

*(21st - 23rd November, 2013)*

# ABSTRACTS

**Dr. Y.S. Parmar University of Horticulture & Forestry**
**Nauni, Solan-173 230 (H.P.), India**

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# National Symposium

## Nematode: A Friend and Foe of Agri-Horticultural Crops

(*21st - 23rd November, 2013*)

# ABSTRACTS

***Compiled & Edited by:***

Pankaj
Gautam Chawla
Harender Kumar

**Dr. Y.S. Parmar University of Horticulture & Forestry**
**Nauni, Solan-173 230 (H.P.), India**

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# PREFACE

Nematodes friend and foe of agri horticultural crops- a theme of symposium emphasizes the fact that in an agro ecosystem nematode play a dual role. It is beneficial for it acts as a natural enemy against the harmful insect pests of agri crops and thereby helps in maintaining natural balance. Nematode also contributes in maintaining soil health through their excreta as well as feeding on soil fungi and bacteria. This is intriguing and creates interest amongst researchers to find the facts (Session VII). Nematodes are also harmful to agri crops for which new ways and means are explored to manage them so that it does not harm the yields of crops (Session V and VI). Besides latest development in the field of nematode biotech has been included and most interestingly how does hormone interplay in disease expression and resistance are the attraction in the seminar. I am firm supporter for the use of chemical in the management of diseases however it has to be used causiously with full information about the safeguards and the modalities of its uses. (Session IV). Besides there would be a contest for young scientist for the Dr. Raski merit awards. Dr. G.I. D' Souza based on nomination by the executives of the NSI.

Nematological Society of India regularly holds a congregation of nematologist to exchange view points and update themselves. The venue of the symposium is very special to us as nematode problems are rampant in Agri horticultural crops. I am indebted to Hon'ble Vice Chancellor, Prof. V.S. Thakur for granting permission to hold the symposium in this beautiful campus. I am grateful to President NSI, Dr. A.K. Ganguly and Dr. Anil Sirohi Principal Scientist, IARI for their valuable suggestions. Financial support arranged by Prof. Sudershan Ganguly and Dr. M.L. Khan is thankfully acknowledged. Also I am deeply thankful to Dr. M.L. Khan for managing the local affair as a local organizing Secretary during the symposium. Besides, I am highly indebted especially to Dr. Pankaj along with Dr. Gautam Chawla for the book of abstract they come out with and also help rendered by them in the organization of symposia. I am also thankful to all my executive committee team members for supporting the cause.

I also put on record by thanks to sponsoring authorities like ICAR, CSIR, various institutes and universities, sending their representatives/nematologists without which this scientific meeting could not been possible. I also welcome all my colleague come from different parts of country and hope this would be a memorable event for all. I wish them a comfortable stay at the venue.

**(Harender Kumar)**
**Organising Secretary**

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# PROGRAMME

**National Symposium on**
**Nematode : A friend and foe of Agri-horticultural crops**

**Held at Solan (HP)**
***(21-23 November, 2013)***

**21-11-2013**

| | |
|---|---|
| 10.00 – 11.00 AM | **INAUGURAL SESSION** |
| 11.00 – 11.30 AM | LECTURE BY DR H.S. GAUR, VICE CHANCELLOR<br>**RECEIPENT OF DR. D'SOUZA MEMORIAL LECTURE AWARD**<br>(Title: My Tryst with the Science of Nematology, Current Scenario and A Dream into its Future) |
| 11.30 – 12 Noon | **TEA** |
| 12.00 – 1.30 PM | **SESSION –I**<br>**Molecular Approaches and Nano-science in Nematology** |

Chairman: AK Ganguly
Co-Chairman : S. Lingraju
Rapporteur: G.C. Sharma and N. Somasekhar

1. Molecular strategies for nematode management - Anil Sirohi
2. Host delivered RNAi approach for control of root-knot nematodes - P.K. Jain
3. Hormonal crosstalk during plant disease and defense - Ajay Arora
4. Development of nanoparticles for encapsulation of bioactive molecules - NA Shakil
5. Nano-formulations of agrochemicals for crop protection - Jitendra Kumar

| | |
|---|---|
| 1.30 – 2.30 PM | **LUNCH** |
| 2.30 – 3.15 PM | **SESSION –II**<br>**Nematodes under potential climate change** |

Chairman : KR Dabur
Co-Chairman : Rajan
Rapporteur : SR Goel and MR Khan (Aligarh)

1. Nematode problems in agriculture under changing climate - N. Somasekhar
2. Air pollution and nematode diseases of crops - MR Khan (Aligarh)
3. Role of nematode in soil sustenance - S. Lingaraju
4. Climate change and Nematode diseases - H. Pathak

3.15 – 3.30 PM **TEA**

3.30- 4.30 PM **POSTER SESSION**

4.30 – 5.30 PM **SESSION – III**
**Use of chemicals for nematode control**

Chairman: Akhtar Haseeb
Co-Chairman : AK Singh
Rapporteur : AD Patel and MR Khan (Kalyani)

1. Pesticide scenario and dynamics in the environment - V.T. Gajbhiye
2. Novel nematocidal molecules - R.L. Gupta
3. Biodegradation and non-target effects of pesticides - H.K. Sharma

**5.30 – 6.45 PM CULTURAL PROGRAMME**

**7.00 PM Onwards DINNER (at Himani, Solan)**

**22-11-2013**

9.30 – 10.00 AM **SESSION –IV**
**Nematode biosystematics and taxonomy**

Chairman: HK Bajaj
Co-Chairman : MA Siddiqui
Rapporteur: SA Tiyagi and Vishal S. Somvanshi

1. Bioinformatics and digital technology for nematode diagnostics - Gautam Chawla
2. A primer on molecular taxonomy - Vishal S. Somvanshi
3. Expedition to Antartica : A nematological perspective - VV Gantait

10.00 – 11.15 AM **SESSION –V**
**Nematode problems in different crops**

Chairman: K.S. Varaprasad
Co-Chairman: HR Patel
Rapporteur: RS Kanwar and Puja Ohri

1. Nematode problems in oilseed crops and their management - K.S. Varaprasad
2. Nematode problems in horticultural crops and forest trees - M.L. Khan
3. Economic significance of PPN in pulses and their management - Bansa Singh
4. Nematode management in wheat - A.K. Singh
5. Nematodes play a dual role in banana cultivation in India - P. Sundararaju
6. Nematode problems of bidi tobacco and their eco-friendly management - H.R. Patel

11.15 – 11.30 AM **TEA**

11.30 – 12.30 PM **SESSION –VI**
**Management strategies for nematodes**

Chairman: RK Jain
Co-Chairman: AU Siddiqui
Rapporteur: Bansa Singh and Anju S Khanna

1. AICRP (Nematodes) – Its role in management of plant parasitic nematodes and roadmap ahead - RK Jain
2. Importance of pest risk analysis for nematode in trade - Rajan
3. Management of Nematodes under rice-wheat cropping system: Issues and challenges - Pankaj
4. Nematode problems of cotton and their management in India - KK Verma
5. Strategies on mass awareness on nematode problems in developing countries such as India - MR Khan (Kalyani)

12.30 – 1.30 PM **LUNCH**

1.30 – 7.00 PM **FIELD VISIT**

**7.00 PM ONWARDS DINNER (At Himani, Solan)**

**23-11-2013**

9.30 – 11.00 AM **Prof. D.J. Raski Award Presentations**

11.00 – 11.15 AM **SESSION –VII**
**Entomopathogenic nematodes for insect-pest management**

Chairman: P Sundararaju
Co-Chairman: Sharad Mohan
Rapporteur: Gautam Chawla and C. Sankaranarayanan

1. Mass production of entomopathogenic nematodes: The need to forge ahead - Sharad Mohan
2. Status of nematodes involving insects and plants in their - H.K. Bajaj
   Life histories in India
3. Scope of Teaching Nematology at UG level in SAUs - R. K. Walia

11.15 AM– 12.15 PM **VALIDICTORY FUNCTION**

12.15 – 1.15 PM **GB Meeting**

# ORGANIZING COMMITTEE

| | | | |
|---|---|---|---|
| 1. | Dr. Harender Kumar | : | National Organizing Convenor |
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| 3. | Dr. Pankaj | : | Co-Convener |
| 4. | Dr. Gautam Chawla | : | Co-Convener |
| 5. | M.L. Khan | : | Local Organizing Secretary |

# LIST OF DIFFERENT COMMITTEES

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| 3. Dr. H. K. Sharma | : | Member |
| 4. Dr. R. P. S. Chandel | : | Member |

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| 3. Dr. Sapna Katna | : | Member |
| 4. Dr. (Ms.) Anju Dhoman | : | Member |
| 5. Mr. Jagan Lal | | |
| 6. Mr. Anil (NSI) | | |

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| 3. Dr. Anil Sood | : | Member |
| 4. Dr. R. S. Rana | : | Member |

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| 4. Dr. S. K. Patyal | : | Member |
| 5. Sh. Gobind Ram Choudhary | : | Member |

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| 2. Dr. H. K. Sharma | : | Member |
| 3. Dr. K. C. Sharma | : | Member |
| 4. Dr. J. K. Dubey | : | Member |

## 8. DECORATION COMMITTEE

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| 1. Dr. Y.C.Gupta | : | Convener |
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| 3. Dr. Sapna Katna | : | Member |
| 4. Dr. Sita Ram Dhiman | : | Member |
| 5. Mr. Chaman Lal | : | Member |

## 9. SEMINAR HALL COMMITTEE

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| 3. Dr. S. C. Verma | : | Member |

## 10. PRESS AND PUBLICITY COMMITTEE

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| 1. Dr. Rakesh Gupta | : | Convener |
| 2. Dr. Mohinder Singh | : | Member |
| 3. Dr. G. C. Sharma | : | Member |
| 4. Dr. Anil Sood | : | Member |
| 5. Mr. P. R. Bhardwaj, PRO | : | Member |

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|---|---|---|
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| 2. Dr. Sunita Chandel | : | Member |
| 3. Dr. (Ms.) Santosh Kumari | : | Member |
| 4. Dr. Sapna Katna | : | Member |

## 12. FIELD TOUR COMMITTEE

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|---|---|---|
| 1. Dr. K. C. Sharma | : | Convener |
| 2. Dr. (Mrs) Usha Chouhan | : | Member |
| 3. Dr. H. K.Sharma | : | Member |

# Lead Talks

# Molecular Strategies for Nematode Management

Anil Sirohi, Pankaj and P.K. Jain[1]

*Division of Nematology, Indian Agricultural Research Institute, New Delhi-110012, India*
*[1]NRCPB, New Delhi-110012, India*
*E-mail: anilsirohi@yahoo.com

Nematodesdwelling in the soil feed either on bacteria, fungi, nematodes, insects or on plant roots. The plant parasitic nematodes are one of the major constraints in obtaining good crop yield and cause loss of more the $100 billion to crops worldwide. Nematode parasitism of plants is one of the most intricate interactions and is yet to be fully understood. Nematodes depending on their species show complex and dynamic interactions like, hatching stimuli, attraction to the host, penetration and migration in the host tissue, recognition of feeding sites, modification of feeding cells, etc. The nematode feeding on a host may induce/ increase/ decrease or inhibit production of certain molecules depending on a favourable or unfavorable interaction of the host, indicating a change in the expression of genes at the site of feeding or else where. Formation of specialized feeding cells in the host by endoparasitic nematodes (syncytia – cyst nematodes; giant cells – root-knot nematodes, nurse cells – citrus nematodes) is a manifestation of parasitism. Understanding of these interactions is helping molecular biologists design new and novel strategies for their management. Several resistance genes against different nematodes have been cloned from plants and will help in engineering resistance across crop species. Molecular strategies for managing specific nematode species (RNAi based) orbroad range (proteinase inhibitor) of plant parasitic nematodes have been developed by researchers. New information being generated through genomics, transcriptomics and proteomics is helping us understand the convoluted nematode –plant parasitism. Identity of the genes involved in parasitism, and their functions or molecular signals associated with physiological, morphological or histopathological changes occurring in the host offer good avenues for designing molecular nematode management strategies. There seems to be an increasingly a major role of peptide signaling in nematode parasitism of plants. The identified peptides show similarity to the plant CLAVATA3/ESR (CLE) peptides though there may be more,having homology with other classes of plant peptide hormones. Detailed understanding of the plant nematode interactions will make available numerous novel targets for engineering nematode management strategies.

# Host Delivered RNAi Approach for Control of Root-Knot Nematodes

P.K. Jain[1], Anil Kumar[1], Gurudiksha Verma[1], R. Srinivasan[1] & Anil Sirohi[2]

*[1]NRC on Plant Biotechnology, Pusa Campus, New Delhi-110012, India*
*[2]Division of Nematology, Indian Agricultural Research Institute, New Delhi-110012, India*

Root-knot nematodes are included in the genus *Meloidogyne* and are commonly called as sedentary parasites of plants (*Meloidogyne* = apple-shaped female). Approx.100 species of *Meloidogyne* are distributed worldwide with a wide host range. The most widespread species are *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. chitwoodi* and *M. graminicola.* Nematodes account for an estimated 14% of all worldwide plant losses, which translates in $100 billion dollars annually. Root knot nematodes are the most destructive nematode pathogens producing some of the most dramatic symptoms and can substantially reduce crop yields. In past few years several strategies have been used to control nematode infection including cultural control, chemical control, biological controletc. In tomato, the *Mi* gene confers genetic resistance to root knot nematodes but this resistance has been reported to break down under certain conditions. Despite their effectiveness against nematodes each control technique has its own drawback and hence requires a novel approach. RNAinterference (RNAi) is a process, where dsRNA corresponding to particular gene, is processed by Dicer to generate siRNA. These siRNA further activates a silencing complex (RISC) which recognizes target mRNA and later degrades it. In 1998, Fire et.al. reported silencing in *C.elegans* using dsRNA, and present it as a potential tool to study gene function by suppressing its expression. RNAi mechanism can be used against nematode infection through a process called host- delivered RNAi. In host- delivered RNAi, dsRNA corresponding to a specific nematode gene is expressed through a host plant, mediating siRNA production. RNAi commences on the basis of homology between dsRNA and target mRNA upon nematode feeding. The target gene should be chosen, on the basis of function, role in development, neurotransmission, nematode effectors and other genes involve in motility and feeding. There are several reports depicting success of RNAi against root knot nematode infection. Gene silencing of dual oxidase gene of *M.incognita*led to 70% reduction in number of eggs. In tobacco, introduction of dsRNA against Splicing factor and Integrase genes of *M. incognita*, resulted in significant reduction (70%) in knot formation as well as in number of females (Yadav et al., 2006). In 2006 Hussey et al., used *in vivo* and *in vitro* techniques to study the transcript level of 16D10 dsRNA of *M.incognita* and observed reduced nematode infection in

Arabidopsis plants. In a different report,introduction of dsRNA for MSP and TP genes of *M.incognita* showed reduction in galls i.e. 94% and 92%, respectively in soybean roots.The reduction in reproduction and motility and fall in transcript level of Rpn7 gene of *M. incognita* in tomato hairy roots was reported by Niu et al., 2012. In Arabidopsis introduction of dsRNA corresponding to8D05 (a parasitism gene) of *M. incognita,* resulted in decrease in gall number (Xue et al., 2013). In a recent report RNAi against Calreticulin gene of *M. incognita*, led to sharp decrease in gall number (Jaouannet et al., 2013). Our group has successfully used a number of secretory gland genes to induce root knot nematode resistance in Arabidopsis plants using HD-RNAi.

# Hormonal Crosstalk During Plant Disease and Defense

Ajay Arora & V.P. Singh

*Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi-110 012, India*
E-mail: romiarora@yahoo.com; ajayarora@iari.res.in

As sessile organisms, plants have to be able to adapt to a continuously changing environment. Plants that perceive some of these changes as stress signals activate signaling pathways to modulate their development and to enable them to survive. Plants are continuously challenged by a variety of abiotic and biotic cues. To deter feeding insects, nematodes and fungal and bacterial pathogens, plants have evolved a plethora of defence strategies. The perception of stress triggers the activation of signal transduction cascades that interact with the baseline pathways transduced by phytohormones. The convergence points among hormone signal transduction cascades are considered cross-talk, and together they form a signaling network. Through this mechanism, hormones interact by activating either a common second messenger or a phosphorylation cascade.

Until recently, most studies on the role of hormones in plant-pathogen interactions focused on salicylic acid, jasmonic acid, and ethylene. It is now clear that pathogen-induced modulation of signaling via other hormones contributes to virulence. A picture is emerging of complex crosstalk and induced hormonal changes that modulate disease and resistance, with outcomes dependent on pathogen lifestyles and the genetic constitution of the host. Recent progress has revealed intriguing similarities between hormone signaling mechanisms, with gene induction responses often achieved by derepression. We will discuss advances and updating on classical defense hormones such as salicylic acid, jasmonic acid and ethylene and the roles of auxin, abscisic acid, cytokinins, and brassinosteroids in molding plant-pathogen interactions. The intricate interactions between hormones during plant defense are extremely complex, and difficult to unravel, but interesting insights and observations have nevertheless emerged. Our endeavour to distill current literature on the role of specific hormones in plant defense and highlight how other hormones may collaborate in influencing the pathological outcome. Efforts will be made to correlate an emerging theme that positive and negative regulators of these disparate hormone signaling pathways are crucial regulatory targets of hormonal crosstalk in disease and defense.

# Development of Nanoparticles for Encapsulation of Bioactive Molecules

N.A. Shakil & Jitendra Kumar

*Division of Agricultural Chemicals, Indian Agricultural Research Institute (IARI), New Delhi – 110 012 (INDIA)*
Email: iamshakil@gmail.com

Extensive use of pesticides has ensured higher level of production in modern agriculture but at the same time has also posed a potential threat to environment and also to human and plant health. The researchers engaged in plant protection have, therefore, started looking for other ecologically friendly, non-polluting means for the control of pests and diseases. In this context, the use of amphiphilic polymers as nanoparticles can be handy as it will help in restricting the use of pesticides repeatedly by employing the pesticides in slow release mode.

Nanotechnology has the potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients etc. Smart sensors and smart delivery systems will help the agricultural industry combat various crop pathogens. In the near future nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used.

Our group has been actively involved in the synthesis of environment friendly amphiphilic polymers having the tendency to aggregate in aqueous medium into nanospheres. This approach is based on the formation of nano micelles by the self assembly of amphiphilic copolymers in aqueous media. Due to high solubilisation power and low critical micelle concentration (CMC) value of amphiphilic polymers, they have been used in drug delivery for giving more stable formulations. The nanoformulated drugs have better target site action with the formation of water soluble nano-scaled micelles.

The lead talk will focus on the synthesis of poly(ethylene glycol) based polymeric materials utilizing different linker molecules to be used for encapsulation of different bioactive products. The details of the synthesis and encapsulation of bioactive products will be presented during the symposium.

# Nano Formulations of Agrochemicals for Crop Protection

Jitendra Kumar & N.A. Shakil

*Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi-110012, India*
E-mail: jitendrakumar7@yahoo.com

Nanotechnology is emerging as the technological platform for the next wave of transformation of Indian agriculture. It has the potential to revolutionize the agricultural and food industry with new tools for the treatment of pests and disease, rapid disease detection, smart delivery of pesticides and nutrients which will enhance the ability of plants to absorb necessary elements. Proponents argue that pesticides application using nanotechnology promise to efficient use of pesticide, due to their more precise and targeted nature. As such, nanotechnology is frequently portrayed as introducing environment benefits.

To make the delivery systems more versatile, researchers the world over have attempted to synthesize copolymers based on PEGs in nano range by attaching a hydrophobic chain to the PEG unit to increase its versatility as it can then encapsulate not just hydrophilic moiety but also the hydrophobic one. Such amphiphilic block copolymers have been investigated extensively for their unique self-organization characteristics. The micellar characteristics of amphiphilic block copolymers depend on the nature of each block and the surface properties of self organized micelles are highly dependent on the structures of the hydrophilic block. These nano-containers are capable of encapsulating hydrophobic pesticide in their core, thus improving the it's water solubility. These products also provide sustained release of pesticides therefore has been used develop controlled release (CR) formulations.

CR products will increase pest control efficiently through utilization of reduced quantity of toxicant, reduced toxicity to non-targeted organism, reduced leaching and extended activity. These formulations will provide economic benefits to the farmers without deteriorating the environment health.

The present paper focuses new area of application of nano-science and its advantages in Crop Protection Products (CPPs) delivery systems for maximizing gains in crop productivity.

# Nematode Problems in Agriculture under Changing Climate

N. Somasekhar

*Directorate of Rice Research, Rajendranagar, Hyderabad – 500 030, A.P., India*

Plant parasitic nematodes are one of the important problems in crop production worldwide. Climate change due to increased emission of greenhouse gases is posing a serious challenge to sustainability of agricultural production due to its influence over biotic and abiotic factors influencing plant growth and their interactions with each other. Global warming resulting in elevated carbon dioxide and temperature in the atmosphere may affect plant parasitic nematodes directly or indirectly through their host plant. Available information on effect of global warming on plant pathogenic nematodes though limited indicates that plant parasitic nematodes show a neutral or positive response to $CO_2$ enrichment effects. Studies have also demonstrated that the geographical distribution range of some plant parasitic nematode species may expand with global warming spreading nematode problems to newer areas. These findings underline the importance of understanding the impact of climate change on soil nematodes and its implications to agricultural systems while developing mitigation and adaptation strategies to address impact of climate change on agriculture.

# Air Pollution and Nematode Diseases of Crops

Mujeebur Rahman Khan

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Fossil fuel combustion is a major cause of generation of phytotoxic air pollutants such as $CO_x$, $SO_2$, $NO_x$, $O_3$ etc., and has resulted in environmental contamination and subsequently the climatic change. Development of plant diseases depends largely on the environment prevailing around the host and pathogen, and a change in the constituents may influence host susceptibility and consequently host-parasite relationship. Air pollutants such as $SO_2$, $O_3$ and acid rain injure the plant tissue directly. However, phytonematodes being mostly soil inhabitants are influenced by air pollutants indirectly, but foliar nematodes may be exposed to the pollutants, are likely to be influenced directly. Hence, air pollutants may affect the severity of plant diseases depending on the kind of nematode parasite involved. $SO_2$ and $O_3$ at concentrations ranging 50-100 ppb enhanced the infection and reproduction of foliar nematodes like *Aphelenchoides fragariae, A. ritzemabosi* and *Anguina tritici*, but higher concentrations proved inhibitory to these nematodes. Air pollutants can also influence the infection of ecto and endo-parasitic nematodes attacking underground parts. Higher concentration of $SO_2$ and $O_3$ (>250 ppb) inhibited the reproduction and development of *Paratrichodorous minor* and *Belonolaimus longicaudatus*, but stimulated the infection of *Pratylenchus penetrans* on tomato. Root-knot severity (galling) and reproduction (egg mass and fecundity) of *Meloidogyne* spp. have been found significantly greater on tomato, tobacco and celery plants exposed to $SO_2$ and $O_3$ at concentrations below 100 ppb, but higher concentration suppressed the nematode. Other pollutants especially acid rains have also been found to influence the pathogenicity of phytonematode. Infection of plants with endoparasitic nematodes may also enhance sensitivity of plants to low concentrations of gaseous pollutants which are considered relatively safer to green plants.

# Role of Nematodes in Soil Health Sustenance

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Nematodes are abundant and diverse in a particular agricultural production system: one cubic centimeter of soil could contain 45 individuals representing 19 species. Likewise, a square meter area of surface soil could yield 5 million nematodes belonging to 90 species. Also, they are ubiquitous and functionally diverse (bacterial feeders, fungal feeders, predators, plant feeders and omnivores). Nematode communities are usually poly-specific that represent various trophic levels in a food web. The numerical proportion of these forementioned trophic groups and nematode species composition reflect the physico-chemical and biological characteristics of the soil. Thus, they have been used as indicators of soil ecosystem condition. Studies which intersect nema community analysis and ecosystem functions/processes are proving to be very fruitful.

Through their efforts in increasing the availability of plant nutrients, nematodes make positive contributions to soil ecosystem processes. Nematodes may affect nutrient mineralization both directly, from their excretion of ingested nutrients that are not used in tissue building, and indirectly, from modification of the microbial community, accelerated turn-over of microbial cells, inoculation of new substrates with microorganisms and leakage into rhizosphere of nutrients from feeding sites. Under field conditions, bacterivores and predatory nematodes are estimated to contribute 8 to 19% of nitrogen mineralization in conventional and integrated farming systems.

The relationships between soil characteristics and nematode abundance have been used to develop soil assessment criteria. As such in agricultural fields, the abundance and diversity of nematodes have been used to infer soil process rates, soil functions and effects of disturbance on soil fauna. Cropping systems/patterns and soil tillage cause profound changes in populations of soil organisms. In fact, reduced tillage practices are used to minimize soil disturbance leading mainly to improved soil structure, positive effects on soil fauna and increased water storage. Cropping systems/patterns and soil management could have a direct bearing on soil carbon and other soil properties. Carbon accumulation and storage are higher in continuous cropping patterns with minimum tillage. The declining trends in the carrying capacity of Indian soils, especially alfisols is mainly due to decreased biological fertility of the soil stemming from the adoption of modern agricultural

practices. Conservation of carbon pool, restoration and conservation of soil biota are important towards improving soil health and sustainability. There is a need to explore our regions for native soil fauna to conserve them with reduced human interference for maintaining soil fertility and productivity. The challenge for Indian agriculture is to balance the demands on soils to optimize soil management measures. Such studies are very few and far between, generally.

The results of a three-year study in two agro-ecological zones (of the region) involving two major soil types (vertisols, alfisols) harbouring the nematode communities/ assemblages as influenced by a couple of dominant cropping systems will be discussed during the talk. Included also will be the relations between components of the nematodes assemblages and the soil quality system milieu in the light of different systems of manure/ fertilizer applications.

# Climate Change and Nematode Diseases

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The Fifth Assessment Report of the Working Group I of the Inter-Governmental Panel on Climate Change (IPCC), published on September 2013 reiterated that the warming of the climate system is unequivocal. Anthropogenic influence on the climate system is evident from the increasing greenhouse gas concentrations in the atmosphere and positive radiative forcing. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen and the concentrations of greenhouse gases have increased. Global climate change will have considerable impacts on the crops, soils, livestock and pests.

Climate change will potentially affect the pest-host relationship in one or more ways: by affecting the pest population; host population and the pest-host interactions. Climate change would cause spread and establishment of pests to new areas. For example, virus transmitted nematodes like *Xiphinema index* and *Longidorus macrosoma*, which were earlier found in northern Europe, have now spread to southern Europe due to increase in temperature. Moreover, at higher temperature the nematodes will be able to complete more number of generations per year because of higher metabolic rate and increased fecundity especially in case of polygamous nematodes. Increase in temperature may alter host physiology and resistance. Conversely, in some forage species, there is increased lignification at higher temperatures and this can enhance the level of host resistance to pathogens. Impacts would, therefore, depend on the nature of the interactions in the pathosystem and mechanism of resistance. The most damaging of nematode, *Meloidogyne* spp., for example, are generally favored by warm to tropical conditions. The predicted global warming would be sufficient to affect the spread of the highly aggressive root-knot species *Meloidogyne javanica* and *M. arenaria* into regions presently unsuitable for these pathogens in many countries. Such a development would require new initiatives in the development of durable heat-tolerant nematode resistance in most crop plants and shifts in crop cultivars.

Some of the potential adaptation strategies for nematode management in relation to climate change could be (1) developing cultivars resistance to pests and diseases; (2) integrated pest management with more emphasis on biological control and

changes in cultural practices, (3) pest forecasting using recent tools such as simulation modelling, (4) alternative production techniques and crops, as well as locations, that are resistant to infestations and other risks.

Recent developments in experimental and modeling techniques offer considerable promise for developing an improved capability for climate change impact assessment and mitigation. Intensified research on climate change-related issues could result in improved understanding and management of plant diseases in the face of current and future climate extremes. The issue of climate change should be considered during the development of sustainable nematode and crop management strategies.

# Novel Nematocidal Molecules

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Plant-parasitic nematodes are responsible for substantial economic losses to agricultural crops. The elimination of nematodes from some crops is very essential for certain export requirements, particularly of high-value horticultural products. Chemical treatment with fumigants or nematicides may be the only technique available, and from the plant quarantine standpoint it is important that their use is retained. Nematicides currently available on world markets include some fumigants and non-fumigant nematicides i.e. organophosphates and carbamates. Nematode control however has become difficult owing to the withdrawal or restricted use of effective soil fumigants, especially methyl bromide and some non-fumigant nematicides. Newer and safer molecules are therefore required for an effective nematode control. Although the established nematicide market is estimated at around US$ 1bn pa, the development of new nematicides is not deemed profitable by many agrochemical companies because the nematicide market is relatively small compared with herbicides, fungicides and insecticides. Research laboratories however are making all out efforts to discover new nematicide molecules. As a result some synthetic molecules belonging to 1,2,4-triazole, Schiff bases, organophosphorus, alkoxycoumarins, dimethyl disulphide and fluroalkenyl groups are being identified as potential nematicidal compounds. Essential oils from various plants have shown promise as potential source for new nematicides. Antinematodal compounds have also been isolated from various fungi and other biocontrol agents. Some of these developments towards development of newer molecules for nematode management will be discussed.

# Biodegradation and Non Target Effects of Pesticides

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When pesticide enter into the soil environment it is acted upon by number of abiotic and abiotic factors beside pesticide also affect them simultaneously. The pesticide is applied for a specific purposes however their efficacy is affected thereof. Beside, pesticide also have inadvertent effect on the other non target species that can ultimately affect the functionalities and the services provided by them to the ecosystem. That is dangerous as it may affect the balance of ecosystem which can lead to development of other pest problems. Pest resurgence are the aftereffect of pesticide which can lead to failure of crops. Thus, it has more then one effects that can be counter productive on one hand and has advantages on other hand. The impact of pesticide on the microorganism in general can be under stood in term of their respiration and the biomass beside having their effect on the enzymatic activities like dehydrogenises, urease, soil nitrogen transformation rate, number and types of soil microbs. The persistence of pesticide is important for its efficacy which increases with dose. Pesticides are mainly degraded by the action of microbes in soil. Some pesticide degrade faster by the repeat application due to enhanced biodegradation which then be not effective against target pest, the pest related damage to crop would be more, at the same time it will not contaminate environment. Cross enhance also happens as there is increase degradation of pesticide after the pre-application of one pesticides.

*Arthrobacter* sp., exhibited an exceptional capacity to completely mineralize carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl N-methylcarbamate). A fungus capable of utilizing carbofuran as a sole carbon and energy source was characterized and identified as being a member of the genus *Gliocladium* (Lc); it exhibits the highest carbofuran degrading ability but did not degrade the other organophosphorus nematicides. Pseudomonas and Flavobacterium gram negative were oxidase- and catalase-positive rods degrade carbofuran for carbon and nitrogen source. Some other like *Pseudomonas, Cupriavidus, Planococcus, Marinococcus, Sporosarcina, Bacillus, Enterococcus and Micrococcus also* degrade carbofuran can be utilized for clean up the environment.

Application of the insecticides also stimulate the population of bacteria, actinomycetes and fungi in the rhizosphere soils, and the stimulation was more pronounced with phorate as compared to carbofuran.

Phorate and carbofuran did not have marked effect on the numbers of *Streptomyces* and Nocardia in the rhizosphere soils. However, the growth of *Bacillus, Escherichia, Flavobacterium, Micromonospora, Penicillium, Aspergillus and Trichoderma* with

phorate and that of *Bacillus, Corynebacterium, Flavobacterium, Aspergillus and Phytophthora* with carbofuran were increased. On the other hand, the numbers of Staphylococcus, Micrococcus, Fusarium, Humicola and Rhizopus under phorate and *Pseudomonas, Staphylococcus, Micrococcus, Klebsiella, Fusarium, Humicola and Rhizopus* under carbofuran were inhibited. Bacterial population also get the boost following the application of pesticides like organophosphates and hydrocarbons however there is decrease in number of heterotrophic bacteria following application pesticides like fenitrothion. With regards to soil fungi pesticide may not have negative impacts while their growth is stimulated e.g phorate and hydrocarbons. The structural and functional diversity is affected with the use of pesticides however number of microorganism is not affected, i.e growth of one is affected while growth of other is stimulated. Parathion a important pesticide is degraded faster with *flavobacterium, Penicillium, Pseudomonas and xanthomonas.* Carbaryl is is hydrolysed by *Trichoderma sp, Aspergillus mucor* and rhizopus. *Fusarium solani* and gram + rod degrade less. Phorate reduce *Rhizoctonia* damage while expose to pythium attack. Phosphordithiote fungicide also kill nematodes reduce growth of Sclerotia but not of Trichoderma or Rhizopus and Aspergillus. PCNB and Ethazole reduce population of nematode as well. Like wise DBCP affect the several fungi growth. Benzimidazole also have antihelminth properties. Similarly thicarbamate herbicides have negative effect on the nematodes. The use of formaldehyde a biocide enhances the activity of *Trichoderma*.

Carbofuran and phorate have failed many times to control the target pest. This may be due to resistance development and lack of persistence and later was observed to play a role to explain the results. The use of carbofuran repeatedly lead this situation compared to one where this was not used repeatedly and after studying the persistence which was merely 30 days which is much less to once applied fields. Long persistence in sterilized soil point out this also. This has been proved many times and 90% chemical disappear within a days in the repeat application. Carbonyl actually condition the soil for enhance biodegradation while organophosphate less support cross enhancement. The analysis of enzymes can predict the enhancing effect or not. Manu ring of soil can reduce microbial degradation. Use of low rate of pesticide can avoid enhanced degradation. Rotation of pesticide of different class can be useful to avoid enhanced degradation. There are also inhibitors and extenders to counter the enhancing degradation phenomenon. Controlled release formulation can also help in this situation by preventing the availability of chemicals to microbes.

It is also known that enhancing effect does happen at a conc. of chemicals, avoiding that conc. can also prevent microbe enrichment.

In order to get the real benefit of pesticide it is proper to use them in scientific manner by having full picture of the environment that also have long term impact and safe to environment as well. Besides it could be used the under precision farming by foresaid analysis.

# Bioinformatics and Digital Technology for Nematode Diagnostics

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Many pests and diseases of agricultural crops cause huge losses in India. Nematodes are one of the important agricultural pests. Losses due to nematodes are increasing with advancements in cropping methods (protected cultivation) and new cropping systems being adopted. Globalization has resulted in frequent movements of agricultural commodities thus requiring regulatory support totally dependent on strong diagnostic capabilities. Also to meet several other needs of survey, surveillance and management more diagnostic capacity is required. Though advances have been made in molecular taxonomy/diagnosis, diagnostics by and large is based on morphology/morphometric. On the other hand there is a decline in number of taxonomists. Experienced experts (taxonomists) are superannuating. There is also a loss of teaching capacity in educational institutions. Students are not attracted to morphology based identification. Few remaining taxonomists scattered in different institutions have limited area of interest and do not like to work for identification. If they do, they seek ways to operate within the realm of their own convenience. Thus to address these problems, a system is needed wherein we are able to improve diagnostic service and change the way in which people provide, access and share information.

Remote Diagnostics are being widely used in medical and human health services (Riley and Cowie, 2009; Henricks, 2012) wherein through 3D visual-cloud based plat form opinions of experts are sought (Philips, 2013) for precise decisions. Motorised microscopes with precise controls can help create virtual specimens/ slides and carry out morphological and morphometric analysis (Campbell et al., 2013; Gheraadi and Bevilacqua, 2013). Remote microscopy is being explored to improve diagnostic capacity and biosecurity (Thompson et al., 2009). Electronic data capture and Internet-enabled timely support and reviews (Reznik, 2013) are being used extensively in other areas and have a role to play in Nematology. As no nation can afford to replicate human resources required for comprehensive diagnostic needs of different institutions, these technology offer a promise for providing services in this underserved area.

The genomes of living organisms are analogous to barcodes. Segments of genome that vary between taxon and are conserved within taxon are useful for identification. Nuclear internal transcribed spacer (ITS) and CO1/COX1 show promise in species identification. Comparison of even small segments of genomic regions between taxons is a huge task requiring a catalogue/database and the methods to align these segments for drawing logical conclusions. Bioinformatics is Merger of biology, computer science and information technology. It is the electronic infrastructure of molecular biology for dry laboratory computation that helps in deciphering information contained in biological sequences. Genetic difference between sequences is a function of time since separation and is useful in understanding the phylogeny.

Morphological and Molecular approach in isolation may fail to serve all the requirements of taxonomy. These methods together could serve the broader needs of taxonomists. Bioinformatics tools store and compare information restricted to nucleotide and amino acid sequences. NemATOL is an open portal for morphological, molecular and ecological data made available for all research on nematode phylogeny and biodiversity.

Morphological and morphometrically- precise digital repository, of nematode species incorporating information on the diagnostic process followed by experts, on a central portal is required for sharing, dissemination and aiding diagnostics. Tele-diagnostics support could be useful meet diagnostics needs. The talk covers some of the issues and solutions to nematode diagnostics.

# A Primer on Molecular Nematode Taxonomy

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Traditional nematode taxonomy is based on the analysis of morphometrical features of nematodes. It is laborious, time consuming and difficult. Lack of a readily accessible global electronic database on morphometrical features of nematodes is a big disadvantage for researchers using morphometrical features for nematode taxonomy. It takes approximately 3-4 months of research work to describe a new species of nematode or ascertain the accurate taxonomic identity of the nematode species using traditional taxonomy.More often than not it is found that the nematode had already been described elsewhere leading to waste of time and resources.Molecular methods depend on study of a genetic marker to ascertain the identity of a nematode species. Different researchers identified and used many different molecular markers for nematode taxonomy. Most of these markers are housekeeping genes such as different parts of ribosomal genes (e.g. 28s rDNA (Long Sub Unit (LSU) rDNA, 18s rDNA (Small Sub Unit (SSU) rDNA, Internal Transcriber Space region, D2/D3 regions of LSU) or mitochondrial genes (e.g. Cytochrome oxidase subunit 1). The purpose of the study i.e. survey, description of species or elucidation of phylogenetic relationships within a group, together with the rate of evolution in these marker genes determine the selection and use of a genetic marker(s) in a study. Availability of global DNA sequence databases make molecular methods a great tool for rapid and accurate identification of nematodes and avoid duplication of nematode taxonomic research work. Molecular tools facilitate rapid discovery of new nematode species and support traditional nematode taxonomy. This talk will focus on the basics of molecular nematode taxonomy and relevance of molecular methods in modern nematode taxonomy.

# Expedition to Antarctica: A Nematological Perspective

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Antarctica is the southernmost continent of the earth surrounded by the Southern Ocean, comprising of the Atlantic Ocean, the Indian Ocean and the Pacific Ocean. It surrounds the Geographic South Pole. It is the 5th largest continent of the earth with a land area of about 14 million sq. km., about double the size of Australia and equal to China and India combined together. The continent is almost circular in shape with an arm-the Antarctic Peninsula, protruding northward. It comprises of two distinct constituents: East Antarctica and West Antarctica, divided by the trans-Antarctic Mountain chain. It is the white continent of the earth, 98% of its land area is covered by ice and remaining 2% covered by rocks and lakes. It is the highest continent with an average elevation of about 2300 meters above sea level; the coldest and windiest continent, technically a desert with practically no rainfall. It is a unique land with 6 months continuous day during summer from October to March and 6 months of continuous night during winter from April to September. It is a continent for all but for none without any permanent inhabitants; a place of peace, tranquility and science. It controls the key of global climate pattern and virtual store house of information. Krill, Albatross, Penguin, Skua, Seal etc. are the curious inhabitants of the continent.

Over 150 years of Antarctic biological research has produced more than 2000 publications in the field of taxonomy, biology, physiology and ecology of different groups of invertebrate fauna of marine, terrestrial and lacustrine fauna. Considerable data exist on the distribution of the terrestrial invertebrate taxa from West Antarctica, including the Antarctic Peninsula, South Orkney Islands and South Shetland Islands, where many biological collections have been made over the last 100 years. Relatively little is known about the species composition of the East Antarctic fauna, Schirmacher Oasis in particular. Less than 2% of land area of the continent is ice-free and the Schirmacher Oasis is one of the largest areas of these ice-free regions. The scientific exploration in Schirmacher Oasis was started in 1965 with the publication of Bardin and Leflat on the chemical characteristics of the lake water system. Ingole and Parulekar (1987) reported that in the Schirmacher Oasis of East Antarctica, the nematodes occupy the dominant position being 22.13% amongst the seven micro faunal groups.

Terrestrial nematodes were first described from the continental Antarctic zone and also from the sub Antarctic zone by de Mann (1904). Maslen (1979) described 11 nematode species under 6 genera from the Antarctica. He also reported the distribution of nematodes in three zones of Antarctica, viz. sub-Antarctic (22 species), maritime-Antarctic (40 species) and continental-Antarctic (10 species). The most abundant taxa are *Scottnema lindsayae* Timm and *Eudorylaimus antarcticus* (Steiner) Yeates. Very little ecological work has been done on Antarctic nematodes. Tillbrook (1973) studied on the population densities of nematodes in different islands of Antarctica.

Hazra (1994) was the first to record 5 genera/species of nematodes from the Schirmacher Oasis, East Antarctica. Mitra (1999) reported 5 genera/species of nematodes from the Oasis. Ghosh *et al.* (2000) reported the distribution of nematode fauna in different lake water system in Schirmacher Oasis, East Antarctica. Hazra and Mitra (2002) studied the distribution pattern of nematodes in 36 sites of Schirmacher Oasis and reported that *Tylenchorhynchus* is the most dominant genus and represented by 41% of the total nematode fauna of the Oasis. A substantial contribution to knowledge of the diversity, ecology and population fluctuation of nematodes in East Antarctica was made by Hazra and Mitra (2002). Ghosh *et al.* (2003) described *Boleodorus motolilus*, this was the first report of a new nematode species from Schirmacher Oasis area. Ghosh *et al.* (2005) described *Antarctenchus motililus*, a tylenchid nematode from the area.

In the 32nd Indian Scientific Expedition to Antarctica, 2012-2013, 26 soil samples, 78 moss and algal samples have been collected from different islands like Mcleoad, Storness, Fischer, Brocknesh etc. and 22 water samples have also been collected from different lakes like Priyadarshini and others from the islands of east Antarctica. Nematode specimens will be extracted from those samples in the laboratory of the Zoological Survey of India, Kolkata for study about the nematode taxa of the continent. The study will definitely contribute and add further valuable information about nematode diversity for better understanding of the whole invertebrate community structure in Antarctica. It will highlight the occurrence, distribution, community analysis and population ecology of nematodes in East Antarctica.

# Economic Significance of PPN in Pulses and Their Management

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Pulses are an integral part of Indian agriculture and are grown on 26.28 million ha with production of 18.09 million tonnes. Pulses are grown in different agro ecological zones. The average productivity of 689 kg/ha of these crops is far below the potential yield of over 2000 kg/ha. Pulses are highly susceptible to nematodes. Surveys have shown that the nematodes are distributed in almost all the pulse growing zones thus becoming one of the important factors responsible for the low yields of pulses. Plant parasitic nematodes can cause yield losses ranging from 5-60% on individual farm depending on the nematode species and the population density present in soil. Although a number of plant parasitic nematodes are reported in the rhizosphere of pulse crops but root-knot nematodes (*Meloidogyne incognita* and *M. javanica*), reniform nematode (*Rotylenchulus reniformis*), pigeonpea cyst nematode (*Heterodera cajani*) and root lesion nematode (*Pratylenchus thornei*) are considered to be the most potential nematodes to cause economic losses in pulse crops. Generally, nematode problems are not realised and are over looked. Many times they are confused with other soil problems. Once the nematode problem is identified in standing crop, there is no immediate control method to overcome that problem. Strategic approach is required to manage the nematode problems for the susceptible crops to be grown afterward. Several efforts have been made to manage the plant parasitic nematodes by using chemical, biological, cultural, physical, genetical and regulatory approaches. However, by and large, it is painful fact that hardly any method of nematode control has become a consciously adopted practice by the common farmers for pulse crops. Interest have been generated recently with training of the farmers and other extension workers about the seriousness of the nematode problems and to utilize the practices which directly or indirectly related to change of environment that may restrict the population build up below the economically threshold level and save the crop considerably from the ravages of these noxious pests infesting pulse crops.

# Nematodes Play a Dual Role in Banana Cultivation in India

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India is one of the centers of origin for banana and produces 30 million tonnes of banana per annum from 8.3 lakh hectares. While banana is known to adopt very quickly and produce high yields under favourable conditions, it is however, prone to attack by different pathogens like fungi, viruses, bacteria and nematodes. Among the production constrains, nematodes play a vital role. Crop losses caused by nematodes to bananas are very high, with an average annual yield losses estimated at about 20 per cent world wide. A total of 132 species of nematodes belonging to 54 genera are reported to be associated with the rhizosphere of banana. The most destructive and widely distributed nematode is the burrowing nematode, *Radopholus similis* which caused an annual yield loss up to 41 per cent. This nematode was reported from banana in almost all the banana growing States in the country including the isolated areas like Andaman and Lakshadweep Islands. The nematode infested banana plants exhibit general decline, stunting, premature defoliation, unthriftness and carry small bunches and fruits. They topple over easily during wet and windy weather because of inadequate anchorage. The root-lesion nematode, *Pratylenchus coffeae* is considered to be an important nematode pest next only to the burrowing nematode. The crop losses caused due to root-lesion nematode in banana cv. Nendran was reported to be 44.4 per cent.

The symptom produced by this nematode was similar to that of *R. similis* and often its damage is attributed to *R. similis.* The root-knot nematode infestation was also noticed heavily in tissue culture plants where no nematode control was taken up at the primary/secondary hardening stage period. The other economically important nematode pests of banana which have some regional differences are the spiral nematode, *Helicotylenchus multicinctus, H. dihystera,* root-knot nematode, *Meloidogyne incognita, M. javanica*, cyst nematode*, Heterodera oryzicola* and reniform nematode, *Rotylenchulus reniformis*. Since all the commercial cultivars are found susceptible to either one or more nematodes, it is rather difficult to manage the nematodes with single method. Therefore, an integrated approach is suggested for the effective implementation of control measures for the economically important nematode diseases of banana. Accordingly various methods like uses of non-chemical methods viz., botanicals, biocontrol agents, organic amendments, resistant / tolerant varieties and beneficial nematodes like Entomopathogenic nematodes (EPN), Earth worm *Eudrilus eugeniae etc.,,* have been developed at NRCB for the management of nematodes in banana are highlighted in this status paper.

# Nematode Problems of Bidi Tobacco and their Eco-friendly Management

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Tobacco (*Nicotiana tabacum* L.) is an economically important non-food narcotic cash crop. India is one of the principal tobacco producing countries of the world. The crop earns nearly Rs. 4210 crores foreign exchange, Rs. 14,000 crores central excise and Rs. 5,000 crores VAT to the Nation besides providing employment to 36 million people including 6 million farmers & workers, is grown on about 0.27 % of the total cropped area of the country. This crop suffers badly from many abnormalities caused by wide rage of pathogens viz., fungi, viruses, nematodes, bacteria and flowering plant parasites.

Root-knot(*Meloidogyne* spp.), stunt (*Tylenchorhynchus vulgaris*) and reniform (*Rotylenchulus reniformis*)nematodes are found predominantly attacking bidi tobacco in Gujarat while root-knot and reniform in Andhra Pradesh on FCV tobacco and root-knot in other parts of the country. Worldwide loss in tobacco yield due to nematodes has been estimated to the tune of 14.7%. In India, losses in production of transplants and yield of bidi and FCV tobacco have been estimated up to 51.0% and 59.4%, respectively.

As an outcome of research efforts, measures advised for effective eco-friendly management of the nematodes are:

**Nursery**

- deep plough nursery area soon after the nursery season and thereafter 3-4 times in summer,
- avoid rabi crops in nursery,
- rabbing with bajra husk or wheat straw + dry tobacco stalks (1:1) in split furrows @ 7 kg/sq.m **OR**
- soil solarization during summer with 25 µm clear LLDPE plastic film for 15 days **OR**
- seeding root-knot resistant bidi tobacco ABT 10

**Field crop**

- avoid summer crops,
- follow summer ploughing
- adopt sanitation,
- use poultry manure,
- use healthy seedlings
- For integrated management of root-knot, leaf curl and frog-eye spot diseases in bidi tobacco field, farmers of Middle Gujarat are advised to plant their crop during 1st to 3rd week of September to gain highest gross realization.
- use root-knot resistant bidi tobacco ABT 10 for transplanting and tolerant varieties like Gujarat Tobacco 5 or Mosaic Resistant Gujarat Tobacco Hybrid 1
- follow crop rotation of bidi tobacco-summer pearlmillet-Hybrid 4 cotton-summer fallow in second year and again tobacco in third year **OR**
- bidi tobacco summer pearlmillet-castor (A 39-1) summer fallow in second year and again tobacco in third year

# All India Coordinated Research Project on Nematodes – Its Role in Management of Plant Parasitic Nematodes and Roadmap Ahead

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Since the inception AICRP in 1977, the project has made significant contribution in national perspective specially in nematological research with the support of 15 centres in various part of the country.Based upon the surveys conducted over the years nematode distribution in the form of Nematode Distribution Atlas has been prepared and published by ICAR during 2010.The national loss due to plant parasitic nematodes in 24 different crops in monetary terms has been estimated to the extent of Rs.21,068.73 millions

Based on the survey work, important hot spots under diverse agro-climatic zones of the country were identified **:**Root-knot nematode, *Meloidogyne graminicola* infecting rice in rice growing areas of Karnataka, Orissa, Assam, West Bengal, Kerala and Haryana.,White-tip nematode, *Aphelenchoides besseyi* infecting rice in Madhya Pradesh, Tamil Nadu and Orissa and Gladiolus in West Bengal and Orrissa and for *Anguina tritici* infecting wheat and barley in Madhya Pradesh, Bihar and Rajasthan,Pigeon pea cyst nematodes (*Heterodera cajani*) infecting pulse crops in Gujarat, Tamil Nadu, Maharashtra and Rajasthan.

Lesion nematode (*Pratylenchus thornei*) on chickpea and soybean in M.P. Rajasthan and U.P. Root-knot nematode (*Meloidgoyne indica*) infecting citrus in Gujarat and (*Meloidogyne incognita*) infecting pomegranate in Maharashtra and Karnataka. And Burrowing nematode (*Radopholus similis*) infecting banana, coconut and pepper

The low costy ecofrienly and viable integrated nematode management technologies have been developed and demonstrated against economically important nematodes at farmers field like *Meloidogyne graminicola, Hirschmanniella* spp. , *Heterodera avenae* ,*Rotylenchulus reniformis*in cereals ,vegetables *Pratylenchus thornei*.

Among various bio-agents tested, seed treatment with *Pseudomonas flourescens* + *Trichoderma viride* each @ 5 g/kg seed was found most effective for the management of reniform nematode, *Rotylenchulus reniformis* infecting cowpea. For effective management of *M. graminicola* infecting rice under organic farming

system, neem cake @ 100 g/$m^2$ or *Trichoderma viride* @ 20 g/$m^2$ or neem seed kernel powder (10% w/w) or *Pseudomonas flourescens* @ 20 g/$m^2$ were effective. In future emphasis will be laid on to further develop cost-effective integrated nematode management technologies for different cropping systems under different agro-climatic zones of the country and also for organic farming systems.

# Importance of Pest Risk Analysis for Nematodes in Trade

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Economic globalization depends on the movement of people and goods between countries. As these exchanges increase, so does the potential for translocation of harmful pests, weeds, and pathogens capable of impacting our crops, livestock and natural resources, with concomitant impacts on global food security. Potential invasions by alien species create a dilemma for nations that engage in international trade. On one hand, free trade may provide new markets for producers, cheaper and more diverse goods for consumers, and increase overall gross domestic product. On the other hand, unfettered trade may allow new pests to arrive and jeopardize domestic agricultural industries. Pests may lower agricultural production, reduce the marketability of a crop, or trigger quarantine restrictions from other countries to prevent the continued spread of the pest. The challenge, then, is to identify the risks associated with particular organisms, commodities or pathways and mitigate those risks to desirable levels. Pest risk assessment, the process by which scientific evidence is used to assess the likelihood that a pest might invade and the extent of harm should the invasion be successful, is commonly applied to decide whether to engage in agricultural trade with another nation and whether phytosanitary precautions might be required in order to manage the risks. When conducted properly, risk assessments can avert economic losses and preserve trade of agricultural commodities.

There are a good number of plant parasitic nematodes which have been intercepted on true seeds (pea, wheat, sorghum, onion), vegetative propagules (tubers, suckers, roots), soil particles, packing material (moss and wood shavings), leaves (Aphelenchoid nematodes) and tissue cultured propagules of potato. Only few years ago several shiploads of Australian wheat were found to contain weed seeds of quarantine importance to India. Even after lot of discussions and persuasion India finds not justified, to import high quality, economically viable timber from forests of Canada because the Indian PRA suggests that there are chances of entry, movement, spread and establishment of pine wood nematode, *Bursaphelenchus xylophilus* through the pathway. American soybean is not able to enter India mainly because of association of soybean cyst nematode, *Heterodera glycines* in the soil clods intercepted with the consignments. Japan and America permit imports of mango from India only after making sure that all consignments are properly treated, and are certified fruit-fly free by the quarantine authorities of both the trading governments. A large number of countries justify not importation of bulk consignments of wheat, with their scientific arguments and risk analysis, due to presence of pests like 'karnal bunt', and *Anguina tritici* in India.

# Management of Nematodes under Rice–Wheat Cropping System: Issues and Challenges

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India is the second largest producer of rice in the world, after China with an annual production and consumption of 85 million tons. More than 50% of the total production is contributed by the four states (West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab). More than 4000 varieties of rice are grown in India. The cultivation of rice is affected by various insects, pests, diseases and plant parasitic nematodes. A number of ecto- and endo-parasitic nematodes of root, stem and foliar parts, e.g., *Aphlenchoides besseyi*, *Ditylenchus angustus*, *Meloidogyne* spp. and *Hirschmanniella* spp. have been reported in rice crop from the rice-wheat cropping areas of the Indo-gangetic plains, causing damage to the tune of 10.54 % in rice alone. Among them, the rice root-knot nematode, *Meloidogyne graminicola* has become a serious threat to rice production owing to the cropping intensification of rice and the increasing scarcity of water. It has gained considerable attention in recent times because of its damage potential to irrigated and upland rice, particularly, under water stress conditions. The major cause for such high incidence of nematode infestation in these areas is attributed to the presence of light-textured soil, the availability of ample irrigation water and transplantation of infected seedlings. With the introduction of resource conservation technologies (RCTs), the nematode is now multiplying under conditions with least disturbance in the soil in the rice-wheat cropping system.

The prevalence and mean intensity of *M. graminicola* were greater under rainfed lowland and irrigated conditions than under upland conditions. In these fields, flooding did not limit the reproduction of the rice root-knot nematode. The low prevalence and mean intensity of *M. graminicola* observed in upland fields may result from the crop rotation used by the farmers or from competition with *P. thornei*.

The frequency and intensity of the root-knot disease were high in eastern India and low in northern India. However, conducive soil, agro-climatic conditions and continuous rice-wheat cropping system led to an increase in the distribution and intensity of this nematode in northern states of India. In northern India, there is a shift in cultivation of rice in the wheat growing belt of Punjab, Haryana and Uttar Pradesh.

In parallel, the identification of plant genes involved in the response to nematodes remains a major challenge and should greatly improve our understanding of the metabolic pathways targeted by nematodes to alter root development and maintain giant cells. Rice (*Oryza sativa*) plants are susceptible to *Meloidogyne* spp. infection and specific resistances were identified in the African relative species *O. glaberrima*. The rice (*O. glaberrima*) – *Meloidogyne spp.* interactions thus may serve as a model to understand incompatible plant- nematode interactions. Current activities involve the genome-wide analysis of rice responses to *M. graminicola* to identify the metabolic pathways that are altered by nematode infection.

Knowledge about the molecular mechanisms of plant immunity and nematode pathogenicity will help the incorporation of effective and durable resistance in rice plants by enhancing the active defence responses or interfering in the disease processes, opening new avenues for *Meloidogyne* spp. control strategies in rice. These polyphagous nematodes can cause significant damage to rice and (or) wheat crops, either alone or in combination with other microorganisms. The research projects on pest management in the region need inter-disciplinary approach and nematologists should be integral members of interdisciplinary teams on improving the productivity and sustainability of the rice-wheat cropping systems.

# Nematode Pests of Cotton and Their Management in India

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Cotton is an important cash and commercial crop valued for its fiber and vegetable oil in India. The area under cotton cultivation during 2012 was 11.6 million hectares with production around 33.4 million bales in India. The successful raising of this crop is hampered by attack of insects pests and diseases. The phytoparasitic nematodes not only cause the disease by themselves directly but also predispose the plants to many fungal and bacterial diseases, thereby limiting the production of cotton in the country. The avoidable yield losses in cotton due to root-knot nematode (*Meloidogyne incognita*) under field conditions in Haryana has been estimated to be 6.8 to 20 %. Besides root-knot nematode (*M. incognita*), other important nematodes are reniform nematode (*Rotylenchulus reniformis*), lance nematode (*Hoplolaimus* spp.) and a few other nematodes of minor importance such as lesion nematode (*Pratylenchus* spp.) and stubby root nematode (*Trichodorus christiei*).

In this presentation, details on distribution, symptoms, life history and disease complexes of root-knot and reniform nematode reveals that both the nematodes are widespread in cotton growing regions of India, the above ground symptoms of stunting, cholorosis, dwarfing are common in both while root galling is diagnostic in root-knot nematode, second stage juvenile is infective stage in root-knot compared to immature female in reniform, form disease complexes with *Rhizoctonia*, *Fusarium* and *Verticillium* fungi. Nematode management strategies employed are chemical, cultural, biological control and use of host plant resistance. In lance nematode, out of dominant species, *H. columbus* is most widespread. This nematode form cavities and tyloses in the cortex and the life cycle of *H. indicus* from egg to egg is completed in 27-36 days.

Despite the fact that a lot of information has been generated on cotton nematology, the areas to be covered for futuristic approaches may be studies on host parasite relationships, intensive surveys on nematodes of *Bt* cotton in India, screening of transgenic plants to nematodes, identifications of resistance genes to root-knot and reniform nematode and studies on integrated nematode management.

# Strategies on Mass Awareness on Nematode Problems in Developing Countries Such as India

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Plant parasitic nematodes (PPNs) are hidden enemies of the crops; they smartly steal nutrients from crops, inflicted crops hardly show any specific symptoms, make injury on plant's root system or aboveground parts depending on the nature of the parasite or the host-parasite relationship thereby making the crops prone to attack of soil-borne plant pathogens, and often manifest complex disease symptoms those are not easily diagnosed for the involvement of primary pathogens. Increased concern of nematode problems in open-field as well as protected systems warrant adequate awareness of this hidden threat that may rob the crop yield beyond the sight of farmers. In the crop protection schedule, plant feeding nematodes are often underestimated for their potential threat on the crops. This has led to less participation of plant nematologists in the planning of integrated pest management (IPM). Worst PPNs, though obligate, have large number of hosts, are widespread pathogen of crops and the dimension of damage and their management options on certain crops (e.g. cereals, pulses, oilseeds, fruits, fibres, fodder, plantations, spices, medicinal and aromatics, forests etc.) are well documented. However, this information along with current concern on biosecurity threats of nematodes has not reached out to the growers, administrators and policymakers as expected level. Therefore, strategies for mass awareness on nematode problems to the target beneficiaries are the major challenge ahead to protect the crops from this unseen hidden enemy. Adequate awareness about nematode-pathogenic potential, host range, survival, dispersal etc. will be an added advantage in biosecurity applications. An innovative means of nematode awareness campaign was initiated by Association for Advancement in Plant Protection (AAPP), Bidhan Chandra Krishi Viswavidyalaya (BCKV) with a private partnership since 2006. Every year 7$^{th}$ July is being observed as a Nematode Awareness Day with the major objective of providing ground level hands-on training on nematode problems in field, diagnosis of disease symptoms, tiny worm, etc. to the farmers, extension workers, agri-input stakeholders and dealers of West Bengal. Over 600 participants from different districts of West Bengal are the beneficiaries of such hands-on training. The participants primarily included were farmers, pesticide dealers, representatives from Farmers' Clubs, Shelf-Help Groups,

Cooperative Flower Societies, NGOs, KVKs, and *Krishi Pryukti Sahayaks* (KPSs), Government Officers from State Department etc. Plant Health Clinic -BCKV extends pest advisory services including nematodes to the farmers of West Bengal through a Toll Free Telephone (1800 345 5235) and this was greatly appreciated by the growers of West Bengal. There are other means of mass awareness on rice root knot nematode (RRKN) have been initiated under *e-pest surveillance* programme; field scouts records the nursery infestation of RRKN and expert opinion on their management options are SMS-ed to the block officers and affected farmers. Soybean cyst nematode (SCN) is a potential pest in soybean in USA. The University of Nebraska-Lincoln Extension in collaboration with Nebraska Soybean Board and Industry successfully has generated great awareness of SCN among producers in south east Nebraska through survey, complementary field sampling and analysis, field research, field days, crop clinics, newsletters, newspaper articles, website news and publication of SCN management. Nematode problems could be easily disseminated through TV- Krishi Darshan, Radio programme, pest alert column on Local dailies, publishing leaf-let, book-let, *Shasya Suraksha* Bulletin in regional language etc., holding *Krishi Mela/*Seminar/Exhibition at block and district level, *Krishi Prayukti Week* etc. Besides, adoption of villages for demonstration of nematode management practices among selected farmers creates huge impact on the growers about nematode problems. Information and Communication Technology (I& CT) has tremendous role on mass awareness programme. Now-a-days, email, SMS, social network (facebook/blog) etc. is being used to upload field symptoms to get possible solutions from expert corners. An online cotton nematode awareness (CNA) module- has been developed jointly by Syngenta Crop Protection and American Society of Agronomy in USA for improving grower's knowledge, understanding of nematodes and their appropriate management. In India, National Centre for Integrated Pest Management (NCIPM), All India Coordinated Research Project (AICRP) on PPNs and its Cooperating Centres are continuing awareness campaign through survey, field demonstration, validation of nematode management technologies, farmers' training, publication of nematode management schedule in local languages, video clips etc. Some of the emerging nematode problems like root knot nematodes (*Meloidogyne* spp.) in pomegranate, citrus, castor, cotton, tuberose, pulses etc.; tuberose foliar nematode (*Aphelenchoides besseyi*) in tuberose and rice; rice root knot nematode (*M. graminicola*) in rice, jute and onion; burrowing (*Radopholus similis*) and spiral (*Helicotylenchus multicinctus*) nematode in banana; lesion nematode (*Pratylenchus thornei*) in chickpea and soybean; mushroom nematodes (*Aphelenchoides composticola, Ditylenchus myceliophagus*) in mushroom; and reniform nematode (*Rotylenchulus reniformis*) in cotton, vegetables and pulses. Many of the above PPNs are still have local or regional distribution on certain crops and their nature of damage, survival, disseminations

and management practices are known. The mass awareness campaign on the nematodes in collaboration with the University, Government extension departments, KVKs, private industries etc. will ensure sustained food productions and to use biosecurity practices to restrict entry of other nematodes in the production system. A mobile Van could move with all portable laboratory equipments and audiovisuals of nematodes to reach out large mass for creating nematode awareness. Nematode is an ideal organism to introduce at school level for teaching biodiversity and it could be easily making them aware of their relative abundance in soil treated with varying level of toxic chemicals. Nematode preventive and other management practices (such as exclusive, cultural but eradicative and/or protective as well as resistant varieties and lines and therapy) can be introduced. We have received cooperation from teachers, researchers and scientists from other universities and institutes. We do use teleconferencing with the active participation from such experts at their head quarters and /or residences in the presence of the scientists at the BCKV Head quarters as well as the extension agents and even the farmers. This can be further enriched with video conferencing.

# Mass Production of Entomopathogenic Nematodes: The Need to Forge Ahead

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Since their discovery in 1923, by Steiner, entomopathogenic nematodes (EPNs) have become integral to biological control programmes all over the world (Kaya and Gaugler, 1993; Grewal *et al.,* 2005; Koppenhoffer, 2007). The EPN attributes of high effectiveness, quick action, safety to non-target organisms and amenability to mass production makes them ideally suitable for use as biopesticides, and this has caught the attention of researchers, and small and big entrepreneurs. In the USA and Europe, efficient mass production protocols have been set up involving either *in vivo* culturing on an insect host (White, 1927; Lindegren et al., 1993), *in vitro* solid cultures (Bedding, 1981, 1984) or *in vitro* liquid cultures (Ehlers, 2001; Gaugler and Han, 2002). Easy availability of large volumes of EPNs and EPN based-products has fed the increasing demands of a rapidly growing global biopesticides market: valued at $1.3 billion in 2011, it is expected to touch $ 3.2 billions by 2017. Over the last ten years, global revenues from EPN-based products have matched the returns from *Bt*, *Beauveria* and *Trichoderma* (Lacey and Georgis, 2012). The biopesticides market is dominated by the US, which accounted for around 40% of the biopesticides demand in 2011. Stringent regulations for pesticides and an increasing demand for organic products are expected to greatly accelerate the growth of the European market.

Multifaceted research is being conducted around the world to optimize the economics of EPN mass production, viz. reduce the cost of production and maximize the yield. A few diverse areas under study are testing the prospective production materials and abiotic factors with the aim to standardize the processes that can enhance EPN production; preparation of basal media using inexpensive products such as agaves juice and whey (Chavarria-Hernandez *et al*., 2005; Islas-Lopez *et al*., 2005); automation of *in vivo* mass production in *G. mellonella* (Gaugler *et al.,* 2002); improvements to the inner design of fermenters (Chavarria-Hernandez et al., 2007, 2010) and parameter settings (Shapiro *et al*., 2002; Young *et al*., 2002; David and Hugh, 2007).

India has yet to register its presence on this vibrant global EPN scenario: our EPN research lacks both energy and imagination. The majority of the laboratories here have not moved beyond *in vivo* mass production of EPNs with *Galleria* as host. A few laboratories in southern India have shown promising results in terms of *in vitro* EPN production on solid medium. But the results have to move beyond the laboratories and translate into viable commercial ventures for the sustained success of EPNs as biopesticides. Although mass production of EPNs in fermenters, in the US and Europe, has revolutionized the global biopestides market, but India still lacks the technical know-how to benefit from the fermenter technology.

It is time we shake off our inertia and forge indigenous and independent EPN research initiatives. Given that India is a tropical country with a huge 1.2 billion population, while broad directions can be sought from the EPN studies undertaken in the US and Europe, cut-and-paste options would have limited scope. Our research has to be designed to conform to our unique ecological parameters and our demographic realities. We have to chart our own path and create our own milestones.

# Status of Nematodes Involving Insects and Plants in Their Life Histories in India

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Information on nematodes involving plants and insects in their life histories is very very meager in India considering huge biodiversity of plants and insects present in the country. Such nematodes can be broadly categorized in six groups. Group 1: Phytophagous nematodes involving insects as means of transportation (external or internal phoresis). They include most dreaded nematodes- *Rhadinaphelenchus cocophilus* and *Bursaphelenchus xylophilus*. Fortunately, they have yet not been recorded in India and are on quarantine list under Schedules IV and V Government of India's Plant Quarantine Order, 2003 (Regulation of Import into India). Another sub group is of *Schistonchus* species that multiply inside syconia of figs and are transported through fig wasps. *Ficus* species are dependent upon specific fig wasps for pollination with which they have presumably co-evolved. Due to interdependence of nematodes, fig wasps and *Ficus* spp., fig associated nematodes have been implicated as important models for studying radiations, convergence, co-speciation and co-evolution, and host switching host parasite mutualists. Only three species of this nematode genus, viz., *S. racemosa*, *S. osmani* and *S. hispida* have been recorded from India. We have collected populations of this genus representing at least four species from *F. racemosa*, *F. carica*, *F. religiosa* and *F. benghalensis* from Haryana, itself. Group 2: Phytophagous nematodes using insects for transportation as well for nourishment and reproduction. These include well known *Fergusobia* species inhabiting plant roots or leaf/ bud galls. Indian species recorded are *Fergusobia indica* and *F. jambophila*. Group 3: Nematodes occupying insect habitations on plant and using insects for transportation. A number of nematodes belonging to orders Rhabditida, Aphelenchida, Panagrolaimida and Diplogasterida feed and multiply on microflora and microfauna growing on the frass and gallery/ wounds made by insects. Majority of these nematodes do not parasitize insects and have phoretic relations with them though their relationships with insects are yet not fully understood. Common nematodes of this group in India are *Aphelenchus avenae*, *Aphelenchoides* spp., *Laimaphlenchus* spp., *Indaphelenchus siddiqii*, *Ruehmaphelenchus sirisus*, *Albiziaphelenchus arthrorostrus*, rhabditids and *Acrosticus* spp. Colonization of plant part by such nematodes attract predatory

nematodes, like *Seinura* spp., and predatory diplogasterids which have the ability to switch over from microvory to predation. Other nematodes belonging to this group, however, do parasitize insect and multiply in their bodies. These include *Panagrolaimus* sp. and Rhabditid sp. from alimentary canal of larvae of *Chilo zonellus* in North India, Rahbditid sp. on grubs of *Oryctes rhincoceros* in Kerala, *Parasitorhabditis* sp. on *Sesamia inferns*, *Chilo auricilis* and *Tryporyza incertulas*. Group 4: Nematodes multiplying inside insect body and using plants a source for dispersal. Some diplogasterids like *Parasitodiplogaster* and *Ceratosolenus* multiply inside fig wasps and enter in figs during oviposition by insects. Inside the fig, these nematodes produce 'dauer larvae' for dispersal by developing next generation wasp. *Ceratosolenus hyderabadensis*, *C. racemosa* and *Teratodiplogaster* sp. from figs *of F. racemosa* occur in India. Other undescribed species of diplogasterid nematodes have also been recorded from syconia of *Ficus* spp. Group 5: Nematodes multiplying on fungi growing on plants and switching over to entomoparasitism. Several tylenchid nematodes like *Deladenus* spp. are dimorphic. They feed and multiply very fast on the fungi growing in the vicinity of insect habitations on the plants. At an appropriate time, entomoparasitic females are produced that penetrate insect larvae after mating with males having specialized small-sized sperm. Once inside the haemocoel, their life cycle synchronizes with insect as they produce eggs that hatch in the haemocoel. Parasitization by these nematodes may cause sterility, adversely affect the fecundity of insect and also the viability of the eggs. Since these nematodes can be easily cultured on fungi and that their life cycle can be manipulated to produce entomophilic forms, they are likely to be very good candidates for the biological control of insect pests. Successful use of *Deladenus siricidicola* in managing Sirex fly (*Sirex noctilio*) problem in Australia illustrates their utility. From India only, *Deladenus aeneus* (=*Physitylenchus aenea*) and *D. durus* (Cobb) have been reported. We have in our collection several populations collected from *A. lebbeck* and *Pinus roxburghii* infested with bark borers, rhizosphere of wheat and paddy etc. from Haryana state in addition to other neotylenchid nematodes having similar mode of life. Group 6: Nematodes parasitizing herbivorus insects and entering in soil only for dispersal. Included in this group are *Contortylenchus* sp., *Howardula phyullotreta*, *H. truncate*, *H. aptini*, which have been found parasitizing insects of agricultural importance in India. Entomopathogenic nematodes also belong to this group but have not been in included here in the present discussion.

# Scope of Teaching Nematology at UG Level in SAUs

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The recommendations of the IV Deans' Committee constituted by Indian Council of Agricultural Research restructured the undergraduate course curricula and syllabi for uniform implementation across the country in different SAUs. These recommendations contained a core course "Introductory Nematology" (1+1) under Plant Pathology during Sem II of 1st year B. Sc. (Hons.) Agriculture programme.

I am firmly of the opinion that this UG course forms the backbone of science of Nematology for multiple reasons.

- The subject of Nematology is introduced to the students for the first time. It is entirely the skill of the instructor to make it simple, interesting and convincing for the students.

- This is the only Nematology course studied by the students who opt for jobs after graduation. Majority of them join State Govt. jobs in Agriculture/Horticulture departments. So, the instructor must keep in mind that a strong base of nematode disease diagnosis and their management forms the crux of this course. Therefore, the discourses should be duly supported by videos and practical component should be very strong.

- Ironically, the syllabus framed for this course lacks treatise on major nematode diseases of agricultural and horticultural crops in India. Nematological Society of India can play a pivotal role in getting it incorporated in the course content and in view of increased course content the credit load may also be increased to 2+1, instead of 1+1.

- This is the only course that motivates the students to go for post-graduation in Nematology.

- The 7th Semester includes 20 credit hours of Elective courses only. The Plant Protection module contains six courses on - IPM and IDM, Management of post-harvest insect pests and diseases, Non-insect pests and their management, Apiculture, Mushoom cultivation, Bio-control agencies and bio-pesticides, and

Pesticides and Plant Protection Equipment. We should strive hard to convince the concerned authorities to include proportionate component of Nematology in these courses as well.

In majority of the SAUs and Agricultural/Horticultural colleges in the country, there is acute shortage of human resource in Nematology. Most of these institutions use the services of faculty from Plant Pathology and Entomology to teach this basic course. Consequently, there is a compromise on the quality, particularly the practical component. It is, therefore, strongly emphasised that such faculty members from other disciplines assigned to teach core course of Nematology, may participate in a capacity building course both in theory and practical components and be provided with complimentary teaching materials (AV aids, diseased specimens etc.) for effective teaching. With funding support from ICAR, the Nematological Society of India can play the role of a facilitator.

# Session I: Molecular Approaches and Nano-Science in Nematology

# Effect of Infection of Reniform Nematode on Polyphenol Oxidase, Peroxidase Activities and Total Phenol in Leaves of Bidi Tobacco

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An experiment was conducted, during the year 2011 and 2012, to estimate polyphenol oxidase, peroxidase activities and total phenol in leaves of root-knot resistant and susceptible bidi tobacco cv. ABT 10 and A 119, respectively due to infection of reniform nematode under pot conditions. Four treatments including the two varieties and two inoculum levels, viz. 0 (Control) and 2000 $J_4$ per pot, were tried repeating four times in CRD. Thus, sixteen disinfested pots of 15 cm diameter were filled with 500 cc sterilized soil and FYM and transplanted with seedling of bidi tobacco keeping one seedling per pot. Second stage juveniles ($J_2$) of reniform nematode from the soil of micro plot were extracted, collected, concentrated and kept for 15 days at room temperature to convert into pre-adult stages ($J_4$). The nematode per ml in water suspension was estimated and required quantity (20 ml) of nematode suspension was inoculated per pot, while in control only 20 ml water was poured. The seedlings were watered regularly and protected from the insect damage using appropriate management measures. Required quantities of the fresh leaf were collected 60 DAI, weighed and analysed for Polyphenol oxidase, Peroxidase activity and Total phenol. The results revealed higher polyphenol and peroxidase activity as well as reduced total phenol content in ABT 10 than A 119. Inoculation of 2000 $J_4$ of reniform nematode reduced polyphenol and peroxidase activity as well as total phenol content than no inoculation. Interaction indicated that inoculation of reniform nematode @ 2000 $J_4$ per plant reduced peroxidase activity and total phenol content in A 119 and increased the same in ABT 10 compared to no inoculation.

# A Proteomic Investigation of Host Specificity in *Photorhabdus*

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Members of the enterobacterial genera, *Photorhabdus* and *Xenorhabdus* are associated with insect parasitic nematodes of the genus *Heterorhabditis* and

*Steinernema*. The nematode-bacteria pair infects and kills insects symbiotically. The nematode provides the bacteria with protection from predators, access to nutrients, and a mechanism of dispersal to suitable environment. The bacteria provides nutrition to the nematode by breaking down the insect cadaver into a nutrient-soup. Nematode-bacterium association is highly species specific. This host specificity might be attributed to differences in the genetic constitution of different symbiont species, which might be reflected in their respective proteomes. *Photorhabdus luminescens* ssp. *laumondii* TT01 is associated with nematode, *Heterorhabditis bacteriophora*, whereas *P. luminescens* ssp. *Akhurstii* is associated with *H. indica*. These two *Photorhabdus* strains are specific to their nematode hosts and do not colonize the nematode host of other bacteria. We hypothesized that these differences would be reflected in their respective proteomes. To investigate this, total protein of the two strains cultured in LB medium for 36 h was extracted and separated on 12.5 % SDS-PAGE gel to obtain qualitative protein profiles. Distinct differences in protein profiles were observed at 30-95 kDa molecular weight range suggesting proteomic divergence. Some of these proteins might be the factors involved in host specificity of the *Photorhabdus.* A 2-D Gel analysis of these proteins is being done in our lab for exact identification of these proteins. These findings will deepen our understanding of the bacterial factors involved in host specificity in *Photorhabdus-Heterorhabditis* symbiotic relationship.

## Influence of Root-Knot Nematode, *Meloidogyne incognita* on Soluble Protein in Tomato

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Influence of root knot nematode, *Meloidogyne incognita* on soluble protein in tomato cultivated under polyhouse and field conditions was studied. In this study, the soluble protein content in leaves of tomato decreased from 13.91 to 7.03 and 11. 87 to 9.83 (mg/g) at vegetative stage under polyhouse and field conditions. During flowering stage, the nematode infested plants showed 5.23 and 6.33 mg/g soluble protein under the respective conditions. The reduction in soluble protein content was more in polyhouse tomato and the rate of photosynthesis was reduced due to the reduction of soluble protein. Correlation of weather parameters (air temperature, soil moisture and soil temperature) and its influence on soil and root nematode population and

soluble protein content also studied. The weather parameters *viz.,* air temperature, soil moisture and soil temperature under polyhouse and field conditions were not positively or negatively correlated with the soil and root nematode population and soluble protein content during vegetative stage. The weather parameters were positively correlated with the soil and root nematode population and soluble protein content of nematode infested tomato which was cultivated under polyhouse. The root nematode population was positively correlated with the soluble protein content in tomato infested with root knot nematode under field conditions.

## Molecular and Morphological Characterization of an Indigenous Entomopathogenic Nematode Infecting Rice Yellow Stem Borer

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Identification of an indigenous entomopathogenic nematode (DRR-EPN1) infecting rice yellow stem borer (*Scirpophaga incertulas*), collected from DRR farm soil was carried out based on morphological and molecular studies. Gross morphological features indicated that this nematode belongs to the genus *Metarhabditis* (syn. *Oscheius*). Further, the detailed morphological and morphometric observations of this nematode were compared with that of previously described species using taxonomic diagnostic keys and it was found that the nematode belongs to the species *Metarhabditis amsactae* (Ali *et al*, 2011) Sudhaus, 2011. Molecular characterization of nematode was carried out based on DNA sequences of ITS regions of ribosomal genes (18s, 5.8s & 26s genes). The DNA sequences ITS regions of this nematode were compared with the nematode sequences present in the NCBI GeneBank and that of *M. amsactae* reported earlier using BLASTn algorithm. It was observed that there was 98% similarity in DNA sequence of this nematode and *M. amsactae*. Therefore, based on morphological studies and DNA sequence homology the indigenous entomopthogenic nematode isolate (DRR-EPN1) was identified as *Metarhabditis amsactae*.

## Molecular Characterization of an Indigenous Isolate of *Heterorhabditis* Pathogenic to White Grubs

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An isolate of entomopathogenic nematode, belonging to genus *Heterorhabditis,* baited from the fields of IARI, has been found to be highly pathogenic to the white grubs. The Division of Nematology, IARI has developed a technology which involves the application of *Galleria* cadavers infected with this particular nematode isolate for the management of white grub infestation in sugarcane crop in western Uttar Pradesh. Field trials have been carried out in collaboration with an NG0-FARMER and local Sugar Mills during 2009-12 seasons in around 12 villages of District Amroha, Saharanpur, Gajraula and Haridwar. These trials have shown 25-66% reduction in white grub population and an increase in sugarcane yields up to 60-80 quintals/ acre at different locations. The non coding internal transcribed spacer sequences, ITS1 and ITS2 including 5.8S region of ribosomal DNA (rDNA) is useful for identification of the species and characterization of molecular genetic variation within the species of entomopathogenic nematodes. In the present study, sequencing of rDNA has been used to confirm the species identity. The sequence of ITS1 and ITS2 including 5.8S showed 100% similarity with the existing sequences of *H. indica* from countries like USA, Belgium and Nepal, thus confirming its species identity.

## Biochemical and Morphological Response of Rice Varieties incited by Rice Root-Knot Nematode, *Meloidogyne graminicola*

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Root-knot disease of rice caused by *Meloidogyne graminicola* has become an important and emerging problem in irrigated rice in Uttar Pradesh and most of cultivated varieties are susceptible to the rice root-knot nematode. Screening for varietal reaction of 18 available rice variety in Aligarh region viz., Anjali, Abhishek, Hazari, JKRH 401, PA6444, R-Dhan, PS-1121, Pusa Sugandha 5, Santhi, Sadabhar, Sambha mehsuri, Sharbati, Sugandha mati, Surya, Swarna, Vandana, Virendra and Vivekdhan-62, against field population of *M. graminicola* (1000 $J_2$/kg soil) under

pot condition had been conducted. The host reaction was evaluated on the basis of morphological parameters (gall formation, egg mass production, plant length and yield/plant) and biochemical parameters (total phenol contents and salicylic acid concentration). All the variety except Santhi and Vandana (1 grade at 0-10 scale) were found susceptible to *M. graminicola* and developed characteristic terminal galls and reduced their plant growth variables. The var. Pusa Sugandha (7 grade at 0-10 scale) was found most susceptible and developed 51-57 galls/root system. Greatest increases in the leaf contents of salicylic acid (26%) and total phenol (51%) were recorded in var. Santhi which also had highest yield per plant (23.4 g), whereas least increases were detected in var. Pusa Sugandha (17% TP and 10% SA). Total phenol and salicylic acid contents of leaves increased up to 5 days of planting, and thereafter, decreased gradually. Increases in total phenol (TP) and salicylic acid (SA) were negatively correlated with numbers of root galls and egg masses/root system. Based on the biochemical reaction, it was revealed that var. shanthi expressed resistance/tolerance reaction against *M. graminicola* and can be exploited commercially.

## Development of Root-Knot Nematode Resistant Tomato Transgenic Lines Through RNAi Approach

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Gene having specific role in the development process in root-knot nematode, *Meloidogyne incognita*, namely, Cathepsin-L-Cysteine Proteinase (*Mi-Cpl-1*) was selected for functional validation through RNA interference. *Mi-Cpl-1*was previously tested for its RNAi effect against *M. incognita* through *in vitro* approach, however *in planta* approach of dsRNA delivery was not adopted before. Gateway cloning was adopted to prepare dsRNA constructs of *Mi-cpl-1* gene to knock down the development process in *M. incognita*. Gene was cloned in an entry vector pDONR221 followed by a destination vector pHellsgate12 in sense and antisense orientation for ihpRNA (intron spliced hairpin RNA) construction under kanamycin antibiotic resistance. Directional cloning was confirmed through PCR and sequencing. Binary vector containing the dsRNA construct was mobilized to *Agrobacterium tumefascience* strain GV 3101 through freeze and thaw method. Leaf disc-*Agrobacterium* co-culture method was adopted to transfer the recombinant T-DNA into tomato (*cv*. Pusa Ruby) leaf cells. Co-cultured leaf discs were sub-cultured in MS medium containing kanamycin sulfate for positive selection of gene

constructs. Callus formation was evident in subsequent sub-culturing of the kanamycin resistant leaf discs in selection and regeneration medium. The $T_0$ plants are being generated from those explants after supplementing the regeneration medium with rooting inducer, NAA.

## FITC Uptake in Rice Root-Knot Nematode, *Meloidogyne graminicola*

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Rice root-knot nematode, *Meloidogyne graminicola* is a major problem in rice-wheat cropping systems in India as well as in Southeast Asia. As the nematode is well adapted to survive on upland rice as well as on flooded condition the conventional method of nematode management could not make the impact. Therefore RNAi based management approach could be a better alternative. There are no reports of *in vitro* or *in vivo* RNAi against *M. graminicola* till date. Therefore, present study was conducted to standardize a protocol for the feeding experiment of *M. graminicola* juveniles for *in vitro* studies. Instead of dsRNA a flouorescent molecule Fluorescein Isothiocyanate (FITC) was used to monitor its uptake on second stage juveniles (J2) with the aid of neurotransmitters like octopamine, serotonin, and several spermidine derivatives and without neurotransmitter under fluorescence microscopy. For 1 mg/ml of FITC 500 J2 of *M. graminicola* were soaked in basic soaking solution containing M9 buffer incubated at different time points like 4, 8, 16 and 24 h. Activity percentage of the J2 showed significant reduction over time with the different treatments like 50mM octopamine, 50mM serotonin, 6mM spermidine, 6mM spermidine phosphate salt hexahydrate and 6mM spermidine trihydrochloride compared to control in M9 buffer and FITC alone, indicating FITC did not have any toxic effect on nematodes. Increase in fluorescence was observed over time in all the treatments and even without the aid of neurotransmitter suggests that FITC might also entered J2 via other apertures like anus, excretory-secretory pore and amphids. Along with that octopamine had increased the movement of J2 while serotonin had slowed down the movement of J2. Therefore *in vitro* RNAi holds a great prospect to study the gene silencing effect on nematodes.

# Effect of *Meloidogyne incognita* and *Ralstonia solanacearum* on Physiology of Ginger

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A replicated pot culture study was conducted in the green house benches of Department of Nematology, O.U.A.T., Bhubaneswar, on ginger inoculated with *Meloidogyne incognita, Ralstonia solanacearum* either alone, together or sequentially. Observations were recorded 90 days after inoculation of pathogens. Persual of data indicated a decline in the rate of photosynthesis (3.83 to 3.50 m ml/ $m^2$/s), leaf water potential (-1.79 to 2.07 Mpa), total cholorophyll (2.55 to 2.06 mg/g) and relative water content (81.43 to 51.26%) acoompanied by increase in dark respiration (1.00 to 1.09 m ml/$m^2$/s). Reduced photosynthesis is attributed to stomatal closure to the diffusion of $CO_2$ which was preceded by leaf water stress in terms of decreased leaf water potential and relative water content of leaves of ginger. Combined inoculation of both the pathogens resulted in further aggravation of physiological parameters.

# Session II: Nematodes Under Potential Climate Change

## Pathogenic Variability of *Meloidogyne incognita* in Turmeric under Ambient and Enhanced $CO_2$ Gradient

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Pot culture studies were conducted under ambient (380 ppm) and enriched $CO_2$ concentration (408 ppm) during 2011-2012 to determine the pathogenicity of *M. incognita* inoculated to turmeric c.v Lakadong, forty days after planting with initial inoculum levels of 0, 10, 100, 1000 and 10000 $J_2$/kg soil. Observations on different growth and nematode parameters were recorded 90 days after inoculation. Perusal of data indicated decrease in plant growth parameters with increase in the initial inoculums density of *M. incognita* under both ambient and enriched $CO_2$ concentration accompanied by increased soil and root population including root-knot index. Plant growth parameters irrespective of inoculum levels of nematode were higher under enriched $CO_2$ concentration. The combined analysis of data indicated significant increase in plant growth and decrease in nematode parameters with progressive increase in the initial inoculums density. Thus 100 J2/kg soil was estimated as the damaging threshold level of *M. incognita*.

## Influence of Temperature and Moisture Regimes on Plant Growth and Root-Knot Nematode *Meloidogyne graminicola* Damage in Rice

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Influence of different temperature and moisture regimes on root-knot nematode *Meloidogyne graminicola* damage and plant growth in rice was assessed. Observations revealed that the nematode damage expressed in terms of number of galls per plant was significantly higher (41-61%) in un-flooded condition compared to the flooded condition at both ambient (30-35$^0$C) and high (40-45$^0$C) temperatures. Plant growth parameters such as shoot weight, root weight and number of tillers were significantly higher under flooded condition compared to the un-flooded condition

in both nematode infected and healthy plants at both the temperature regimes. Further, number of galls was observed to be significantly higher at ambient temperature (17-33%) compared to the high temperature under both flooded and un-flooded conditions. Overall, shoot weight, root weight and number of tillers were higher at high temperature compared to the ambient temperature under both flooded and un-flooded conditions. The results suggest that root-knot nematode damage in rice will be more under un-flooded situation at ambient temperature.

## Seasonal Incidence of Root-Knot Nematode, *Meloidogyne incognita* on Pomegranate

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The seasonal incidence of root-knot nematode, *M. incognita* infested on pomegranate (cv. Bhagwa) was undertaken during November, 2010 to October,2011 under root-knot nematode sick microplots. The highly significant negative correlation co. efficient (r) was observed between root–knot nematode population, number of root galls and egg masses and maximum and minimum temperatures of air and morning and evening temperatures of soil. With increasing temperatures there is corresponding increase in root-knot nematode, root galls and egg masses from July 11 to November 2010 and December 2010 to October 2011. The root-knot nematode population, number of root galls and egg masses showed the fluctuation in their incidence throughout the year. The maximum root knot nematodes 1260 J2 /200 $cm^3$ , 117 root galls and 120.0 egg masses/5 g roots were recorded in the second fortnight of December (52 meteorological week, when the maximum and minimum temperature of air and morning and evening at 28.1 & 10 $^oC$ and 30.8 and 14.7 $^oC$, respectively. However, the minimum root-knot nematode population ( 60 J2/200 $cm^3$ of soil ), number of root galls ( 9.0/ 5 g roots ) and egg masses (10.0 / 5 g roots) were recorded in the second fortnight of May (21$^{st}$ Meteorological week), when the maximum and minimum temperatures of air and morning and evening temperatures of soil were 37.1and 23.1 $^0C$ and 48.8 and 39.6 $^0C$, respectively.

# Effect of Intermittent Exposures with $CO_2$ and $SO_2$ on Root-Knot Nematode Infecting Sponge Gourd

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Sponge gourd plants inoculated with 2000 juveniles of *Meloidogyne incognito* or not-inoculated were exposed to $CO_2$ (400, 450 and 500 ppm) and $SO_2$ (25, 50 and 75 ppb) for 5 hrs on alternate day for 3 months. Plants exposed to 75 ppb $SO_2$ showed mild chlorotic and necrotic lesions on the leaves. Nematode infection caused extensive galling on the roots of sponge gourd. The galls were large, complex, fleshy and bead like. Nematode inoculation enhanced the transpiration rate during the first month of inoculation. Elevated levels of $CO_2$ especially at 500 ppm promoted the plant growth and yield of sponge gourd. $CO_2$ exposures also increased the transpiration rate stomatal conductance and photosynthesis being greater at the highest concentration. When plants were exposed jointly to $SO_2$ and $CO_2$, a significant difference in plant growth parameters was not recorded, but foliar injury induced by $SO_2$ was relatively greater in the presence of $CO_2$. The nematode disease in terms of gall formation was relatively higher on the plants exposed to $SO_2$ and $CO_2$ singly or jointly. Reproduction of the nematode was also influenced by the gas exposures.

# Session III: Use of Chemicals for Nematode Control

## Efficacy of Nursery Treatment and Bare Root Dips in Plant-Based Nematicidal Formulations on *Meloidogyne incognita* in Aubergine

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An experiment was conducted under field conditions to assess the efficacy of nursery treatment with phorate and root dips in three plant-based nematicidal formulations (Max Raze, Max Cannon and Nimbecidine) on the root-knot nematode, *Meloidogyne incognita* Race 2, and on growth and yield of egg plant. Seedlings from the nursery treated with phorate were free of galls while those from the non treated nursery showed galling. Seedlings from treated nursery, when transplanted in infested field, showed better plant status, produced more and suppressed nematode population compared to seedlings from untreated infested nursery. Plant height increased significantly with all the tested formulations irrespective of the dipping period which showed an overall non-significant effect Root gall indices were significantly different not only amongst formulations but also amongst dipping durations. The mean gall index in the roots dipped for an hour was significantly higher than the root galling in the roots dipped for two or three hours. A significant effect of nursery treatment, formulation dips, duration of dipping and their interaction was observed on the yield of tomato. This was significantly greater in all plots receiving seedlings from treated nursery with any of the tested formulations as compared to those from untreated nursery. Though, all plant based formulations controlled the root-knot nematode and increased yield of egg plant, Max Cannon having combination of some plant extract was significantly more effective than other two having neem only as the active ingredient.

## Comparative Efficacy of Management Practices Against *Meloidogyne* spp. In Fenugreek and Coriander

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Fenugreek and coriander are important seed spice crops of Haryana. Both these crops are highly vulnerable to root-knot nematode (*Meloidogyne spp.*) resulting

significant reduction in yield. Keeping in view, the common occurrence of this pest on these crops, field trials on management practices which were found effective under screenhouse conditions (i.e., soil application with mustard cake @ 5q/ha, carbofuran @ 1 kg a.i./ha, seed dressing with carbosulfan @ 3.0 % (w/w), and seed soaking @ 1000 ppm (0.1 %) for six hours were evaluated for their comparative efficacy under field conditions. These trials were conducted with the above mentioned treatments along with untreated check at two locations (i.e., one in micro-plot at Research area of Department of Nematology, CCS HAU, Hisar and at farmer's field in village Dharnia of Fatehabad district of Haryana). In microplots, the observations were recorded on plant height, plant weight, root-knot index and final nematode population in soil whereas in the second experiment under field conditions, the observations were recorded on yield, root-knot index and final nematode population.

The data in microplot experiment, showed maximum plant height of fenugreek (59.3 cm) and coriander (80.3 c.m.) in mustard cake treatment in comparison to untreated check (44.3 cm in fenugreek and 56.7 cm in coriander). Amongst various chemical treatments, plant growth parameters (plant height and weight) were highest in carbofuran treatment and minimum in seed soaking with carbosulfan but the differences (except plant height in fenugreek) amongst these treatments were non-significant. The results in field trials revealed maximum grain yield of fenugreek (6.5 kg/plot) and coriander (5.0 kg/plot) in mustard cake treated plots followed by 5.8 and 4.0 kg respectively in soil treatment with carbosulfan @ 5.5 and 3.7 kg in seed dressing treatment with carbosulfan @ 3.0 (w/w) and 4.2 and 3.3 kg in seed soaking treatment with carbosulfan @ 0.1 % for 6 h in comparison to 4.0 and 2.7 kg in untreated control. Final root-knot nematode population in treated plants was significantly less, ranging between 230.7-248.7 J2/200 cc soil in fenugreek and 220.7 to 250.0 J2 in coriander in comparison to 283.0 and 270.0 in untreated control in fenugreek and coriander respectively. Mustard cake application showed maximum increase in yield of fenugreek (62.78 %) and coriander (56.23 %) over untreated check, it was also quite economical in other treatments also ranging between 1:3.57 to 1:4.46 in fenugreek and 1:3.58 to 1:7.57 in coriander. Cost benefit ratio was also found quite favourable i.e. 1:3.5 in fenugreek and 1:6.17 in coriander.

On the basis of increase in yield and reduction in nematode population obtained from the experiments conducted under microplot and field conditions, the efficacy of various practices for the management of root-knot nematode in fenugreek and coriander is in the order of mustard cake treatment, followed by soil application with carbofuran, seed dressing with 3.0 % carbosulfan and seed soaking in 0.1 % carbosulfan.

# Management of Root Inhabiting Endoparasitic Nematodes of Green Gram, *Vigna radiata* (L.) Wilczek

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An experiment was carried out during 2012 at BCKV, Nadia, West Bengal to find out the effective management tactics for nematode pests infecting green gram. Experiment was conducted in Randomized Block Design with eight treatments and each treatment was replicated thrice. Treatments include neem cake @100 g/ $m^2$, vermicompost @100g/$m^2$, *Trichoderma viride* @ 2.5 kg/ha, seed treatment with carbosulfan 25DS @ 3.0% a.i. (w/w) and their combinations. Combination of neem cake with seed treatment by carbosulfan 25DS or soil application of *T. viride* achieved higher grain yield of green gram being, 9.19q and 8.60q per ha, respectively. Conjunctive use of neem cake and carbosulfan (seed treatment) recorded maximum reduction of *Meloidogyne incognita* (31.1%) and *Rotylenchulus reniformis* (46.0%) population and 65.3 % increase in grain yield over control. The least root-knot index 1.7 was observed in combined application of neem cake + carbosulfan (seed treatment). The treatment also recorded minimum egg mass index 2.7 due to infestation of *Rotylenchulus reniformis*. The incremental cost benefit ratio of the treatments used in managing phyto-nematodes of green gram revealed carbosulfan 25 DS best, being 4.56. Application of neem cake either alone or with *T. viride* did not found economic. Application of vermicompost either as sole or in conjunction with *T. viride* or carbosulfan were found remunerative. It may be inferred that application of carbosulfan 25 DS @ 3% a.i. as seed dressing was most effective and remunerative over all other treatments for the management of nematode pest complex of green gram.

# Management of Plant Parasitic Nematodes in Tomato Through Chemicals and Organic Amendments

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Investigations were undertaken to work out cumulative effect of seven insecticides (Cartaf- hydrochloride, Fipronil, Methyl parathion, Chloropyrifos, Imidacloprid, Carbofuran and Dazomet) against nematodes (*Meloidogyne incognita, Helicotylenchus dihystera* and *Mesocriconema xenoplax*) in tomato through; nursery soil treatment (granular/dust formulations) + bare root dip treatment of transplanting seedlings (EC/WSP/SP formulations) + field soil treatment (granular/dust formulations). Besides, three oil seed cakes (neem, mustard and cottonseed) and three systemic insecticides (thiomethoxam, dimethoate and oxy-methyl dematon) were also evaluated for their efficacy through organic amendments of field soil and bare root dip treatment of transplanting seedlings, respectively. All the seven insecticides with their successive treatments (in nursery soil + root dip treatments + field soil treatment) were found highly effective in reducing the nematode populations, root galling and increasing the crop yield with superiority of Dazomet. Chemical bare root dip treatment (with thiomethoxam, dimethoate and oxy-methyl dematon) remained 2$^{nd}$ best treatment in restricting the nematode multiplication and improving the crop yield, while soil amendment practice with three oil cakes (neem, mustard and cotton seed)was rated 3$^{rd}$ in efficacy. However, in comparison to control all the treatments tested were considerably effective against the nematodes.

# Evaluation for Effectiveness of Pesticides Against Root-Knot Nematode, *Meloidogyne incognita* on Pigeonpea Cultivars

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Seed treatment with five nematicides *viz*., Dimethoate 30 EC @ 0.8ml/ kg seed, Carbosulfan 25 EC @ 1ml/ kg seed Endosulfan 35 EC @ 1.5 ml/ kg seed , Chlorpyriphos 20 EC @ 1ml/ kg seed and Triazophos 40 EC @ 0.75ml/ kg seed were evaluated against root-knot nematode *Meloidogyne incognita* on two short duration pigeonpea cvs. UPAS 120 and CO 6 under pot condition. Dimethoate (0.8%) resulted in significant (*P* d" 0.05) suppression of galls (33.4% in cv. CO 6 and 30.6% in UPAS 120) followed by Chlorpyriphos (31.2% in CO 6 and 27.8% in UPAS 120). Egg masses/ root system was also lowest on the plants received seed treatment with these two nematicides. Maximum reduction in egg mass production (46.5% in CO 6 and 39.2% in UPAS 120) was recorded with the seed treatment with Dimethoate followed by Chlorpyriphos (30.2% in CO 6 and 28.5% in UPAS 120). Seed treatment with Carbosulfan Triazophos or Endosulfan was found least effective in suppressing the galls and production of egg masses on pigeonpea roots. Dimethoate and chlorpyriphos resulted in a significant increase (*P* d" 0.05) in the yield of pigeonpea cv. CO 6 (23% and 20%) and UPAS 120 (25% and 21.7%) over nematode inoculated control, respectively. Functional nodules/ root system increased by 22% in the cv. UPAS 120 due to treatment with either Dimethoate or Chlorpyriphos whereas in cv. CO 6 the increase was 25 and 19% with the two pesticides, respectively. Greatest reduction (*P* d" 0.05) in nematode population was observed with the application of Dimethoate (26.5 and 35.5% in UPAS 120, and 19.5 and 29% in CO 6 at mid season and harvest stage, respectively), followed by Chlorpyriphos (24.5 and 32% in UPAS 120 and, 15 and 26.75% in CO 6). Other treatments also reduced the nematode population in the soil but not up to significant level ($P \leq 0.05$).

# Nematicidal Activity of Schiff Bases of 4-Amino-3-Mercapto-5-Pyridin-2-yl-*4H*-1,2,4-Triazole

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Fusaric acid, 5-n-butyl picolinic acid isolated from *Fusarium oxysporum* EF119 have been recently reported to possess very good nematicidal activity. A series of twenty Schiff bases incorporating the picolinic acid moiety i.e., 4-amino-3-mercapto-5-pyridin-2-yl-4H-1,2,4-triazoles having different substitutions in the aryl ring attached to the amine group were designed and synthesized following the synthesis scheme which involved five steps starting with picolinic acid which was first converted to Ethyl ester HydrazideDithiocarbazinic acid saltTriazole and then finally to Schiff base.The Schiff bases were evaluated for nematicidal activity against the root-knot nematode, *Meloidogyne incognita* and reniform nematode, *Rotylenchulus reniformis*by water screening method. Among all the compounds in this series, 4-(4-Methoxybenzylideneamino)-3-mercapto-5-pyridin-2-yl-4H-1,2,4-triazole [GM13] exhibited the highest nematicidal activity against *M. incognita* ($LC_{50}$=218 ppm); and *R. reniformis*($LC_{50}$=174 ppm) respectively. Three most active compounds *viz.* GM13 ($LC_{50}$=218 ppm), GM12 ($LC_{50}$=230 ppm), GM11 ($LC_{50}$=244 ppm)were further studied for attraction and penetration studies against *M. incognita* $J_2$s in assays carried out in pluronic gel resembling the three-dimensional natural soil environment.GM13 had the most inhibitive effect against attraction and penetration of *M. incognita* $J_2$s towards tomato root.

# NEMATICIDAL ACTIVITY OF *ANISOMELES INDICA* EXTRACTS AGAINST ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA*

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*Anisomeles indica* (Lamiaceae), native to Southeast Asaia including India, is a strong-scented herbaceous shrub having a wide range of medicinal properties. It is generally used in Ayurvedic traditional system of medicine for the treatment of various conditions. *A. indica* has been evaluated for potential inhibitory activity against *Phalaris minor* and other weeds of the wheat crop. It is also used as a natural herbicide for managing weeds in wheat fields. Phytochemical investigations on this plant have revealed the presence of important phytochemicals such as stigmasterol, â-sitosterol, flavonoids, apigenin, triterpenes and ovatodiolides etc. Root-knot nematodes are the major pest of vegetables belonging to the family of solanaceae, cucurbetaceae, leguminosae, cruciferae, okra and several other root and bulb crops, cereals, ornamentals, fruits, medicinal and aromatic plants, spices, condiments and plantation crops etc. Under heavy infestation, there may bre total crop failure. The menace caused by root knot nematode, one of the most wide spread nematode, limiting the world agricultural productivity is well known. The present study deals with the effect of different extracts and their fractions on *Meloidogyne incognita*. The whole plant was extracted with solvents of increasing polarity viz. hexane chloroform and methanol and their bioefficacy evaluated. The hexane extract showed moderate activity. The results of the study and future strategies will be presented at the symposium.

# 24-Epibrassinolide Regulated Morphological Changes in Tomato Infested with *Meloidogyne incognita*

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The present investigation was undertaken to evaluate the *in vitro* effect of 24-Epibrassinolide (EB1) on morphological parameters (% germination, plant height, root length, shoot length, root weight, shoot weight and numbers of galls) of tomato plants infested with *Meloidogyne incognita.* Uniformly sized, sterilized tomato seeds of cv. Pusa Ruby were treated with different concentrations of EB1. The seeds were then allowed to germinate in B.O.D. incubator at 24±2$^0$C. After germination, seedlings were inoculated with second stage juveniles (J2s) of *Meloidogyne incognita* (@ 5 J2/seedling). The morphological parameters were then studied in both roots and shoots of tomato seedlings 5 days after nematode inoculation (5 DAI). An overall increase in the plant growth parameters was observed in EBl treated plants as compared to untreated ones but non significant changes were observed in germination of the seeds. Number of galls also decrease in treated plants and it was found that number of galls significantly decreased with an increase in concentration.

# Session IV: Nematode Biosystematics and Taxonomy

## Predatory Nematodes (Order: Mononchida) Associated with Flower Crops Under Protected Cultivation in Himachal Pradesh

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A survey was conducted to study the incidence of predatory nematodes (Order: Mononchida) from the rhizospheres of flower crops (carnation, rose and chrysanthemum), grown in polyhouses, located in and around district Solan, Himachal Pradesh. Results revealed the presence of *Mylonchulus brachyuris, Iotonchus monhystera, Mononchus papillatus* and *Clarkus papillatus* along with some plant parasitic nematodes *viz., Meloidogyne incognita*, *Helicotylenchus dihystera*, *Tylenchorhynchus mashhoodi* and *Pratylenchus coffeae*. Among the predatory mononchids, *Mylonchulus brachyuris* was found to be the most predominant as revealed by the community analysis of the flower crops. Results also indicated negative correlaton between predaory and plant parasitic nematode populations in the rhizosphere. Population densities of predatory nematodes were also correlated with different abiotic factors (soil temperature, soil pH, soil moisture and organic carbon).

## Characterization of the Root-Knot Nematode (*Meloidogyne* sp.) from Maharashtra

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Root knot nematodes (*Meloidogyne* sp.) are infesting carrot and pomegranate in Rahuri; and pomegranate in Sangamner of Ahmednagar district of Maharashtra. Infested root samples of both the crops were collected for identification and characterization of the species. The species was attempted to identify primarily based on perineal pattern morphology; supplemented with morphological characterization of female, second stage juveniles (J2s) male and egg. However,

perineal patterns showed considerable variations in the populations. Permanent mounts of different life forms were investigated for generation of information on intra-specific variations within the species. This was further confirmed by esterase phenotype pattern. An identified single egg mass population of *M. javanica* from Bankura of West Bengal was used as standard reference for comparison of phenotypic patterns (J3; Rm-0.69, 0.81 and 0.89). Populations from Rahuri infesting carrot and pomegranate were morphologically identified as *M. incognita* (Kofoid &White) Chitwood, 1949 and esterase phenotype showed I1 pattern (single band; Rm- 0.70). Similarly, pomegranate population from Sangamner infesting pomegranate was identified as *M. javanica* (Treub, 1885) Chitwood, 1949 and its esterase enzyme activity showed J3 pattern (three bands; Rm- 0.69, 0.81 and 0.89). Thus, esterase enzyme phenotype was found to be a reliable supplemental tool for confirmation of common morphospecies of *Meloidogyne*.

## Two New Species of Soil Nematodes from Manipur, India

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Two new species of nematodes belonging to genus *Tylenchus* sp. and *Telotylenchus* sp. nov. are described. *Tylenchus conicaudatus* sp. nov. is characterised by having short and gradually tapering tail to a rounded tip, slightly elongated basal bulb and uterine sac, L =0.45 – 0.62 (0.51 ± 53.4) mm, a=32.4 – 46 (37.8.3 ± 4.4) , b= 3.6 - 5.4 (4.5 ± 0.5), c= 7.1 - 18.4 (9.8 ± 3.8), c´=5.3 - 8.2 (6.6 ± 0.9),V=67.4 - 75.5 (71 ± 2.5), Spear=8.5 µm and Tail= 34 - 69.7 (56.3 ± 10.9)µm. *Telotylenchus manipureinsis* sp. nov. is characterised by having shortest body and stylet length but longest conically elongated tai, L=0.37 - 0.46 (0.41 ± 42.9)mm, a= 24.3 - 30.5 (27.1 ± 2.3), b= 3.5 - 4.4 (4 ± 0.3), c= 5 - 6.4 (5.6 ± 0.5), c´= 6.8 - 9.1 (7.9 ± 0.8), V= 63.6 - 71.6 (66.5 ± 3.1), spear = 6.8 - 10.2 (8 ± 1.4)µm and Tail = 64.6 - 93.5 (74.3 ± 11.2)µm.

# Community Analysis of Plant Parasitic Nematodes Associated with Various Crops in Kumaun Region of Uttarakhand, India along with description of *Criconema (Nothocriconema) minutum* n. sp.

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A survey of 6 districts viz. Almora, Bageshwar, Champawat, Pithoragarh, Nainital and Udham Singh Nagar of Uttarakhand was conducted and 63 composite soil samples were taken to record the nematode fauna associated with various vegetables, cereals, pulses, oil-seeds and fruit crops. Analysis of nematode communities revealed the presence of plant parasitic nematodes, of which the predominant ones were; *Rotylenchulus reniformis* associated with castor, okra, papaya, amaranthus, tomato, plum, paddy, pear and pigeon-pea; *Meloidogyne incognita* and *M. javanica* with soybean, okra, black gram, French bean, potato, cowpea; *Helicotylenchus dihystera, H. indicus* and *H. microcephalus* with soybean, maize, lemon, tea; *Tylenchorhynchus annulatus* with sugarcane, litchi; *Trichodorus pakistanensis* with bittergourd; *Quinisulcius capitatus* with maize; *Tylenchulus semipenetrans* with sweet orange. The *R. reniformis* was found to have highest importance value (49.51), followed by *Longidorus elongatus* (41.89), *Meloidogyne* spp. (34.09), *Helicotylenchus* spp. (33.04), *Xiphinema americanum* and *X. insigne* (28.75), *Hoplolaimus seinhorstii* and *H. indicus* (15.98), *T. annulatus* (15.70), *Q. capitatus* (15.33). These nematodes were adjudged to be the top ranking plant parasitic nematodes in these areas. This is the first attempt of nematode based survey in Kumaun region. *Criconema (Nothocriconema) minutum* n. sp. from soil around roots of guava tree in the Reema village of the state was described and illustrated. It was characterized by having smallest body length (284-360 µm), smallest stylet (42-60 µm), anteriorly located excretory pore, a total of 74-78 body annules, two differentiated head annules, closed vulva with conical lips and absence of males.

## A New and A Known Species of Nygolaimoidea (Nematoda: Dorylaimida) From West Bengal, India

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A few specimens of *Aetholaimus indicus* Jairajpuri, 1965 were collected from soil around the roots of guava and that of *Nygelllus* sp. nov. were collected from soil around the roots of litchi (*Litchi chinensis* Sonn.) at South 24-Parganas district, West Bengal, India. The present female specimens of *Aetholaimus indicus* agree well with type specimen except the *a*-value (*a* = 32.1–36.7 in the present specimen and 45–51 in type specimens). This is the first report of the species from the state. *Nygellus* sp. nov. is characterized by almost rounded small cardiac glands, sclerotized vaginal wall, mono-opisthodelphic female reproductive system with complete absence of anterior reproductive branch and by clavate tail. It comes closer to *N. subclavatus* Timm and Ameen, 1960, *N. mozammili* Jairajpuri, 1965 and *N. zingli* Dhanam *et al.*, 2002. But it differs from all known species of *Nygellus* by the complete absence of anterior uterine sac except *N. zingli*. Further the new species differs from *N. subclavatus* in having slightly longer tooth, inconspicuous and smaller cardiac glands, shorter tail and in having a cardia. *Nygellus* sp. nov. differs from *N. mozammili* in having a longer tooth, a distinctly shorter tail evident from *c* and *c¢* value and in having cardia. The proposed new species shows closest resemblance with *N. zingli* but it differs in having slightly short body, continuous and symmetrical lip, greater *a* value, sclerotized vaginal wall, shorter tail, narrower anal body diameter and by shorter rectum length.

## Studies on Nematodes of Hauz Khas Lake Area, New Delhi

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Surveys of HauzKhas lake area were conducted to know the presence of nematodes. Altogether, 20 sediment and water samples were collected. After processing of samples, extracted nematodes were heat killed and fixed in 4% formalin. For further taxonomical studies, nematodes were kept for dehydration. Analysis of nematodes revealed the presence of genera viz. *Panagrolaimus* Fuchs,

1930; *Mesorhabditis* (Osche, 1952) Dougherty, 1953; *Dolichorhabditis*Andràssy, 1983 *Micoletzkya* (Weingärtner, 1955) Paesler, 1962; *Rhabdolaimus* De Man, 1880; *Dorylaimus* Dujardin, 1845 and *Brevitobrilus* Tsalolikhin, 1981 belonging to orders Rhabditida, Araeolaimida, Dorylaimida and Enoplida. The *Dorylaimus* species was found to be the most frequent occurring having relative frequency (26.47), followed by *Brevitobrilus* (20.58), *Micoletzkya* (17.64), *Rhabdolaimus* (5.88). The minimum relative frequency (2.94) recorded for *Dolichorhabditis*. Out of seven genera *Panagrolaimus* Fuchs, 1930, *Dolichaorhabditis* and *Brevitobrilus* seems to be new to science.

# Session V: Nematode Problems in Different Crops

# Population Analysis of Plant Parasitic Nematodes Associated with Soybean Cultivation at Research Farm of Directorate of Soybean Research, Indore

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A survey was carried out in the research farm of Directorate of Soybean Research (DSR), for studying the association of plant parasitic nematodes with soybean cultivation. A total of 26 representative soil samples were collected from 26 blocks of DSR campus. Population analysis of soil samples revealed the presence of Spiral (*Helicotylenchus* sp.), Reniform (*Rotylenchulus* sp.), Lesion (*Pratylenchus* sp.), Lance (*Hoplolaimus* sp.), Cyst (*Heterodera* sp.) and Stunt (*Tylenchorhynchus* sp.) nematodes with different population densities. Based on the Prominence Value (PV), Reniform nematode (PV: 330) was found to be more important followed by Lance (PV: 93), Lesion (PV: 31), Spiral (PV: 26), Cyst (PV: 23) and Stunt (PV: 2) nematodes in the same order. The prevalence of plant parasitic nematodes in the research farm was documented as nematode distribution map.

# Estimation of Loss in Bidi Tobacco Due to Reniform Nematode Under Pot Conditions

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An experiment was conducted during 2011 and 2012 at Bidi Tobacco Research Station, Anand to estimate avoidable yield loss in tobacco due to reniform nematode under pot conditions. Two varieties ABT 10 (Root-knot resistant) and A 119 (Root-knot susceptible) and two inoculum levels 0 (Control) and 2000 $J_4$ per pot were tried. The treatments were replicated eight times in CRD. Thirty-two disinfested pots (15 cm diameter) were filled with 500 cc sterilized soil and FYM and transplanted with one seedling per pot. Second stage juveniles ($J_2$) of reniform nematode from soil of micro plot were extracted, concentrated and kept for 15 days at room temperature to get pre-adult stages ($J_4$). The nematode population per ml of suspension was estimated and required quantity (20 ml) of the suspension was

inoculated in the respective pot, while in control 20 ml water was used and the seedlings were watered regularly. After 60 days of inoculation observations on plant growth, nematode penetration and multiplication were recorded and pulverized cured leaf powder from respective treatments were used for analyzing nicotine, reducing sugar and chloride. Results revealed that inoculation of the nematode significantly reduced the plant growth characters and increased nematode multiplication in A 119. Avoidable yield loss in ABT 10 and A 119 was 30.5 and 34.2 per cent respectively with overall loss of 31.9 per cent in both. ABT 10 irrespective of nematode infection avoided 29.5 per cent yield loss with significantly high nicotine, reducing sugar and chloride than A 119. Inoculation of reniform nematode significantly increased nicotine, reducing sugar and chloride as compared to control while in ABT 10 reducing sugar reduced and chloride increased significantly without any impact on nicotine.

## Nematodes Inhabiting Syconia of *Ficus* Species in Haryana, India

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Syconium (fig) is a multiple fruit developed from a hollow fleshy receptacle containing numerous flowers. Figs are visited by a number of pollinating as well as non pollinating wasps for oviposition. These wasps also introduce nematodes in to the figs during this process. *Ficus* species growing in Hisar (Haryana) namely, *F. benjamina* L., *F. benghalenesis* L., *F. carica* L., *Ficus racemosa* L., *F. religiosa* L., *F. retusa* L. and *F. virens* Ait, were studied for the presence of nematodes in their synconia. Two species of *Schistonchus* Cobb, 1927 (Aphelenchida) were found multiplying in *F. racemosa*, one on synconial walls and other on stamens. These nematodes were also recorded in association with three species of Aganoid wasps either externally or internally. *Teratodiplogaster* sp. and at least two other genera of Diplogasterid nematodes were also common inside the figs of this *Ficus* species. *Teratodiplogaster* Kanzaki *et al*., 2009 is a new record of this genus from India. *F. benghalenesis*, *F. carica* and *F. religiosa* also harboured *Schistonchus* species multiplying in stamens. Entomophilic forms of *Schistonchus* sp. collected from *F. benghalensis* were also recovered from inside the abdomen of its pollinating wasp. Syconia of *F. religiosa* also housed an undescribed diplogasterid nematode. Specific identification of nematodes and wasps collected during this study is in progress.

## Screening of Legume Germplasm for Resistance to Root-Knot Nematode, *Meloidogyne incognita*

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Root-knot nematodes (*Meloidogyne* spp.) are one of the most widespread agricultural pests in the world and are considered to be the most potential nematodes of legumes. Cultivation of nematode-resistant cultivars is a simple and economical way to prevent nematode-induced damage and to avoid environmental pollution due to excessive use of nematicides. During 2012-13 a total of 714 accessions (acc) of various legume crops such as cowpea, *Vigna unguiculata* (200 acc); lentil, *Lens culinaris* (397 acc); black gram, *Phaseolus mungo* (52 acc) and pea, *Pisum sativum* (65 acc) were screened for resistance to *M. incognita*. Screening experiments were conducted in 10-cm diameter pots filled with 500g naturally infested soil containing 4 Juveniles/g soil. Sixty days after sowing, the plants were uprooted and washed in tap water to observe gall formation. The host status of each accession was assessed on the basis of number of root galls induced. A total of 8 acc found resistant to *M. incognita* with <10 root galls/plant, which include 2 acc of cowpea (EC149444, EC517140), 4 of lentil (IC-559744, IC266800, IC398691, IC520809), 2 in black gram (IC-219025, EC-502159) and none of pea acc was found resistant.

## Effect of Rice Root-Knot Nematode on Wheat and *Kanki* (*Phalaris minor*)

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Rice root knot nematode is mainly a nematode pest of upland and irrigated rice during *kharif* season. It also parasitizes many crops and weed flora belonging to family Gramineae. During *Rabi* season, wheat and some weeds do support it, on which it completes its life cycle during *Rabi* season. They serve as collateral hosts

for the nematode. A study on the impact of rice root-knot nematode on wheat and *Phalaris minor* (*Kanki*) was conducted on farmer's field, naturally infested with rice root knot nematode. In the experimental field rice was taken as preceding crop. Wheat (cv. DBW-17) was sown in the 1st week of November and data on plant height, plant and root weight (fresh), dry shoot and root weight, number of tillers were recorded 85 days after sowing. The same growth parameters were recorded for *P. minor* also. The same parameters from healthy plants from uninfested field were also recorded for comparison. Data on number of galls from infected plants were also recorded.

The results revealed that average plant height from uninfested field was 30.8 cm as compared to 26.0 cm in infested plot, registering a 15.38 % increase. Fresh shoot weight was 9.8g in healthy plot compared to 7.1g in infested plot giving an increase of 38.01 %. Fresh root weight and number of tillers recorded an increase of 28.8 and 19.4 %, respectively in healthy plot compared with infested plot. Dry shoot and root weight in healthy plot registered an increase of 38.0 and 30.0%, respectively. In case of *Phalaris minor* plant height increased up to 5.1 % in uninfested plot as compared to infested one. Fresh plant and root weight had 83.3 and 31.3 % increase, respectively. Number of tillers had an increase of 16.7 % as compared to that of infested plot. Dry shoot and root weight had an increase of 97.7 and 28.6 %, respectively. Number of galls per plant were 23.3 and 49.2, in wheat and *Phalaris minor,* respectively.

## Quick Wilt Complex of Ginger caused by *Meloidogyne incognita* and *Ralstonia solanacearum*

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Root knot nematode, *Meloidogyne incognita* was frequently associated with quick wilt symptoms in ginger caused by *Ralstonia solanacearum*. The present study was undertaken to investigate the interaction between *M. incognita* and *R. solanacearum* for two years under pot culture condition in Ginger inoculated with nematode and bacterium either singly, simultaneously or sequentially after a period of 10 days. Incidence of wilting commenced 27 days after inoculation (DAI) in bacteria alone, 22 DAI in nematode + bacteria, 17 DAI in nematode followed by

bacteria and 31.5 days in bacteria followed by nematode. Prior inoculation of *M. incognita* reduced the incubation period *R. solanacearum* by 10 days. Combined inoculation of both the pathogens either simultaneously or sequentially resulted in decrease in leaf water potential thereby inducing quick wilt symptom. Further, significant decrease in various parameters such as number of branches, plant height, dry weight of shoot and rhizome yield including decrease in root knot index over check was recorded in the combined inoculation.

## Population Dynamics of Plant Parasitic Nematodes in Paddy Based Cropping Sequence

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A cropping sequence experiment was conducted during 2011-12 to study the population dynamics of predominant plant parasitic nematodes such as *Meloidogyne incognita*, *Hirschmanniella mucronata* and *Helicotylenchus abunaamai* in upland situation. There were eight nutrient based treatments along with use of neemcake, biopesticides, green manuring and trap crop in different combinations. Initial and final soil samples were collected from paddy (Kharif), patato (Rabi) and okra (Summer) crops. Populations of plant parasitic and saprophytic nematodes were estimated. At the end of Kharif season, the populations of *H.mucronata* and *H.abunaamai* were increased in paddy crop whereas the population of *M.incognita* was reduced irrespective of treatments. Potato crop at the end of Rabi season as well as okra crop at the end of Summer season supported the multiplication of *M.incognita* and *H.abunaamai* but not *H.mucronata*. However, the rate of population increase of *M.incognita* and *H.abunaamai* was comparatively less in the treatments where neemcake, green manuring and FYM were the major components. Higher final populations of saprophytic nematodes were recorded in all the treatments.

## Prevalence of Nematode Populations in System of Rice Intesification (SRI)

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Initial soil sampling from paddy transplanted under SRI and conventional methods during Kharif, 2012 revealed the presence of three predominant plant parasitic nematodes viz. *Meloidogyne graminicola, Hirschmanniella mucronata* and *Helicotylenchus obunaamai*. At maximum tillering stage populations of *M.graminicola* and *H.abunaamai* were increased in SRI method in comparison to conventional method. On the contrary, population of *H. mucronata* was increased in conventional method as compared to SRI method. At harvest, the populations of all the three plant parasitic nematodes were increased in SRI method. However, the population increase of *H.mucronata* was more pronounced in conventional method than that of SRI method. Populations of *M.graminicola* and *H.abunaamai* were reduced in conventional method during harvest. At different growth stages of paddy crop, the increase in populations of saprozoic nematodes was gradual and moderate in both the methods.

## Survey of Plant Parasitic Nematode Fauna Associated with Castor (*Ricinus communis*) in Selected Districts of Andhra Pradesh, India

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Soil and root samples were collected from castor (*Ricinus communis*) grown in Rangareddy, Nalgonda, Mahbubnagar, Kurnool and Prakasam districts of Andhra Pradesh during rabi, 2012-13. Analysis of the samples revealed that 68 out of 86 samples were infested with reniform nematode, *Rotylenchulus reniformis* with prominence value (PV) of 2.0 followed by spiral nematode, *Helicotylenchus* sp. (PV = 0.9); lance nematode, *Hoplolaimus* sp. (PV = 0.4) and stunt nematode, *Tylenchorhynchus* sp. (PV = 0.3). Reniform nematode was recorded as most

abundant plant parasitic nematode on castor with an absolute and relative density of 216 and 16.1 respectively, followed by spiral nematode (105 & 8.1); lance nematode (51 & 3.9) and stunt nematode (37 & 2.9). Spiral nematode was the most occurring plant parasitic nematode with an absolute and relative frequency of 80.9 and 20.8 respectively, followed by reniform nematode (76.9 & 19.9); lance nematode (71.4 & 17.9) and stunt nematode (64.4 & 15.9).

## Traditional Medicinal Plants — Non-Host of Root-Knot Nematode (*Meloidogyne incognita*)

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A total of 40 root samples of some commonly available medicinal plants, viz. Bahok (*Adhatoda zeylanica*), Nayantora (*Catharanthus roseus*), Nephaphu (*Clerodendron colebrookianum*), Mosondori (*Houttuynia cordata*), Doron (*Leucas plukeneti*), Bhedailota (*Paederia scandens*), Bhringaraj (*Wedelia calendulacea*) were collected from the district Tinsukia. The roots of each medicinal plants were washed by clean water and observed by 60x magnification glass. It was observed that no gall formation in the root system of the above mentioned medicinal plants except Doron (*Leucas plukeneti*).Seedling/rooted cuttings of the medicinal plants were transplanted in half kg capacity earthen pots containing sterilized soil (with 5 replication each along with check) in the Department of Nematology, AAU, Jorhat. Seven days after transplanting five hundred freshly hatched second stage larvae of *Meloidogyne incognita* were inoculated over the surface roots to each of the medicinal plants. Harvesting of the plants was done 30 days after inoculation. The root system was washed with clean tap water very carefully to avoid root damage. Observations were made on number of egg mass, galls, root length in all treatments. We have observed that root growth was good and no galls or egg masses on all the above mentioned medicinal plants except Doron(*Leucas plukeneti*).Root growth was retarded with galls and egg masses on Doron (*Leucas plukeneti*).This is the first survey on root-knot nematodes on some commonly used medicinal plants in Tinsukia district of Assam. As these plants are non-hosts of *M. incognita*, further works are needed for management of root-knot nematode by using the phytotherapeutic substance of these medicinal plants.

## Incidence of Phytonematodes in Vegetable and Ornamental Plants Grown Under Protected Cultivation in Haryana

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Thirty eight soil and root samples from vegetable and ornamental crops grown under protected cultivation were collected from six districts (Hisar, Fatehabad, Sirsa, Kaithal, Kurukshetra and Karnal) of Haryana during 2012-13. The results revealed that root-knot nematode (*Meloidogyne* spp.) emerged as the key nematode pest infesting vegetable crops (cucumber, tomato & capsicum) with low to high population. Per cent incidence of nematode infestation in the samples was found as 37.5, 52.9 and 33.3 in capsicum, cucumber & tomato, respectively. Other important nematodes found in these crops were *Rotylenchulus reniformis* and *Pratylenchus* spp. However, in tomato *Tylenchorhynhus mashhoodi, Ditylenchus* spp. and *Aphelenchus* spp. with low to medium population were also recorded. In ornamental plants (rose & lilium), the incidence of *Tylenchus* spp., *Ditylenchus* spp. *Rotylenchulus* spp. and *Tylenchorhynchus* spp. was recorded. However, none of the samples showed the incidence of rot-knot nematode, *Meloidogyne* spp.

## Observations on *Radopholus similis* and *Helicotylenchus multicinctus* Infesting Banana in Gujarat

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Soil along with root samples around banana (cv Grand nine) were collected from Ratnapura village (Taluka-Umreth; GPS: $22^0$.39.842N, $73^0$.05.554E) of Anand district, Gujarat. The nematode populations were extracted by Cobb's decanting and sieving followed by modified Baermann technique, fixed in FAA 4:1, further processed and mounted on anhydrous glycerine. Morphometric analysis and photomicrographs were made using light microscopy (AXIOSKOPE 40) and Image Analyzing Software.

Two most damaging nematode species viz. *Radopholus similis* (Cobb) Thorne, 1949 and *Helicotylenchus multicinctus* (Cobb) Golden, 1956 were identified based on morphology and morphometrics. About 18-21 taxonomic characters of male and female populations for each species were recorded for characterization of *R. similis* (20 females; 9 males) and *H. multicinctus* female (18 females; 5 males). Considerable variations on the morphology and morphometrics were recorded in Gujarat populations of *R. similis* and *H. multicinctus* from banana. The data generated on Gujarat populations in this study was compared with the published literature and deviations were noted in some taxonomic parameters for both the species. Therefore, the current morphological and morphometric information could be useful for easy identification of Indian populations of both species.

## Pathogenic Variability in Rice Root-Knot Nematode (*Meloidogyne graminicola*) from India

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Rice root-knot nematode, *Meloidogyne graminicola* is an emerging problem in rice growing tracts of India and outbreak of this nematode on rice nursery is posing a threat to the staple food crop of Indian populace. The study was focused to understand the pathogenic variability among the three isolates (West Bengal-Kalyani, Delhi and Assam-Jorhat) of *M. graminicola* on six rice resistant genotypes *viz*., Suraksha, ARC-13516, INRC-8843, INRC-8867, BG-380-2, KMP-179 procured from Directorate of Rice Research (DRR-ICAR), Hyderabad and ZAHRS (Shimoga-Karnataka) and on one susceptible check variety (IET-4786). Rice genotypes were sown during August, 2013 in a plastic pot contained sterile soil. Each one had nine replications and freshly hatched 100 second stage juveniles (J2s) of *M. graminicola* was inoculated near the base of each 10 day-old rice seedling. Each rice plant was observed after 35 days of inoculation for the root-galling severity and eggmass production. The isolates from Kalyani and Delhi readily infected and reproduced on five rice genotypes except INRC-8843. The Jorhat isolate infected and reproduced well on all rice genotypes including INRC-8843. This indicated clearly that Jorhat isolate of *M. graminicola* is quite different in terms of its infectivity from Kalyani and Delhi isolates. Further, Jorhat isolate showed high virulence to the rice genotype,

BG-380-2 in comparison to other isolates. The pathogenic variability of Jorhat isolate on INRC-8843 is an indication of physiological variations (race) in *M. graminicola* and the rice genotype could be utilized as a host differential.

## Comparing Carrot Disc and Alfalfa Callus Techniques for Culturing Root Lesion Nematode, *Pratylenchus thornei*

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Carrot disc and alfalfa callus techniques were compared for culturing *Pratylenchus thornei* Sher and Allen. Carrot discs were prepared in 1% water agar and alfalfa callus on MS medium (4.08g MS basal medium, 30 g sucrose, 10 g agar-agar, 4 mg 2, 4- D) in 150 ml conical flasks. Forty surface sterilized nematodes were inoculated in each flask, under aseptic conditions and they were incubated at 22 $^{o}$C. After 8 weeks of inoculation, nematodes were extracted from calli and carrot discs by modified Baermann funnel technique. Results revealed that final nematode population and reproduction factor were greater in the carrot disc technique (723 and 18.01, respectively) than in alfalfa callus technique (530 and 13.25, respectively). Carrot disc technique proved better as it is simple, economical and yielded more number of nematodes than alfalfa callus technique. MS medium proved better than yeast extract agar medium for alfalfa callus production and alfalfa cotyledons produced better callus than hypocotyls or whole seeds.

## Occurrence and Status of Some Ectoparasitic Plant Nematodes (Dorylaimida:Longidorodea) in Apple Belts of Kashmir, India

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As a risk communication for risk management from scientists, signalling (alarming) the farming community to adopt feasible control measures against such virus vector nematodes for ensuring protection of apple and woody perennials in the national interest under successful lab to land program, extensive survey was carried out in apple pockets of Kashmir to record their occurrence and status for further advanced

studies. During the extensive survey, the analyzed data of eighty one collected composite soil samples of around 25-30 years aged apple trees in district during 2008, involving three fruit belts and comprising nine localities from each belt revealed that. most pre dominant ectoparasitic nematodes recorded with apple trees were *Xiphinema insigne*, *X. index* & *Longidorus elongatus* each with 100% frequency in all localities as wel as in the entire three belts. These ranked first, second and third important adenophoreans in the district on the basis of percent relative density (20.89, 13.97 and 12.31) and on the basis of prominence value (698.4, 467.0 and 395.93).Their average population range was recorded as 66.67 – 73.52, 43.03 – 50.37 and 37.50 – 44.84 per 250 cc soil at 95% confidence interval respectively. Their importance value in the district were found as 46.67, 45.28 and 38.68 respectively but on the basis of percent biomass *Longidorus elongatus* ranked first (18.00), *Xiphinema index* as second (16.42) and *X. insigne* as third (12.55).Other ectoparasitic nematodes were present with less frequency and their importance values in descending orders were recorded as 9.94, 8.68, 7.39, 6.83 and 5.310 for *Longidorus mirus*, *Xiphinema americanum, X. diversicaudatus, L. brevicaudatus,* and *X. basiri* respectively. The well establishment / setup of the important plant parasitic adenophoreans in apple orchards indicates that the possibility of high population build up in some sites cannot be ruled out in future with the approach of global warming as the present data of *X. insigne, X. index* and *L. elongatus* can emerge as dangerous. The data can serve here the means of alarming or forecasting shadow for coming dangerous events of tomorrow because the viruliferous nematodes have the potential for long survival in soil and transmit the nippo viruses with small isometric particles in soil by feeding ectoparasitically.

## Distribution of Soil Nematodes in Relation to Physico-Chemical Properties of Soil in Manipur, India

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A study was conducted for distribution pattern of soil and plant parasitic nematodes in four selected mulberry farms of Manipur. For the study, data on soil pH, organic carbon, phosphorous and potassium content of soil were collected along with soil samples from four different farms of the valley districts of Manipur for a period of two years 2009 – 2010. Highest nematode population was found at site II where soil

type was clayey-loam with lesser organic carbon content of 3.6; greater nitrogen content, phosphorous and potassium with somewhat higher soil pH value. Least nematode population was found at site IV where soil type was sandy loam with least nitrogen and phosphorous content.

## Pathogenicity of *Meloidogyne incognita* (Kofoid & White) Chitwood in okra, *Abelmoschus esculentus* L.

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An experiment was conducted during April-July, 2013 to determine the pathogenic potential of *Meloidogyne incognita* race 2 in okra, at BCKV, Nadia, West Bengal. The experiment was laid out in Completely Randomized Design with seven treatments and three replications. Healthy seeds of okra cv. OH-152 were directly sown in 15cm earthen pot containing 1000cc of sterilized soil. Three weeks after germination one healthy seedling per pot was inoculated with freshly hatched J2 of *M. incognita* @10, 100, 1000, 5000, 10000 and 15000 per plant. Uninoculated plants were kept as control. Observations were recorded at 60 days after inoculation on final nematode population, plant height, fresh as well as dry shoot and root weight, root length and root-knot index. The total nematode population in soil was calculated from representatives of 200cc soil/pot. The root samples were examined after differential staining. Total number of eggs/egg mass was counted by taking 5 egg masses of uniform size followed by immersion in 0.5% solution of sodium hypochlorite for 5 minutes. Reproduction factor (R) was calculated as Pf/Pi where, Pf and Pi are final and initial nematode population/plant, respectively. There were significant decreases in all the observed growth attributes of okra at 1000 and above nematodes. A negative correlation existed between initial inoculum density and plant growth parameters. Occurrence of root gall was increased with the increase in inoculum level. The rate of reproduction was inversely related to the inoculum levels and was maximum (35.97) at lowest level and minimum (1.02) at highest level. An initial population density of 1000 nematodes per 1000cc of soil may be considered as the minimum density level of *M. incognita* race 2 for expression of pathogenic effects on okra.

# Spectrum of Hosts for Rice Root-Knot Nematode, *Meloidogyne graminicola* (Haryana Population) Under Green-House Conditions

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A green house study was undertaken to screen six cultivars of rice - *Oryza sativa* (cvs. CSR-30, Pusa-1121, Basmati-370, Annapurna, TN-1, Ramakrishna), two *kharif* weeds *viz., Dactyloctenium aegyptium, Leptochloa chinensis,* sorghum - *Sorghum bicolor* (cv. HJ-541)*,* pearl millet - *Pennisetum typhoides* (cv.HHB67), brinjal - *Solanum melongena* (cv. BR-112), tomato - *Lycopersicum esculentum* (cv. PKM-1) against a local isolate of *Meloidogyne graminicola* (Hisar population). The infested soil was collected from a farmer's field with initial inoculums of 134 $J_2$ per 100 cc soil. The soil was filled in earthen pots (10 cm dia., 500 g capacity) with three replications for each cv./plant sp. The plants were uprooted after 50 days of planting. The host reaction was evaluated on the basis of gall formation and egg count. All test plant species/cvs. used in the study were infected by *M. graminicola* except tomato. Rice varieties CSR-30, TN-1, Ramakrishna, along with brinjal exhibited maximum galling (142-180 per plant), and these were at par. This was followed by rice varieties Pusa-1121 (132), Annapurna (108), Basmati-370 (107), and sorghum (130), pearl millet (127). The galling on two weeds was relatively poor - 63 for *D. aegyptium* and 45 for *L. chinensis.* Total egg production per plant was maximum on rice varieties Annapurna, CSR-30, Basmati-370, Pusa-1121 and Ramakrishna (11066-17844). Egg production on rice cv. TN-1, two weeds, sorghum, pearl millet was at par (611-6288). *M. graminicola* produced only 1467 eggs on brinjal although galling was severe. The gall and egg count on tomato was nil.

## Phytoparasitic Nematodes in Vegetable Crops Under Polyhouse Conditions in Himachal Pradesh

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The systematic survey was conducted to determine the status of plant parasitic nematodes associated in vegetable crops under polyhouse conditions. About 52 localities from different districts of Himachal Pradesh were surveyed. The genera recorded were *Meloidogyne* spp., *Pratylenchus* spp., *Helicotyenchus* spp., *Tylenchorhynchus* spp., *Hoplolaimus* spp., *Criconimoides* spp. and *Paratylenchus* spp. During the present study, *Meloidogyne* spp. was predominent with population range (80-20,000) followed by *Helicotylenchus* spp. (100-750), *Tylenchorhychus* spp. (70-300) and *Criconimoides* spp. (50-70) associated with tomato. Similarly, in the case of cucurbits (cucumber, squash and bitter gourd) *Meloidogyne* spp., *Pratylenchus* spp., *Helicotylenchus* spp. and *Criconemoides* spp. were recorded with population range (60-1000), (70-300), (0-240) and (0-35) respectively. Four genera *Meloidogyne* spp., *Tylenchorhychus* spp., *Helicotylenchus* spp. and *Paratylenchus* spp. were recorded from capsicum. During the present study *Helicotylenchus* spp., *Meloidogyne* spp., *Tylenchorhynchus* spp. and *Cricomimoides* spp. were also recorded with bean, cruciferous (chinese sarson, broccoli and pakchoi), potato and coriander crops under polyhouse conditions in Himachal Pradesh.

## Directly Proportional Detrimental Effect of Root-Knot Nematode (*Meloidogyne incognita*) Threshold on Turmeric *Curcuma domestica* val.( *C.longa* L.)

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In the Punjab State turmeric an important spice crop is commonly known as *haldi* is grown for its rhizomes which are used as spice in many culinary preparations. It is

also used in drug and cosmetic industries. M. incognita infests its roots, thereby, affect the rhizomes significantly qualitatively as well as quantitatively. Root knot nematode in the presence of root rot fungus infested rhizomes loose their bright yellow golden color and exhibited unpleasant appearance as compared to healthy ones. The initial population of root knot nematode juveniles in the field was 2 J 2/ g of soil was recorded in the first week of April. Root knot nematode infected plants show yellowing of leaves, stunted growth, marginal & tip drying of leaves; reduced tillering of above ground plant parts, thereby, reducing the vigor of the plant. Heavy infested galling of the roots and rotting in the presence of root rot fungus in advance stages were observed on the root system. The root s were heavily infested with root knot nematode, yet , no egg masses were founds on the galls /roots and no infestation occurred on the rhizomes till the last week of September. The RGI scale 1-5 was used to record the observations. More than 20 galls on the roots of a plant resulted in deterioration of the roots as well as very poor growth of the plant and rhizomes which show rotting in the present of root rot fungus in advanced stages. All the clones of turmeric have shown the same results in the field. Though , root were heavily infested with RKN , yet rhizomes remained unaffected which compelled the in vitro studies to be conducted which revealed that fresh rhizome extract of N concentration completely inhibited the emergence of RKN J2 from the egg masses and killing/inactivation/ immobilization of those which emerged.

## Distribution and Infestation Rate of Root-Knot Nematode in Crossandra in Rayalaseema of Andhra Pradesh

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Crosssandra is a small evergreen shrub grown as intercrop in horticultural gardens and has the ability to produce beautiful flowers with a remarkable range of colours almost all the year. This has made it extremely popular in southern states of India (Tamil Nadu, Andhra Pradesh, Pondicherry and Karnataka) where the flowers are widely used in temple and veins to make as hair adornments. Through extensive surveys of crossandra fields in Andhra Pradesh during 2011 -2012, heavy damage of crossandra plants were encountered due to root-knot nematodes in district of Kadapa and Chitoor. It was observed that 76 of 33 fields of crossandra were infested

with root-knot nematode (*Meloidogyne* spp). The most common species identified were *Meloidogyne incognita* (42.42%). The *M. javanica* and *M. incognita* that were found in mixed population at the rate of 51.85%, identified by using perineal pattern. The highest frequency (56.25%) of occurrence of root-knot nematodes was found in Kodur, closely followed by Khajipeta (55.55) and Rajampet mandal (44.44%) in Kadapa district while 50% in Peddathippasamudram mandal of Chittoor district. In both these districts the frequency was 43.42%. Our preliminary results indicated *Meloidogyne* spp., might be the major nematode pests of crossandra and it warrants to investigate its impact on plant health and yield.

## Diversity of Nematodes Associated with Vegetable Crops Grown in and Around Hyderabad

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Nematodes are the most numerous multicellular animals on earth. Free-living species are abundant, including nematodes that feed on bacteria, fungi, and other nematodes, yet the vast majority of species encountered are poorly understood biologically. A survey was conducted to assess the nematodes associated with rhizosphere of vegetable crops like cabbage, cauliflower, carrot, beetroot, tomato and green chillies in and around Hyderabad . The areas surveyed were Shamshabad, Maheshwaram, Yacharam, Ibrahimpatanam, Shamirpet, medchal, Shankarpally, Chevella, Moinabad and Vikarabad. Collection of soil and root samples was done during mid cropping season from the rhizosphere of vegetable crops. Root Knot nematode *Meloidogyne incognita and M javanica* were found to be the major plant parasitic nematode in all the vegetable grown areas in all the crops surveyed. The spiral nematode *Helicotylenchus Sp*. was the next major abundant plant parasitic nematode. Other nematode associated were lesion nematode *Pratylenchus Sp*, lance nematode *Hoplolaimus sp*, reniform nematode *Rotylenchulus reniformis* and *Tylenchus Sp*. The infection by root knot nematode was severe in Shankarpally area. Plant parasitic nematodes were abundant even in black soil areas of Renga reddy district.. The population of bacterial feeding, fungal feeding and ominivorous nematodes were very less in these areas. This may be due to less addition of organic matter and continuous cultivation of vegetables round the year. Soils analysed from rhizosphere of less preferred hosts like onion and garlic was also

found to sustain high population of root-knot nematode. Addition of organic manure may enrich the soil with freeliving forms of nematodes and reduce the harmful plant parasitic forms.

## An Outbreak of White Tip Nematode (*Aphelenchoides besseyl*) In Rice

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Rice is the steple food for more than 45% population in India. A IPM project entitled conducted in Biswan under agro-ecological situation-11 covering 15 different location in villages Akhtarpur, Tiwaripur, Shuklapur, Katia, Oripur, Ghuripur, Padariya and Dafara. At following time some panicle exhibited white ears and some showed non-specific symptoms with sterility in the panicles. 500 penicles bearing tillers were collected from 124 locations and it was noticed that 12 out of 124 locations, the whole panicle become chaffy due to damaged caused by white tip nematode. It was also recorded that there was ill emergence, partial filling and chattiness of the grains in those plants which were attacked by the white tip nematode. This nematode could become one of the major nematode problem in rice in the above said area.

## Plant-Parasitic Nematodes Associated with Mentha Field of Sitapur, Uttar Pradesh, India

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An extensive survey was carried out for the infestation of plant parasitic nematodes associated with Japanese Mint, *Mentha arvensis* var *piperascense* growing fields. Soil and root samples were collected from 24 Mentha fields represents 15 different locations (villages) Akhtarpur, Tiwaripur, Shuklapur, Katia, Oripur, Ghuripur, Padariya and Dafara. It was observed that 19 out of 24 samples collected had the plant parasitic nematodes population. Result revealed that incidence of root-knot nematodes *Meloidogyne incognita*, *Hoplolaimus* spp., *Helicotylenchus* spp., *Tylenchorhynchus* spp. were present. It was also found that 39% of fields had the root-knot nematode populations, whereas 87% had other major plant-parasitic nematodes.

## Nematode Populations in Different Wheat Based Cropping Systems in Punjab

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Nematode populations were studied in different wheat based cropping systems ; rice – wheat, cotton–wheat, maize–wheat, soybean-wheat , pearl-millet–wheat and sugarcane-wheat being followed in Punjab. In rice –wheat cropping system *Heterodera avenae and Meloidogyne sp*. *Hirschmanniella oryzae,* and *Tylenchorhynchus* sp. were recorded. The highest population was of *Tylenchorhynchus* sp in wheat crop. In rice *H. oryzae* was higher as compared to wheat. The frequency of occurrence was 100 per cent of *Tylenchorhynchus* sp in wheat and number was 480 nematodes / 250 cc soil. During wheat season the

cysts of *H. avenae* were extracted from the roots. Besides larvae of root-knot nematodes, galling was also observed on wheat roots of some samples. In cotton-wheat cropping system *H. avenae,* species of *Meloidogyne, Tylenchorhynchus. Helicotylenchus,* and *Hoplolaimus* were important plant parasitic nematodes. During cotton season the highest number of nematodes was of *Meloidogyne* species. *H. zeae* and *Xiphinema spp.* were found in maize-wheat system along with *Pratylenchus* and *Criconemoides spp*. which were also of common occurrence in sugarcane-wheat besides species of *Tylenchorhynchus, Helicotylenchus,* and *Hoplolaimus.* In soybean-wheat , pearlmillet–wheat the main nematodes were *Hoplolaimus* and *Tylenchorhynchus* and their population was higher during soybean and pearl-millet crop. The population of *Tylenchorhynchus* sp was recorded highest in wheat crop in all the other cropping systems studied.

## Reaction of Muskmelon Cultivars to *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *melonis*

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Root knot nematode is one of the most significant biotic stress to muskmelon crop and have been reported to be aggravators or resistance breakers in fungal diseases. Muskmelon wilt is a complex disease associated with two pathogens root knot nematode and fungus. Its occurrence is widespread and the damage is particularly striking in the case of continuous cultivation in Punjab reducing quality and yield. Hence, the present studies were carried to study the reaction of ten muskmelon cultivars to *M. incognita* and *F.o.* f. sp. *melonis* alone and in combination (simultaneous inoculation of both pathogens- eight cultivars). The seedlings of muskmelon were transplanted in the 10" diameter pots containing 2 kg steam sterilized soil/pot at pothouse of Department of Plant Pathology, PAU, Ludhiana. After 10 days when the seedlings were established, they were inoculated with i) nematode alone; ii) fungus alone; iii) nematode and fungus simulataneously. Nematode inoculum was prepared by collecting eggmasses from pothouse where pure culture of *M. incognita* was maintained on tomato. For fungus culture, the infected parts were cut into bits and the bits are transferred aseptically on to a sterilized Potato Dextrose Agar (PDA) slants. Pure culture was maintained in PDA petriplates. About 2000 hatched larvae/kg of soil and 2g of fungal culture/kg of soil were inoculated to each pot at the time of transplanting and covered with the soil.

Observations were recorded after 50 days of transplanting. Observations revealed that all ten cultivars were found to be highly susceptible to root-knot nematode. Response of different cultivars of muskmelon to fungus was varied from high, moderate to low susceptible. Maximum wilting symptoms were observed in 4026(DI=100%), followed by 4021 & 3966 and chlorosis symptoms were observed in 4091 & 4078. More yellowing and less chlorosis observed in 4248(DI=62.5%). In simultaneous inoculations of nematode and fungus, wilting was observed to be higher in six cultivars as compared to fungus alone indicating increase in wilt in muskmelon crop in presence of nematode.

## Galling Pattern of *Meliodogyne graminicola* in Shimoga district of Karnataka

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Rice is a major staple crop in Karnataka. It is grown under a variety of soils and wide range of rainfall and temperature. Rice is cultivated in places where the rains are as heavy as 3000 mm and in others where it is just 600 mm. In some areas, only one crop is grown and in certain other areas three crops are raised. The unique feature of rice culture in the state is that either sowing or transplanting is seen in all seasons of the year. The unique feature of rice culture in the state is that either sowing or transplanting is seen in all seasons of the year. Rice root-knot nematode appeared in devastating form in parts of major rice growing areas of Shimoga during 2001, which was a first report from Karnataka and subsequently reported from Mandya district of the state. Initially it was noticed only in aerobic condition. Since 2011, it has been observed in unaerobic condition also and appearing in all type of rice cultivating situations.

The symptoms produced due to the infestation of *M. graminicola* are manifested in the form of characteristic terminal hook or typical ring like spindle or bead/nodule shaped galls on the roots leading to stunting and chlorosis of the rice plants in patches within nursery or main field and consequently reduced crop yields. But, during the survey for the nematode infestation in Shimoga district, samples analyzed showed divergence from the typical symptom of galls at the root terminal.

Here we report galling patter in rice samples collected from different taluks of Shimoga district namely Shimoga, Shikaripur, Bhadravati, Hosnagara, Sorba and Sagar. Different galling patterns like bulbous galls at the mid of the roots, bunch of galls, superficial galls, discreet multiple galls, bulbous galls at the branching of roots were observed along with the typical symptoms of *M. graminicola*. As the samples analyzed were collected from farmers' field it may be the sign of different species of root-knot nematodes infecting rice or indication of presence of different *M. graminicola* biotype, which has to be confirmed further.

## Role of Root-Knot Nematode, *Meloidogyne incognita* Infection on Nodulation and Nutritional Status of Mungbean (*Vigna radiata*)

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The investigation was carried out to find the effect of different inoculum levels of root-knot nematode, *Meloidogyne incognita* on plant growth, nutrition status of mungbean plants, development of nematode and nodulation. Results revealed that there was a progressive decline in plant growth *viz.,* fresh and dry shoot weight and shoot length with the increase of inoculum levels. However, the root weight, dry and fresh showed opposite trend. The dry and fresh shoot weight was decreased by 44% and 66% respectively, at 4000 J2/plant. There was also decline in the chlorophyll content in the leaves with the increase of inoculum levels from 100-6000 J2s/pot. With regards to nutrition status of the plant, N, P, K, Ca and Mg contents were significantly reduced in shoots and increased in roots with an increase of inoculum levels. Nodulation was affected by 80% at the highest inoculum level. Also leghaemoglobin, bacteroid content and nitrogenase activity were reduced progressively with increased nematode infection. Thus, root-knot nematode, *Meloidogyne incognita*, interferes with the process of symbiotic nitrogen fixation between mungbean host and *Rhizobium* and affects the yield of crop significantly.

# Session VI: Management Strategies for Nematode

## Effect of Soil Application of Oil Seed Cakes under Two Ploughing Conditions on Growth of Pigeonpea and Population Density of Plant-Parasitic Nematodes

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Oil seed cakes of neem/margosa (*Azadirachta indica*),castor (*Ricinus communis*),mustard (*Brassica compestris*),rocket salad/duan (*Eruca sativa*) and groundnut (*Arachis hypogaea*) were found to be highly effective in reducing the multiplication of nematodes and consequently plant growth and bulk density of woody stem of pigeonpea (*Cajanus cajan*) increased significantly. The multiplication rate of nematodes was less in deep ploughing than in normal ploughing plot. The damage caused by the nematodes was further reduced when oil seed cakes were applied in deep ploughing plot. The most effective combination was that of deep ploughing with neem cake.

## Nematicidal Potential of Azolla Extracts

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Azolla is a microphytic aquatic fern, globally distributed in still water, ponds, lakes, swamps,ditches and paddy fields of temperate and tropical regions. Azolla has symbiotic association with Anabaena which resides in its leaf cavity and provides nitrogen for the fern. Thus, this association has high nitrogen fixing ability, rapid growth and high biomass accumulation which determine the potential of Azolla as biofertilizer for rice. Besides, N biofertiliser, Azolla biomass has numerous applications as feed supplement for cattle and fish, for polishing of wastewaters and as green manure. A study was conducted to evaluate Azolla extracts (aqueous extracts prepared from fresh and dried biomass and methanolic extracts from dried biomass) for biocontrol of nematodes. Three types of nematodes (polyphagus *R.remiformis, Tylenchorhynchus*), *Meloidogyne* sp. (harmfull) and free living (beneficial) were grown in presence of different concentrations of extracts and

mortality was observed at different intervals of time (24-72h). Methanolic extracts of *Azolla* showed high nematicidal activity (80-90% in 24hrs. exposure) against root knot nematode Meloidogyne sp. and polyphagus nematodes *Tylenchorhynchus* and *R. reniformis* in 48h while aqueous extracts from fresh and dried biomass were not effective upto 72h also. It was observed that in case of fresh Azolla extract , its effects is not stable and nematode larvae start rejuvenating again in 72h while in case of but dried *Azolla* extract highest mortality (about 90%) under 2x and 4x dilution was observed in 72h for polyphagus nematodes. Thus, Azolla biomass extracts can be exploited for control of nematodes and avoiding losses.

## Eco-Friendly Management of Root-Knot Nematode, *Meloidogyne incognita* by Some Plant Leaves on *Cicer arietinum* L.

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A large number of researchers worldwide are showing attention towards organic amendment of soil as means of nematode control. Several plant species having nematicidal properties have been foundout. A green house experiment was conducted to evaluate the effect of chopped leaves of various plants as soil amendment for the management of *Meloidogyne incognita* affecting *cicer arietinum* L.var. Avarodhi. During the course of studies it was noted that the chopped leaves (25g and 50g) of *Jatropha pandurifolia*, *Polyalthia longifolia, Wedelia chinensis*, *Nerium indicum, Duranta repens* and *Cassia fistula* reduced galling, as result of the reduction of root galling the plant growth improved. Soil amended with *Jatropha pandurifolia* (50g) leaves were found most effective in reducing the reproductive potential of root-knot nematode and increased plant growth parameters .Among all the treatments *cassia fistula* (25*g)* was found to be least significant. This study revealed that chopped leaves as organic amendment improve the plant growth and reduced the nematode infestation in chickpea.

# Integrated Management of Potato Cyst Nematodes *Globodera rostochiensis* and *G. pallida* in The Nilgiris

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Potato cyst nematodes (PCN) *Globodera rostochiensis* and *G. pallida* are the important biotic constraints in potato cultivation with quarantine significance in the Nilgiris region of Tamil Nadu. In spite of the massive chemical control measures taken up to eradicate the nematode, it was found inadequate to keep the nematode under check for longer periods besides being expensive and environmentally hazardous. Hence investigations are being carried out at Central Potato Research Station, Ootacamund towards the development of an integrated nematode management package to bring down the population of PCN to levels that permit profitable potato cultivation in the Nilgiris. Field experiments were conducted during 2010 to 2012 to evaluate the effect of soil solarization alone (with LDPE sheet of 150m thickness for 6 weeks) and integrated with application of organic amendment neem cake (5t/ha) + biocontrol agent *Trichoderma viride* (0.5 kg/ha) and chemical nematicide carbofuran (2 kg a.i./ha) in potato cv. Kufri Giriraj. The treatments were replicated four times in a randomized block design. The results revealed that all the treatments with soil solarization were effective in reducing nematode multiplication. Among all, soil solarization integrated with neem cake and *T. viride* application recorded the maximum yield (30.92 t/ha) and minimum nematode multiplication (Reproduction Factor (RF) -1.20). It was followed by soil solarization combined with carbofuran (29.09 t/ha and Rf- 1.26).

## Conjoint Effect of Botanicals and a Bioagent *Paecilomyces lilacinuss* on Root-Knot Nematode Infesting *Vigna mungo* L. Hepper

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Root knot nematode, *Meloidogyne incognita* is a catastrophic nematode pest of plants accountable for wide spread destruction in vegetables, pulses and ornamentals. Although synthetic nematicides are most effective against these phytonematodes but due to their unsafe nature alternative, eco-friendly methods of management of phytonematodes are gaining importance. A pot trial was conducted under greenhouse conditions to evaluate the efficacy of ethanol extracts of plant leaves of *Nerium indicum,Calotropis procera* and *Tagetes erecta* alone and in combination with biocontrol agent *Paecilomyces lilacinus* against root knot nematode affecting Blackgram, *Vigna mungo* L.Hepper. All the treatments effectively reduced the nematode multiplication and improved the plant growth significantly compared to inoculated control but the maximum plant growth and reduction in nematode index was observed with the combined application of ethanol extract of *Calotropis procera* and *Paecilomyces lilacinus*. The present study was found as a promising substitute of synthetic nematicides for the effective management of root knot nematode.

## Intercrop for the Management of Plant Parasitic Around Banana Rhizosphere

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In a field experiment; cowpea, sunhemp and marigold was tried as intercrop with banana plantation for management of plant parasitic nematodes around banana rhizosphere. Banana suckers were paired and then dipped into 0.5% Monocrotophos

for one hour before planting. Intercrops were grown around banana plantations and then incorporated in soil 90 days after sowing. One unpaired control and two chemical treatments (Carbofuran and Thimat @1.25 g a.i/ha) were maintained for comparison. Growing of marigold around banana rhizosphere and then incorporated in to soil at 90 days after sowing exhibited significant improvement in plant growth parameters of banana and reduction in nematode population. There were 8.70, 28.99 and 57.46 per cent increase in pseudostem height, pseudostem girth and yield of banana, respectively; and 64.06 per cent reduction in soil nematode population in this treatment.

## Biomanagement of Root-Knot Nematode *Meloidogyne incognita* on Green Gram

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A micro plot study was carried out at Department of Nematology, Assam Agricultural University, Jorhat during 2011-12 to evaluate the effectiveness of *Trichoderma viride*, *T. harzianum*, Biofor-pf (a bio-formulation, combining *T. harzianum* and *Psuedomonas fluorescens*) and neem cake against root-knot nematode (*Meloidogyne incognita*) on green gram (var. Pratap). Results indicated that all the bio-agents significantly increased the plant growth parameters of green gram and reduced nematode population. Maximum increase in shoot length (90.9%), fresh shoot weight (68.22%) and dry shoot weight ( 65.0%) at harvest was recorded with the application of neem cake @ 2 t/ha followed by application of *T. viride* @ 2.5 kg/ ha (shoot length, fresh shoot weight and dry shoot weight was 85.03%, 64.56% and 64.26%, respectively). All the bio-agents significantly reduced the nematode multiplication. Among the bio-agents, maximum reduction in galls (93.88%) and egg masses per root system (91.34%), number of eggs per egg masses was obtained in application Biofor-pf @ 100 kg/ ha followed by the application of neem cake @ 2 t/ha.

# Efficacy of Formulated Bioproducts Against *Meloidogyne incognita* Infesting Bitter Gourd in West Bengal, India

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Experiments on bioformulations for management of root knot nematode (*Meloidogyne incognita*) infesting bitter gourd (*Momordica charantia*) was carried out for three consecutive seasons in 2010-11, 2011-12 and 2012-13 at Central Research Farm**,** Bidhan Chandra Krishi Viswavidyalaya located in the New Alluvial Zone of West Bengal, India. The comparative efficacy of *Paecilomyces lilacinus* (PL), PL enriched Farm Yard Manure (PL+FYM), *Trichoderma harzianum* (TH), *Pseudomonas fluorescens* (PF)*, Pochonia chlamydosporia* (PC), Neem Cake (NC), and carbofuran (C) at 1.0 kg a.i./ha as check were evaluated over untreated control (UC). Bioformulations were delivered as soil application before sowing of seeds and each formulation was used at 10g/pit, NC at 30g/pit and FYM at 10 tones/ha. The bitter gourd (cv Meghna) was grown in the plot size of 3.5m.x 2m in root knot nematode (RKN) infested field. The treatments were evaluated on the basis of reduction of RKN juvenile ($J_2$) population, root gall index (GI) on 1-5 scale and increase of yield over UC. Experimental results based on three years data showed that application of PL enriched with decomposed manure (PL+ FYM) provided greater protection to bitter gourd from *M. incognita* through reduction of $J_2$ population (37 - 70 %), root galling severity (Gall Index-GI: 2.27 -2.93), and increasing of yield (60-111 %). This was followed by PF ($J_2$ reduction 25-52%, GI 2.47-2.80 and yield increase 62-77%) and PL($J_2$ reduction 15-26 %, GI 1.92-3.40 and yield increase 38-52%) application. Pooled data analysis revealed that highest gain in yield was obtained in PL+FYM treated plot (9t/ha vs 4.85 t/ha and 6.77 t/ha, untreated and carbofuran, respectively).

# Comparative Efficacy of Management Practices Against Citrus Nematode Infesting Citrus (Kinnow)

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A field trial was carried out in citrus nematode (*Tylenchulus semipenitrans)* infested citrus (kinnow) orchard at village Jevara (District Hisar) using various management practices like organic amendments and bio-control agents. Organic amendments viz., neem cake and FYM and bio-control agents, viz., *Pseudomonas fluorescens* and *Trichoderma viride* were added to the soil treatment-wise. Chemical and untreated checks were also maintained.. The results revealed that among organic amendments and bio-control agents, neem cake @100g/ $m^2$ as soil application was found most effective in enhancing citrus yield by 21.6 per cent over untreated check and reduced citrus nematode population by 24.4 % over INP followed by *T. viride* @20g/$m^2$ where nematode population reduced by 20.5% and citrus yield was enhanced by 10.8 % over untreated check. *Pseudomonas fluorescens* @20g/$m^2$ reduced citrus nematode population by19.2 percent over INP and enhanced yield by 9.8 percent over untreated check.

# Management of Root-Knot Nematode, *Meloidogyne javanica* in Papaya (*Carica papaya*) Through Bio-Agents

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Papaya is an important fruit crop grown in Haryana. This crop is highly vulnerable to root-knot nematode, *Meloidogyne* spp. Keeping in view, the common occurrence of this pest on papaya, a field trial was laid out at farmer's field, infested with root-knot nematode, *Meloidogyne* spp. at village Dharnia (distt. Fatehabad) during 2012-13 using VAM @ 20g/pit as soil treatment before transplanting of papaya seedlings cv. Christin Red Lady. The results revealed that application of VAM in the pits enhanced papaya yield (23.3 kg/plant) by 18.3 % over untreated check (19.7 kg/ plant). Final nematode population in VAM treated plants was increased only by 15.3 % (355-382 J2/200 over initial nematode population in comparison to 38.4 % increase in untreated plants (430-455 J2/200cc soil).

## Effect of Resistant Variety, Nematicides and Crop Rotation on *Heterodera avenae* and Other Plant Parasitic Nematodes Infecting Late Sown Wheat

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A field trial was conducted to study the effect of *Heterodera avenae*-resistant wheat variety (Raj MR1), nematicides and crop rotation with oats on nematode populations and wheat yield under late sown conditions. Treatments included- resistant variety, phorate, carbofuran, crop rotation and untreated control. Wheat var. PBW373 was used in the trial and nematicides were applied in soil at sowing time @1.0 kg a.i./ha. Initial populations (Pi) were recorded at sowing and final populations (Pf) after 110 days of sowing. Final population of *Heterodera avenae* was 5.5 times compared to Pi in resistant variety whereas it was 6, 2.3, 2.5 and 5 times higher in phorate, carbofuran, rotation and control, respectively. The population of *Pratylenchus thornei* was high in all the treatments except in case of resistant variety. Whereas, *Tylenchorhynchus* sp. decreased only in treatments where nematicides were applied, and *Hoplolaimus indicus* population decreased all the treatments. Yellowing of leaves (recorded after first irrigation i.e. 30 days after sowing) was minimum in resistant variety (4.6%) and maximum in control (41.6%). Increase in yield over control was 96.1, 85.5, 77.1 and 15.3 %, in rotation, carbofuran, Raj MR1, and phorate, respectively.

## Biomanagement of Root-Knot Nematode (*Meloidogyne incognita*) in Okra

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Field trials were carried out during 2011-12 to test the efficacy of bioformulations against root knot nematode (RKN-*Meloidogyne incognita*) infecting okra. The

experiment was laid out with eight treatments in a sick-plot previously had the severe infestation of RKN on vegetables. Two consecutive seasons (*kharif* and *rabi*) of okra were grown for management of nematode infestation. Experimental results of 2011 (April-August) revealed that adoption of treatments on RKN infested fields significantly reduced nematode population, root galling and enhanced the yield of okra (cv Arka Anamika). Final population of *M. incognita* was relatively low in plots receiving seeds of okra treated with *Pochonia chlamydosporia* followed by soil application of carbofuran at 1.0 kg a.i./ha and *Pseudomonas fluorescens* (10g/kg seed). The highest fruit yield (85q/ha) was obtained in the plots treated with *Paecilomyces lilacinus* (10g/kg) + FYM 10t/ha. The same experiment was repeated in field using okra (cv. Shakti F1-Hybrid) during October-January, 2011-2012 further revealed that bioformulations on RKN infested fields with relatively higher initial nematode population (INP: 465/200cm$^3$ soil) showed marginal impact on reduction of RKN population, infestation and root galling. Considering incremental cost benefit ratio (ICBR), seed treatment (at 10g/kg of seed) proved most economical (ICBR~ 1: 99 to 1: 296) recommendation for management of RKN in okra. This was followed by carbofuran at 1.0 kg a.i./ha and combined application of *P. lilacinus* (10g/kg seed) +FYM at 10t/ha. The performance of treatments at low INP (~210/200 cm$^3$ soil) was proved quite effective in the first season but least effective at higher INP (~ 465/200cm$^3$ soil) in second season. This observation clearly indicated that infestation of RKN with high INP on okra is difficult to manage using bioformulations of *Pochonia chlamydosporia, Paecilomyces lilacinus* and *Pochonia chlamydosporia* particularly in short duration crop like okra.

## Comparative Efficacy of Bio-Agents Against *Meloidogyne incognita* Affecting *Abelmoschus esculentus*

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Root knot nematode, *Meloidogyne incognita* is a serious nematode pest causing enormous losses to vegetables worldwide. Synthetic nematicides although form the prime strategy to control these hidden soil enemies but their high cost and ill effects on environment and human beings have made many developed countries to ban their use. The more feasible and environmentally safe methods like use of

biocontrol agents are gaining importance day by day. A pot experiment was conducted to evaluate the efficacy of fungal bioagents *Paecilomyces lilacinus, Trichoderma viride* and *Pochonia chlamydosporia* against *M. incognita* affecting Okra, *Abelmoschus esculentus* (L.) Moench. All the bioagents caused varied but significant improvement in plant growth and significantly reduced the nematode multiplication but *P. lilacinus* proved to be the best in all respects. The maximum plant growth in terms of height, weight and yield was observed with the soil application of *P. lilacinus* @3g/pot followed *by P. chlamydosporia* and *T. viride.* Similarly highest reduction in nematode index i.e. no. of galls, eggmasses/plant, eggs/eggmass and nematode population/250g soil was observed with the application of *P. lilacinus* @3g/pot followed by *P. chlamydosporia* and *T. viride*.

## Role of Oil Cakes and *Pochonia chlamydosporia* for the Management of *Meloidogyne javanica* Attacking *Solanum melongena* L.

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A pot experiment was conducted to evaluate the efficacy of a fungal biocontrol agent *Pochonia chlamydosporia*, oil cakes of neem, mustard and cotton and nematicide (carbofuran) in the management of root knot nematode, *Meloidogyne javanica* infecting brinjal *(Solanum melongena* L. cv.Neelam) under glasshouse conditions. All the treatments were effectively suppressed the nematode population and kept the infection at significantly low levels. Among oilcakes individual treatment of neem was more effective than other oil cakes in controlling *M. javanica*, whereas among combined treatment, *P. chlamydosporia* + neem cake was more effective in the management of *M. javanica* followed by *P. chlamydosporia*+mustard cake and *P. chlamydosporia* + cotton cake. However, the efficacy of *P. chlamydosporia* increased in the presence of oilcakes. Oilcakes when combined with nematicide (carbofuran) showed best results in terms of plant growth parameters, reduce root knot diseases and nematode multiplication after combining with *P. chlamydosporia*. These organic amendments are capable of producing secondary metabolites, which have an allelopathic effect and develop resistance in plants.This approach is non hazardous, cheaper and easily available to the farmers.The present findings would

go a long way in evaluating suitable nematode management strategies without any environmental pollution.

## Field Evaluation of Antagonistic Potential of Rhizobacteria Against Root-Knot Nematode (*Meloidogyne* spp.) in Mungbean

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Experiments were conducted in root-knot nematode infested fields at two locations (field area of Department of Nematology, CCS Haryana Agricultural University, Hisar and at farmer's field in village Dharnia of Fatehabad district of Haryana) in mungbean crop during July, 2011 by using two rhizobacterial strains (i.e. st. 35-47 of *Gluconacetobacter diazotrophicus* and HT-54 of *Azotobacter chroococcum*) as seed treatment. The grain yield in rhizobacterial treated plots at both the locations was found maximum (8.8-10.3 q/ha) in 35-47 strain of *G. diazotrophicus* followed by (8.4-10.1 q/ha) in HT-54 strain of *A. chroococcum* in comparison to 7.7 and 8.5 q/ha in untreated check. Final root-knot index at harvest in rhizobacterial treatments at both the locations, ranged between 4.3-4.6 in comparison to 4.6 and 4.8 in untreated check. These differences were statistically at par with one another. Per cent decrease in final nematode population in rhizobacterial treatments over untreated check ranged between 3.3-14.4 only. The results on the basis of yield, root-knot index and final nematode population (FNP) in the present investigation clearly revealed that use of rhizobacteria (35-47 strain of *G. diazotrophicus* and HT-54 of *A. chroococcum*) as seed treatment alone is not a good proposition for the management of root-knot nematode (*Meloidogyne* spp.) in mung bean crop under field conditions.

## Effect of Non Host Crops/Resistant Varieties on Population Dynamics of Root-Knot Nematodes in Vegetable Based Cropping Systems

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An experiment was conducted in root-knot nematode, (*Meloidogyne* spp.) infested field in permanent plots during *Kharif* and *Rabi* seasons of 2009-10 to 2011-12 adopting following rotation.

Nematode susceptible tomato *cv.* Alankar, okra *cv.* Parbhani Kranti and resistant tomato *cv.* Hisar Lalit and cowpea *cv.* Anand Vegetable Cowpea 1 (AVC 1) were rotated during *Kharif* and *Rabi* seasons. Pooled results of six seasons of three years showed non significant results for income and significant effect for root-knot index and final nematode population, indicating root-knot nematode susceptible okra *cv.* Parbhani Kranti in *Kharif* and tomato *cv.* Alankar in *Rabi* increases root-knot nematode population while growing root-knot resistant cowpea *cv.* AVC 1 in *Kharif* and tomato *cv.* Hisal Lalit in *Rabi* reduced root-knot index and final nematode population.

## Evaluation of Rice Cultivars Against Root-Knot Nematode, *Meloidogyne graminicola* (Golden and Birchfield) in the Field

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Of late, rice root-knot nematode *Meloidogyne gramionicola* has become a serious menace in all type of rice situations in Karnataka. A field study was under taken during kharif, 2013 to evaluate one thirty five local rice cultivars collected and maintained at organic farming research centre of ZAHRS, Navile, Shimoga against *Meloidogyne graminicola*. The results revealed that the varieties show varying degrees of responses. Out of 135 cultivars, 32 cultivars were highly resistant, while,

45 varieties were resistant. However, 40 varieties evaluated to be moderately resistant and 9 varieties susceptible. The remaining 9 cultivars were learnt to be highly susceptible.

## Management of Plant Parasitic Nematodes in Banana using *Pseudomonas fluorescens*

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Demonstration trial was conducted during 2012-13 for management of prevailing plant parasitic nematodes such as *Meloidogyne incognita* and *Hoplolaimus indicus* infecting banana. A total of three treatments were imposed viz. $T_1$: *Pseudomonas fluorescens* @20g/$m^2$ at planting; $T_2$: Paring + hot water treatment at 55$^0$C for 20 min. + carbofuran @ 0.5 g a.i/plant + neemcake @ 1kg/plant and $T_3$: Untreated control. Soil and root samples were collected from different treatments at bi-monthly intervals. Application of *Pseudomonas* formulation reduced populations of both the plant parasites in comparison to untreated control. The treatment comprising of paring and hot water treatment with application of carbofuran and neemcake ($T_2$) though reduced the nematode populations at early growth stages of banana crop, yet failed to maintain the trend during harvest. Minimum root knot index and highest increase in yield were recorded with the *Pseudomonas* application, the effect of which was almost similar to standard recommended practice ($T_2$).

## Effect of Different Intercrops on Nematode Population and Yield of Tomato (*Solanum lycopersicon* L.)

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Six antagonistic/ non-preferable host crops viz., sesame, soybean, chenopod, maize and marigold were evaluated for their angonistic action through their intercropping with tomato, in the farmer's field and experimental farm of department of Entomology

(UHF, Solan) during the years 2012 and 2013. The results revealed that three intercrops viz., sesame, maize and marigold did not support any population of root-knot nematode (*Meloidogyne incognita*) as sencond stage juveniles (J2s) of the nematode were recorded from these plots at harvesting. Although, in soybean and chenopod intercropped plots, juveniles of *M. incognita* did show its incidence (20-40 J2s/ 200 cc soil), the populations remained negligible in comparison to control (150-160 J2s/ 200 cc soil). As comparison to control, there was no/ little impact of intercrops on the population build up of *Helicotylenchus dihystera, Tylenchorhynchus mashhoodi* and *Paratylenchus* sp. In different intercrops, there was recorded 10-24 per cent increase in tomato yield over control.

## Mutual Selection and Dynamic Balance of *Pasteuria penetrans* in Greengram

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*Pasteuria penetrans,* an obligate parasite of root-knot nematodes is widely distributed in vineyards and agro ecosystems of many parts of the world. The spores of *P. penetrans* found to attach to the juveniles of *Meloidogyne* spp. *P. penetrans* has the attributes of a successful biocontrol agent aganist plant parasitic nematodes. An experiment was conducted to assess the dynamic balance that exists between *P. penetrans* and plant parasitic nematodes. The experimental results revealed that a dynamic balance exists in spores of *P. penetrans* if the availability of host nematode reduced. The presence of related genera or a compatible genus helps in the survival of the spores. The comparative population change of *Heterodera cajani* and *M. incognita* was studied in greengram. The experiment revealed that significantly higher number of *M. incognita* females was parasitized by *P. penetrans* from 30$^{th}$ day (70.15%), where as in *H. cajani* significantly less females were parasitized (9.84%). Therefore, the number of females parasitized by *P. penetrans* was significantly increased in all the genetrations of *H. cajani*.

# Use of Alternative Products for Sustainable Nematode Management in Banana

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Among production constraints, plant parasitic nematodes recognized as a major constraint in banana production and are responsible for serious yield losses. Crop losses caused by nematodes to bananas are very high, with an average annual yield loss of 20 per cent worldwide. The most destructive and widely distributed nematode is the burrowing nematode, *Radopholus similis* causing an annual yield loss up to 41 per cent. The nematode infested banana plants exhibit general decline, stunting, premature defoliation, unthriftness and carry small bunches and fruits. They topple over easily during wet and windy weather because of inadequate anchorage. The root-lesion nematode, *Pratylenchus coffeae* is considered to be an important nematode pest caused an annual yield loss up to 44.4%. The other economically important nematode pests of banana which have some regional differences are the spiral nematode, *Helicotylenchus multicinctus, H. dihystera,* root-knot nematode, *Meloidogyne incognita, M. javanica*, cyst nematode*, Heterodera oryzicola* and reniform nematode, *Rotylenchulus reniformis*. Though, the chemical nematicides are giving sharp decline of nematode populations, but their residual effects on environment health require serious attention in looking for alternate methods to tackle nematode menace and to increase the economic return. In order to overcome the deleterious effects of climate change as well as by the application of chemical nematicides, alternative method of using bacterial and fungal endophytes, botanicals (*Acalypha indica, Cassia fistula, Cassia auriculata, Crotolaria juncea, Calotropis gigantea, Abutilon indicum, Azadirachta indica and Solanum tarvu*m), biocontrol agents (*Paecilomyces lilacinus, Pseudomonas fluorescens, Trichoderma viride, T. harzianum etc.*),intercropping of various plants viz. sunhemp, sesamum, coriander, mustard, marigold are the successful technologies identified for the management of nematodes in banana. The economic importance of nematodes, symptoms produced under field condition by these nematodes and management practices using non-chemical methods will be discussed in detail during the presentation.

# Efficacy of Organic Matter and Phosphate-Solubilizing Bacteria on Growth and Yield Attributes of Chickpea in Relation to the Management of Plant-Parasitic Nematodes

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An experiment was carried out to study the efficacy of oil-seed cakes (neem and castor cake) a botanical *Solanum xanthocarpum* and phosphate-solublizing bacteria (PSB) *Pseudomonas fluorescens* singly and in combinations for the management of plant-parasitic nematodes in field condition infecting chickpea (*Cicer arietinum* L.) . Significant improvement was observed in growth parameters such as fresh as well as dry weights, per cent pollen fertility, number of anthesis buds and open flowers per plant, number of pods and nodules per plant, nitrate reductase activity and chlorophyll content in most of the treatments. Agronomic parameters were determined in terms of N, P and K in plants as well as in residual soil. Although, all the parameters enhanced significantly in these treatments however, combined application was more effective than the individual one. Neem cake was found more prominent in promoting plant growth than castor cake followed by *S. xanthocarpum* and PSB. Highest growth and productivity were observed in the combined inoculations of neem cake, castor cake, *S. xanthocarpum* and PSB as compared to other treatments including inorganic nitrogenous fertilizer and untreated control. The multiplication of plant-parasitic nematodes was found greatly affected due to the application of organic matters and phosphate-solubilizing bacteria and more to be with combined inoculatins. The number of root-galls caused by *M. incognita* was also found significantly decreased due to the application of organic matters and PSB in different treatments.

# Integrated Management of Root-Knot Nematode in Bottle Gourd Through Biopesticides - A Recommendation for Farmers

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Root-knot nematode is a major yield limiting factor in vegetable crops particularly cucurbits such as bottle gourd. The galling symptoms are so pronounced and compounded that the vegetable growing farmers are aware of this menace. Of the ecofriendly and non-chemical management strategies, there is more emphasis now a days on use of biopesticides such as neem and its products and also native strains of PGPR such as *Gluconacetobacter diazotrophicus*. In the present study, neem cake (NC) was used as soil treatment @ 30g/spot one week before sowing while GD 35-47 which proved to be most effective strain of *G. diazotrophicus* (liquid culture having $2x10^7$ cfu) was used as seed treatment @ 50 ml/ 5 kg seed. These components were integrated against *Meloidogyne javanica* in bottle gourd varieties/ hybrids separately. The pooled data of the trials laid out at farmers' fields starting from 2009 onwards revealed that NC + GD 35-47 had highest yield (113.6q/ha) as compared to 87.9q in untreated check showing thereby 29.0 % increase in yield, 32.5 % decrease in final nematode population over check and BC ratio of 9.4 in bottle gourd varieties followed by neem cake alone. Similarly in hybrids, the results were so pronounced that 38.4 % yield increase and BC ratio of 15.0 were recorded. After detailed deliberations with Horticultural Officers of Haryana and University Scientists, the findings had been included in the Package of Practices for wide spread applications of this technology by the farmers.

# Bioagent's for Biological Management of Root-Knot Nematode, *Meloidogyne incognita* infesting Pomegranate

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A statistical designed field experiment was conducted during ambia bahar 2010-2011 for the biological management of root-knot nematode, *M. incognita* infesting pomegranate. It was the evident that the split application (10 kg at bahar and 10 kg/

ha 90 days after bahar) of nematicide, phorate 10 G and bioagents Phule *Trichoderma* plus were found to be effective. The treatment of phorate 10 G (10 kg at bahar and 90 days after bahar) was found effective on 30 and 120 days after bahar in reducing root-knot nematode ( 55.06 to 69.7% ) whereas, the treatment dose of Phule *Trichoderma* plus split at (10 kg/ha at each bahar and 90 days after bahar) was found to be effective from 60 to 150 day in reducing root-knot nematode (39.17 to 62.60%), followed *by P. chlamydosporium* (34.07 to 53.60%). The persistence of colony forming units (cfu/g of soil) in split treatment application of Phule *Trichoderma* plus and *P.chlamydosporium* was recorded in the range of 7.0 to 8.6 and 6.6 to 7.6 cfu/g of soil, respectively. The split treatment of phorate10 G , Phule *Trichoderma* plus and *P.chlamydosporium* registered better yield of marketable fruits 17.83,17.75 and 17.25 t/ha , respectively with 1:3.51 1:3.48 and 1:3.51 CB ratio and 1:24.68 1:24.20 and 1:22.30 ICBR, respectively.

## Management of *Meloidogyne graminicola* in Rice Nursery

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Among *Meloidogyne* sp., the rice root-knot nematode, *Meloidogyne graminicola* attacking rice and wheat, is considered the most serious nematode in upland rice cultivation and causes economic losses in upland, lowland, and deep water rice and also in rice nurseries. A field experiment was conducted at during *kharif* season of 2010-12 to study the effect of soil solarization, carbofuran 3G and biocontrol agent *Pseudomonas fluorescens* on growth of rice seedlings and rice root-knot nematode, *Meloidogyne graminicola*. Combined application of solarization (15 days) either with carbofuran 3G @ 1kga.i./ha or *P. fluorescens* @1% W.P. @ 50g/sq.m, increased the seedling growth upto 30 day after sowing and reduced the number of galls and eggs per egg mass at 24 day after sowing. Therefore, 21-24 day old seedlings should be preferred for transplanting in the main field.

## Management of Root-Knot Nematode, *Meloidogyne graminicola* in Rice at Bulandshahr District of Uttar Pradesh: A Case Study

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The rice root-knot nematode, *Meloidogyne graminicola* has become a major problem under rice-wheat crop rotation and is spreading in the Indo-Gangetic plains. This nematode was first recorded during 2009-10 in Bulandshahr district of Uttar Pradesh, causing an average yield loss of 20-25% and in some cases to the tune of 50-60%. The disease can assume epidemic proportion causing extensive damage to the crop. During the systematic survey it was found that this nematode spread through the use of infested nursery seedlings. We proposed soil application of carbofuran 3G @ 1kg a.i./ha (3.3g/$m^2$) before laying nursery. Thus, this intervention was propagated among the farmers of 4 villages (Nekpur, Salempur Jat, Shahpura, Java) with the help of IARI adopted centre (under out-reach programme) at Nekpur village, Bulandshahr district of Uttar Pradesh.Within a span of 3 years the technology has quickly diffused to neighbours as well as friends and relatives of the early adopted farmers. During this period the incidence of root-knot disease in rice has come down to 10% with improved yield of basmati rice by 10-15%. The farmers were benefited and earned Rs. 4400/- per acre with the application of just 500 g of carbofuran 3G applied in the nursery bed @ 3.3 g/$m^2$. Therefore, incurring Rs. 36 for carbofuran he earned Rs. 4400/-.

## Efficacy of Botanicals Against *Meloidogyne incognita* Infesting Pigeonpea

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Neem Seed Powder, Mahua cake, Castor cake, Mustard cake and latex of Arka (*Calotropis procera*) were evaluated for their efficacy as seed treatment of pigeonpea cvs. UPAS 120 and CO 6 against root-knot nematode *Meloidogyne incognita* under

pot condition. Both the pigeonpea cultivars were found susceptible to the nematode and developed 36 and 48 galls/ root system, respectively. Seed treatment with botanicals reduced the nematode infection and increased the growth of pigeonpea. Maximum suppression of galls (*P* d" 0.05) was recorded on the plant roots where seeds were treated with neem seed powder (42% in cv. CO 6 and 36% in cv. UPAS 120) followed by latex of *C. procera* (37.5% in cv. CO 6 and 33% in UPAS 120). The greatest number of egg masses per root system (43 in cv. CO 6 and 28 in cv. UPAS 120) were observed on the plants that did not receive treatment with any botanicals. Seed treatment with neem seed powder caused 56% and 50% suppression (*P* d" 0.05) in egg mass production on cvs. CO 6 and UPAS 120, respectively followed by the treatment with latex of *C. procera* (49% in CO 6 and 43% in UPAS 120) and mustard cake (32% each in cvs. CO 6 and UPAS 120). Castor and mahua did not cause any significant effect on galling and egg mass production. Neem seed powder (*P* d" 0.05) also significantly improved the functional root nodulation (31% in CO 6 and 28% in UPAS 120). Seed treatment with Neem seed powder and latex of *C. procera* caused a significant increase (*P* d" 0.05) in yield of pigeonpea (20% in cv. CO 6 and 30% in cv. UPAS 120; *P* d" 0.05) as compared to *M. incognita* inoculated control. Other treatments could not prevent the yield loss caused by *M. incognita* upto significant level. Soil population of nematodes decreased with the application of neem seed powder by 33% and 23% (mid season) and 40.5 and 31.5% (harvest) in the root zone of cvs. UPAS 120 and CO 6, respectively. Decrease in the soil population of *M. incognita* juveniles were not up to significant level in rest of the treatments.

## Field Trial of Newly Developed Biopesticides for the Management of Fusarial Wilt, Root-Knot and Disease Complex of Chickpea

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Newly developed biopesticides, viz., Biowilt-X (*Trichoderma harzianum*), Bionem-X (*Pochonia chlamydosporia*) and Biocure-X (*Bacillus subtilis*) were applied to seeds (5 g/kg seed) and soil (40 g/microplot) to evaluate their effectiveness against the wilt (*F. oxysporum* f. sp. *ciceri*), root-knot (*M. incognita*) and the wilt disease complex of chickpea (cv. BG-256) under field conditions. The pesticides viz.,

carbendazim and nemacur were applied @ 1.25 kg a.i./h and 6.0 kg a.i./h as soil application, and 2g/kg seed as seed treatment. Application of biopesticides checked the severity of the diseases and the resulting yield declines. Application of Biowilt-X decreased the wilt incidence (60%) and promoted the yield (46%) of chickpea grown in *F. oxysporum* f. sp. *ciceri* infested plots. The biopesticides Bionem-X and Biocure-X were found effective against root-knot disease and suppressed the galling by 20 and 12% and promoted the yield of infected chickpea plants by 28 and 34% in comparison to the control, respectively. Application of Biocure-X was found highly effective against the fungus-nematode wilt disease complex; its seed treatment substantially controlled the wilt and root-knot, and increased the yield of concomitantly infected chickpea by 49%. Biocure-X was found more effective in increasing the nodulation as compared to other treatments. Seed treatment and soil application of Biocure-X caused 28 and 20% increase in total nodules of chickpea as compared to uninoculated control. The cost benefit ratios estimated for the biopesticide application revealed a monetary gain of Rs 4000 and Rs 1750 with Biowilt-X and Bionem-X against wilt and root-knot diseases, respectively (US $ 1 = Indian Rs. 44). The seed treatment with Biocure-X against wilt disease complex increased the yield by 3.1q/ha equivalent to Rs. 7750 (@ Rs 2500/q chickpea). This biopesticide was also found effective against wilt and root-knot disease and gave a profit of Rs. 6000 and Rs. 2000/ha, respectively and also acted as a biofertilizer and improved the yield of chickpea in the plots not inoculated with either pathogens by 3 q/ha. Soil population of the wilt fungus and root-knot nematode decreased in the plot applied with biopesticides/pesticides. Population of the biocontrol agents applied through biopesticides, however, increased in the presence as well as absence of pathogens, being greater in the former.

## Management of Root-Knot of Rice in Nursery and Field with Seed Priming and Soil Application of Some Organophosphate Pesticides

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Effects of single and combined treatments of seed priming (SP, 5 g or ml/kg seed) and soil application (2 kg or L/ha)of eight organophosphate pesticides at different days of planting (DAP) on the root-knot of rice caused by *Meloidogyne graminicola* under pot and field condition were studied. Seed priming or soil application with the

pesticides in nursery-bed (1000 juveniles of *M. graminicola* /kg soil) suppressed the galling in rice nursery by 12-92% and 22-88% with greatest decrease with phorate (92 and 99%), carbosulfan (80 and 88%) and chlorpyriphos (76 and 80%), respectively over control. More or less similar decrease in galls was recorded when this nursery was grown for four months in sterilized soil. Rice cv. PS-5 grown in naturally infested soil in earthen pots (1000 $J_2$/kg soil) became stunted with chlorotic foliage, and terminal galls developed on roots. Application of pesticides suppressed the root-knot with greatest decrease in the galls and egg masses/ root system with SP + 15 + 30 DAP i.e., 59 and 43% (Phorate), 48 and 36% (Carbosulfan), 46 and 33% (Chloropyriphos), respectively over control leading to significant improvement in the length and dry weight of plants. Overall effect of SP +15 DAP treatments was marginally less than the SP + 15 + 30 DAP treatments. Under field condition, pesticide treatment through SP + 15 DAP and SP + 15 + 30 DAP decreased the galling by 65-67% and 69-71% (phorate), 41-45% and 49-52% (carbosulfan) 37-41% and 46-49% (chloropyriphos) and improved the rice yield by 32-36% and 29-34% (phorate), 17-20% and 22-25% (carbosufan) 10-12 % and 17-19% (chloropyriphos) over control, respectively. Soil population of *M. graminicola* decreased by 24-58% and 27-84% during four months due to application of the three pesticides through SP + 15 DAP and SP + 15 + 30 DAP. The study has demonstrated that seed priming with phorate can effectively control to nematode infection in nursery and soil application at 15 DAP (2 kg ai/ha) can prevent root-knot development in infested field under irrigated condition.

## Management of Root-Knot Nematode on Spinach, Dill Soa and Fenugreek with the Application of Biocontrol Bacteria

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A study was undertaken to control root-knot of spinach, fenugreek and dil soa caused by Meloidogyne incognita with seed and soil application of biocontrol bacteria viz. *Bacillus subtilis* and *Pseudomonas fluorescens*. The leafy vegetables were found susceptible to *M. incognita.* Spinach developed 57 galls/root system and exhibited 12-22% decrease in the plant growth variables. On dill soa and fenugreek, 49 and 41 galls/root system, respectively, were recorded. Seed or soil application of biocontrol agents suppressed the galling, egg mass production and soil population of *M. incognita* and improved the plant growth of the vegetables tested. Treatments

with *P. fluorescens* provided maximum control of the nematode and significantly increased the growth and biomass production of dill soa (10-18%) and spinach (18-24%). *B. subtilis* also suppressed the population of root-knot nematode but the effect was significantly less than *P. fluorescens* (Pd"0.05). The study has demonstrated that seed treatment with *P. fluorescens* in non-infested or moderately infested soil may significantly improve productivity of leafy vegetables like spinach, fenugreek and dill soa.

## Biocontrol of *Fusarium-Meloidogyne* Disease Complex of Gladiolus Cultivars and its Management Through Corm Treatment with Biopesticides and Pesticides

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The gladiolus cultivars King Lear (KL), Her Majesty (HM), Friendship (FR), White Prosperity (WP) and American Beauty (AB) were found susceptible to *Fusarium oxysporum* f. sp. *gladioli* (FOG) and *Meloidogyne incognita* (MI). The cvs. WP and KL did not exhibit significant reduction in the plant growth and flowering. The MI inoculation caused maximum galling on the cv. HM (40 galls/root system) and lowest on cv. KL (10 galls) and significantly reduced flowering of gladiolus cultivars (11-22%, Pd"0.05) except cv. KL. A treatment with nemacur or *P. fluorescens* suppressed the galling and egg mass production of MI, and improved the plant growth and flowering variables (9-20%) over control (Pd"0.05). In concomitantly inoculated plants, severity of CRY increased in all cultivars including the cv. WP and KL, but gall formation and egg mass production were decreased. Treatment with carbendazim-nemacur mixture or *P. fluorescens* effectively controlled the FOG-MI disease complex leading to significant (Pd"0.05) decrease in CRY (7-32% and 8-20%) and galling(9-26% and 6-17%) and increase in the plant length (14-18% and 12-19%), spikes (13-43% and 13-57%) and florets (40-55% and 30-46%) over control, respectively.

## Evaluation of Rice Germplasm for Susceptibility to *Meloidogyne graminicola* and its Management with Carbofuran at Different Time Schedules

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Rice cultivars R-Dhan, Sadabhar, Sharbati, Swarna and Virendra grown in 15 cm earthen pots filled with naturally infested soil (1000 *Meloidogyne graminicola* juveniles/kg soil) developed 28-47 galls/root system and exhibited 8-22% decrease in the plant growth variables with greatest effects recorded on cv. R-Dhan. Soil application of carbofuran 15 day after planting (DAP) suppressed the galls, egg masses and nematode soil population by 34-73%, 5-25% and 63-82%, respectively, leading to 15-19% and 14-36% increase in the shoot and root length of rice plants. Effects of 30 DAP were also significant, but 5-10% less effective than 15 DAP treatment. Rice cv. R-Dhan grown in nematode infested fields (1100 *M. graminicola* juveniles/kg soil) developed 72 and 79 galls, and 59 and 52 egg masses/root system, and exhibited 24 and 28% decrease in the grain yield in two consecutive years, respectively. Soil application of carbofuran 15 DAP significantly decreased the galls (68 and 65%), egg masses (80 and 71%) and nematode population, and improved the rice yield (21 and 18%) in two years over control. The 30 DAP treatment was 8-20% less effective than 15 DAP.

## Effect of Different Mode and Time of Application of Biocontrol Agents on Root-Knot of Rice Caused by *Meloidogyne graminicola*

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Investigations were carried out to evaluate the relative effectiveness of different mode of application of *Trichoderma harzianum, Aspergillus niger, Pochonia chlamydosporia, Bacillus subtilis* and *Pseudomonas fluorescens* against root-knot nematode, *Meloidogyne graminicola* or rice cv. PS-5. Pure cultures of the biocontrol

agents were applied as root-dip and soil application (2 ml/kg soil) in both nematode infested (1000 juveniles/kg soil) and non-infested soil with five treatments viz., root-dip, one soil application 15 days after planting, two soil applications (15 and 30 days after planting), root-dip + one soil application and root-dip + two soil applications. Plants grown in non-infested soil and applied with biocontrol agents showed better growth in respect to improved length and dry weight of root and shoot. The maximum growth promoting effect was recorded with *P. fluorescens* applied through root dip + 1 or 2 soil applications. In the nematode infested soil, terminal and spiral galls developed on the roots, and plants suffered 19-31% decrease in the plant growth parameters. Application of *P. chlamydosporia* or *A. niger* as root dip + one soil application was found highly effective and suppressed the gall formation (22-25%), egg mass production (21-24%) and soil population (16-60%) of *M. graminicola,* and subsequently increased the plant growth variables by 15-21%. Relatively greater nematode control was recorded with root dip + two soil applications, but statistically the effect was at par with root dip + one soil application.

## Effect of Local Strains of Biocontrol Fungi and Bacteria Against Root-Knot Disease of Rice Caused by *Meloidogyne graminicola*

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Pure cultures of local strains of *Trichoderma harzianum* AMUTH-5 (@ $2 \times 10^8$ cfu/ml), *T. virens* AMUTV-1 (@ $2.5 \times 10^8$ cfu/ml), *T. viride* AMUTV-2 (@ $3.2 \times 10^8$ cfu/ml), *Aspergillus niger* AMUAN-1 (@ $3.1 \times 10^8$ cfu/ml), *Bacillus subtilis* AMUBS-1 (@$1.2 \times 10^{12}$ cfu/ml) and *Pseudomonas fluorescens* AMUPF-2 @$1.02 \times 10^5$ cfu/ml) were applied to seedlings as root-dip ($10^{8\text{-}12}$ cfu/ml) and soil application (2 ml/pot) in both nematode infested and non-infested (autoclaved) soil with three modes of application viz., root-dip, single soil application (15 days after planting), root-dip + one soil application. In non-infested soil, maximum growth promoting effect was recorded with *P. fluorescens* (MUPF-2) applied by root dip + soil applications (*P d"* 0.01). In the nematode infested soil, terminal and spiral galls developed on the roots of rice cv. Pusa Sugandha-5 and plants suffered 20-31% decrease in the plant growth parameters. Application of *P. fluorescens* or *T. harzianum* strains as root dip + one soil application was found highly effective and suppressed the gall formation (22-26%), egg mass production (25-27%) and soil population (16-60%)

of *M. graminicola*, and subsequently increased the plant growth variables by 17-22%.

## Wider Area Validation and Economic Analysis of Adaptable Integrated Nematode Management Technology in Groundnut

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Groundnut is one of the major oilseed crops of India. It accounts around 25 percent of total oilseed production of the country. Annual production of Groundnut is around 5-8 million tonnes. Ground Production is highly vulnerable to rainfall deviations and pest attack and display huge fluctuation between years. Gujarat is one of the largest producers of groundnut (Produces 1-3.5 million tons every year. However due to its tender and supple nature and its cultivation under high moisture and input regimes, groundnut is more prone to pest attack especially nematode. Nematodes are widespread and destructive pests on groundnut in Gujarat and cause 5 to 10 percent potential statewide groundnut yields. In some fields, total crop failure has been attributed to heavy nematode, Meloidogyne arenaria infestation. Nematode infection doesn't suppress yield, but causes serious qualitative damage and predisposes seeds to fungal infection Fusarium spp., Macrophomina phaseolina, Rhizoctonia solani and Sclerotium rolfsii. These infected seeds are under graded and unmarketable (Bridge and Hunt 1985; Minton and Baujard 1990; Stokes 1980). Nematode populations are usually highest in light, sandy soils. For effective management of root knot nematode in one of the hot spot areas and validation of nematode management technologies developed by AICRP (Nematodes) was undertaken by NCIPM, New-Delhi in active collaborations with AICRP (Nematodes), Junagarh centre.

# Effect of Bare Root Dip Treatments of Neem-Based Formulations and *Trichoderma* spp.

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An experiment was conducted to test the effect of bare root dip treatments in five neem-based formulations *viz.* econeem, nimbecidine, neem azal, neem gold and neem seed kernel extract (NSKE) at 1% v/v and two nematode parasitizing fungi, *Trichoderma viride* and *T. harzianum* @ $10^8$ spores/m on the growth of tomato, root galling and multiplication of *Meloidogyne incognita.* Both, neem-based formulations and nematophagus fungi were applied as bare root treatments for 2, 4, 6 and 8 h. Test nematophagus fungi improved plant growth than neem-based formulations. A significant decline in mean nematode population per 200 cc soil was observed in all the root dip treatments than untreated control (345.4 juveniles). Minimum soil population (87.0 juveniles) was observed in pots with plants dipped in *T. harzianum* followed by *T. viride,* NSKE and econeem (101.3, 110.6 and 129.3 juveniles, respectively). All dip treatments reduced root galling of tomato. Similarly, root nematode population reduced in all the treatments than untreated control. A non-significant reduced root gall index of 1.3, 1.3, 1.4,1.5 and 2.0 was observed in plants dipped in *T. viride, T. harzianum,* NSKE, econeem and neem azal, respectively. Thus, dipping exposure for 2h was as effective as longer exposure periods.

# Soil Application of *Crotalaria juncea* for the Management of Rice Root-Knot Nematode, *Meloidogyne graminicola* Infecting Rice

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Rice *(Oryza sativa* L.) is a staple fpod of more than 50% of the world's population. Various ecto and endo-parasitic nematodes of root, stem and foliar parts, e.g., *Aphlenchoides besseyi, Ditylenchus angustus, Meloidogyne* spp. and *Hirschmanniella* spp. have been reported infecting rice crop from Indo-gangetic plains (IGP), causing yield damage of 10.54 % in rice alone. Among these, the rice root-knot nematode, *Meloidogyne graminicola* poses a serious threat to rice production owing to the cropping intensification of rice and the increasing scarcity of water. The investigation was carried out to evaluate the effect of different concentrations of *Crotalaria juncea* extracts @ 62.5, 125, 250 and 500 μg/ml as soil drench treatment on *M graminicola* infesting rice. In general, the plant growth parameters (shoot length, shoot weight, root length, root weight) of rice increased in *crotalaria* extracts treated plant, at all the concentrations. At 7DAI, there was no significant difference in shoot length at lower concentrations (62.5, 125, 250 μg/ml) of both the extracts, except at 500 μg/ml where shoot length was maximum (18.58 cm and 17.28 cm in methanol and hexane extracts respectively). Similar trend was observed at 14 and 60 DAI. The penetration of J2s showed a decreasing trend with the increase in the concentrations at 14 DAI. Both the extracts were effective in restricting the penetration and further development ofJ2s, with concentration > 125 μg/ml. The penetration at 7 DAI followed the pattern as M 500 μg/ml<H 500 μg/ml< M 125 μg/ml. Maximum significant reduction (4.00) in number of galls was seen in methanol extract @ 500 μg/ml followed by hexane @ 500 μg/ml (9.20). Maximum increase in plant growth parameters was observed in treatment (T3) where leaf and roots of C. *juncea* was incorporated simultaneously during transplanting of rice seedlings.

## Effect of Different Organic Matter on the Efficacy of Carbofuran Against RootKnot Nematode *Meloidogyne incognita* Infecting Brinjal

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Investigation were undertaken to find the effect of different organic matter on the efficacy of carbofuran against root knot nematode infecting brinjal in 15 cm. earthen pots. Different organic manure viz leaf compost, vermicompost, FYM, crop residue and phosphorus enriched compost were mixed in soil at the rate of 5%. Simultaneously carbofuran was added to soil at the rate of 1 and 2 Kg a.i/ha. Nematode control and carbofuran nematode inoculated and untreated control were also maintained for comparison. After seven days of brinjal seedling transplantation inoculation of freshly hatched juveniles of *M. incognita* @ 2j2/g soil by making hole around rhizosphere of plant was done. After two months of inoculation seedling were uprooted for observing the nematode multiplication by counting root knot galls. Besides, plant growth parameters like fresh biomass, shoot and root wt. and shoot length were recorded. Results revealed that at higher dose of carbofuran number of galls were enhanced with all the compost in comparison to low dose. Besides, number of gall were also enhanced in carbofuran with manure treated plant in comparison to organic manure alone. Invariably number of galls was lower in organic manure treated alone in comparison to untreated. However, biomass was enhanced in carbofuran and organic manure combined in relation to carbofuran alone or manure alone treated plants. Vermicompost effect on plant has not been different in term of biomass and gall formation in relation to plant based manure.

## Effect of *Trichoderma harzianum* Under Different Organic Matter on Root-Knot Nematode *Meloidogyne incognita* Infecting Brinjal

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A glass house experiment was undertaken to find the effect of different organic matter on the efficacy of *T. harzianum* against root knot nematode infecting brinjal

in 15 cm earthen pots. Various organic manure viz leaf compost, vermicompost, FYM, crop residue and phosphorus enriched compost with the mix of *T. harzianum* culture mixed in soil at the rate of 5%. *Trichoderma harzianum* was added to soil at the rate of 10 Kg /ha with a cfu of $10^8$/g. Nematode control and *T. harzianum* nematode inoculated and untreated control were also maintained for comparison. After seven days of brinjal seedling transplantation inoculation of freshly hatched juveniles of *M. incognita* @ 2j2/g soil by making hole around rhizosphere of plant was done. After two months of inoculation seedling were uprooted for observing the nematode multiplication by counting root knot galls. Besides plant growth parameters like fresh biomass, shoot and root wt and shoot length were recorded. The number of galls was significantly lower in treated plant than the untreated. A maximum of 41% reduction in gall was observed with *T. harzianum* not mixed with any organic manure. While with organic manure FYM reduction in number of galls was 36% while in other organic manure the reduction in root knot gall was still lower (24%) It may also be mentioned that total fresh biomass was higher in *T. harzianum* alone than with mixed with organic manure. With regards to shoot length the trend was opposite i.e. as the length was higher in organic manure combined with *T. harzianum* than the *T. harzianum* alone.

## Management of Root-Knot Nematode in Organic Farming Systems

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Soil borne plant pathogens survive in the soil and cause extensive damage to many crops. Control of soil-borne diseases, including plant-parasitic nematodes, in organic farming systems is difficult, because effective control methods and monitoring systems are not available compared to foliar diseases and insect pests. Of the various soil borne pathogens, plant parasitic nematodes is one such group of which root-knot nematode (*Meloidogyne* species) is the most widespread and damaging nematode in vegetable crops. It is also becoming a significant biotic factor limiting yields in polyhouses/nethouses. Hence the present studies were planned to exploit the alternative strategies to chemicals for management of root knot nematode in infested fields. For this, the use and effect of different green manures recommended by PAU was studied in a root knot nematode infested field maintained at Department

of Plant Pathology, PAU, Ludhiana. In all, four treatments were taken. Green manure crops, Sunnhemp(*Crotolaria* sp) and *dhaincha (Sesbania* sp) were grown in an infested field and incorporated into soil after 50 days of growing. Brinjal was taken as an indicator crop. Each treatment was replicated thrice in 7x4 sq m beds. Recommended practices of PAU were used in trials. Root knot nematode population in field was assessed by taking root galling index (RGI) of 10 plants from each replicate. Observations were taken on RGI of green manure crops just before incorporation into field. RGI of indicator crop and yield/plot were taken at the mid and at the end of crop season. Observations on green manure crops revealed heavy buildup of RKN on *Sesbania*(RGI= 7.83) but there was no buildup of nematode on sunnhemp (RGI = 0.00) at the time of disking the crops into soil (50 days after sowing) . In indicator crop brinjal , RKN infestation was observed to be significantly less in plots green manured with sunnhemp ( RGI=3.01 in brinjal ). However,green manuring with *dhaincha* increased RKN infestation in field (RGI= 8.03). Yield of brinjal was increased in sunnhemp green manured plots by 32.7% and it was decreased in plots green manured with *dhaincha* . The present studies revealed that green manuring with sunnhemp can be effectively used to reduce root knot nematode infestation in field .

## Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cowpea (*Vigna unguiculata* L.) Using Bio-Agents

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An experiment was conducted for the management of root-knot nematode, *Meloidogyne incognita* infecting cowpea (*Vigna unguiculata* L.) using bio-agents under cage house condition during *kharif* 2012 .The efficacy of *Trichoderma harzianum*, *Trichoderma. viride* and *Pseudomonas fluorescens* @ 1g, 2g and 3g/ kg soil as a soil application was tested against root-knot nematode, *M. incognita* infecting cowpea. The experiment was conducted in six-inch earthen pots filled with 1 kg infested soil having an initial inoculum of about 2 larvae per g of soil and talc–based formulation of *T. viride, T. harzianum* and *P. fluorescens* were added to soil each @ 1g, 2g and 3g per kg soil. Each treatment was replicated three times. Untreated and chemical check (Carbofuran 3G @ 2kg a.i./ha) were also maintained for comparison. The results revealed that *T. harzianum* @ 3g/kg soil as soil application was found most effective in improving plant growth characters and

reducing nematode reproduction over the control followed by *T. viride* @ 3g/kg soil and *P. fluorescens* @ 3g/kg soil. However, all the treatments @ 3g/kg soil significantly increased the plant growth characters and suppressed nematode population over control.

## Study on The Effect of Radiofrequency Waves on Root-Knot Nematode, *Meloidogyne incognita*

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Thermal death kinetics of root-knot nematode, *Meloidogyne incognita* was determined using hot-water bath at temperature range between 45-60 $^0$C. Minimum time required to kill 100% second stage juveniles (J2s) decreased with the increase in temperature; it was 4 min for 50 °C; 2 min for 55 °C and 1 min for 60 °C treatments. Minimum hatching (2.57%) was recorded at 60 °C for 4 min treatment. Treatment of egg masses and J2s to three radio frequencies (RF) *viz.* 13, 27 and 42MHz showed that the effect of 27 and 42MHz on inhibition of the egg hatch and mortality was statistically at par and better than that of 13MHz treatment. The thermogram of tuberose after RF heating at 27 MHz showed that the rise of temperature was not uniform throughout the bulb tissues. Often the rise of temperature was more in the narrower part (point of emergence of shoot) of the bulbs compared to the broader equatorial region. RF heating also resulted in the higher temperature at the centre of the bulb compared to its peripheral regions. The bulbs of tuberose, treated at 27 MHz RF (1.2 kW power) for 8 and 10 min showed delayed germination and poor plant growth compared to untreated bulbs. Infected bulbs were treated keeping the same treatments. Egg mass from infected bulbs were isolated and their viability was evaluated by observing egg hatch. Hatching of eggs occurred in the egg masses from all the treatments. Minimum (15%) hatch was recorded with maximum time of RF exposure (i.e. 10 min) to infected bulbs.

## Variability in the Effect of Marigold Lines Against Reniform Nematode, *Rotylenchulus reniformis*

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Plant parasitic nematode, *Rotylenchulus reniformis* has worldwide distribution. This nematode has a broad host range and it causes considerable yield losses. Intercropping, cover crops and crop rotation with resistant or non-host plants are some of the cultural practices recommended for management of plant parasitic nematodes. Marigold (*Tagetes* spp.) is one such crop that releases alpha-terthienyl compounds in the soil toxic to plant parasitic nematodes. Marigold species and/or cultivars vary in their ability to suppress nematode population. Fifteen lines of marigold cultivated at Division of Floriculture and Landscaping, IARI, New Delhi were screened for their antagonistic effect on reniform nematode (*R. reniformis*) infecting cowpea. Two plant of each line were sown along with 2 cowpea (var Pusa Komal) plants in 12 inch diameter pots containing soil uniformly infected with reniform nematode. Soil population of reniform nematode was recorded 60 days after transplanting. All the lines were able to reduce nematode population in soil. The reduction of nematode population over control ranged from 35.6 to 95.8%. More than 80% reduction was observed in lines Af/SR-2, Af/SR-17, Af/SR-6, Af/SR-34, Af/SR -49, Af/SR 19-1, Af/SR-27 and were superior to other with respect to their antagonistic effect against reniform nematode.

## On-Farm Management of Root-Knot Nematode Infecting Chilli

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An on - farm trial was conducted on chilli (cvs. Pus Sadabahar and Pusa Jwala) infested with root-knot nematode, *Meloidogyne incognita* in two villages of Gurgaon district. Initial population of root-knot was recorded at the time of field preparation. On the basis of initial population (3-5 second stage juveniles per cc soil), 3 fields (size 0.20 ha each) per village were selected. Two treatments (soil application of carbofuran @ 1 kg a.i./ha and seedling root dip in Triazophos 40 EC @ 250 ppm for

1h before transplanting) were compared with the farmers practice i.e. two spray of Dimethoate 30 EC @ 2ml/L water at 30 and 40 days of transplanting. It was observed that the nematode population decreased with the increase in yield by 24.41 -30.59%. The population decrease ranged between 40.1 – 49.2% at different locations. At present the carbofuran is being recommended at nursery stage as well as under field condition @ 1kg a.i./ha.

# Session VII: Entomopathogenic Nematodes for Insect-Pest Management

# Effect of Different Formulations on the Viability and Pathogenicity of Entomopathogenic Nematode, Meghalaya Isolate *Steinernema carpocapsae* (EPN-S-I) and *Heterorhabditis indica* (EPN-H-I)

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*Steinernema carpocapsae* (EPN-S-I) and *Heterorhabditis indica* (EPN-H-I) were mass cultured on *Galleria mellonella* larvae. Different formulations (water, 0.1% formaldehyde, water + charcoal, water + 0.1% formaldehyde + charcoal, sodium alginate capsule, 0.1%formaldehyde + sodium alginate capsule) were tested for their viability and pathogenicity. The infecting juveniles (IJs) were harvested by white trap and washed with clean water. The clean nematodes (100 IJs) were mixed with each different formulations and stored in sealed bottles at $15^0$C. Percent viability was recorded at different exposure period (10, 20, 30 days). For pathogenicity test the clean nematodes were rehydrated in water for 48 h before inoculation to *G.mellonella* larvae. Percent mortality of *G.mellonella* larvae was recorded at different exposure period (48 and 96 h) following a sand assay. Data were analyzed by Two Factorial Completely Block Design. The results demonstrated that the viability of *S. carpocapsae* (EPN-S-I) and of *H. indica* (EPN-H-I) in formulation containing 0.1% formaldehyde + sodium alginate was 95% and 100% respectively after being stored for 30 days at $15^0$C. When exposed to *S. carpocapsae* (EPN-S-I) and *H. indica* (EPN-H-I) mortality of *G. mellonella* larva was 72.5%-75% respectively, infectivity declined slightly after storage.

# Intraspecific Variations Amongst Indian Isolates of *Photorhabdus luminescence ssp. Akhurstii*

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*Photorhabdus* spp. are Gram negative enterobacteria which have a life cycle involving mutualism with a nematode partner and pathogenicity towards insects. *Photorhabdus* reside as intestinal symbionts of the infective juvenile (IJ) stage of

*Heterorhabditis* that together form an entomopathogenic complex which kills the soil dwelling larval stages of a wide variety of insect species.The symbiont bacteria are known to produce a range of bioactive compounds having insecticidal, nematicidal, antifungal and antibacterial properties. These bacteria co-evolve with their nematode hosts, therefore it is expected that new species of symbionts may be isolated from new species and strains of nematodes which might lead to discovery of novel secondary metabolites and protein toxins.

Strains of *Photorhabdus* symbionts associated with indigenous *Heterorhabditis* species were isolated from different regions of India (Meghalaya, Gujrat, Haryana and Nagpur) and characterized them based on morphological, biochemical and molecular parameters was done. Characterization of 16s rDNA sequences identified all five strains as *Photorhabdus luminescens* spp*. akhurstii,* which were submitted to NCBI gene bank. However, distinct differences were observed amongst the strains in the required growth temperatures, stability in the first phase, bioluminescence, morphology, behaviour towards different biochemical tests and utilization of carbon sources. Out of 46 carbon sources and 25 biochemical tests, all strains showed differences in utilization of carbon sources and certain biochemical tests e.g. gelatin, L-Histidine, Guanidine, L- Galactonic acid, alpha-keto Butyric acid, Aztreonam, Sodium Butyrate, Adonitol, Saccharose, Lactose. The robustness of the phylogenetic tree obtained by multi-locus sequence typing (MLST) approach is significantly better than that obtained by a single gene approach; therefore using MLST approach may lead to the description of new *Photorhabdus luminescens* subspecies.

## Bioefficacy of *Steinernema abbasi* and *S. siamkayai* Against Mango Leaf Webber (*Orthaga euadrusalis*) Under Laboratory Condition

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Mango is an important fruit crop grown in tropical and subtropical regions of the world. The leaf webber (*O. euadrusalis*) is one of the major menaces limiting mango production in Uttar Pradesh. Their scrapping behavior results in loss of chlorophyll which impacts the overall photosynthetic efficiency leading to yield loss. The available management tactics through synthetic insecticides ultimately eliminates the natural enemies of mango ecosystem. Entomopathogenic nematodes are effective bio-

control agents and could be an ideal alternative to synthetic insecticides. The efficacy of two strains of entomopathogenic nematodes, *viz., S. abbasi* and *S. siamkayai* collected from Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow were tested against final instar larvae of *O. euadrusalis*. Insects were exposed to two doses of 50 and 500 infective juveniles (IJ) for each larva, following the standard protocol of Koppenhoffer and Kaya, 1998. Mortality was observed at 24 hours interval. The study revealed that *S. abbasi* caused 100% mortality of larva at both the concentrations within 72 hours and *S. siamkayai* caused only 83 and 88% mortality, respectively at both dosages within 3 days, while no mortality was observed in control. The percentage mortality of larvae increased with increasing dosage and time. Moreover, the emergence of IJs was observed from all EPN infected cadavers thus asserting its ability of self perpetuation. The study proves that *S. abbasi* is able to exert an excellent control over final instar larva of *O. euadrusalis* even with low nematode density under controlled conditions. However field studies optimizing the application rate has to be worked out before its inclusion as one of the viable components of integrated pest management.

## First Report of Occurrence of an Entomopathogenic Nematode, *Heterorhabditis bacteriophora* (SKUASTK-EPN-Hr 01) Poinar (Rhabditida: Heterorhabditidae) from Cold Temperate Region of Kashmir (J&K)

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A random survey for entomopathogenic nematodes (EPNs) was undertaken at various locations in Kashmir (J&K) during 2008-09 using *Galerria mellonella* and/or *Corcyra cephalonica* as bait. Out of 244 soil samples collected, 15 soil samples were found positive for EPNs with per cent frequency of occurrence of 6.15%. The isolation of native species / strains of EPNs from Kashmir Valley may provide a valuable resource not only from biodiversity perspective but also is an indication of the suitable climate for the pathogenicity, multiplication and survival of EPNs that prevail in the Valley. Using molecular biological approach, the isolate SKUASTK-

EPN-Hr 01 was identified as *Heterorhabditis bacteriophora* Poinar (Rhabditida: Heterorhabditidae). It is the first report of occurrence of an EPN from the cold temperate region of Kashmir. After the first record of occurrence of EPN, *H. bacteriophora* in Kashmir valley, it is expected that the use of this indigenous isolate of EPN against local insect pests will become an important alternative to chemical insecticides.

## Effect of Temperature and Population Density on Survival of Kashmir Isolate of EPN, *Heterorhabditis bacteriophora* (SKUASTK-EPN-Hr 01) in Kashmir

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The survival of infective juveniles ($IJ_3$) of Kashmir isolate of EPN, *H. bacteriophora* studied under different temperature regimes, viz., refrigerator, BOD, summer room temperature (Max.,19.91-31.57 °C, Min., 6.93-16.45 °C) and winter room temperature (Max., 8.27-22.24 °C, Min., -0.03-5.16 °C), was greatly influenced by the temperature regimes and exposure durations. The survival of the $IJ_3$ was recorded 100% up to 14th week in refrigerator and at winter room temperature, up to 4th week in BOD and up to 11th week at summer room temperature from the date of storage. The population density of $IJ_3$ was found inversely proportional to the nematode survival, as the population density during storage increased the survival of $IJ_3$ of *H. bacteriophora* decreased. Among the three population densities tested, the least population density of 200 IJs/ml resulted in significantly higher survival (100 and 94.00%) of the EPN followed by population density of 400 IJs/ml (98.00 and 93.33%) and of 800 IJs/ml (94.67 and 90.33%) at 15th and 18th weeks of exposure in refrigerator, respectively.

# Comparative Bioefficacy of Indian Strains of Entomopathogenic Nematode *Steinernema* sp. Against Fourth Instar Larvae of *Galleria mellonella*

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The long lasting impact of the chemicals on the non-target organisms, development of insect resistance to chemical pesticides and their hazardous effects on human health and the environment stimulated the interest of the scientists for an alternate insect pest control measures, e.g. biological control. Entomopathogenic nematodes are currently used world-wide for the biological control of insect pests. Wide host range, high efficacy, lack of mammalian toxicity and the availability oftechniques for economic mass production have ledto the rapid increase in the use of these biologicalcontrol agents in recent years. Keeping this in view, present study was conducted underlaboratory conditions to evaluate the bio-efficacy of three native *Steinernema* strains from Kerala, Meghalaya and Chhattisgarh against fourth instar larvae of *Galleria mellonella*. The experiment was conducted by inoculating IJs of each strain in 12 wells culture plate @ of 10, 20, 40, 60, 80, 100, 500 & 1000 IJs per larva in each well. The plates were kept at 27 ± 2°C and observations were recorded after 24, 36and 48 h to check insect mortality.The data revealed that after 48 h of infection, median lethal concentration ($LC_{50}$) of Kerala strain (5.5 IJs/larva) was lower than those of Chhattisgarh strain (6.3 IJs/larva) and Meghalaya strain (8.5 IJs/larva). $LT_{50}$ analysis revealed that Kerala strain was quicker in killing the insect with lower $LT_{50}$ (36 h for 10-100 IJs/larva) as compared to Chhattisgarh strain (48 h for 10 IJs/larva, 42 h for 20-40 IJs/larva and 36 h for 60-1000 IJs/larva) and Meghalaya strain (48 h for 10-40 IJs/larva, 42 h for 60-80 IJs/larva and 36 h for 100-1000 IJs/larva). Hence, Kerala strain was found to be most pathogenic on *Galleria* among the tested strains.

# Natural Occurrence of Entomopathogenic Nematodes in Ginger Ecosystem in India and First Report of *Steinernema carpocapsae* Associated with Ginger (*Zingiber officinale* Rosc.)

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Random survey for naturally occurring entomopathogenic nematodes (EPNs) from ginger (*Zingiber officinale* Rosc.) ecosystem were undertaken from different agro-climatic regions in India. One hundred and fifty seven soil samples were collected from different locations of districts Kozhikode, Wayanad, Kottayam, Idukki (Kerala), Kodagu (Karnataka), Coimbatore (Tamil Nadu), Kolasib (Mizoram), Faizabad (Uttar Pradesh) and Barapani (Meghalaya) for determination of EPN population. Out of 157 soil samples baited out, eight samples were found to be positive to EPNs. Among these strains, three EPNs were from Kozhikode District, three from Idukki District and one each from Wayanad and Faizabad districts. Out of the eight EPNs isolated, three species belong to genus *Steinernema*; one to *Heterorhabditis* and four to *Oscheius*. These species have been identified on the basis of morphometric and morphological characterization. Four hundred and twenty four pseudostems of ginger infested with shoot borer (*Conogethes punctiferalis*) larvae were collected from the different localities of Kozhikode, Wayanad and Kodagu districts and 112 larvae were found dead. Among dead larvae, only one EPN, namely *Oscheius* sp. was recorded from the shoot borer larvae. Our survey revealed that, *Oscheius* spp. and *Steinernema* spp. widely occur and *S. carpocapsae* is reported for the first time from the rhizosphere of ginger. These species have great potential for biological control of insect pests of ginger.

# Isolation of Entomopathogenic Nematodes from White Grub Endemic Areas of Sugarcane and its Biocontrol Efficacy against White Grub *Holotrichia serrata* Under Field Conditions

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The beetle family Scarabaeidae has a high diversity of species and many of them have become important pests. White grub *Holotrichia serrata* is one such polypahagous pests of the Scarab family and is a pest of national importance currently endangering sugarcane cultivation in many areas. White Grub species because of their subterranean habit spends a large portion of their life cycle in the soil and consequently are vulnerable to soil borne entomopathogenic nematodes (EPN). It is for this reason biological control of white grubs with entomopathogenic nematodes has been particularly successful. Survey was conducted in white grub endemic areas of sugarcane to collect soil samples for isolation of EPN. The soil samples and some third instar white grub larvae with natural infection of EPN *Heterorhabditis* sp. obtained from the survey were tested for the presence of steinernematid and heterorhabditid nematodes by baiting with *Galleria mellonella* larvae. Morphological and molecular studies identified nine *Heterorhabditis* and six *Steinernema* spp from the 15 EPN isolated from our survey. Pathogenicity of five *H. indica* isolates (DSM8, DSM22, DSM78, DSM81 and DSM85) was studied against first and second instar larvae of white grub, *H. serrata* under laboratory condition. The mortality of 1$^{st}$ instar larvae due to EPN ranged between 33.3 and 83.3 per cent and the lowest $LD_{50}$ value of 34.8 IJs/grub was recorded for *H. indica* (DSM 85). Similar result was also observed against 2$^{nd}$ instar white grubs. The mortality of 2$^{nd}$ instar grubs due to EPN ranged between 16.6 and 83.3 per cent. EPN isolate *H. indica* (DSM 85 & DSM78) recorded lowest $LD_{50}$ value (370 IJs/grub) for 2$^{nd}$ instar grubs. Two field trials were conducted to test the efficacy of *H. indica* (isolate DSM 78) against white grub *H. serrata* at Bannariamman Sugar Mill, Thalavady, Tamilnadu and Dharmapuri Sugar Mill, Palacode, Tamilnadu. In both trials, lesser number of grubs was observed in the EPN treated plots as compared to the control plot. The reduction of grub population due to EPN treatment was 43 to 77 per cent and 30 to 78 per cent for Thalavady and Palacode respectively.

# Compatibility of Entomopathogenic Nematodes with Insecticide Imidacloprid and its Synergistic Effect Against White Grub *Holotrichia serrata* on Sugarcane

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White grub *Holotrichia serrata* is one of the most important groups of subterranean pests of sugarcane. Generally, the damage caused by white grubs is in patches, but sometimes the entire crop in a field may also be wiped out. Previous reports suggest that entomopathogenic nematode (EPN) may be a good candidate for suppressing white grubs because of its subterranean. It is also reported that synergism occur when EPN and imidacloprid are used in the control of scarabid grubs. Hence experiments were conducted to study the compatibility of EPN with insecticide Imidacloprid and their synergistic role in controlling white grub *Holotrichia serrata* on sugarcane. Compatibility of different concentration of Imidacloprid was studied under laboratory condition with five EPN *viz*., *Heterorhabditis indica* (isolates BNR, LN2 and DSM78), *H. bacteriophora* (Hb) and *Steinernema siyamkai* (SSM3). Movement assay was done and survival of the EPN was recorded after five days. All the EPN isolates tested were compatible with different concentration of Imidacloprid with a 100 per cent survival rate but for DSM 78 which showed a reduced survival of 70 to 90 per cent. In infectivity assay against *Galleria mellonella*, 100 per cent mortality of the *Galleria* was recorded with EPN and imidacloprid combinations. In another laboratory assay, faster mortality of 3$^{rd}$ instar white grub *H. serrata* was recorded in combined treatments of EPN and Imidacloprid than the individual treatments alone indicating synergistic action. About 44 to 100 per cent mortality of grubs was recorded with combined treatment of EPN and Imidacloprid while the mortality was 11 to 60 per cent for individual treatments. Under pot culture condition**,** *H. indica* isolates (BNR & DSM 78) when combined with Imidacloprid separately also showed a maximum mortality of 100 per cent for 3$^{rd}$ instar white grub as compared to individual treatments showing lower mortality. Results for combined application of *H. indica* isolate BNR with Imidacloprid however under microplot condition revealed a slightly lesser grub mortality of 60 to 75 %.

## Effect of Storage Media and Temperature on Viability and Pathogenicity of Indigenous Strains of Entomopathogenic Nematodes

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Entomopathogenic nematodes belonging to families, Steinernematidae and Heterorhabditidae are important biocontrol agents of insect pests due to their wide host range, rapid kill, lack of mammalian toxicity and ease in mass production and application. Long term storage is an important constraint in utilization of these nematodes in insect pest management. In present studies, the effect of storage media (sterilized distilled water with a drop of Triton X-100 and sterilized sponge) were studied at 10 and 25 $^0$C on viability and pathogenicity of local strains of *Heterorhabditis bacteriophora* and *Steinernema feltiae*. The storage quality of *S. feltiae* was proved better than *H. bacteriophora*. The infective juveniles (IJ) of *S. feliae* could be stored at 10$^0$C temperature up to 4 months without much loss of viability (98.56 and 98.01% viability up to 4 months in water and sponge, respectively) and pathogenicity. No significant differences in juvenile viability were recorded in storage at 10 and 25$^0$C up to two months of storage. *H. bacteriophora* had poor storage ability. All the IJs were dead at 25$^0$C after 4 months. At 10$^0$C the juvenile viability was 34.63 and 44.17% in distilled water and sponge, respectively. However, the surviving population did not lose much of its infectivity.

## Comparison of EPN Fauna in Disturbed and Undisturbed Ecosystems

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A survey of Haryana Agricultural University (Hisar) farm was carried out to assess EPN fauna in disturbed, semi-disturbed and undisturbed ecosystems. Ninety soil samples (10 samples per location) were collected from nine sites; three each from

forest plantations (neem, eucalyptus and *Sheesham*), fruit trees (jujube, guava and citrus) and vegetable crops (okra, onion and tomato). Maximum occurrence of EPNs was found at jujube and okra sites (40% each), followed by neem (30%) while at *sheesham* and tomato sites, 10% samples were found positive. No EPNs were detected at citrus, guava, onion and eucalyptus sites. Out of total 90, 12 sites were found positive with *Steinernema* sp. and only one with *Heterorhabditis* sp. Based on the juvenile length, presence or absence of head papillae and colour of cadaver, the EPN isolates were assigned to different groups i.e., *Steinernema pakistanense* group, *S. abbasi* group, *S. asiaticum* group, and *S. bicornutum* group. On the basis of their occurrence, three sites - one representing each ecosystem was selected for studying the natural persistence of the nematodes throughout the year. At site I – Neem (completely undisturbed ecosystem), *Steinernema* was recovered throughout the year, except in the months of January and February. A highly significant correlation was established between soil temperature and per cent larval mortality of EPNs. Soil moisture did not affect the occurrence of EPNs significantly. At site II – Jujube (partially disturbed ecosystem), *S. pakistanense* was isolated in all the months, except during November, December and January. At this site also, a very highly significant correlation was established between soil temperature and per cent larval mortality of EPN. Soil moisture continued to be less than 9 per cent from September to November but did not play any significant role. At site III – Okra (disturbed ecosystem), the field was planted with okra – cabbage – *dhaincha* sequence. *Steinernema* sp. (*abbasi* group) was intercepted on all the sampling dates except during January and February. A significant correlation was recorded between soil temperature and larval mortality. The role of soil moisture was non-significant.

## Effect of Storage Medium and Temperature on Entomopathogenic Nematodes (EPNs) Inside Host Cadavers

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Storage of infective juveniles (IJs) of entomopathogenic nematodes (EPNs) for long periods is not easy. Host cadaver provides protection to IJs for development, which led to development of host cadaver-based formulation. In such formulation IJs can survive dry conditions for extended periods if they remain inside the host cadaver. For this study, three different media were used viz., sterilized river sand, activated

charcoal powder and empty tubes (37 x 50 mm) with filter paper at bottom. *Galleria melonella* larvae were inoculated with *Heterorhabditis indica* and *Heterorhabditis* (HP Isolate) separately and allowed to develop up to IJs of second generation at 25±1° C. Fifteen surface-sterilized infected cadavers were kept per tube and shifted to temperature treatments (5, 10, 15, 20 and 25±1° C). Observations on emergence of IJs were taken after 15, 30, 60, 90 and 120 days. Both *H. indica* and *Heterorhabditis* (HP isolate) could not be stored beyond 15 days at 25° C. At 20° C, both the species could be stored up to 30 days in sand as well as in tubes without medium, but not in charcoal powder. Maximum period for which either of these species could be stored was 90 days. At 15° C, *H. indica* could be stored up to 90 days, whereas, *Heterorhrabditis* (HP isolate) up to 60 days only in both sand and empty tubes. At 10° C, *H. indica* could be stored up to 90 days only in sand and the number of IJs emerging out was also reduced, whereas the other species could be stored in empty tubes as well and emergence of IJs was recorded though less than sand medium. *Heterorhabditis* sp. (HP isolate) could be stored for a month at 5° C too. Charcoal was not a good medium for storage.

## Quantification and Comparison of Lipid Reserves in Anhydrobiotic Nematode *H. indica* and *M. incognita*

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The behaviour of the infective juveniles (IJs) of *H. indica* when stored at $28^0$C in water was determined and correlated with the lipid energy reserves. Immediately after emerging from the host cadaver, 98.4% of the IJs were highly active and 95.8 % of them displayed 'waving', the normal method of forward movement. These tendencies declined gradually with age. Over the 8-week storage period, 63.4% were active and the 'waving' behavior was displayed only by 24.2% IJs. Nematodes visibly became more transparent due to depletion of energy reserves. The total lipid reserve decreased by 1.8%, 19.0%, 30.3% and 35.1% after 2, 4, 6 and 8 weeks, respectively. However, the total lipid reserves of anhydrobiotic IJs decreased only by 0.3%, 1.9%, 2.2% and 4.4% following similar storage conditions. In comparison, the non-anhydrobiotic nematode, *M. incognita,* visibly became more transparent due to depletion of lipid reserves. Immediately after hatching from the egg masses 98.6% J2 were active and 98.8% of them displayed waving behavior. After 8 weeks of storage in water at $28^0$C, only 33% were found to be active and none showed any movement. The lipid reserves declined by 17.8%, 48.6%, 83.2% and 94.2% after 2, 4, 6 and 8 weeks of storage, respectively.

# Entomopathogenic Nematode: Friends of The Farmers

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Entomopathogenic nematodes are most promising and second most utilized bio-control agent against insect pests after *Bacillus thuringiensis* used in high value crops including cryptic environments. They are also eco-friendly and cost effective. Increasing environmental concern about the use of chemical pesticides and availability of fewer of them reawakened interest in IPNs for control of insects' pests. Most species are virulent having a broad host range.

A survey of the agricultural fields in four districts of Meerut region was laid down to search for the presence of entomopathogenic nematodes (EPN). A total of 597 samples were collected from 65 villages of Meerut, Ghaziabad, Baghpat and Saharanpur districts. The soil samples were brought to laboratory and processed for determination of EPN from the soil samples by using the soil trap method as given by Bedding and Akhrust (1975). Out of the total collected soil samples, 8.5% samples were found positive. The prevalence of EPN was estimated highest in Baghpat (35.2%) followed by Meerut (31.3%), Ghaziabad (25.4%) and Saharanpur (7.8%).

Interestingly *Steinernema* spp. was recovered from all the studies districts and showed highest prevalence (82.3%) while *Heterorhabdits* (17.6%) was found only in the soils of Meerut and Baghpat districts. *Steinernema* spp. was prevalent in Ghaziabad and Saharanpur (100%) followed by Baghpat (88%) and Meerut (56.2%) whereas *Heterorhabditis* was recorded highest in Meerut (43.7%) followed by Baghpat (11.1%) samples. Some of the isolates were found to be more pathogenic against *Helicoverpa armigera*, the serious pest of western Uttar Pradesh.

Papers deals with the prevalence, pathogenecity and morphotaxonomy of some of the isolates of *Heterorhabditis indica*; *Steinernema asiaticum*; *S. masoodi* and *S. thermophilum* from the soils of western Uttar Pradesh.

# Compatibility of *B. cereus* and *H. indica-Photorhabdus* Symbionts for the Management of White Grubs

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*B. cereus* (WGPSB-2) when fed orally to 3rd instar grubs of *Holotrichia* spp. (@ $0.75 \times 10^4$ spores/grub) resulted in reduction in the feeding of the grubs finally leading to mortality within 5 to 9 weeks. There was up to 36.08% reduction in the weight of the diseased grub over control. Mortality in the grubs started after 5 weeks (10%), which increased to up to 90% by the seventh week. The dead grubs turned dark black, flaccid and the body was filled with grayish fluid giving foul odour. In a separate experiment, healthy and diseased (exposed to *B. cereus* for 4 weeks) 3rd instar grubs were exposed to *H. indica* IJ @ 250, 500 and 1000 IJ/grub. At the lowest inoculum level of 250 IJ/grub the mortality in healthy grubs started on the 6th day while in the diseased grub it started after 2 days of nematode inoculation. 100% mortality was recorded after 12 days in healthy as compared to 7 days in diseased grubs. At 500 IJ/ grub dosage the mortality in healthy started after 4 days and reached 100% after 9 days, while in diseased grubs it started after 2 days and took 4 days less to kill all grubs. At 1000 IJ/ grub inoculum level 100% mortality was recorded in healthy within 5 days as compared to 3 days in diseased grubs. The grubs infected with *H. indica-Photorhabdus* symbionts alone turned characteristically reddish in color and the nematode could successfully complete the life cycle. Grubs infected with *H indica-Photorhabdus-B. cereus* exhibited patches of red, brown and black color and the nematode could not complete their life cycle, thus, hampering the re-cycling ability of these nematodes.

# Evaluation of Bacterial Bioagents Against *Aphelenchoides swarupi* in White Button Mushroom, *Agaricus bisporus*

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The experiment was laid to evaluate three bioagents, *viz. Pasteuria penetrans* @ 104 spores/g of compost, *Bacillus thuringiensis* @ 0.4 mg/10 kg compost and *Pseudomonas fluorescens* @ 1 g/10 kg of compost against the *Aphelenchoides swarupi* in *Agaricus bisporus.* The bioagents and test nematodes were inoculated at spawning time. The mycelial growth at casing time in the bags treated with test nematode and bioagents or only nematodes ranged non-significantly between 57.5 to 62.3 per cent. Yield losses to the tune of 81.0, 74.6 and 76.7 per cent with respect to uninoculated control were recorded in the treatments receiving *P. penetrans, B. thuringiensis* and *P. fluorescens* along with nematodes, respectively. *B. thuringiensis* initially showed a suppressive effect against *A. swarupi* ($6.75x10^4$ nematodes per 200 cc compost as compared to $9.34x10^4$ in untreated control at casing time. Similarly, corresponding figures at pinhead formation were $59.34x10^4$ and $96.64x10^4$. None of the test bacterial bioagents produced any promising results as expected against test nematode in *A. bisporus* as they neither promoted the mycelial growth nor checked the nematode population significantly. As a result, sporophore production did not improve by addition of these bioagents at spawning.

# DJ Raski Award

# Studies on Application Technology of Entomopathogenic Nematode, *Steinernema thermophilum* for Managing Insect Pests

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Entomopathogenic nematodes of the families Steinernematidae and Heterorhabditidae are soil inhabiting insect pathogens that possess potential as biological control agents against various insect pests. *Steinernema thermophilum* described from India has been found to be well adapted to local environmental conditions and efficacious against several insect pests of national importance. So, there is a need to generate information on its application technology with respect to its compatibility with various crop production and protection agents as well as its effect on the non-target beneficial organisms to facilitate its use in integrated pest management programmes. Keeping in view the above mentioned gaps in knowledge, the present investigation was carried out to evaluate the interaction of *S. thermophilum* with different *agrochemicals*, bioagents, organic amendments etc. and its interspecific interaction and non-target effects. The compatibility evaluation of entomopathogenic nematode (EPN), *S. thermophilum* with different agrochemicals revealed the incompatible interaction with Hostathion (Triazophos), Dursban (Chlorpyrifos) and Thiodan (Endosulfan), in their recommended doses. However, all the other insecticides, herbicides fungicides and surfactants/adjuvant evaluated were found to be compatible. The bacterial bioagents namely *Bacillus thuringiensis* and *Pseudomonas fluorescens* were found to be harmful to the survival of infective juveniles, where as all the fungal bioagents studied were found to be safe towards the nematode. In contrast, *S. thermophilum* and its symbiotic bacterium *Xenorhabdus indica* could suppress the growth of entomopathogenic fungal bioagents namely *Metarrhizium anisopliae* and *Beauveria bassiana.* The result indicated the incompatibility of *S. thermophilum* with *M. anisopliae* and *B. bassiana* especially when both target the same host. The organic amendments like vermocompost, farm yard manure, bone meal and neem cake were found compatible with *S. thermophilum.* The experiment on interspecific interaction of different EPN species namely *S. thermophilum, S. glaseri* and *Heterorhabditis indica* showed dominance of *S. glaseri* at 27 $^0$C and *S. thermophilum* at 35 $^0$C. But combined infections in all the combinations resulted in reduced progeny production as compared to single infectious. The studies on non target effects of these three species of EPNs showed no harmful effect earthworms, where as ants and spiders were observed to be affected at higher doses. The synergistic interaction of S. *thermophilum* and biopesticidal formulation Tracer (spinosad) was observed in the pot experiment on *Helicoverpa armigera* infecting tomato.

# Bio-management of Nematode Induced Disease Complex Using Molecular Marker Identified Nematicidal Strains of *Bacillus* spp. and *Trichoderma harzianum*

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Plant parasitic nematodes inflict direct and indirect damage to crops by pre-disposing the plants to other co-inhabiting pathogenic bacteria, fungi and pathogens etc. They are an important biotic stress for the successful cultivation of field and horticultural crops. Among these, root-knot nematodes (*Meloidogyne* sp.) are economically important nematodes. Nematode induced disease complexes cause severe losses to the farmers. The chemical pesticides used for controlling nematodes and other pathogenic fungi/bacteria are expensive and hazardous. As an alternative strategy for crop management several bio-control strategies have been developed by several researchers in the country. At IIHR efforts were made to develop technology that can effectively manage the nematode induced disease complexes in horticultural crops.

The bio-control bacteria *Bacillus* spp. is being used for their bio-bactericidal activity and ISR since few decades. Recently they are also being used for controlling nematodes. Till now there are no reports on the bacillus related nematicidal genes. In this study we have identified a gene responsible for the nematicidal activity in *Bacillus amyloliquifaciens* and *Bacillus subtlis.* Similarly *Trichoderma harzianum* (Rifai), another versatile bio-control agent has been extensively used for the management of pathogenic fungi infecting various crops. In our preliminary studies a few strains of this bio-agent were found to be infecting root knot nematodes (*Meloidogyne incognita* Chitwood) besides other pathogenic fungi. However a few other strains were only infecting pathogenic fungi. In this study we have also studied the *Trichoderma* strain specific nematicidal gene. These genes were studied using *in silico* methods, evaluated *in vitro* and *in vivo*. Mutant strains with the nematicidal genes knocked out were designed where the mutants lost their nematicidal activity. Molecular screening proved that the the nematicidal genes were destroyed in mutant strains. Nematicidal activity was recovered when they were complemented with plasmid containing *PRA 1* gene in *T. harzianum* and *purl* gene in *Bacillus amyloliquifaciens* and *Bacillus subtlis*.

Studies were conducted to develop a consortia formulation using these two unique bio-agents together for controlling nematode induced fungal and bacterial wilt disease complexes in horticultural crops. Efficient combination formulation was developed with better shelf life and higher bio-efficacy. This combination formulation was evaluated on Gerbera and Capsicum crops and bio-management strategies were standardized for controlling nematode induced disease complexes in open and protected crop conditions.

## Development of Controlled Release Novel Formulations (CRNF) of Salicylic Acid and Their Bioefficacy Evaluation on Wheat against Cereal Cyst Nematode, *Heterodera avenae*

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Wheat (*Triticum aestivum*) is the second most important food crop of the world. India occupies the second place in the world after China, presently, wheat accounts 29.2 m ha of the total area in India and contributes about 93.9 million tonnes of the total production with the productivity of 31.40q/ha. Cereal cyst nematode, a causal organism of Molya disease, causes 50-90% yield loss which is about 9 crore per annum in India. Chemical control is one of the options to control nematodes, but due to environmental and human health hazards their use has been banned and many will be phased out in near future. Under these circumstances there is a need to develop some new generation nematicidal molecule which is safe to environment, required in lower dose, show lower residual activity and target specific in action. The elicitor molecule, Salicylic acid (SA), able to trigger systemic acquired resistance (SAR) and activated by necrogenic pathogen attacks, also reported to induce a broad-spectrum disease resistance in plants.

Investigations were carried out to study the bioefficacy of controlled-release novel formulations (CRNF) of Salicylic acid (SA) which were prepared using amphiphilic polymers, synthesized from PEG-1000 and three different linker molecules [Adipic acid (AA), Pimelic acid (PA) and Suberic acid (SuA)] (@ 62.5, 125, 250 and 500 µg/ml for *in-vitro* study on nematode mortality and foliar spray and seed dresser on wheat which induces defense responses in plant against the cereal cyst nematode, *Heterodera avenae*. *In vitro* studies showed that the mortality of J2s increases with increase in concentration of all the three CRNFs of SA *i.e.* AA, PA and SuA and

100% mortality was observed at 500 µg/ml with all the formulations after 96 h. There was an improvement in the plant growth parameters of wheat with the application of CRNF of SA (foliar as well as seed treatment). The developed CR formulations provided better initial protection to the wheat plants as it was evident from the less penetration of J2s during 7 DAI till 14 DAI. The percent penetration of J2s ranged between 0.24 to 0.77 %, 0.44 to 0.55 % and 0.11 to 0.55% with the foliar application of CRNF of SA: AA, PA and SuA respectively compared to control (34.6%). Later on, restricting the further development of J2s to white females. This was perhaps due to the sustained SA release from these formulations. The above study was confirmed with the changes in biochemical parameters, where in, the data indicated the peroxidase (PO) and phenylalanine ammonia lyase (PAL) activities enhanced in all the treatments over control at 7 and 14 DAI in both shoots as well as roots. Among the three formulations tested, SuA @ 125 µg/ml, and SuA @ 125 µg/ml or above were highly effective when applied as foliar spray and as seed dresser respectively. Thus, CRNF of SA (AA, PA & SuA) induces tolerance in wheat plants against *H. avenae.* Thus, these formulations could be further utilized under micro plot/field conditions for the management of *H. avenae* in wheat.

## Elucidation of Phenotypic Characters in Brassinosteroid Treated Compatible and Incompatible Tomato Plants During Nematode Stress

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Root-knot nematodes (RKNs) are one of the important biotic factors that limit worldwide agricultural production. They cause high yield losses to most of the cultivated plant species in subtropical and tropical regions. *Meloidogyne* spp. are sedentary endoparasitic nematodes and obligate biotrophs that induce the formation of complex feeding sites and the typical galls in the roots. Plants share a very intimate relationship with these pathogens. They produce a wide array of growth regulatory compounds with broad spectrum effects. One such novel group is brassinosteroids (BRs) that are ubiquitously distributed throughout the plant kingdom. Brassinosteroids are the steroidal lactones and hydroxylated derivatives of cholestane having structure similar to animal steroid hormones. Among the various

known brassinosteroids, 28-Homobrassinolide (HBl) is the most potent steroid that confers resistance to plants against environmental stresses.

In the present study, in vitro analysis of HBl treated tomato cultivars: compatible (Pusa Ruby) and incompatible (PNR-7), was conducted during the pathogenesis of root-knot nematode. Sterilized seeds of selected cultivars were treated with different concentrations of HBl and grown under controlled conditions. Seedlings were further inoculated with infective juveniles of *Meloidogyne incognita*. Phenotypic characters (percentage germination, total plant height, total plant biomass and number of galls) were assessed at different time intervals (24, 72, 120, 168 hrs) post-nematode inoculation in both cultivars. Analysis of results showed a positive impact of HBl on plant growth while a deleterious effect was seen on nematode development. Furthermore, when the two cultivars were compared for plant growth parameters, overall higher values were determined in PNR-7 as compared to Pusa Ruby. Nematode inoculation resulted in an increase in the total height of plants which was further enhanced with HBl treatment. On the other hand, during compatible interaction, total plant biomass decreased with nematode inoculation, but regained with HBl application. However, during incompatible interaction, nematodes were not able to invade the plant, as a result, the total plant biomass was further enhanced with HBl application. Likewise, when these cultivars were compared at different time intervals for plant growth parameters, more prominent results were found 72 hrs post-nematode inoculation. In addition, when comparisons were made for gall number, lesser number of galls were seen in the incompatible cultivar as compared to compatible one. Also, it was found that in both the cultivars, number of galls decreased with increase in HBl concentrations. Hence, the study revealed an elucidated effect of 28-Homobrassinolide on phenotypic characters of tomato cultivars even during nematode stress.

## Studies on Bacterial Parasite, *Pasteuria penetrans* (ex Thorne) Sayre & Starr on Root-Knot Nematode, *Meloidogyne javanica* (Treub) Chitwood

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*Pasteuria penetrans* has emerged as a very promising bio-control agent of root-knot nematodes (*Meloidogyne* spp.), particularly after the success achieved in its

*in vitro* cultivation. Therefore, studies on some aspects related to both basic and applied aspects were conducted with the following objectives – (i) effect of plant root exudates and cell free plant root extracts on the induction of *P. penetrans* endospore germination, (ii) to determine the role of *P. penetrans* in the suppression of root-knot nematode in naturally infested field soils, and (iii) development of *P. penetrans* under open field and poly-house conditions.

Influence of root exudates (REs) and cell free plant root extracts (CFPREs) of brinjal, cowpea, cluster bean, garden bean, okra and tomato was tested on the germination of *P. penetrans* endospores. REs and CFPRE of all the plant species did not induce the germination of *P. penetrans* endospore. In garden bean CFPRE, cauliflower-like colonies similar to *P. penetrans* were observed in endospore suspension treated with alcohol. In all the treatments rod-shaped lumps of bacteria were evident; they may be contaminants because intact endospores of *P. penetrans* were also present. Based on a laboratory bioassay, a statistical model was developed for the estimation of *P. penetrans* endospores in field soils. The regression equation $y= 0.045x + 3.779$ with $R^2 = 0.89$ was calculated for *M. javanica*. In a green-house experiment, the role of *P. penetrans* in the suppression of *M. javanica* was estimated in naturally infested field soil. Field soil was steam sterilised or treated with formalin/fungicides. Formalin and Bavistin proved to be phytotoxic. *P. penetrans* alone infected 87.5% nematode females and reduced egg production by ca. ten times. Native fungal and bacteria promoted attachment of *P. penetrans* endospores but inhibited parasitisation of nematode females by *P. penetrans* in untreated soil. The development of *P. penetrans* under open-field and poly-house (ordinary and hi-tech) conditions was studied in winter season. Poly-houses (both ordinary and hi-tech) enabled raising the maximum temperature by 10-12 ˚C during day time, but there were negligible differences in the minimum temperatures. *M. javanica* completed it life cycle (females with egg sacs) in 60 days in hi-tech, 70 days in ordinary poly-house and 80 days in open-field conditions. *P. penetrans* development could not keep pace with that of nematode and it stopped at thallus stage. No mature endospores were found. *P. penetrans* failed to curtail the reproduction *of M. javanica* even in hi-tech poly-house, although infection did take place.

# Development of Integrated Nematode Management Module for Rice Root-Knot Disease Caused by *Meloidogyne graminicola*: A Success Story for Endemic Area

Ziaul Haque

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Extensive survey of paddy fields was conducted during 2009 and 2010, as farmers informed the epidemic of rice root-knot nematode, *Meloidogyne graminicola* in Aligarh and Hathras districts of Uttar Pradesh. The frequency of disease occurrence in Aligarh and Hathras districts found 46.3% and 37.5%, respectively. Maximum disease incidence with 4.33 gall index of 0-5 scale was recorded in Iglas tehsil (74.2%) of Hathras, where farmers plowed their field after one month of transplanting. The average soil population of *M. graminicola* was 1098 J2/kg soil with highest in Iglas tehsil (3458 J2/kg soil). Most farmers grow two susceptible varieties, Pusa Sugandha-5 and PS-1121, and no chemical pesticides/nematicides had been proven effective even after applying overdose/repeatedly. To undertake this situation, pot and field experiments were conducted to device effective management module for endemic area. Screenings of 18 rice varieties for varietal reaction were evaluated on the basis of gall formation/egg mass production and biochemical parameters against field populations of *M. graminicola* under pot condition. All the variety except Santhi and Vandana were found susceptible and developed characteristic terminal galls (11-57 galls/root system). Greatest increases in the leaf contents of salicylic acid (26%) and total phenol (51%) were recorded in var. Shanthi, whereas least increases were detected in var. Pusa Sugandha-5 (17% TP and 10% SA). Increases in total phenol (TP) and salicylic acid (SA) were negatively correlated with numbers of root galls and egg masses/root system. Based on the biochemical reaction, it was revealed that var. Shanthi and Vandana expressed resistance/tolerance reaction against *M. graminicola* and can be exploited commercially. Keeping into consideration of the failure of chemical pesticides/nematicides, investigation on the biocontrol potential of local strains of *Trichoderma harzianum* (MUTH-5), *T. virens* (MUTV-1), *T. viride* (MUTV-2), *Aspergillus niger* (MUAN-1), *Pochonia chlamydosporia* (IMTC-6898), *Bacillus subtilis* (MUBS-1) and *Pseudomonas fluorescens* (MUPF-2) had been undertaken against field population of *M. graminicola*. Biocontrol agents (BCAs; 2 ml/pot) were applied with five modes of application. In infested soil, terminal galls developed and plants suffered 20-31% decrease in the plant growth parameters.

Application of *P. fluorescens* or *T. harzianum* as root dip + two soil application was found highly effective and suppressed the gall formation (40-46%), egg mass production (45-57%) and soil population (56-64%) of *M. graminicola*, and subsequently increased the plant growth variables by 37-42%. To device the integrated management module, field trials (Location–I) were conducted for two consecutive years (2010-2011) with integration of a dose half of the recommended dose of nematicides (carbofuran or carbosulfan) and BCAs (based on compatibility tests of BCAs with nematicides *in-vitro*). The combined treatment of root dip and three soil application (15+30+45 DAP) with integrated dose of carbosulfan and *T. harzianum* or *P. fluorescens* found highly effective against the nematode and suppressed root-knot severity by 65-72% (*P ÀÛ”Ü* 0.001) and increased the yield by 30-35% (*P ÀÛ”Ü* 0.001. Based on trial results of Location-I, field trial was conducted in farmer's field at Iglas, Aligarh (Location-II; 2011-12) and integrated management module was recommended and significant decrease in disease incidence (85%) was recorded with an increase of 36-45% in yield compared to epidemic condition.

# Biography of Dr. G.I. D'Souza

Late Dr. G.I. D'Souza
March 1971 to Jan. 1977

Dr. G.I .D'Souza Former Director of Research Coffee Board hailed from a respectable family of coffee planters in Chickamagalur Karnataka. After his post graduation from IARI, He obtained his PhD from University of California USA. He joined as an extension Officer in 1953 and became the Head of the Division of Entomology and Nematology of Central Coffee Research Institute in 1964. Subsequently He became the Director of Research in 1970 and functioned in that capacity till 1977.

He did pioneering work in solving the nematode problem in coffee and released nematode resistant grafted plants with robusta as root stock and Arabica selections as scion. He was instrumental in getting the PL 480 project for nematode control and became the Principal Investigator of the project.

Dr. D'Souza authored many valuable publications for the benefit of coffee industry in the country. He was an excellent guide trainer, an extension worker and research personnel. He was also a keen lover of nature and had great concern for the protection of ecosystem of coffee environment

After his voluntary retirement from the Board in 1977, He was actively involved in freelance Journalism and contributed several articles on the social and scientific pertaining to national issues in various journals, news paper. He was a regular writer on coffee in *Indian Coffee*. He died on 28th October 199 in Bangalore at the age of 79 years.

*The contribution and the photo of Dr. G.I .D'Souza provided by Dr. P.K. Vinod kumar, Head Division of Entomology, Central Coffee Research Institute Chikmagalur,Karnataka which is duly acknowledged .

The family members of Dr G.I.D.Souza contributed Rs 48,000 for organizing a memorial lecture in 2002.The prize money of the value of Rs 6000/= in cash including all connected expenses with a citation and a memento.

The Awardee shall deliver a lecture at the biennial symposium/conference organized by the society and one page profile of the awardee along with the photograph shall be printed in the journal. Full text of the lecture of the awardee shall also printed in the journal. The manuscript should not exceed 20 pages (typed in Double space)

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The earlier receipient of the award are Dr. P.K.Koshy, Dr M.S.Jairajpuri, Dr D.J.Patel and Dr J.S.Gill .

This Year executive committee of the Nematological Society identified Dr H.S. Gaur Vice Chancellor Sardar Ballabhai Patel University of Agriculture and Technology for the award for his outstanding contribution in the field of Nematology to contain the losses caused by Plant Parasitic Nematodes and basic and applied research of practical importance on the subject.

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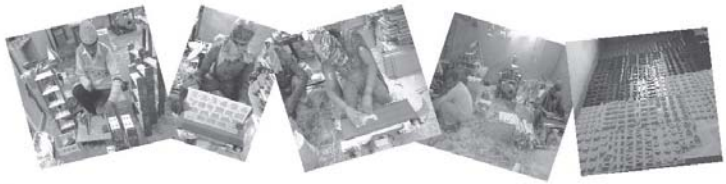

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# The Nematological Society of India

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# DR. D'SOUZA MEMORIAL LECTURE

## My Tryst With The Science of Nematology, Current Scenario And A Dream Into Its Future

H.S. Gaur

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### *Extended Summary*

Nathan Augustus Cobb, through his explorations, descriptions and vision laid the foundation of the science of Nematology a century ago, that slowly developed roots in different parts of the world. Although the pioneering report of Barber describing the root-knot nematode infecting tea and possible methods for its management appeared in 1901, followed by other important reports on foliar nematodes in rice or control of root-knot nematodes, it was not until the mid-1960s that the science of Nematology came into existence in India. The sustained effort and vision of Dr. D'Souza, and other stalwarts, made this happen. I feel fortunate to have ventured into this science 13 September, 1971, within five years of the establishment of a separate Division of Nematology at IARI, New Delhi. Little did I know then that I was destined to have the intimate patronage of the founders like Prof. S.K. Prasad and Prof. Gopal Swarup and the first regular Head Dr, A.R. Seshadri, who alongwith Dr. M. Oostenbrink, took me into the fold as an M.Sc. student who over the next four decades ventured and rubbed soldiers with many a nematologist in the world. I was instantly fascinated by the structural beauty, diversity, behavioural manoeuvres and ecological adaptations of these tiny organisms called nematodes, a word that triggers my actions and thoughts in any situation and that was my tryst with this wonderful science.

I began in 1971 with studies on the relationship between population densities of root-knot and lesion nematodes and the growth of plants, population behaviour under different cropping systems and integration of cultural, botanical, genetic and chemical methods to develop 'integrated nematode management strategies' that was included in the topic for my Ph.D. thesis submitted in 1975. Relationships between nematode population density and crop yield were studied for a number of cereals, vegetables, pulses and fibre crops. The damage threshold levels were determined. Models were constructed for nematode damage, population growth and management

optimization. I also had interest in nematode taxonomy, published my first nematology paper as a short note on nomenclature of *Helicotylenchus teres* in 1972. In the brief stay at PAU, Ludhiana in 1976, I noticed heavy infestations of *Heterodera cajani* and *Meloidogyne incognita* in the mungbean intercropped with sugarcane which also got infected by the root-knot nematode. The fanfare with which the ARS was introduced drew me into it and I landed back at my almamator, IARI in 1976, to spend the next 37 years in various capacities, barring brief periods abroad.

Dr. Seshadri, while assigning me duties, put me a question about the reasons for 'erratic' behaviour of nematodes and the damage they cause, making forecasting difficult. That question guided much of my research effort and I did find some plausible answers and still haunts me. I began by studying the population dynamics of plant-parasitic and saprozoic nematodes in relation to various edaphic conditions, cropping systems and agronomic soil management systems. I tried to correlate the spatial and temporal variations and size & diversity of nematode communities with the abiotic and biotic factors in the niche. This helped me in (i) understanding the survival strategies of the root-knot, reniform, cyst and root-lesion nematodes under adverse environments and (ii) design integrated nematode management systems. Some of my students and colleagues helped me greatly or joined in these efforts. I kept in mind that nematode management methods cannot be recommended in isolation but only as modules to fit into overall pest and crop management systems, to suit location, and farmer specific situations. Understanding of temperature related variations led to soil solarisation and adjustment of sowing dates, while the negative correlations with organic matter content of soil led to organic matter utilization for nutrient supply.

I developed integrated nematode management modules for root-knot, reniform and cyst nematodes using soil solarization, nematicidal seed/ nursery-bed treatments, date of sowing, organic amendments, neem, cropping system, tillage, green manuring, resistant variety and cyanobacteria for vegetables, pulses, rice and wheat. Soil solarization of nursery-beds or of soil in polyethylene bags for transplanted crops like rice, vegetables, fruits, ornamentals and forestry plantations provided excellent control of nematodes. It gives healthy seedlings and reduces spread of nematodes to new areas. It is also best suited for organic farming systems. Nematicidal and nematostatic potential was discovered in terrestrial cyanobacteria with the aim of their use for dual purposes, viz., nitrogen fixation and nematode suppression.

I was fascinated by the adaptive powers and survival strategies of nematodes when faced with uncertainty and stress conditions. This led to the work on anhyrobiosis

plant-parasitic nematodes like second stage juveniles of *Meloidogyne incognita* and *Tylenchulus semipenetrans;* young females and males of *Rotylenchulus reniformis* and juveniles and adults of *Pratylenchus zeae* the entomopathogenic nematode, *Heterorhabditis indica.* It was proved that the moulted cuticles of the previous stages of *Rotylenchulus reniformis* help in reducing the rate of water loss and survival in subsaturated environment in drying soil. Hatching behaviour of *Heterodera cajani* and *H. sorghi* cysts was found to change in harmony with host senescence and desiccation.

Cereal cyst nematode (different from *Heterodera avenae*) that was discovered in wheat fields at high altitudes in Leh is likely become a very serious concern in future. Observations in 1990-91 on the widespread occurrence of root-knot nematodes*, M. graminicola* and description of a new species *M. triticoryzae,* both infecting wheat and rice and also multiplying on a number of graminaceous weed and other crops in north India has been an unsung milestone in the history of Nematology in India. I used morphological and molecular techniques for characterising these nematodes and discovered distinct sub-generic differences in the DNA of two groups of *Meloidogyne* species and went on to study their biology, physiology, ecology and management methods. I tried to understand the role and potential of nematodes to cause indirect and unappreciated losses in the form of reduced uptake and translocation of macro- and micronutrients by plants, reduction in grain and straw quality, reduced vigour of seed produced, unaccounted variability in plant breeding and agronomic trials sometimes leading to wrong conclusions, and increased health hazard due to increased content and accumulation of toxic heavy metals.

Like many other nematologists, I too got drawn towards the entomopathogenic nematodes, limiting my efforts to understand and make use of their limited desiccation tolerance, inducing anhydrobiosis and cryopreservation through vitrification.

My early days in Nematology presented a contrasting atmosphere, curiosity and excitement studying different aspects of these beautiful creatures on the one hand and ignorance-led professional underestimation, neglect and pessimism of the future of Nematology and uncertainty of jobs on the other. I used to read articles on the 'future of nematology' that have appeared in each decade over the past century. Over the period the major lamentation has been the poor recognition of the damage potential of plant parasitic nematodes by farmers and administrators and poor adoption of nematode management practices. Number of nematologists in all countries has remained too small to compete in prominence with other disciplines.

The plant-breeders and agronomists who should have been the main beneficiaries of the selections and technologies evolved by nematologists have been too busy addressing other more apparent priorities. Nematicides of various types came in and went out. Hope was laid on biocontrol but with limited success. Nematode resistant varieties actually adopted by farmers are rare. The importance of nematology is now being again realized, especially due to the growing menace of plant nematodes especially in protected cultivation, damage to staple food crops in rice-wheat cropping system, conservation agriculture, phytosanitary requirements and potential of entomopathogenic nematodes as biocontrol agents of insect and mollusc pests.

Molecular techniques have been extensively used and will be increasingly used over the next two decades at least for identification and classification, host resistance induction, genetic modification of entomopathogenic nematodes, microbial biocontrol agents, precision agriculture etc. As new ways of production of different kinds of food and other agricultural products evolve, the nematodes so far considered harmless will gain increasing importance. Nematodes, that form the evolutionary transition stage between the acoelomate and multi-organ system coelomate eukaryotes, will find greater use in understanding and monitoring the impact of climate change. Nematodes will also emerge as ideal models for physiological and biomedical research. I dream and wish that nematologists tomorrow will be in much demand to tackle emerging nematode problems, as well as to carry out molecular and climate-change research. Pharmacological research will find greater use of nematodes as models and preliminary test organisms when many animals go out of the list of those sacrificed in biological studies. The tides of times and technologies will come and go but nematodes will thrive, unfolding for nematologists new vistas and challenges for still proving their importance and professing newer ways of combating the harmful and propagating the useful nematodes to attain increasingly higher production. The light is already seen at the end of the tunnel, but the tunnel is never likely to end until some young nematologists come forward to do marvellous research on fundamental and applied aspects, to bring out the science Nematology out of the undue oblivion.

All the achievements that I could make were possible only with the copious help, support and collaboration of a number of students and colleagues at IARI, New Delhi and Rothamsted Research, UK. In my dream I see all of them growing in eminence and so does the science of Nematology!

# LEAD TALK

## Emerging Nematode Pest Challenges in Vegetable Oilseeds Production in India

K.S. Varaprasad & P. Giri Babu

*Directorate of Oilseeds Research, Rajendranagar, Hyderabad*

Oilseeds are cultivated in diverse agro-ecological situations in India by over 14 million farmers. Important oilseeds cultivated in India are soybean, rapeseed mustard, groundnut, sesame, sunflower, safflower, cotton (annual edible); coconut, oilpalm (perennial edible); castor, linseed, niger (non-edible), jatropha and pongamia (biodiesel). Rice bran is the most important nontraditional oil source. Our country is earning considerable foreign exchange by exporting table purpose groundnut, castor oil and sesame. It is a matter of concern that indigenous production of oilseeds meet only about 50% of the domestic demand. Edible oil import is valued at Rs 56,000 crores in 2012-13. In this context, current concerns and emerging nematode pest challenges and their management strategies are briefly discussed.

Globally, nematode threats to oilseed production include soybean cyst nematode, root-knot, lesion and pod nematodes of groundnut, cyst nematodes on rapeseed mustard and red-ring nematode of coconut and oilpalm. Estimated annual yield losses due to soybean cyst nematode around the world were $4.0 billion. Major nematode pests on oilseeds in India include root-knot nematodes on groundnut and sunflower, reniform nematode on castor and sunflower, cyst nematode on sesame and safflower and burrowing nematode on oilpalm and coconut. Annual yield losses of groundnut due to root-knot nematodes and castor due to reniform nematode were Rs 191 crores and Rs. 18 crores respectively. Similarly, yield losses of cotton by root-knot and reniform nematodes and yield losses of sesamum by cyst nematode were Rs. 23.5 and Rs. 4.3 crores respectively.

Emerging concerns that need nematologists' immediate attention are report on soybean cyst nematode from Madhya Pradesh, root-knot nematode on castor in Gujarat and cyst nematode on castor in Andhra Pradesh, spread of Kalahasty Malady of groundnut beyond Andhra Pradesh and pigeon pea cyst nematode infestation on sesame in Rajastahan and Gujarat. It is also necessary to explore and assess nematode pest challenges of soybean and safflower in Maharashtra, sesame in Tamil Nadu and West Bengal and castor in potential districts of Haryana and

Rajasthan. There is a need to strengthen capacity building of biosecurity personnel to prevent the entry and spread exotic threats to native oilseed crops especially with reference to cyst nematodes of soybean and rapeseed mustard, pod nematode and testa nematode of groundnut and red ring nematode of oilpalm and coconut.

Development of high yielding and nematode resistant cultivar is the best viable option to meet the challenge of nematode pests in oilseed crops as these crops are largely grown by small and marginal farmers in less fertile soils mostly under rain-fed conditions. In view of the great potential of the latest scientific advancements such as decoding of genomes of root-knot and cyst nematodes, identification of QTLs for cyst nematode resistance, marker assisted selection to release interspecific nematode resistant hybrids and potential demonstration of transcriptional gene silencing using RNAi technology for durable resistance to cyst and root-knot nematodes, nematologists need to integrate their work with plant breeders and biotechnologists in order to develop tangible, effective, durable and economic solution to nematode challenges at field level to enhance the oilseeds productivity.

# Host Delivered RNAi for Root-Knot Nematode Resistance Using A Nematode Specific Secretory Gene

Anil Kumar[1], Alka Dwivedi[1], Gurudiksha Verma[1], M.Z.Abdin[4], Anil Sirohi[2], K. Subramaniam[3], R. Srinivasan[1] & P.K. Jain[1]

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Root-knot nematodes (RKN; *Meloidogyne spp*.) are sedentary endoparasites with a very wide host range. The major nematode control strategies include growing resistant cultivars, application of nematicides and crop rotation, but each has its own limitations. RNA interference (RNAi) is a process of post-transcriptional gene silencing in which dsRNA impedes the expression of the corresponding mRNA. In this study, efforts were made to provide resistance against the root-knot nematode *M. incognita* by silencing a nematode gene encoding for a parasitism protein (msp23) expressed in the dorsal esophageal gland cells. Arabidopsis transgenic lines (T3) expressing the dsRNA construct was infected with 1000 J2s to validate the efficacy of gene silencing. Host-mediated RNAi of this gene led to reduction in the number of nematode females (58.9%), galls (61.3%) and egg masses (75.5%), respectively, in selected RNAi line over wild type. Thus, silencing of msp23 gene in the nematodes through host mediated RNAi significantly reduces the root knot nematode population.

# Management of Root-knot Nematode Using Neem Products, Vermicompost, *Trichoderma* and Nematicides in Chickpea

Bansa Singh, R. Jagdeeswaran & Ummed Singh

Indian Institute of Pulses Research, Kanpur

Field trail on management of root-knot nematode, *Meloidogyne javanica* in chickpea using treatments, Vermicompost @ 500 kg/ha; *Neem* cake @ 500 kg/ha; *Neem* seed powder @ 50 kg/ha; *Trichoderma harzianum* @1 kg in 1 q FYM/ha; Carbofuran 3 G @ 1 a.i. kg/ha; Carbosulfan 25% EC @ 0.1% v/w and check was undertaken at

NRF, IIPR, Kanpur. Initial population was 300 juveniles/100 cc soil. Data recorded on plant height, nodulation and galls after one, two and three months of sowing showed that application of *neem* cake @ 500 kg/ha increased the plant height maximum compared to other treatments. This was followed by application of carbofuran @ 1 kg ai./ha. Dry weight of nodules/plant was more when *Trichoderma* was applied with FYM this was followed by *neem* cake application. Three months after sowing, galls were minimum (36 galls/ plant) in plots where carbofuran was applied. Maximum galls (61galls/plant) were recorded in check plots. At harvesting, grain yield was maximum (1295.4 kg/ha) in treatment *neem* cake @ 500 kg/ha followed by 1293.6 kg/ha in treatment carbosulfan 3G @ 1 kg a.i./ha. Similarly, biomass was maximum (1934.2 kg/ha) in treatment carbosulfan 3G @ 1 kg a.i./ha followed by 1874.5 kg/ha in neem cake @ 500 kg/ha and carbosulfan 25% EC@ 0.1% v/w. Gall index and soil population of root-knot nematode were minimum (1.9 and 287 juveniles/100 cc soil) in plots treated with carbofuran followed by 2.4 and 351 juveniles/100 cc soil in plots treated with *neem* cake. Maximum gall index and soil population 4.0 and 680 juveniles/100 cc soil were recorded in check plots.

## Aboitic Factors Influencing The Prevalence of the Plant Parasitic Nematodes on Sunflower Crop (*Helianthus annuus* L.)

Neelam Thakur, Harpreet Kaur & M. Luqman Khan

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During the present study, the nematode genera infesting sunflower crops in different districts of Malwa region of Punjab were *Hoplolaimus* spp., *Helicotylenchus* spp., *Meloidogyne incognita*, *Hirschmanniella* spp., *Pratylenchus* spp., *Tylenchorhynchus* spp., *Quinisulcius indicus*, *Filenchus sheri*, *Longidorus pisi* and *Xiphinema* spp. On the analysis of nematode genera encountered, it was observed that *M. incognita* population range 1200-5080 2$^{nd}$ stage juvenile/200 cc of soil followed by *Hirschmanniella* (20-3020), *Hoplolaimus* (00-2040) and *Xiphinema* spp. (20-220) adults/200 cc of soil in sandy loam soil. Soil samples collected were checked for temperature, pH and moisture and correlation with nematode population was statistically analysed. In the case of *Hirschmanniella* spp. and *Meloidogyne incognita* correlation with the soil moisture was positive and significant indicating that with increase in soil moisture the population also increased. The correlation of another recorded genera with abiotic factors was found to be statistically non significant.

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