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**Association of nematodes with fruit crops in  
Bhubaneswar**

*A Thesis submitted to the  
Orissa University of Agriculture and Technology  
in Partial fulfilment of the Requirement for the degree of  
Master of Sciences in Agriculture  
(Nematology)*

By

**PRANAYA PRADHAN**

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**DEPARTMENT OF NEMATOLOGY  
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BHUBANESWAR**

**2017**



ORISSA UNIVERSITY OF AGRICULTURE & TECHNOLOGY  
DEPARTMENT OF NEMATOLOGY  
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## CERTIFICATE - I

This is to certify that the thesis entitled “**Association of nematodes with fruit crops in Bhubaneswar**” submitted in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (NEMATOLOGY)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **Pranaya Pradhan** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

  
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Advisory committee




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BHUBANESWAR

## CERTIFICATE II


This is to certify that the thesis entitled "Association of nematodes with fruit crops in Bhubaneswar" submitted by PRANAYA PRADHAN to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE (NEMATOLOGY)** has been approved/disapproved by the student's Advisory Committee after oral examination on the same in collaboration with an external examiner.

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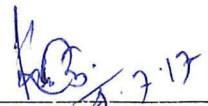
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## ACKNOWLEDGEMENT

I deem it unique opportunity to express my profound sense infinitum gratitude, indebtedness and reverence to the chairman of my Advisory Committee Dr. N.K. Sahu, Former Professor and Head on Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar for his sustained interest. Persistent guidance, ceaseless encouragement and pensive remarks through out the study to take this endeavour a reality.

I feel very much grateful to Dr. Niranjan Sahoo sir, for his generous help in identifying and counting the nematodes guidance.

I feel also indebted to Dr. S. Sahoo, Professor and Head, Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar for his co-operation, love and parental help for this.

I profess my heartfelt gratefulness and sincere esteem to Dr. D.K. Nayak, Associate Professor, Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar for his valuable insinuation, constructive suggestion and noble guidance during the course of my investigation.

I also express my deep sense of gratitude and reverence to Dr. S.M.A. Mandal, Associate Professor, Department of Entomology, College of Agriculture, O.U.A.T., Bhubaneswar

It will be a matter of regret, if i fail to acknowledge the love, accelerating inspiration and help I got from Dr. N.K. Sahu, Associate Professor, Dr. S. Mohalik, Associate Professor of Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar during my post graduation thesis work.

I sprightly acknowledge all the staff members of Department of Nematology for the help rendered by them all through the thesis work specially Deepak bhaina and Rajashree mam for the help during soil sample collection and sample preparation.

I also wish to place on record my sincere and heartiest feelings to my classmates Abhishek, Dikhsha, Saroj bhai, Bindhani, Amita, Shubrashree, Abinash, Santosh, Manaswini, Gouri, Rudra vai and Sasmita di for their good will and steady encouragement.

I am unable to express in words, the inspiration and blessings I got from my father, Sj. Narottam Pradhan and mother, Smt. Jyotimanjari Pradhan who made me to stand in the society.

I extend my special and hearty thanks to Ashok, Deepak, Jayashankar, Riju, Ram, Jyoti, Jaga, Dhal, Ambarish, Binay, Niru, Niranjan, Nila, Ardhendhu bhai, Pradesh, Kunal, Girija Shankar, Satyendra, Sooraj, Kiran, Rahul, Mohonteswar bhai, Sibun, Mithun, Sandeep, Sartaj, Maitri for their consistent love, help, co-operation

and encouragement during my entire studentship in this institution and completion of thesis.

It will be my preposterousness to verbalise deep sense of exaltation for my vulnerable parents, Dhyanesh Little, Pragyan didi, Saroj jiju, Pritam, Sujit, Tulu, Subrat, for their inviolable sacrifice solicitous contrivance and blissful blessing which have made me so today.

Finally I solicit the benediction of omnipresent scared divine for the progress and prosperity in the every sphere of my life.

Bhubaneswar

Date. 03/07/2017

  
(PRANAYA PRADHAN)

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# CONTENTS

CHAPTER	TITLE	PAGE NO.
I	INTRODUCTION	1-2
II	REVIEW OF LITERATURE	3-21
III	MATERIALS AND METHODS	22-26
IV	RESULTS	27-63
V	DISCUSSION	64-67
VI	SUMMARY AND CONCLUSION	68-70

REFERENCES

---

# LIST OF FIGURES

FIGURE NO	PARTICULARS	PAGE NO
01	<i>Aphelenchus avenae</i>	29
02	<i>Caloosia heterocephala</i>	29
03	<i>Helicotylenchus dihystra</i>	30
04	<i>Hemicriconemoides mangifera</i>	30
05	<i>Hoplolaimus indicus</i>	31
06	<i>Pratylenchus coffeae</i>	31
07	<i>Rotylenchulus reniformis</i>	33
08	<i>Tylenchorhynchus mashhoodi</i>	33
09	<i>Xiphinema insigne</i>	35
10	<i>Dorylaimids</i>	35
11	<i>Mononchids</i>	36
12	<i>Rhabditids</i>	36

# LIST OF TABLES

TABLE NO	TITLE OF THE TABLE	PAGE NO
1	Association of nematodes with fruit crops in Bhubaneswar	37
2	Association of nematodes with cashewnut	39
3	Association of nematodes with guava	40
4	Association of nematodes with jackfruit	42
5	Association of nematodes with lime	43
6	Association of nematodes with litchi	44
7	Association of nematodes with mango	46
8	Association of nematodes with papaya	47
9	Association of nematodes with sapota	48
10	Community analysis of nematodes associated with cashewnut	50
11	Community analysis of nematodes associated with guava	51
12	Community analysis of nematodes associated with jackfruit	54
13	Community analysis of nematodes associated with lime	55
14	Community analysis of nematodes associated with litchi	56
15	Community analysis of nematodes associated with mango	59
16	Community analysis of nematodes associated with papaya	60
17	Community analysis of nematodes associated with sapota	61
18	Community analysis of nematodes with fruit crops in Bhubaneswar	63

## ABSTRACT

Association of nematodes in the rhizosphere of 8 fruit crops by collecting 120 samples during Kharif and Rabi 2016-17 in Bhubaneswar revealed presence of ten plant parasitic nematodes and three groups of free living nematodes. Among plant parasitic nematodes, *Rotylenchulus reniformis* and *Hoplolaimus indicus* were encountered in all 8 fruit crops. *Tylenchorhynchus mashhoodi* (7), *Hemicriconemoides mangiferae* (6), *Helicotylenchus dihystra* (5), *Caloosia heterocephala* (5), *Xiphinema insigne* (5), *Aphelenchus avenae* (5), *Pratylenchus coffeae* (3) and *Meloidogyne sp.* (1) only in guava. In context to free living group nematodes *Dorylaimids*, *Mononchids* and *Rhabditids* were each associated with all the 8 fruit crops. While computing community analysis of individual fruit crops, *Rotylenchulus reniformis* in papaya, *Hoplolaimus indicus* in jackfruit, *Dorylaimids* in all fruit crops except cashewnut and *Rhabditids* in lime and papaya exhibited highest Absolute frequency (100%) followed by *Rhabditids* and *Mononchids* in cashewnut indicating (86.67%) Absolute frequency. The lowest Absolute frequency was recorded in *Hemicriconemoides mangiferae* (13.33%) in guava, with respect to density of nematodes in individual fruit crops, maximum Absolute density of *Rotylenchulus reniformis* in papaya (341), Mango (291.07), Lime (246.57), Guava (211.63), Litchi (52.66). *Tylenchorhynchus mashhoodi* in jackfruit (251), *Hoplolaimus indicus* in sapota (59.14) and *Dorylaimids* in cashewnut (33.58) were recorded. The least density was reported in *Aphelenchus avenae* in sapota (4) and *Hemicriconemoides mangiferae* in guava (4). In consideration to Prominence value, *Rotylenchulus reniformis* was adjudged as the most prominent species in papaya (PV=340), mango (270.79), lime (238.21), guava (181.23), while *Tylenchorhynchus mashhoodi* in jackfruit (224.5), *Hemicriconemoides mangiferae* in litchi (41.97), *Dorylaimids* in cashewnut (85.93) and sapota (54) were recorded. In contrast, *Hemicriconemoides mangiferae* in guava (PV=1.46) was the least prominent species. So far as community analysis of nematodes in 120 samples of 8 fruit crops altogether was concerned, *Dorylaimids* indicated highest frequency of occurrence (118) with 98.33% Absolute frequency, the lowest being in *Meloidogyne sp.*(5). Maximum density was noticed in *Rotylenchulus reniformis* (182.22) with the lowest density in *Aphelenchus avenae* (7.54). When *Rotylenchulus reniformis* was treated the most prominent species (PV=155.15), *Aphelenchus avenae* was marked the least prominent species (33.23).

# **CHAPTER-1**

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## **INTRODUCTION**

# INTRODUCTION

---

India ranks as the second largest producer of fruits after china. It has emerged as the largest producer of fruits like mango banana, sapota, papaya, and acid lime as well as plantation crops like coconut, arecanut, and cashewnut. Apart from that, new crops like kiwi fruit, olive and oil palm have been successfully introduced for commercial cultivation in the country.

India's export of fruits in terms of quantity increases from 1.02 lakh tons in 1991 to 2.6 mt in 2008-09 and in terms of monetary value, this increase was from Rs.348 crores in 1991 to Rs. 3659 crores in 2008-09(singh,2010)

During 2005-06, with the launch of National Horticultural Mission by government of India, a major push has been expected in horticulture sector with boosting up export of horticultural produce and products.

During the past one decades, the shifting in cropping pattern has been more towards horticulture sector. Agricultural diversification is an important component for economic growth and it is meagrely dependent on the opportunities and responsiveness of farmers to technological breakthrough, consumer demand, government policies, trade arrangements and development of infrastructure.

Indian agriculture is gradually diversifying in favour of high value food commodities, and their production in particular of fruits, vegetables, milk, meat, poultry and fish has increased remarkably during last two decades. Such a shift in the result of rising income of consumers, changing consumption pattern and growing urbanisation. Consumption patterns are fast changing in favour of high value food commodities with rising per capita income, changing tastes and preferences of consumers.

Despite the augmentation of fruit and vegetable production in the country. major constraints in production of fresh fruits and vegetables are non-availability of quality seeds or planting materials, inadequate irrigation, lack of integrated nutrient management, huge post-harvest losses and risk of pests and diseases. Among various pests and diseases, the role of plant parasitic nematodes in limiting the production and yield of fruits cannot be ruled out.

The alarming problem of citrus nematode (*Tylenchulus semipenetrance*) in citrus at Aligarh. Root knot nematode (*Meloidogyne incognita*) and citrus nematode in pomegranate in Maharashtra, devastation of banana crop due to wide spread of attack of *Radopholus similis* in Tamilnadu. Karnataka and Andhrapradesh gear up for a preliminary investigation of nematode survey with various fruit crops such as mango, cashewnut, jackfruit, sapota, guava, papaya, litchi, lime from locality of Bhubaneswar.

Since study of nematodes in fruit plants is few and far between (Ray and Das, 1989), so it was planned to take up the research work as the title entitled –

**“Association of nematodes with fruit crops in Bhubaneswar.”**

With the following objectives

1. Identification and estimation of various nematode genera associated with rhizosphere of various fruit plants.
2. Community analysis of nematodes in fruit plants.

## **CHAPTER-2**

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### **REVIEW OF LITERATURES**

## **CHAPTER-2**

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### **REVIEW OF LITERATURES**

# REVIEW OF LITERATURE

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## Cashew

Orisajo(2012) examined the root and soil samples for the presence of plant-parasitic nematodes from seven selected locations in North Central Nigeria noted for cashew production. Ten genera of plant parasitic nematodes were found associated with cashew in North Central Nigeria. *Meloidogyne sp.*, *Helicotylenchus coffeae* and *Radopholus sp.* were wide spread in all the locations while in *Rotylenchulus reniformis* was recorded only in Ochaja. Ayingba and Ejule. There was significant reduction in the height of cashew seedlings inoculated with root knot nematodes. *Meloidogyne incognita* in the nursery.

Vasanthi *et al.*(2014) cited A Survey was conducted in the cashew plantations of the Directorate of Cashew Research and Karnataka Cashew Development Corporation at Puttur, Karnataka to observe the presence of entomopathogenic nematodes and fungi which could be potent natural enemies of cashew stem and root borer, *Plocaederus* species. Entomopathogenic nematodes were obtained by baiting them from soil samples using *Galleria mellonella* larvae. Out of the 110 soil samples collected from various cashew plantations, 10 soil samples indicated the existence of nematodes, which was noticed by the mortality of wax moth larvae due to infection. These entomopathogenic nematodes were identified by utilizing currently available molecular tools, four isolates matched with *Heterorhabditis bacteriophora* and two with *Steinernema abbasi*. The results revealed that, field collected fungus, was pathogenic to laboratory reared larvae of cashew stem and root borers and was identified as *Metarhizium anisopliae* (Metsh).

## Guava

Carneiro *et al.* (2012) reported the worst nematode problem affecting guava created by RKN, which is a recognized limiting factor in commercial guava production in central and south america. Considering the difficulty of identifying *Meloidogyne enterolobii*(=*M. mayaguensis*) only by the perineal pattern, this species has been misidentified in different regions around the world and identified frequently as *M. incognita* or *Meloidogyne sp.*

Ansari and Khan (2012) conducted an extensive survey of plant parasitic nematodes associated with guava from fourteen localities of Aligarh district was conducted during November, 2011 to March, 2011. A total of 164 samples were collected and analyzed for plant parasitic nematodes and their importance through community analysis. Analysis of soil samples revealed the presence of twelve genera of plant parasitic nematodes viz; *Meloidogyne*, *Hoplolaimus*, *Pratylenchus*, *Helicotylenchus*, *Tylenchus*, *Tyl enchorhynchus*, *Hemi criconemoides*, *Aphelenchoides*, *Longidorus*, *Trichodorus*, *Xiphinema* and *Rotylenchulus*. Among plant parasitic nematodes, the highest absolute density and relative density were recorded in *Meloidogyne* sp. followed by *Hoplolaimus* spp., Moreover, in relation to absolute frequency and relative frequency the *Hoplolaimus* spp. ranked first. The prominence value of *Meloidogyne* spp. ranked first followed by *Hoplolaimus* sp.

Iwahori *et al* (2009) reported that in southern Vietnam, citrus was interplanted with guava (*Psidium guajava* L.) for the management of citrus greening disease. Guava seedlings exhibited decline symptoms including leaf browning, growth inhibition, leaf drop, and death. These symptomatic seedlings were accompanied by severely galled roots, possibly attributable to root-knot nematodes. The perineal patterns of most specimens were similar to those in the original description of *Meloidogyne enterolobii* (3). However, some were similar to that of *M. incognita*. Such variability among perineal patterns precluded unequivocal identification. Therefore, DNA was extracted from these nematodes and their sequences were compared with those in the DNA sequence database. For the comparison, we employed the primer sets of Powers and Harris (1) to amplify a region between cytochrome oxidase II and the 16S ribosomal DNA gene of mitochondria by PCR. An approximate 700-bp fragment was obtained and analyzed, revealing more than 99.6% homology to *M. mayaguensis*, a synonym of *M. enterolobii* (2), when aligned with sequence data of isolates from France (GenBank Accession No. AJ421396), the United States (GenBank Accession No. AY446978), and China (Gen Bank Accession No. AY831967). These results indicate that the nematode species responsible for guava damage in southern Vietnam is *M. enterolobii*. To our knowledge, this is the first report of *M. enterolobii* in Vietnam. References: (1) T. O. Powers and T. S. Harris. J. Nematol. 25:1, 1993. (2) J. Xu et al. Eur. J. Plant Pathol. 110:309, 2004. (3) B. Yang and J. D. Eisenback. J. Nematol. 15:381, 1983.

Castro *et al.*(2012) cited the presence of the root-knot nematode, *Meloidogyne enterolobii*, in guava commercial orchards in many Brazilian states which caused severe loss to growers. 146 guavas and araçazeiro (wild guava) accessions were evaluated in a greenhouse and nursery in order to find resistant accessions to be used as rootstock for commercial guava cultivars. The current strategy to overcome this guava pest includes developing interspecific *Psidium* hybrids among resistant araçazeiros and susceptible guava to obtain hybrids with adequate plant height and stem diameter, highly compatible when used as rootstock for commercial guava cultivars.

Gomesa *et al.*(2014) evaluated the effect of joint infection by *Meloidogyne enterolobii* and *Helicotylenchus dihysteroides* on vegetative growth of guava seedlings (*Psidium guajava* L.), as well as to observe symptoms caused by pathogens in host plants. An experiment was conducted in microplots. In these experimental units, suspensions were used containing *H. dihysteroides* and *M. enterolobii*. The plants were separately inoculated with *H. dihysteroides* and jointly inoculated with *H. dihysteroides* and *M. enterolobii*, and the blank controls were represented by non-inoculated plants. No significant differences were observed between treatments related to morpho-physiological variables of guava seedlings, but joint inoculation resulted in a reduced final population of *H. dihysteroides*. It was also concluded that neither infection by *H. dihysteroides* alone nor a joint infection by the two pathogens caused any damage to guava seedlings.

Daneel(2017) cited *Meloidogyne incognita* and *Meloidogyne javanica* as the most important and widespread nematode pests of a number of minor tropical and subtropical crops in South Africa (SA).*Meloidogyne enterolobii* is an important pest on guava and commonly occurs in all guavaproducing areas. Cultivar TSG2 is highly susceptible to this rootknot nematode species, resulting in severe damage to infected trees. Litchi production is hampered by infection of *Criconema*, *Hemicriconemoides* and *Hemicycliophora spp.* in papaya, *Meloidogyne spp.* and *Rotylenchulus reniformis* cause substantial yield losses. *Criconemoides xenoplax* and *Xiphinema vitis* are perceived as the predominant nematode pests of pecan, with *Meloidogyne partityla*only occasionally being recorded in pecan orchards. Symptoms of damage caused by plantparasitic nematodes on these crops are described and management strategies to control these pests are presented. Observations by nematologists in SA

suggest that plantparasitic nematodes are not a significant problem on avocado, mango or macadamia.

Khan *et al.*(2007) cited that survey on plant and soil nematodes associated with rhizosphere of guava (*Psidium guajava* L.) from Baruipur, 24-Paraganas(south) and Mondouri (Haringhata) and Ghoragachha (Chakdaha), Nadia, West Bengal, India revealed the occurrence of ten genera, viz. *Meloidogyne*, *Pratylenchus*, *Hoplolaimus*, *Rotylenchulus*, *Helicotylenchus*, *Tylenchorhynchus*, *Criconemoides*, *Xiphinema*, *Longidorus* and *Aphelenchus*. All together thirteen species of eight plant parasitic genera identified which were *Meloidogyne incognita*, *M. javanica*, *M. graminicola*, *Pratylenchus coffeae*, *P. brachyurus*, *Hoplolaimus indicus*, *Rotylenchulus reniformis*, *Helicotylenchus goodi*, *H. indicus*, *H. abunamai*, *Tylenchorhynchus mashhoodi*, *T. nudus* and *Aphelenchus avenae*.

Gasti *et al.*(2015) studied the diversity of plant parasitic nematodes in the rhizosphere of the mango and guava at IARI farm. Seven species of plant parasitic nematodes were found in mango and guava orchard. These were *Helicotylenchus indicus*, *Hemicriconemoides strictathecatus*, *Rotylenchulus reniformis*, *Hoplolaimus indicus*, *Mesocriconema sphaerocephala*, *Tylenchorhynchus mashhoodi* and *Tylenchulus semipenetrans*. Amongst the plant parasitic nematodes in mango orchard *H. strictathecatus* was in high numbers followed by *Helicotylenchus indicus*. *T. mashhoodi* was in low numbers. *M. sphaerocephala* was recorded for the first time on guava and mango. In guava, *Helicotylenchus indicus* was having maximum density followed by *H. strictathecatus* and *Hoplolaimus indicus*. The identity of citrus nematode, *Tylenchulus semipenetrans* juvenile from the rhizosphere of guava was confirmed based on the ITS region.

Jindapunnapat *et al.*(2013) reported that Thailand, Nakhon Pathom, Samut Sakhon, and Ratchaburi provinces, which are in the central region of the country, are the largest areas for guava cultivation. Kimju and Pansithong are the most extensively grown cultivars and they have been seriously damaged by two species of root-knot nematodes, *Meloidogyne incognita* and *M. enterolobii* (or *M. mayaguensis*). The latter species was only recently reported in Thailand but is common in China, Brazil, and the United States. Substantial numbers of guava trees are in decline and show reduced fruit production. In this survey study of six guava orchards in central

Thailand, it was found that common above ground symptoms of nematode infection included yellowing, stunting, folded leaves, blighted and wilted leaves (especially when water was lacking), and slow ripening of fruits.

### **Jackfruit**

Long *et al.* (2015) cited that in September 2014, several jackfruit trees in orchard in Wanning, Hainan, China were observed with symptoms of decline including wilting and trunk cracking. The causal pest was identified as *Meloidogyne enterolobii* based on morphological and molecular analysis. This is thought to be first report world wide of jackfruit as a host of *M. enterolobii* and the first record of *M. enterolobii* parasitizing jackfruit in china.

Mukherjee *et al.* (2001) cited that sixty states st six widely separated jackfruit orchard of different age-groups (5 to 55 years) in Tripura were sampled for qualitative and quantitative analysis of plant parasitic nematode communities. A total of 12 spp. of plant parasitic nematodes within eight genera were isolated from roots and soils around jackfruit plants. All species of plant parasitic nematodes are new records of association with jackfruit plants from Tripura as well as in India. Analysis showed that the important and prominent nematodes in jackfruit in the states were *Meloidogyne incognita*, *Pratylenchus coffeae*, *Helicotylenchus dihystrera*, *Xiphinema brevicolle* and *Hoplolaimus indicus*. A linear increase in the index of diversity(H) with increase in the age of jackfruit plants up to certain age groups was observed.

### **Lime**

O'Bannon *et al.* (1972) observed in Florida that *Tylenchulus semipenetrans* on citrus has too high and too low population levels each year. High levels occur in April-May and November –December and low levels in February-March and August-September. Population increase occurred about 4-5 weeks after the spring and fall flush of root growth. Populations of *Pratylenchus coffeae* on citrus varied widely, and were not related to season. Populations of *P. brachyurus* showed seasonal variation with a high in June- July and a low in March-May. Males of *T. semipenetrans* and *P. coffeae* were found throughout the year, whereas males of *P. brachyurus* were rare and were found only during November and December.

Reddy & Singh (1979) reviewed work on nematode parasites of citrus in India from 1956 to 1977. 70 species within 37 genera of plant parasitic nematodes in association with citrus roots have been reported from India. Work on four nematode species, *Tylenchulus semipenetrans*, *Pratylenchus coffeae*, *Hoplolaimus indicus* and *Meloidogyne* spp. For which proof of pathogenicity to citrus is extensively reviewed.

Khan *et al.* (1979) described *Caloosia brevicaudata* N. Sp. found in the soil around the roots of citrus which had the shortest female tail.

Mani *et al.* (1988) conducted a survey of citrus nurseries in Andhra Pradesh, India, 14.2%, 75.4% and 75.0% of those in Kadium, Kodur and panyam were infested with *T.semipenetrans* respectively. Nurseries in Palacole and Tirupati were uninfected. Percent infection of *Meloidogyne javanica* in Kadium, Kodur and Palacole nurseries was 60.7, 7.0 and 45.0 respectively. Nurseries in Panyam and Tirupati were not infected.

Ganguly(1988) observed during a survey at RamTek, Nagpur, during 1987. *Tylenchulus semipenetrans* was associated with almost all the varieties of *Citrus reticulata* (mandarin) surveyed in Katul while *Xiphinema basiri* was found in large numbers on some varieties. *Citrus limon* (lemon) var. Kagzi Gooti had moderate populations of *Rotylenchulus reniformis*.

Bridge(1988) studied nematode problems of citrus in Pacific islands and observed that citrus was having the problem of *Tylenchulus semipenetrans* along with *Rotylenchulus reniformis*, *Pratylenchus zaeae*, *Pratylenchus brachyurus* and *Helicotylenchus* spp., *Meloidogyne* spp., etc.

Davide(1988) studied major nematode pests on most economic crops in the Phillipines, including citrus. *Tylenchulus semipenetrans* was a problem on citrus.

Teben'kova and Ivanova(1989) examined soil and root samples from fruit farms in the Gissarsk, Dangarinsk and Kolkhozobadsk lowland districts in the Tadzhik SSR(USSR) in 1984-1988, including greenhouse lemon and orange. 17 plant parasitic nematodes were recorded, of which the most pathogenic were *Xiphinema index*, *X. pachtaicum*, *Helicotylenchus digonicus*, *H.vulgaris*, *Pratylenchus thornei* and *Criconemella xenoplax*.

Darekar *et al.* (1990) collected soil and root samples from different fruit crops including citrus and were examined for plant parasitic nematodes. Twenty-two species were found associated with the crops and were listed.

Zhang *et al.* (1990) described and illustrated *Meloidogyne citri* sp. nov. from the roots of *Citrus unshiu* collected in Shunchang, Fujian, China. The female is similar to that of *M. fujianensis* but has a slightly posterior protuberance; stylet cone is dorsally curved; perineal pattern is rounded with low, flattened arch and cheek like inner striae in ventro-lateral areas. The male stylet length is 25 microm, stylet knobs set off from the shaft; four incisures in the lateral field and areolated. The male stylet length is 25 microm, stylet knobs set off from the shaft; four incisures in the lateral field and areolated. The body length is 465 microm; stylet length 11.5 microm; tail length 46.5 microm and hyaline tail terminus length 16.1 microm.

Anwar *et al.* (1991) recorded damage caused by *Tylenchulus semipenetrans* during a survey of crops in Punjab area of Pakistan during 1987-89.

Zhu *et al.* (1991) reported 16 species of plant parasitic nematodes including three new species, viz. *Meloidogyne jianyangensis* sp. nov., *Ogma hechuanensis* sp. nov. and *Rotylenchoides cheni* sp. nov. identified from 78 mixed samples of soil and citrus rootlets taken from citrus orchards of 26 counties in Sichuan Province. The distribution of each species was recorded. *Tylenchulus semipenetrans* and *Meloidogyne jianyangensis* have been determined as pathogenic to citrus, but the relationship between the species and citrus has not yet been determined.

Hu (1991) conducted a survey during 1986-1989 and collected 78 samples of soil around the rhizosphere of citrus trees from seven cities and 19 counties of Sichuan, China. Fifteen nematode species were identified which were found as *Tylenchulus semipenetrans*, *Meloidogyne jianyangensis* sp. Nov., *Ogma hechuanensis* sp. nov., *Tylenchorhyncus martine*, *T. nudus*, *Helicotylenchus belli*, *H. crenacauda*, *H. dihystra*, *H. exallus*, *Rotylenchus caudaphasmidius*, *R. devonensis*, *Scutellonema brachyurum*, *Xiphinema americanum*, *X. brevicolle* and *X. insigne*.

Viachopoulos (1991) made a survey during the period 1985-1989 in nurseries of various districts of Greece which revealed presence of *Tylenchulus semipenetrans* in citrus. The species *Tylenchus davanei* was recorded for the first time in Greece, in

the regions of Korinthos in citrus trees. Also *Hoplotylus femina* was found for the first time in Tirnavos, Larissa.

Khan (1991) surveyed lemon plantations in the Thatta districts of Sindh, Pakistan which revealed eight genera and 10 species of nematodes associated with roots. *Xiphinema basiri* was found in most soil samples followed by *Helicotylenchus dihystra* and *Bitylenchus brevilineatus* reported for the first time from Pakistan.

Germani and Anderson (1991) described and illustrated *Hemicriconemoides scottolamassesei* n. sp. from lemon fields of New Caledonia. Primary diagnostic characters are females with a continuous head and three lip annules, the first annule being the smallest, stylet length of 65-75  $\mu\text{m}$ , vulva without lateral flaps, and acute tail terminus; J4 has a smooth cuticle without scales or spines the male has a lateral field with two incisures. Emended measurements, descriptions, illustrations, and new records of distribution are given for *H. brachyurus* (Loos, 1949). Chitwood & Birchfield, 1957, *H. mangiferae* Siddiqui, 1961 and *H. Kanayaensis* Nakasono & Ichinoe, 1961.

Zhang (1993) described and illustrated *Meloidogyne mingnanica* sp. nov. from the roots of *Citrus unshiu* collected in Hubei, Longhu and Jinjiang county in South Fujian. *M. mingnanica* is similar in certain characteristics to *M. Kongi* but the latter differs from the new species in perineal patterns with circular striae around the tail tip and anus, perivulval region with striae and phasmids large and rounded.

Mukherjee and Dasgupta (1993) recorded the seasonal variation in the population and vertical distribution of natural nematode populations (*Helicotylenchus abunaomai*, *Hemicriconemoides cocophilus*, *Hoplolaimus seinhorsti*, *Caloosia parlona* and *Xiphinemainsigne*) which were monitored in the rhizosphere of *Citrus limetoides* trees. The population density of different nematode species differed in the pattern of vertical distribution in relation to the state of decline in citrus trees. Population peaks were generally observed in August-September and in March-April. Moderately declined trees supported maximum populations of *H. abunaomai* and *X. insigne* suggesting their involvement with decline. But population levels of *H. cocophilus*, *H. seinhorsti* and *C. parlona* were maximum in healthy trees, suggesting their non-involvement with decline. The highest population density prevailed in the upper 20 cm soil depth and gradually the numbers declined in lower depths (20-40

and 40-60 cm). Rainfall pattern, air and soil temperatures, soil moisture and host root growth appeared to be more predominant in influencing the population of pathogenically significant nematode species.

Yin (1994) studied the most important nematodes on citrus in China. *Tylenchulus semipenetrans* was distributed very widely, while *Meloidogyne* spp. were serious in sandy soils. Nematodes on citrus caused a yield decrease of 20-50%.

Sundaram and Vadivelu (1995) reported *Tylenchulus semipenetrans*, *Helicotylenchus* spp., *Rotylenchulus reniformis*, *Xiphinema basiri*, *Hemicriconemoides* spp., and *Pratylenchus coffeae* which were found associated with Mandarin Orange in the Nilgiris district of Tamil Nadu, India. Among them, *Tylenchulus semipenetrans* was the predominant nematode pest with an absolute frequency & relative frequency of 90.52 and 37.07% respectively in soil, and 75.78 and 33.02% respectively in root. Among the seven villages surveyed, Kengarai & Kolagiri villages in Kotagiri taluk recorded severe infestation. A high degree of decline and dieback symptoms were observed in the infested areas.

Ambrogioni and Tacconi (1995) observed *Radopholus citrophillus* as the agent of 'spreading decline' of citrus crops in the USA (Florida, Louisiana and Hawaii), Cuba, Dominican Republic and Guyana. In Brazil, it is also viewed that on citrus plant they do not produce symptoms of decline.

Al-Qasem and Abu-Gharbieh (1995) collected 162 composite soil samples during October 1990 and March 1991 from citrus groves in the Northern Jordan Valley, Central Jordan Valley, Southern Jordan Valley, Southern Ghors, Jerash and Wadi Shueib. Field sampling revealed that *Tylenchulus semipenetrans* was widely distributed in citrus groves in Jordan. Slow decline disease of citrus caused by the citrus nematode appeared to be of large magnitude in the older plantations in the Northern Jordan Valley. Second stage juvenile population densities at Dier Alla Station were found to increase in the autumn and spring seasons, but fell down to minimum levels in mid-summer. Nematode numbers were high in sandy-loam soils (30.8%-69.8% sand, 11.2%-33.2% clay and 19.0%-36.0% silt). Moreover, soils containing lower organic matter (0.77%-1.43%), sustained higher numbers of the citrus nematode.

Guidice (1995) observed from a survey in 1994 in the orange groves of eastern Sicily, the Province of Catania that 93.8% of 267 sampling areas were infested by *Tylenchulus semipenetrans*. Population densities were between one and 700 adult females per gram of roots in 90.6% of the cases and 701 to 1400 in 3.2%.

Philis (1995) collected soil and root samples over several years around Cyprus which revealed the presence of 58 plant parasitic nematode species, the most economically important being *Globodera rostochiensis*, *Meloidogyne* spp., *Tylenchulus semipenetrans*, *Helicotylenchus multicinctus*, *Pratylenchus penetrans*, *Xiphinema index*, *Ditylenchus dipsaci* and *Heterodera latipons*. The crop loss caused by nematode attack to citrus and vegetables is estimated at 12% of their productive value.

Elekcioglu (1995) conducted a survey on plant parasitic nematodes in the East Mediterranean region of Turkey. Sixteen nematode species were found associated with citrus. Out of these, only four species, *Helicotylenchus pseudorobustus*, *Rotylenchulus macrodoratus*, *Tylenchorhynchus goffarti* and *Tylenchulus semipenetrans* are able to infect citrus. About 90% of the orchards sampled were infected with the citrus nematode, *T. semipenetrans* where 62.5% of the examined orchards revealed population densities above the economic threshold.

Inserra *et al.* (1995) and Inserra and Duncan (1996) showed that rough lemon was not a suitable host for a population of *Rotylenchulus reniformis* from South Florida, USA.

Ferguson *et al.* (1996) conducted a survey in five central, eastern coastal and southwest Florida counties. Citrus nematodes (*T. semipenetrans*) were found in 45 of 50 mature citrus groves. From a total of 1000 samples, the citrus nematode was detected in 475 and 548 soil and root samples, respectively. Approximately half of the infested groves contained trees beneath which no citrus nematodes were found. Many infested groves contained a patchy distribution of infested trees, possibly from random inoculation events. Linear correlations existed between citrus nematode population densities and levels of soil K, Cu, and soluble salts in the Flatwoods counties. In the Central Ridge counties, nematode density was correlated with levels of soil P and K.

Vovlas and Inserra (1996) listed out *Meloidogyne* spp. detected on citrus in the western and eastern hemispheres from their survey and detection also discussed.

Duncan *et al.* (1996) initiated a survey to determine the incidence of *Belonolaimus* spp. (sting nematodes) in citrus orchards in the central ridge region of Florida, following widespread damage by these nematodes to young trees replanted after freezing weather in 1989-90. Sting nematodes were detected in 50% of 210 samples and in 64% of 84 orchards surveyed. More orchards in Polk County were infested with sting nematodes (82%) than in counties to the north (36%) or south (48%). Principal component analysis of morphometric data separated six of seven sting nematode populations in northeastern Polk County from six populations in adjacent regions. Stylet: tail ratio for nematodes in north-eastern Polk County tend to be > 1.0 and were < or > 1.0 for all other populations. Patchiness of nematodes within an orchard was associated with stunted trees (23% smaller), reduced root mass density (25% lower), and low fruit yield (57% reduction). Soil texture did not vary among trees of different size in the orchard, but soil water potential between irrigation events was highest beneath small trees with low root mass density. Results of the survey indicated that the incidence of sting nematodes in orchards on the central ridge was much higher than previously estimated and that sting nematodes can cause substantial damage in replanted orchards. Further research is needed to evaluate the significance of sting nematode population variability and its relationship to citrus crop loss in Florida.

Bridge *et al.* (1996) conducted a series of surveys on plant nematode at 55 farm sites in six districts of Belize, Central America, during February, November and December, 1993. Soil and root samples were taken and a total of 17 plant parasitic nematode spp. were identified from different crops including citrus. *Tylenchulus semipenetrans* was prominent nematode on citrus, including some spiral nematodes *Helicotylenchus multicinctus* and *H. mucronatus*. However, *T. semipenetrans* was specific on citrus.

Rahman *et al.* (1996) reported *Criconemoides chamoliensis* sp. nov. from soil around roots of orange in Chamoli, UP, India is characterized by 54-65 ornamented body annules, absence of submedian lobes, enlarged pseudolips connected laterally, stylet 64-65 µm long and acutely conoid tail.

Machon and Bridge (1996) described and illustrated *Radopholus citri* sp. nov. from the roots of citrus seedlings and trees growing in sandy soils in East Java, Indonesia. The new species is characterized by the relatively strongly developed conus of the male stylet and less well developed, but distinct, knobs. It comes closest to *Radopholus vangundyi*, *R. neosimilis*, and *R. nativus*.

Khan & Khanna (1997) found out of 14 genera of plant parasitic nematodes *Tylenchulus semipenetrans* was the most prevalent and recorded in all the localities surveyed.

McSorley (1997) observed population densities in soil of nematodes belonging to different genera were monitored for 3 years in a citrus grove in Florida, USA, to determine whether indices of community structure or densities of key genera were more useful in characterizing the soil nematode communities of these very different perennial agroecosystems. Population densities of *Acrobeles*, *Aphelenchus*, *Cervidellus*, *Ironus*, *Paratrichodorus* and *Zeldia* were consistently greater ( $P \leq 0.10$ ) in the citrus site, where 64% to 83% of the nematodes found were bacterivores and only 1% to 16% herbivores.

Crozzoli *et al.* (1997) carried out a nematode survey in 1995 (February-April) in the citrus growing areas of Valles Altos of Carobobo and Yaracuy States, *Tylenchulus semipenetrans* was present in 14.1% of 357 samples. The largest populations of the nematode were in association with *Citrus volkameriana* and the smallest with *Citrus reshni*. *T. semipenetrans* did not occur in groves with *Citrumelo* swingle.

Gambhir *et al.* (1998) extracted 450 soil samples collected from around the rhizosphere of 32 commonly growing fruit plants including citrus spp. In eight districts of Manipur yielded 19 genera of phytophagous tylenchid nematodes. *Helicotylenchus*, *Tylenhorhynchus*, *Aglenchus*, *Basiria*, *Psilenchus*, *Neopsilenchus*, *Scutellonema*, *Macroposthonia* and *Hemicriconemoides* were more abundant and widely distributed than the related genera *Imphalenchus*, *Hoplolaimus*, *Ditylenchus*, *Paratylenchus*, *Hemicycliophora*, *Discocriconemella*, *Caloosia* and *Hemicaloosia*.

Mor and Spiegel (1998) reported the presence of *Tylenchulus semipenetrans* in 13, and *Xiphinema brevicolle* in four of the 15 citrus nurseries during a survey in

1996 in the Negev area (southern Israel). It is suggested that these nematode species were brought to the plantation area, alongwith the citrus seedlings from the central region of Israel in 1993.

Crozzoli *et al.* (1998) carried a survey in the main citrus growing areas of Venezuela. A total of 1110 soil and root samples were collected and analysed. 34 species were identified : *Aorolaimus holdemani*, *A. macbethi*, *Criconema demani*, *Gracilacus aculeta*, *Helicotylenchus crenacauda*, *H. dihystra*, *H. erythrinae*, *H. multicinctus*, *Hemicriconemoides communis*, *H. mangiferae*, *Hoplolaimus seinhorsti*, *Meloidogyne exigua*, *M. incognita*, *Mesocriconema onoense*, *M. ornatum*, *M. sphaerocephalum*, *Monotrichodorus monohystera*, *Paratrichodorus minor*, *Paratylenchus elachystus*, *P. minutus*, *Pratylenchus brachyurus*, *P. zae*, *Rotylenchulus reniformis*, *R. caudaphasimidius*, *Scutellonema brachyurum*, *Tylenchorhynchus annulatus*, *T. capitatus*, *T. semipenetrans*, *Xiphinema brasiliense*, *X. brevicolle*, *X. krugi*, *X. peruvianum*, *X. simillimum* and *X. vulgare*. The most economically important and widespread species is *Tylenchulus semipenetrans*. Other species which may cause damage to citrus are *P. brachyurus*, *M. exigua*, *M. incognita*, *H. multicinctus*, *P. minor* and *X. brevicolle*. Brief descriptions and a key to the identification of genera and species reported from Venezuela are provided.

Souza *et al.* (1999) studied the occurrence and distribution of nematode parasites of fruit crops including citrus spp. from 31 counties of states of Brazil. Plant parasitic nematode genera obtained with their percentage occurrence in relation to the total number of samples were: *Helicotylenchus* (84.4%), *Meloidogyne* (50.9%), *Criconemella* and *Tylenchulus* (24.9%), *Pratylenchus* (15.6%), *Aphelenchoides* (8%), *Radopholus* (6.9%), *Xiphinema* (6.4%) and *Rotylenchulus*, *Discocriconemella*, *Paratylenchus*, *Rotylenchus* and *Scutellonema* (0.6%). The most important species and their frequency of occurrence in relation to the total number of samples were: *Helicotylenchus dihystra* (54.3%), *H. multicinctus* (46.8%), *M. incognita* (26%), *T. semipenetrans* (24.9%), *M. javanica* (24.3%), *Pratylenchus brachyurus* (18.8%) and *Radopholus similis* (6.9%).

Paz *et al.* (1999) surveyed young citrus orchards which are affected by chlorosis, necrosis of branches and withering, all of which are caused by presence of pathogens in root system. Three types of nematodes were found *Tylenchulus* spp.

(possibly *T. semipenetrans*) was found in 15.2% of soil sample analysed and in 10.2% of roots. Less frequent findings were *Rotylenchulus* spp., *Meloidogyne* sp., *Pratylenchus* sp. and *Xiphinema* sp. The nematode which presented the highest incidences of population was *Meloidogyne* sp. (350 and 125 individuals per 100cc and 1 g of dry roots) followed by *Tylenchulus* with 30 and 18 individuals in soil and roots, respectively.

Erdal *et al.* (2001) tabulated plant parasitic nematodes (Tylenchida) inhabiting various crops including citrus. In Turkey in the mid 90's a total of 140 species belonging to 43 genera were determined. The most common species were *Filenchus filiformis*, *F. thornei*, *Boleodorus thylactus*, *Bitylenchus dubius*, *Bitylenchus parvus*, *Quinisulcius capitatus*, *Merlinius brevidens*, *M. nanus*, *Helicotylenchus digonicus*, *Pratylenchus penetrans*, *P. thornei*, *Zygotylenchus guevarai*, *Pratylenchoides alkani*, *Pratylenchoides conincki*, *M. arenaria*, *M. incognita*, *M. javanica*, *H. avenae*, *H. schachtii*, *Ditylenchus destructor*, *D. dipsaci*, *D. myceliophagus*, *A. tritici* and *T. semipenetrans*.

Siddiqui (2005) studied two economically important species of citrus fruits viz. orange, *Citrus reticulata* and lemon, *C. aurantifolia*. These were selected for studying the changes in the population of plant parasitic nematodes around their roots. The nematode population of *Hoplolaimus indicus*, *Helicotylenchus indicus*, *Xiphinema americanum*, *P. coffeae*, *T. semipenetrans* and *Hemicriconemoides mangiferae* was observed at 10 cm (upper layer) followed by 20 cm (middle) and 40 cm (lower) depths. The population was higher at higher soil moisture level. Soil moisture and temperature directly affect the nematode population. The nematode population declined in drought conditions. The PH also indirectly affects the nematode population densities.

Mokbel *et al.* (2006) collected 2100 rhizosphere soil samples from fruit trees. A total of 20 nematode genera were found in the samples. The citrus nematode, *Tylenchulus semipenetrans* was predominant in the citrus soil samples showing 82.1-87.5% frequency of occurrence.

Vyas *et al.* (2008) surveyed Indira Gandji Nahar Project (IGNP) command area in Rajasthan. Eight important genera of plant parasitic nematodes, namely *M. incognita*, *Tylenchorhynchus mashhoodi*, *Hoplolaimus indicus* (*Basirolaimus*

*indicus*), *Helicotylenchus indicus*, *Xiphinema spp.*, *Longidorus spp.*, *Paralongidorus spp.* and *Paratrichodorus porous* were found from lemon(*citrus limon*) including 13 other crops.

Grandison *et al.* (2009) carried out a survey of plant parasitic nematodes in New Caledonia and presented the economic importance of various species. The most commonly found nematodes are R.K.N.(*Meloidogyne spp.*), spiral nematode (*Helicotylenchus spp.*), citrus nematode (*Tylenchulus semipenetrans*), burrowing nematode (*Radopholus similis*) and ring nematode (*Hemicriconemoides mangiferae*).

Zalpuri *et al* (2013) studied community analysis of plant nematodes which is an important criterion for assessment of their pathogenic potential in a particular region. This investigation involves a study of the community structure of phytonematodes associated with the citrus plants in the various districts of Jammu, J&K. The predominant nematode species were *Meloidogyne javanica*, *Hoplolaimus sp.*, *Pratylenchus sp.*, *Xiphinema sp.* and *Tylenchulus semipenetrans*.

### **Litchi**

Nath *et al.*(2008) conducted an extensive survey during march to july 2017 in three sub division of North Tripura district for isolation and identification of plant parasitic nematodes affecting Litchi plants. Analysis of soil and root samples collected from 70 sites in 14 locations of three sub division showed that nine plant parasitic nematodes species within seven genera being associated with litchi plants. The isolated and identified nematode species were *Hemicriconemoides litchi*, *Rotylenchulus reniformis*, *Meloidogyne incognita*, *Helicotylenchus dihystra*, *H.indicus*, *Hoplolaimus indicus*, *Xiphinema brevicolle* and *Xiphinema spp.* Among them *H.litchi*, *R.reniformis* and *Meloidogyne incognita* were the most abundant, frequent and prominent nematode species.

### **Mango**

Anwar *et al.*(2012) assessed the effect of plant parasitic nematodes and fungal pathogens associated with decline of mango within southern Punjab plantations. The fungi most often isolated from symptomatic terminal branches of decline mango trees were *Alternaria altrnata*, *Ceratocystis fimbriata*, *Colletotrichum gloeosporioides*, *Fusarium spp.*, *Botryodiplodia theobromae*, and *Nattrassia*

*mangiferae*. Plant parasitic nematodes associated with declining trees included *Criconemella sphaeocephala*, *Helicotylenchus dihystra*, *Hemicriconemoides mangiferae*, *Hoplolaimus indicus*, *Meloidogyne spp*, and *Rotylenchulus reniformis*. *Trichodorus spp*, *Tylenchus filiformis*, and *Xiphinema spp*. Populations of *H. mangiferae*, *Macroposthonia spp*, and *Rotylenchulus reniformis* were very high. Association of fungi with tissues symptomatic of mango decline in the presence of none to high population levels of plant parasitic nematodes is an area in need of further study to understand the relationship between nematodes and fungal pathogens in inducing decline syndrome in mango.

Kumar and Khan (2015) made systematic investigation in four districts of Uttar Pradesh to assess the plant parasitic nematode community associated with mango orchards. Eight genera of phytonematodes were encountered viz., *Hemicriconemoides mangiferae*, *Hoplolaimus indicus*, *Rotylenchulus reniformis*, *Tylenchorhynchus sp.*, *Helicotylenchus dihystra*, *Pratylenchus sp.*, *Tylenchus sp.* and *Meloidogyne incognita*. The absolute density of *H. indicus* was the maximum followed by *H. mangiferae*. The highest absolute frequency and prominence values was recorded for *H. mangiferae* followed by *H. indicus*, while, *M. incognita* was the least frequent, abundant and prominent species. Sedentary ectoparasitic nematode, *H. mangiferae* was the most predominant nematode in Lucknow, Unnao and Faizabad districts. *M. incognita* was recorded only in Faizabad district and *Tylenchus sp.* was observed in all surveyed districts except Barabanki.

David *et al.* (1990) collected compound samples from the rizosphere of mango in the Iguala's Valley, Gro., Mexico, where 10 genera of plant-parasitic nematodes were found. The nematodes *Hemicriconemoides mangiferae* Siddigi and *Rotylenchulus reniformis* Linford and Oliveira were found with a frequency of 100 and 90 and with average of 1,680 and 331 nematodes per 200 cc of ground, respectively. *Hoplolaimus sp.*, with frequency of 42 and 16 and with averages of 33 and 4 nematodes per 200 cc of ground, respectively; *Xiphinema sp.* was recovered only at the southeast of the Lagoon on Tuxpan, locality where there were found nine of the ten genera of nematodes present in the Valley. the species *H. mangiferae* and *R. reniformis* were found with the highest levels of population and widest distribution on the Iguala's Valley; it could be a potential problem to the farming because those species have been associated with declinations of the yield in other latitudes.

Chen *et al.*(2017) conducted *Hemicriconemoides mangiferae* and *H. litchi*, which have been considered as junior synonyms of *H. strictathecatus*, are morphologically similar, making identification difficult. In the present study, six populations of *Hemicriconemoides spp.* were collected from mango and litchi in Taiwan and were differentiated based on morphometrics and molecular characteristics, since *H. mangiferae* and *H. litchi* are closely related to *H. strictathecatus*, more rDNA sequence information could be valuable to deal with molecular phylogenetic relationships of these species in depth.

## **Papaya**

Khan *et al.*(2007) conducted a survey of nematodes associated with papaya in Hyderabad and Kjarachi district, Sindh, Pakistan was conducted during September-October, 2005. A cluster analysis of nematode data of localities was performed. Two main groups could be recognized; group 1 and 2 which comprise of seven and three localities was respectively. In group 1 species namely *Meloidogyne incognita*, *Tylenchus larvae*, and *Helicotylenchus indicus* are common. On the other hand, Group 2 comprises of localities in which species like *Aphelenchus avenae*, *Hoplolaimus indicus*, and *Pratylenchus zaeae* are abundant.

Sayed *et al.*(2008) collected naturally infested roots of papaya (*Carica papaya* L. var. bengali) were collected from Khawaja farm, Superhighway, Sindh from a depth of 5-25 cm. Histopathological studies revealed that *Rotylenchulus reniformis* cause severe damage to the roots. The syncytial cells had densely stained granular cytoplasm in the stele of plant roots and became slightly hypertrophied. Partial cell lysis and giant cell formation and eggs in gelatinous matrix were obvious. Several cells had broken walls appearing as a mesh like network.

McSorley (1992) reported the plant parasitic nematodes caused problems on a number of tropical fruit tree crops, Root-knot nematodes (*Meloidogyne spp.*) can severely damage Fig, guava, papaya, acerola, and pomegranate and injured seedling of date and olive. *Hemicriconemoides mangiferae* is associated with serious decline of litchi and mango, and is pathogenic to sapodilla and tamarind. *Rotylenchulus reniformis* is associated with many fruit species and can be damaging to papaya. Since few control measures are available for nematode problems on existing trees, it

is critical to examine potential planting sites for plant-parasitic nematodes. So that planting can be planned to avoid damaging host-parasite combinations.

Perera *et al.*(2008) identified the root-knot nematode *Meloidogyne javanica* was identified in papaya roots in Western Australia. Species identification was based on esterase isoenzyme patterns and PCR diagnostics.

Castillo and Barcina(1993) conducted a survey on the most representatives tropical and sub-tropical crops in southern Spain during autumn 1989 and spring 1990 to determine the distribution and population density of plant parasitic nematodes in soil and roots. Migratory ecto parasites were the most abundant and widespread. The predominant ectoparasitic species were *Mesocriconema curvatum*, *Helicotylenchus digonicus*, *Criconema mutabile*, *Criconemoides amorphous*, *Ogma civellae*, *Helicotylenchus dihystra* and *Xiphinema pacbataicum*. Important endoparasitic and semiendoparasitic nematodes were found in soils and root samples of papaya (*Meloidogyne javanica* and *Rotylenchulus reniformis*) and banana (*Meloidogyne javanica* and *Pratylenchus vulnus*).

Singh *et al.*(2012) cited that Papaya (*Carica papaya L.*) and banana (*Musa paradisiaca L.*) are important fruit crops in India. Root-knot nematode *Meloidogyne spp.* infects several agricultural and horticultural crops of the world. Nematode infestation is one of the most important factors contributing to low productivity of the crop. Information on monetary losses due to nematodes on fruit crops under Indian conditions is still meager. The estimated overall annual yield loss of world's major crops due to damage by plantparasitic nematodes has been reported to the extent of 12.3% (Sasser & Freckman, 1987). A heavy infestation of root -knot nematode was observed on papaya in Udhewala village (Fig. 1), and on banana in Chatha village (Fig. 2) of Jammu district of J&K respectively.

Srivastava (2002) cited that amongst fruit crops, root knot nematodes are important limiting factors in papaya production. Taylor et al. (1982) have estimated 10-20 per cent crop loss due to the *Meloidogyne sp.* Occurrence of root knot nematode on papaya has been recorded from almost all parts of India. A high yielding papaya cv. Pusa dwarf is popular in North Bihar and Almost invariably infested severely with *Meloidogyne incognita*, Frequent association of root knot nematode at

certain locations and low yield of papaya prompted the present investigations. A sick orchard at Regional Station of IARI, Pusa, Samastipur was selected for this purpose to evaluate efficacy of some organic amendments for management of this problem.

Khan (2002) stated that Larval penetration in papaya roots was reduced in the presence of *Fusarium solani*. Further, only 66.3% penetrated larvae developed into females in *Meloidogyne incognita* alone in comparison to 42.7% where *F. solani* was present along with *M. incognita*. Fecundity was also reduced with an average of 207 eggs per eggmass in roots infected with *M. incognita* and *F. solani* as compared to 356 eggs with *M. incognita* alone. Also, the percentage of male was high (7.3) in roots infected with *M. incognita* and *F. solani*. Presence of *F. solani* delayed the life cycle of the root-knot nematode by 9 days.

Babatola (1985) cited that Eight cultivars of papaya, *Carica papaya L.*, screened for reactions to the root-knot nematode, *Meloidogyne incognita*, were very susceptible. Rates of growth of the seedlings were depressed over a 12-week period at inoculum levels of 5,000 to 20,000 eggs and secondstage juveniles; leaves of such seedlings were smaller than those of uninoculated plants. These leaves were also very chlorotic and roots of the seedlings were heavily galled.

Ganguly *et al.*(1995) observed poor growth and high mortality (about 60%) of papaya (*Carica papaya*) seedlings at the farm area of IARI Regional Station, Karnal. Analysis of the samples from diseased seedlings revealed the association of reniform nematode, *Rotylenchulus reniformis* in high densities in soil (100-800 nematodes per 100g soil) as well as roots (1-5 mature females per g root). This observation led to the survey of papaya fields in other parts of India for knowing the association of plant parasitic nematodes with this fruit crop. Altogether 60 soil samples along with root material were collected/procured from the rhizosphere of papaya growing in five states of Delhi (8), Haryana (8), Uttar Pradesh (24), Punjab (9) and Andhra Pradesh (11).

## **CHAPTER-3**

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### **MATERIALS AND METHODS**

# MATERIALS AND METHODS

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## Experimental Site

Soil samples around root zones of various fruit plants were collected from different locations of Bhubaneswar during Kharif and Rabi 2016-17

## MATERIALS USED

### 3.1. Glass wares and Equipments

The following laboratory appliances and other materials required during the Course of investigation are cited below.

- a. Khurpi
- b. Spade
- c. Polythene Bags
- d. Label Cards
- e. Rubber bands
- f. Glass beaker
- g. Aluminium pan
- h. Petridish
- i. Tissue Paper
- j. Aluminium wire gauze
- k. A set of 20, 60 and 350 mesh sieves
- l. Counting dish
- m. Capillary micro-pipette
- n. Wet collection bottles
- o. Measuring cylinder
- p. Hand tally counter
- q. Cavity block with lid
- r. Glass slides
- s. Glass wool
- t. Round cover slips
- u. Glycerol
- v. Desiccators
- w. Hot air oven

x. Binocular stereoscopic microscope

y. Olympus research microscope

z. Nylon bristle

### **3.2. Chemicals used**

a. 96% Ethanol

b. Glycerol

c. Formaldehyde

d. Calcium chloride

## **METHODS ADOPTED**

### **3.3. Collection of Soil Samples**

Soil sample measuring each of 500gm approximately from the rhizosphere of 8 fruit plants by collecting 120 samples in Bhubaneswar were scooped up with the help of kauri/spade. Each soil sample was filled into polythene bag tied with a rubber band and tagged with a label card indicating on it the name of the host, locality and date of collection.

### **3.4. Technique for Extraction of Nematodes from Soil**

Nematodes were wet screened from the soil samples by a combination of Cobb's sieving and decanting technique (Cobb 1918) and improved Baremann funnel technique (Schindler, 1961). Volumetrically measured 200cc soil samples were taken into aluminium pan. Sufficient amount of water was added and stirred well in order to prepare a soil suspension. The remaining clods were broken by hands while removing more of plant debris and gravels. The suspension was allowed to stand for about 20 seconds so that sand and heavier particles quickly settled down. The muddy soil suspension was passed through an assembly of phosphor-bronze wire-netted sieves of 20, 60 and 350 mesh sieves. Residues of 20 mesh sieve were washed out while the contents of 60 mesh were separately collected in a glass beaker, by back washing of sieve with gentle stream of water and the suspension was directly examined under stereoscopic microscope, for presence of any cyst nematodes, if present. Contents of 350 mesh sieve were collected in to 250 cc beaker by backwashing the sieve with

gentle stream of water running from the tap. Each soil sample was wet screened in the same manner to collect most of the nematodes. The whole suspension collected in the beaker was poured onto a double layer tissue paper resting on a supporting wire-gauze matching the petri dish. The wire gauze assembly was then placed on petri dish containing sufficient water such that the bottom of the wire gauze tissue paper assembly was slightly submerged in water. The assembly was covered by a lid to prevent loss of water due to evaporation and left as such for 24 hours, so as to allow maximum number of nematodes to wriggle out through the tissue paper into the bottom of petri dish. Next day, the wire gauge was removed. Petri dishes were put on the stage of the stereoscopic microscope to examine the presence of nematodes.

In this manner all total 120 samples screened were processed following improved Baremann funnel technique to get clear nematode suspension.

### **3.4. Counting the Nematodes**

For counting the nematode suspension, a square counting dish 7 x 7 squares was chosen. The nematode suspension present in petri dish was transferred to counting dish and examined under stereoscopic microscope. Observation was started from one corner square of the counting dish and gradually sliding the dish, all the squares are completed. By means of a hand tally counter, the number of nematodes and different nematode species present in the counting dish for each soil sample (200cc) collected from an individual host. This process was recorded genera wise from all soil samples belonging to different host plants.

### **3.5. Killing and Fixing Nematodes**

The nematode suspension collected in Petri dishes was transferred into 100cc glass beaker. Nematodes were then killed, fixed and finally preserved in wet collection bottles in the following manner.

The nematode suspension collected in a glass beaker was allowed to rest for at least one hour, so that the nematodes would settle down at the bottom. The aluminium pan containing water was put over the heater for heating which act as hot water bath. The supernatant suspension was siphoned out through capillary micropipette so as to concentrate the nematode suspension to approximately 10ml. The beaker containing nematode suspension was manually stirred uniformly on hot water bath for about

2minutes for killing the nematodes. The nematode suspension was cooled down and poured in to wet collection bottle. Equal volume of freshly prepared double strength formalin glycerol fixative (Formalin 8ml, Glycerine 2ml, water 45ml) was added into the wet collection bottle for mixing the nematodes. Then the wet collection was screw capped and put in the wooden cabinet.

### 3.6. Processing of Nematodes

Seinhorst solution – I was freshly prepared by mixing 96% ethanol- 20 ml, glycerol- 1 ml and distilled water - 79 ml. 0.5 ml of Seinhorst Solution-I was pipetted out into a cavity block. Fixed nematodes were transferred with the help of bamboo splinter into the cavity block. Then lid of cavity block was partially opened after transferring the nematodes from fixed suspension through bamboo splinter and cavity block containing nematode was put inside one desiccator containing 96% ethanol about 1/10<sup>th</sup> of its volume. The entire assembly was put inside an incubator at 35°C - 40°C temperature for 12 hours. After 12 hours the partially processed nematodes in cavity block was taken out and the saturated alcohol was allowed to evaporate in the open air, so that minimum quantity of solution was finally left in cavity block. One ml of Seinhorst II solution (96% ethanol-95 ml & glycerol 5 ml) was transferred into cavity block and the cavity block was put inside another desiccator containing CaCl<sub>2</sub>. Similarly lid of cavity block was partially opened, so that quantity of alcohol and traces of water present inside cavity block was absorbed by CaCl<sub>2</sub> and finally nematodes were retained in glycerol.

### 3.7. Mounting of Nematodes

A plain glass (clean) slide was put on the stage of the stereoscopic microscope. A small drop of anhydrous glycerol was put in the centre of slide. Five to ten processed nematodes were transferred into glycerol mount through bamboo splinter. Nematodes were arranged in glycerol in such a way that all their heads pointed to one direction and nematodes were allowed to rest at the bottom of glycerol mount without floating on the surface. Three glass wools were separately placed radially in the glycerol mount. A round cover slip was warmed up and placed carefully over the glycerol mount, so that glycerol is uniformly spread without

disturbing nematodes. Periphery of cover slip was sealed with glycerol. Finally, the prepared slide was observed under microscope.

### 3.8. Identification of Nematodes

Nematode specimens mounted on slides were examined under Olympus Research microscope for identification of various plant parasitic (*Tylenchids* and *Aphelenchids*) and free living (*Dorylaimids*, *Mononchids* and *Rhabditids*) nematodes associated with fruit crops.

#### Parameters used for community structure analysis:

The following parameters were used for analysis of community structures of nematodes associated with various fruit crops.

1) Frequency: (a) Absolute frequency

$$= \frac{\text{Number of samples containing a species}}{\text{Number of samples collected}} \times 100$$

(b) Relative frequency

$$= \frac{\text{Frequency of species}}{\text{Sum of frequency of all species}} \times 100$$

2) Density: (a) Absolute density = Number of individuals per unit of soil.

$$\begin{array}{l} \text{(b)Relative} \\ \text{density} \\ = \frac{\text{Number of individuals of a species in a sample}}{\text{Total of all individuals in a sample}} \times 100 \end{array}$$

3) Prominence value (PV) = Density $\sqrt$ Frequency

## **CHAPTER-4**

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### **RESULTS**

# RESULTS

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## 4.1. Association of nematodes with fruit crops in Bhubaneswar.

Results on diversity of nematodes in the rhizosphere of 8 fruit crops in different localities of Bhubaneswar during Kharif and Rabi, 2016-17 revealed presence of 10 plant parasitic and 3 groups of free living nematodes which were cited below.

### Plant parasitic nematodes

1. *Aphelenchus avenae*
2. *Caloosia heterocephala*
3. *Helicotylenchus dihystrera*
4. *Hemicriconemoides mangiferae*
5. *Hoplolaimus indicus*
6. *Meloidogyne spp.*
7. *Pratylenchus coffeae*
8. *Rotylenchulus reniformis*
9. *Tylenchorhynchus mashhoodi*
10. *Xiphinema insigne*

### Free living nematodes

1. *Dorylaimids*
2. *Mononchids*
3. *Rhabditides*

The aforesaid plant parasitic and free living nematodes were identified based on the morphological characters. The morphological identification marks of the aforesaid nematodes were indicated below.

#### 4.1.1. Plant parasitic nematodes

##### *Aphelenchus avenae* (Bastian, 1865)

Cuticle thin and finely striated, cephalic region moderately sclerotized, stylet with weakly developed knobs; median bulb strongly developed, large, offset covering two third of body which orifice of dorsal oesophageal gland above the median valve in median bulb, dorsally lobbed oesophagus, monodelphic prodelphic outstretched ovary with v-70-80%; Tail elongate conoid with blunt end.

##### *Caloosia hetrocephala* (Rao and Mohandas, 1976)

Cephalic region wide and cephalic annules are well separated, stylet with posteriorly sloping round knobs, oesophagus criconematoid type with procorpus metacarpus fused and reduced broad isthmus with small basal bulb being enclosed with the oesophageal glands monoprodelphic outstretched ovary without post uterine sac, tail elongate, tapering to subacute end.

##### *Helicotylenchus dihystra* (Siddiqi, 1972)

Nematode body shows helical posture upon relaxation of the body, cephalic region high, continuous, stylet with round knobs, latero ventrally lobed oesophagus, didelphic outstretched ovary with vulva at post median position, female tail dorsally convex, conoid with a mucron ( in *H. Dihystra*) at the tail tip, male tail short, conical with peloderan bursa.

##### *Hemicriconemoides mangiferae* (Siddiqi, 1961)

In female body elongate, cylindrical with presence of double cuticle, body annules round, sub median lobbed absent, conus of the stylet longer than shaft, anchor shaped stylet knobs, Criconematoid type oesophagus procorpus metacarpus fused with reduced broad isthmus with small basal bulb, monodelphic prodelphic outstretched ovary with v-95%, tail short conoid with sub acute end.

##### *Hoplolaimus indicus* (Sher, 1963)

Vermiform in shape, cephalic region high and offset, stylet robust with tulip shaped knob, dorsally lobed oesophagus, didelphic amphidelphic outstretched ovary

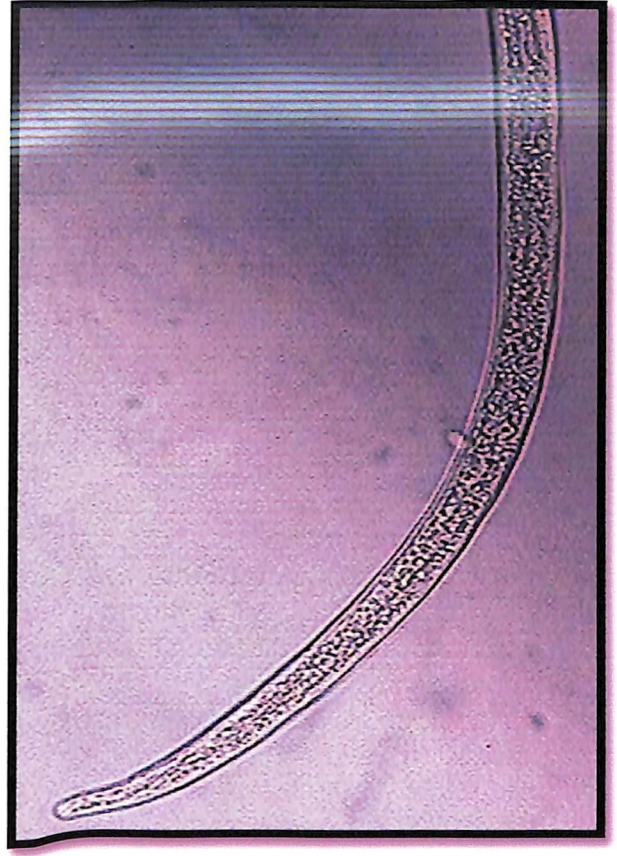
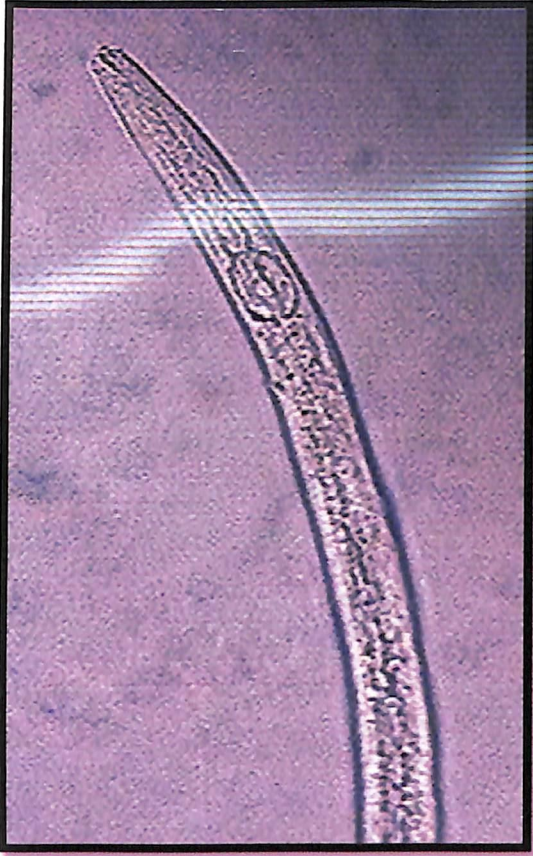


Plate-1 *Aphelenchus avenae*

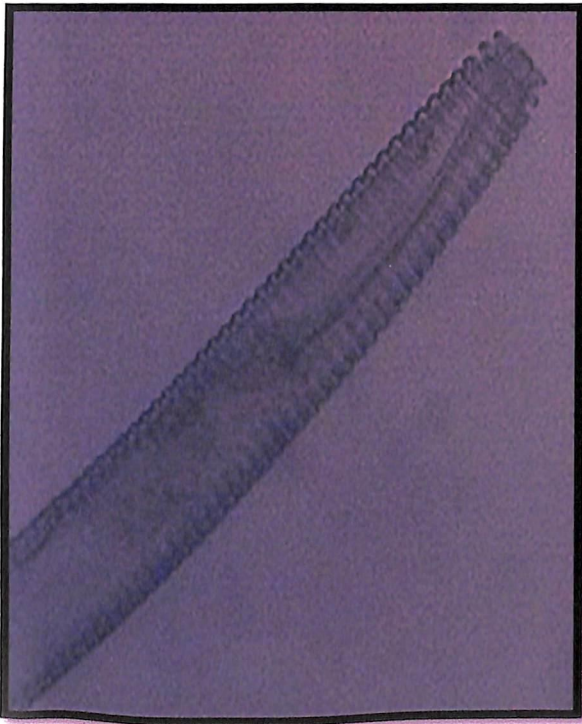
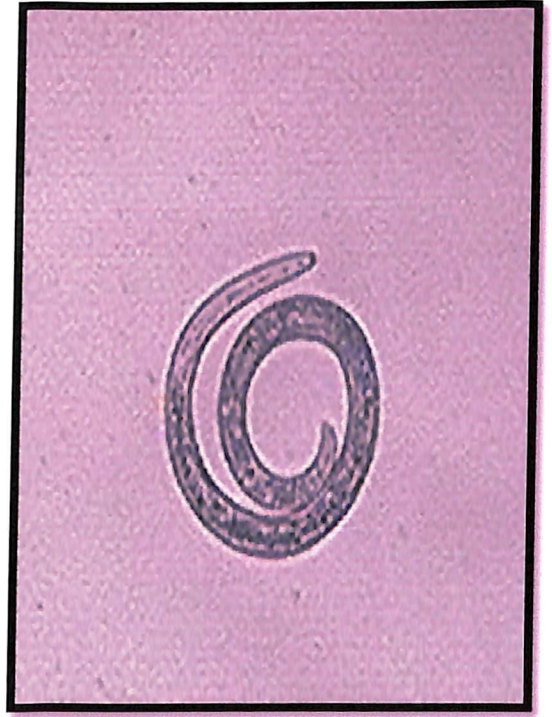
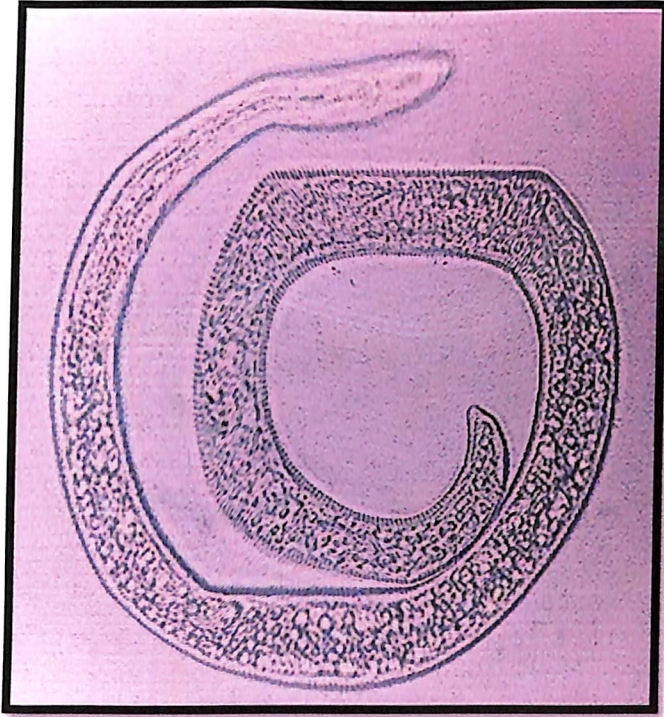
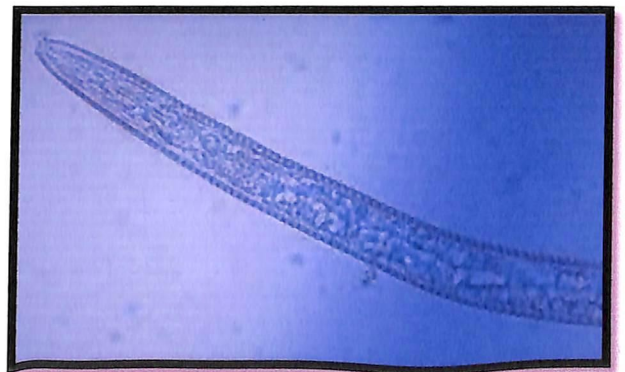


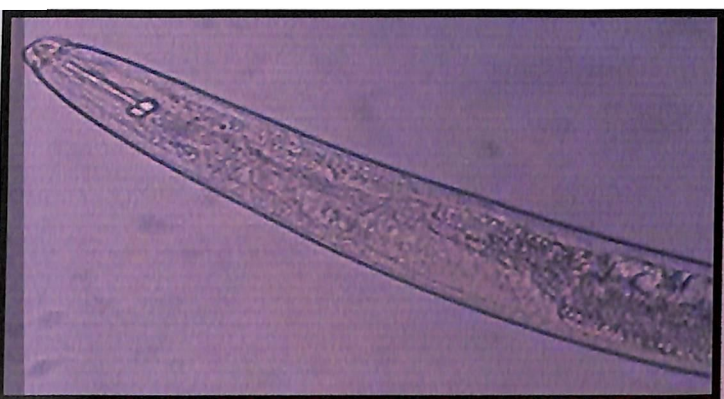
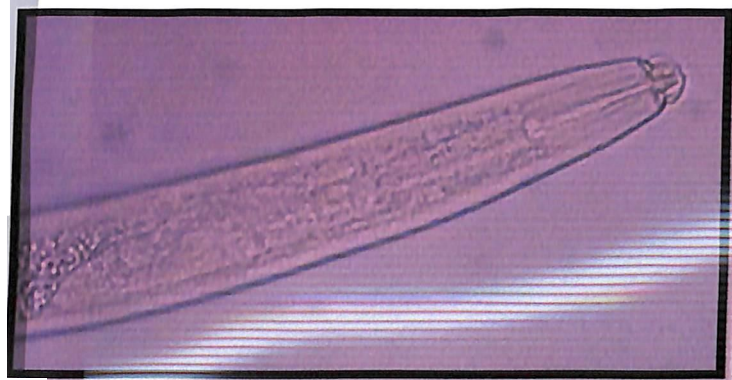
Plate-2 *Caloosia heterocephala*



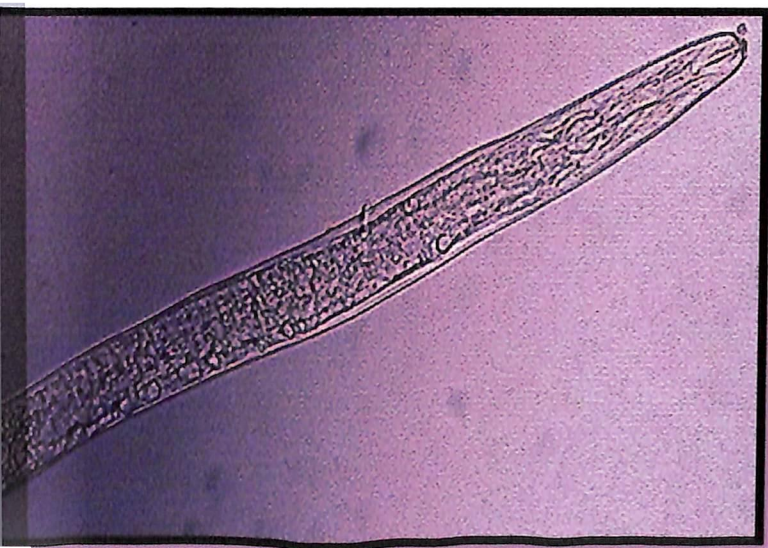
**Plate-3** *Helicotylenchus dihystra*



**Plate-4** *Hemicriconemoides mangiferae*



**Plate-5** *Hoplolaimus indicus*



**Plate-6** *Pratylenchus coffeae*

with vulva at median position, female tail hemispherical but male tail conoid with peloderan bursa.

***Meloidogyne sp.***

2<sup>nd</sup> stage Juvenile: Vermiform, migratory infective, body straight upon death, cephalic region weakly sclerotized, stylet delicate with round knobs, excretory pore posterior to hemizonoid, oesophageal glands ventrally lobed, tail conical with hyaline region, tail tip narrow and irregular in outline.

***Pratylenchus coffeae* (Zimmermann, 1898; Filipjev and Schumann, 1991)**

Female: Vermiform, body gradually tapering posteriorly; cephalic region low, truncate with strong cephalic sclerotization. Stylet strong, 15-20µm, with well developed round knobs; oesophageal glands ventrally lobed. Female genital tract monodelphic prodelpic outstretched vulva posterior. Tail conoid with blunt end.

Male: Bursa extending up to tail tip.

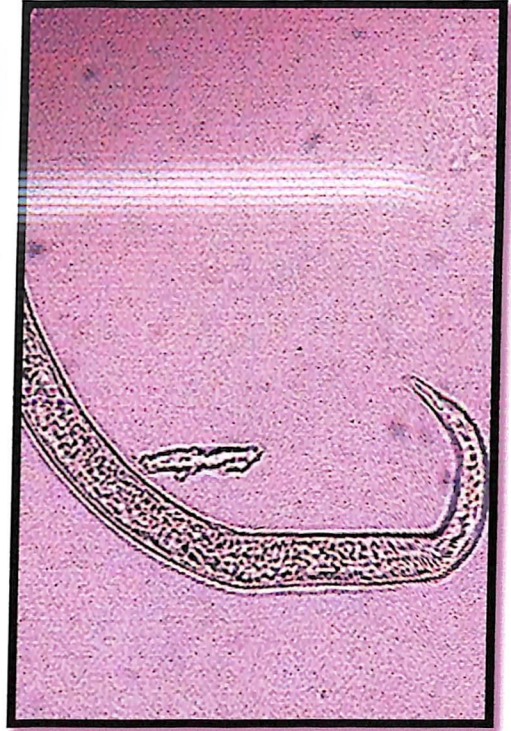
***Rotylenchulus reniformis* (Linford and Oliveira, 1940)**

Young female: Vermiform with C posture upon death, Cephalic region high, continuous, stylet with round knobs, orifice of dorsal oesophageal gland usually about 1 stylet length behind stylet base, ventrally lobed oesophagus, Didelphic amphidelphic ovary with vulva at about 65% from the anterior end. Tail elongate, conoid with blunt end.

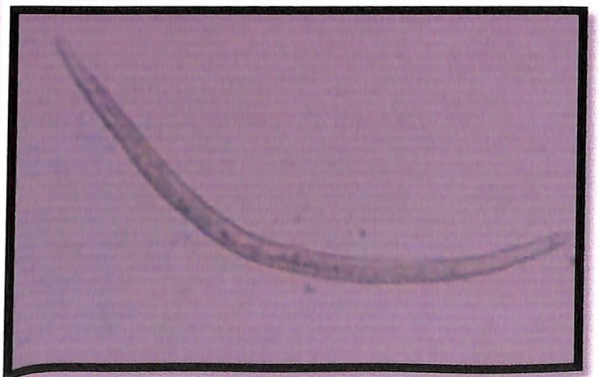
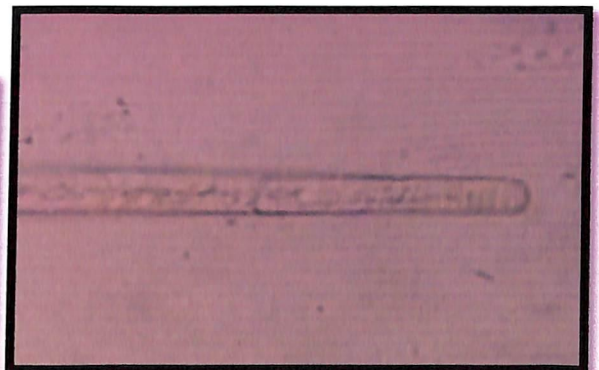
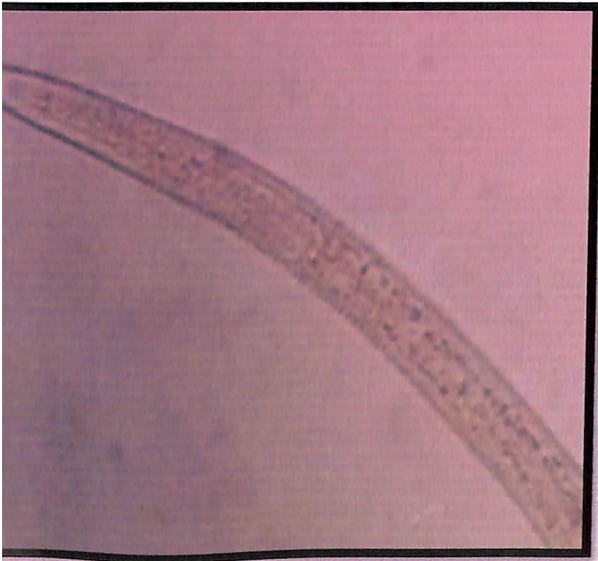
Adult female: Kidney shape with rudimentary tail. Other characters are same as young female.

***Tylenchorhynchus mashhoodi* (Siddiqi and Basir, 1959)**

Cephalic region high, offset, stylet with dorsoventrally flattened knobs, oesophagus tylenchid type with glands enclosed inside basal bulb, didelphic amphidelphic outstretched ovary with median vulva, female tail sub cylindrical with spatulated end, spicules distally flanged and bursa peloderan.



**Plate-7** *Rotylenchulus reniformis*



**Plate-8** *Tylenchorhynchus mashhoodi*

### ***Xiphinema insigne* (Loos, 1949)**

Body cylindrical and ventrally curved upon relaxation. cuticle smooth, lip region offset, amphid funnel shaped, odontostyle very long where base of the odontophore is having 3 flanges, guiding ring is present near the junction of odontostyle and odontophore, two part oesophagus with anterior end narrow, convoluted part followed by expanded glandular part, ovary didelphic amphidelphic and reflexed with pre-median vulva, tail tapering with terminal digitate end.

### **4.1.2. Free living nematodes:**

#### ***Dorylaimids* (de Man, 1876)**

Body cuticle smooth, odonto stylet without knobs, bottle shaped oesophagus with a anterior narrow part followed by expanded glandular part enclosed with oesophageal glands, didelphic amphidelphic reflexed ovaries.

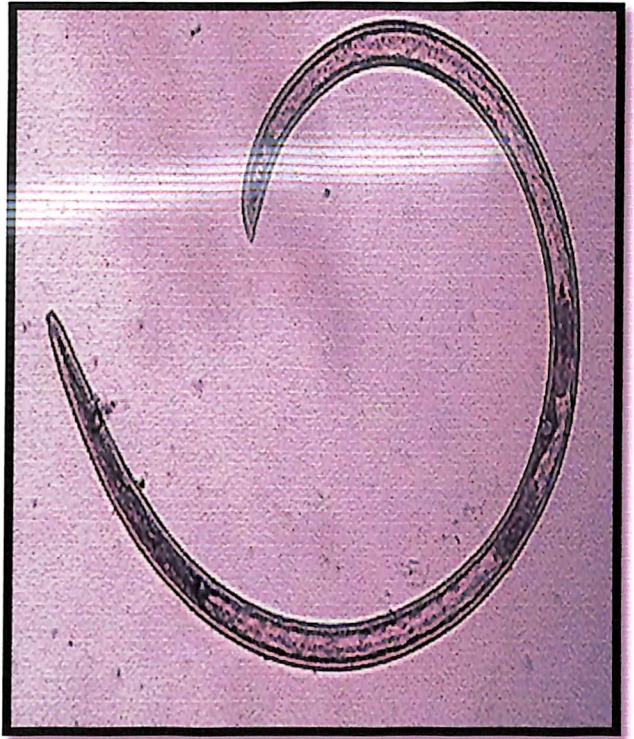
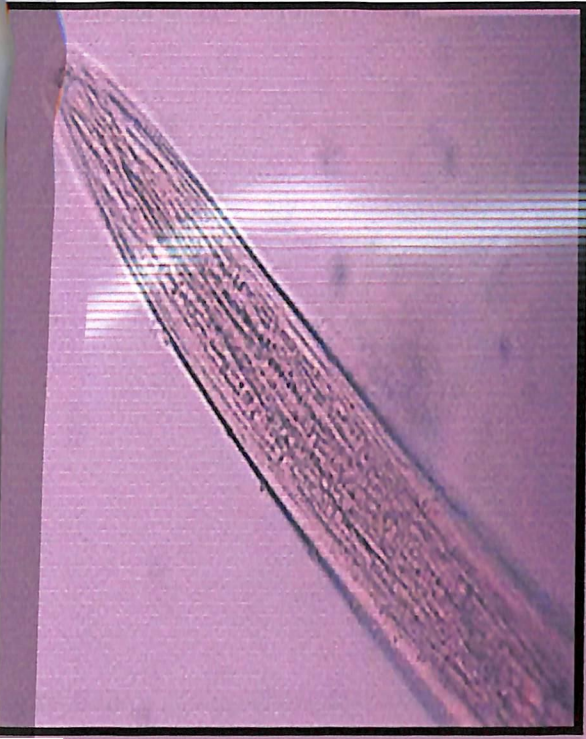
#### ***Mononchids* (Bastian, 1865)**

Body cuticle smooth, cephalic region wide with capsular type of mouth part provided with dorsal tooth opposed by denticles, one part oesophagus which is long cylindrical with wide cuticularized lumen, 5 oesophageal glands remain enclosed within the oesophagus. cardia tuberculate ovary didelphic amphidelphic reflexed, tail usually conical short or long.

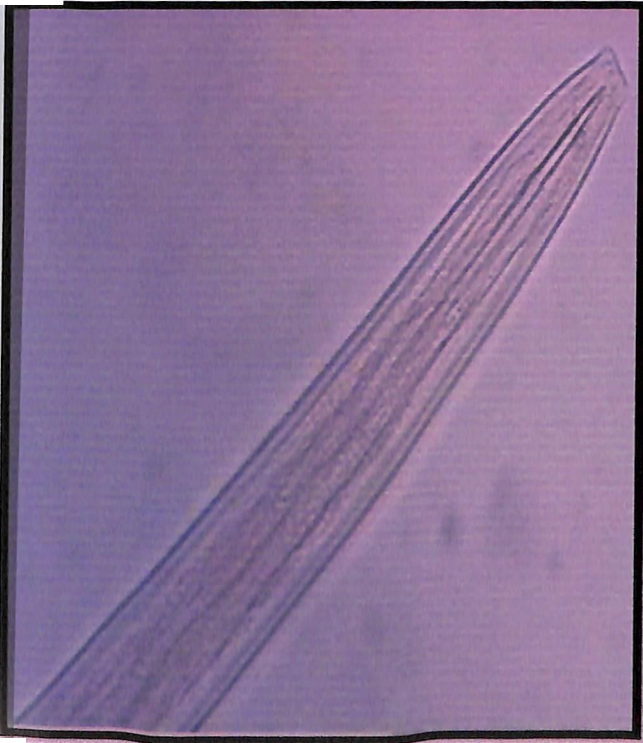
#### ***Rhabditids* (Dujardin, 1845)**

Small sized nematodes move faster in water, stoma open cylindrical provided with glottoid, oesophagus tripartite with corpus, isthmus and basal bulb, conspicuous refractive valve present within the basal bulb, monoprodelfic outstretched ovary, tail pointed.

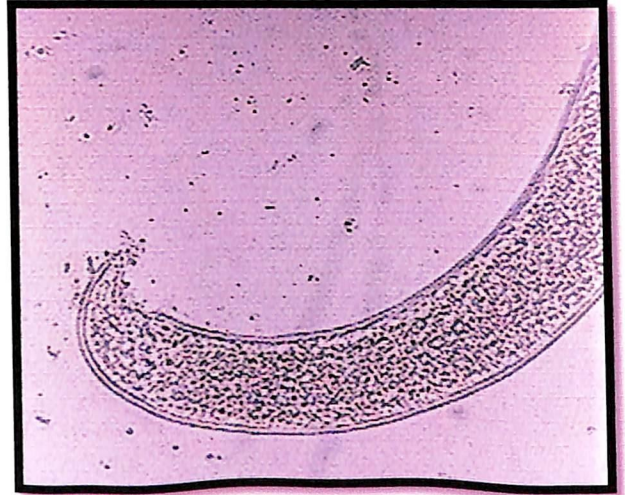
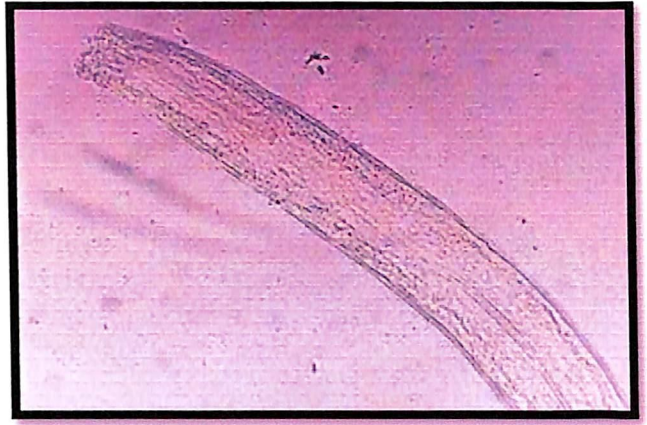
Among plant parasitic nematodes, *Rotylenchulus reniformis* and *Hoplolaimus indicus* were found in all the 8 fruit crops examined. *Tylenchorhynchus mashhoodi* was encountered with all fruit crops except lime. *Meloidogynesp.* was recorded only in guava, while *Pratylenchus coffeae* was in guava, lime and sapota. Barring cashewnut and jackfruit, *Hemicriconemoides mangiferae* was reported in other fruit crops. *Xiphinema insigne* was associated with five fruit crops except



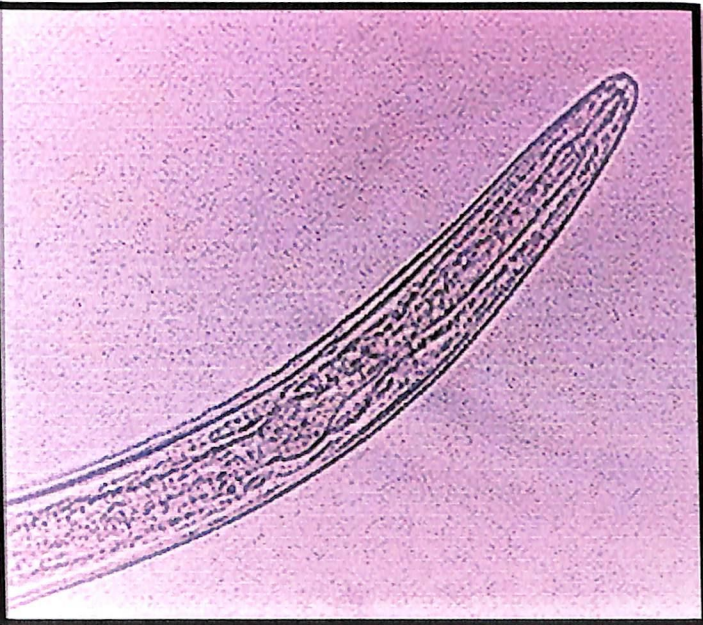
**Plate-9** *Xiphinema insigne*



**Plate-10** *Dorylaimids*



**Plate-11 *Mononchids***



**Plate-12 *Rhabditids***

Table -01 Association of nematodes with fruit crops in Bhubaneswar

SL.NO	NEMATODE SPECIES	CASHEW	GUAVA	JACKFRUIT	LIME	LITCHI	MANGO	PAPAYA	SAPOTA
1	<i>Aphelenchus avenae</i>	2-10	4-18	-	-	4-10	4-12	-	2-6
2	<i>Caloosia heterocephala</i>	-	2-44	-	4-14	-	6-22	12-56	6-14
3	<i>Helicotylenchus dihystrera</i>	-	2-66	12-42	8-34	6-28	-	14-552	-
4	<i>Hemicriconemoides mangiferae</i>	-	2-6	-	10-28	24-84	8-32	4-14	4-12
5	<i>Hoplolaimus indicus</i>	4-26	3-26	10-74	14-54	8-66	12-74	16-86	14-154
6	<i>Meloidogyne spp.</i>	-	18-66	-	-	-	-	-	-
7	<i>Pratylenchus coffeae</i>	-	06-22	-	4-30	-	-	-	4-10
8	<i>Rotylenchulus reniformis</i>	20-76	68-366	12-46	84-552	22-88	24-664	18-1530	8-28
9	<i>Tylenchorhynchus mashhoodi</i>	22-84	8-50	94-412	-	12-42	30-462	10-20	8-36
10	<i>Xiphinema insigne</i>	-	12-28	8-32	4-10	-	4-20	6-10	-
11	<i>Dorylaimids</i>	28-256	4-142	8-68	20-106	4-76	10-206	12-142	12-156
12	<i>Mononchids</i>	2-48	2-28	6-86	6-102	6-36	10-68	4-46	8-96
13	<i>Rhabditids</i>	6-138	2-54	2-24	8-134	4-32	4-20	6-80	6-37

cashewnut, litchi, and sapota. Similarly *Melicoides* *dihystera*, *Coloasii* *heterocephala* and *Aphelenchus avenae* were each associated with five fruits except in order of cashewnut, mango, sapota; cashewnut, jackfruit, litchi and jackfruit, lime, papaya. In context to free living nematodes such as *Dorylaimids*, *Mononchids* and *Rhabditids* were each associated with all the 8 fruit crops.

Guava is the only fruit crop found associated with all 10 plant parasitic and 3 free living nematodes followed by lime, mango, papaya, sapota each associated with 7 plant parasitic and 3 free living nematodes. Similarly litchi, jackfruit and cashewnut in descending order were associated with 6, 5 and 4 plant parasitic nematodes respectively but each crop was associated with all the free living *Dorylaimids*, *Mononchids* and *Rhabditid* nematodes. That apart, *Rotylenchulus reniformis* and *Tylenchorhynchus mashhoodi* were recorded in high range density, while *Aphelenchus avenae* and *Pratylenchus coffeae* were observed in low range diversity.

## 4.2. Estimation of nematode population in fruit crops

### 4.2.1. Cashewnut

Density of various plant parasitic and free living nematodes per 200 cc soil from 15 samples of cashewnut were cited in Table-2, which indicated that population of free living *Dorylaimids* were found the highest in cashewnut followed by *Rhabditids*. But density of plant parasitic nematodes, were found less in cashewnut. Among plant parasitic nematodes, population of *Tylenchorhynchus mashhoodi* was comparatively higher followed by *Rotylenchulus reniformis*, the lowest being recorded in case of *Aphelenchus avenae*.

### 4.2.2. Guava

Population of various plant parasitic and free living nematodes per 200 CC soil from 15 samples of guava were indicated in Table-3. Population of *Rotylenchulus reniformis* was estimated the highest in guava, the lowest being *Hemicriconemoides mangiferae*. Among free living nematodes *Dorylaimids* were recorded comparatively higher than *Rhabditids* followed by *Mononchids*. Considering density of plant parasitic nematodes associated with guava, *Rotylenchulus reniformis* was followed by population of *Meloidogyne sp.*

Table -02 Association of nematodes with cashewnut

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	-	2	8	-	-	6	6	-	10	-	-	8	-	-	6
2	<i>Hoplolaimus indicus</i>	4	10	-	-	18	-	-	-	-	22	10	-	-	20	26
3	<i>Rotylenchulus reniformis</i>	48	-	20	-	76	-	34	28	36	-	54	46	-	48	-
4	<i>Tylenchorhynchus mashhoodi</i>	56	-	42	68	-	-	22	84	46	38	-	54	76	-	50
5	<i>Dorylaimids</i>	-	28	56	38	256	130	84	176	72	100	68	42	96	54	-
6	<i>Mononchids</i>	02	04	08	10	-	06	02	18	08	24	22	48	-	14	32
7	<i>Rhabditids</i>	102	42	06	-	16	60	22	138	12	26	84	54	18	-	44

Table -03 Association of nematodes with guava

SL.NO	NEMATOPDE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	-	16	18	-	-	-	4	-	-	-	8	-	10	-	-
2	<i>Caloosia heterocephala</i>	44	-	2	-	-	-	-	-	-	14	-	-	-	-	-
3	<i>Helicotylenchus dityastera</i>	66	-	-	-	-	-	4	-	-	2	-	24	-	20	-
4	<i>Hemicriconemoides mangiferae</i>	-	-	-	-	-	-	2	-	-	-	6	-	-	-	-
5	<i>Hoplolaimus indicus</i>	10	-	3	-	-	-	-	-	-	-	26	-	-	-	18
6	<i>Meloidogyne spp.</i>	-	66	-	-	-	-	60	18	-	26	-	-	-	-	32
7	<i>Pratylenchus coffeae</i>	14	06	10	-	22	-	12	12	06	-	-	-	08	10	-
8	<i>Rotylenchulus reniformis</i>	360	294	-	268	-	100	366	240	320	154	-	80	68	78	-
9	<i>Tylenchorhynchus mashhoodi</i>	-	-	-	12	-	-	24	-	50	08	26	16	-	38	-
10	<i>Xiphinema insigne</i>	14	-	12	-	28	-	-	-	-	-	-	-	24	16	-
11	<i>Dorylaimids</i>	64	38	28	04	142	80	22	14	06	26	18	12	70	32	66
12	<i>Mononchids</i>	28	-	12	06	04	14	-	02	24	04	-	18	-	08	-
13	<i>Rhabditids</i>	8	12	02	10	10	08	02	-	02	10	54	38	16	24	-

#### 4.2.3. Jackfruit

Estimation of nematode population from 15 samples of jackfruit each of 200cc soil recorded in Table-4 revealed that population of *Tylenchorhynchus mashhoodi* was noticed highest, the lowest being free living *Rhabditids*. Among plant parasitic nematodes, population of *Tylenchorhynchus mashhoodi* was followed by *Hoplolaimus indicus*. Similarly, in context to free living nematodes, population of *Dorylaimids* was comparatively higher than *Mononchids*. Moreover, population of *Hoplolaimus indicus* and *Dorylaimids* were recorded in all 15 samples.

#### 4.2.4. Lime

Density of plant parasitic and free living nematodes per 200cc soil from 15 soil samples of lime were cited in Table-5 which implied that population of *Rotylenchulus reniformis* was recorded the highest, the lowest being noticed in *Xiphinema insigne*. Among free living nematodes, population of *Rhabditids* was found highest followed by *Mononchids*. In context to plant parasitic nematodes associated with lime, density of *Rotylenchulus reniformis* was followed by *Helicotylenchus dihystra*. Moreover, population of *Dorylaimids* and *Rhabditids* were recorded in all samples of lime.

#### 4.2.5. Litchi

Estimation of plant parasitic and free living nematode population from 15 soil samples of litchi each of 200cc soil indicated in Table-6 revealed that nematodes in most of the samples yielded very low population. However highest population of *Rotylenchulus reniformis* was recorded in litchi followed by *Hemicriconemoides mangiferae*, the lowest being *Aphelenchus avenae*. Among free living nematodes, population of *Dorylaimids* was found higher than *Mononchids* followed by *Rhabditids*. Moreover, population of *Dorylaimids* was only found in all samples examined.

Table -04 Association of nematodes with jackfruit

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Helicotylenchus dihystrera</i>	-	-	-	-	42	12	-	-	-	-	30	-	-	-	-
2	<i>Hoplalaimus indicus</i>	26	74	46	32	20	28	38	10	12	62	38	56	24	50	72
3	<i>Rotylenchulus reniformis</i>	24	42	-	-	12	08	12	12	24	-	20	-	36	-	46
4	<i>Tylenchorhynchus mashhoodi</i>	94	412	124	138	-	274	402	370	220	186	-	314	166	312	-
5	<i>Xiphinema insigne</i>	12	28	22	-	-	-	-	08	-	16	24	-	32	-	-
6	<i>Dorylaimid s</i>	24	68	42	58	60	14	62	08	20	50	18	38	54	40	32
7	<i>Mononchids</i>	18	86	08	06	14	-	28	34	12	32	16	36	52	-	44
8	<i>Rhabdiitids</i>	10	02	06	02	16	04	10	02	-	14	08	24	12	-	20

Table -05 Association of nematodes with lime

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Caloosia heterocephala</i>	-	-	04	14	08	-	-	-	-	-	-	-	12	-	-
2	<i>Helicotylenchus dihystra</i>	-	-	08	22	-	12	-	34	-	-	30	-	18	-	-
3	<i>Hemicriconemoides mangiferae</i>	-	-	28	18	20	-	-	-	10	-	22	14	-	-	-
4	<i>Hoplolaimus indicus</i>	22	-	36	14	48	-	-	34	-	54	-	42	-	-	-
5	<i>Pratylenchus coffeae</i>	-	-	12	-	30	-	-	-	-	04	-	-	-	18	-
6	<i>Rotylenchulus reniformis</i>	552	-	126	244	404	254	336	228	160	212	248	212	186	206	84
7	<i>Xiphinema insigne</i>	06	-	-	08	-	-	-	-	-	-	-	-	10	-	04
8	<i>Dorylaimids</i>	78	54	58	44	36	106	72	20	24	34	26	32	48	42	22
9	<i>Mononchids</i>	102	76	38	22	34	-	-	06	08	14	68	56	82	-	96
10	<i>Rhabditids</i>	18	134	26	12	08	10	84	72	128	58	20	18	76	32	130

Table -06 Association of nematodes with litchi

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	-	-	-	04	-	-	-	10	-	-	-	-	06	-	08
2	<i>Helicotylenchus dihystera</i>	20	28	-	-	-	-	12	-	-	06	-	-	16	-	14
3	<i>Hemicriconemoides mangiferae</i>	72	56	-	32	-	24	42	-	28	-	60	68	-	48	84
4	<i>Hoplolaimus indicus</i>	24	38	26	-	08	-	14	-	22	-	54	-	66	-	50
5	<i>Rotylenchulus reniformis</i>	74	-	52	-	26	88	64	48	-	22	-	54	-	46	-
6	<i>Tylenchorhynchus mashhoodi</i>	-	36	22	-	-	30	28	24	26	12	42	-	18	-	16
7	<i>Dorylaimid s</i>	18	76	38	16	54	32	44	56	26	14	68	04	50	72	24
8	<i>Mononchids</i>	06	30	12	12	36	22	20	16	-	-	-	18	26	28	32
9	<i>Rhabditids</i>	16	04	12	-	08	14	-	32	18	24	08	18	06	-	08

#### 4.2.6. Mango

Density of plant parasitic and free living nematodes per 200cc soil from 15 samples of mango reflected in Table-7 implied that population of *Rotylenchulus reniformis* was found maximum followed by *Tylenchorhynchus mashhoodi*. Among free living nematodes, population of *Dorylaimids* was found higher than *Mononchids*. But the lowest population of *Aphelenchus avenae* was recorded in mango. Moreover population of *Dorylaimids* was only found in all 15 samples.

#### 4.2.7. Papaya

Estimation of plant parasitic and free living nematode population from 15 soil samples of papaya each of 200 cc soil cited in Table-8 revealed that population of *Rotylenchulus reniformis* was found maximum followed by *Helicotylenchus dihystera*, the lowest being *Xiphinema insigne*. In context to free living nematodes, population of *Dorylaimids* was comparatively higher followed by *Rhabditids*. Moreover, population of *Rotylenchulus reniformis*, *Dorylaimids* and *Rhabditids* were detected in all 15 samples.

#### 4.2.8. Sapota

Density of plant parasitic and free living nematodes per 200cc soil from 15 samples of sapota reflected in Table-9 implied that nematodes in most of the samples yielded very low population. However, highest population of *Hoplolaimus indicus* was recorded in sapota followed by *Dorylaimids*, the lowest being *Aphelenchus avenae*. Moreover, population of *Dorylaimids* only was found in all 15 samples.

Table -07 Association of nematodes with mango

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	04	-	-	06	-	-	-	-	08	-	12	-	-	-	-
2	<i>Caloosia heterocephala</i>	22	12	-	-	-	-	-	-	-	08	-	-	06	-	10
3	<i>Hemicriconemoides mangiferae</i>	20	18	12	24	-	32	-	-	-	-	26	-	08	-	-
4	<i>Hoplolaimus indicus</i>	52	12	18	-	48	-	28	28	-	30	-	62	34	74	22
5	<i>Rotylenchulus reniformis</i>	494	514	388	84	-	24	72	522	664	146	324	212	188	-	152
6	<i>Tylenchorhynchus mashhoodi</i>	-	-	462	-	46	-	104	142	70	56	30	-	48	-	36
7	<i>Xiphinema insigne</i>	-	20	-	-	16	-	-	-	-	04	-	08	-	18	-
8	<i>Dorylaimid s</i>	48	58	206	56	48	14	10	100	70	44	14	88	72	102	64
9	<i>Mononchids</i>	32	14	-	12	40	36	10	52	42	18	68	24	32	26	-
10	<i>Rhabditids</i>	16	10	08	20	10	04	18	16	-	06	08	12	10	12	-

Table -07 Association of nematodes with mango

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	04	-	-	06	-	-	-	-	08	-	12	-	-	-	-
2	<i>Caloosia heterocephala</i>	22	12	-	-	-	-	-	-	-	08	-	-	06	-	10
3	<i>Hemicriconemoides mangiferae</i>	20	18	12	24	-	32	-	-	-	-	26	-	08	-	-
4	<i>Hoplolaimus indicus</i>	52	12	18	-	48	-	28	28	-	30	-	62	34	74	22
5	<i>Rotylenchulus reniformis</i>	494	514	388	84	-	24	72	522	664	146	324	212	188	-	152
6	<i>Tylenchorhynchus mashhoodi</i>	-	-	462	-	46	-	104	142	70	56	30	-	48	-	36
7	<i>Xiphinema insigne</i>	-	20	-	-	16	-	-	-	-	04	-	08	-	18	-
8	<i>Dorylaimid s</i>	48	58	206	56	48	14	10	100	70	44	14	88	72	102	64
9	<i>Mononchids</i>	32	14	-	12	40	36	10	52	42	18	68	24	32	26	-
10	<i>Rhabditids</i>	16	10	08	20	10	04	18	16	-	06	08	12	10	12	-

Table -08 Association of nematodes with papaya

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Caloosia</i>	56	-	-	12	-	-	28	-	-	-	-	36	-	-	-
2	<i>Helicotylenchus ditystera</i>	552	24	-	88	-	-	18	-	28	14	72	-	68	146	-
3	<i>Hemicriconemoides mangiferae</i>	-	12	-	-	-	04	-	-	-	-	14	-	-	-	-
4	<i>Hoplolaimus indicus</i>	28	68	16	-	18	-	52	22	-	-	86	-	-	-	74
5	<i>Rotylenchulus reniformis</i>	88	18	26	254	140	260	312	1530	42	150	356	284	470	558	612
6	<i>Tylenchorhynchus mashhoodi</i>	-	-	-	14	10	-	-	-	20	-	-	16	-	-	-
7	<i>Xiphinema</i>	06	10	-	-	-	-	-	-	-	08	-	08	-	-	-
8	<i>Dorylaimids</i>	18	142	34	28	14	16	24	38	14	20	56	34	42	12	46
9	<i>Mononchids</i>	18	46	06	04	-	12	26	-	06	22	08	24	16	20	14
10	<i>Rhabditids</i>	80	18	06	12	24	08	14	70	10	16	42	30	22	28	26

Table -09 Association of nematodes with sapota

SL.NO	NEMATODE SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	<i>Aphelenchus avenae</i>	04	-	06	-	-	-	-	-	-	-	-	02	-	-	-
2	<i>Caloosia</i>	-	08	-	-	10	-	14	-	-	-	06	-	-	12	-
3	<i>Hemicriconemoides</i>	12	-	-	-	-	04	-	-	06	-	-	-	08	-	-
4	<i>Hoplolaimus indicus</i>	26	38	-	14	-	-	154	22	-	-	-	76	-	-	84
5	<i>Pratylenchus</i>	-	04	08	-	06	-	-	-	-	08	-	-	-	10	-
6	<i>Rotylenchulus</i>	-	-	28	-	16	-	20	-	-	-	-	-	-	08	18
7	<i>Tylenchorhynchus</i>	-	10	22	36	-	-	08	28	16	14	32	24	18	-	-
8	<i>Dorylaimids</i>	12	58	54	38	76	156	72	26	58	28	62	46	24	52	48
9	<i>Mononchids</i>	14	-	96	10	08	24	50	30	28	36	18	52	16	68	46
10	<i>Rhabditids</i>	-	22	37	-	-	18	-	06	26	-	24	-	32	-	-

### 4.3. Community analysis of nematodes in individual fruit crop

#### 4.3.1. Cashewnut

Perusal of data in Table-10 implied that *Dorylaimids*, *Mononchids* and *Rhabditids* each registered highest frequency of occurrence(13) with Absolute frequency(86.67%) and Relative frequency(18.3%).As regards to plant parasitic nematodes, *Tylenchorhynchus mashhoodi* exhibited comparatively higher frequency of occurrence(10) with Absolute frequency(66.67%) and relative frequency(14.1%) followed by *Rotylenchulus reniformis* showing frequency of occurrence(9), Absolute frequency(60%) and Relative frequency(12.7%).The lowest frequency of occurrence(6), Absolute frequency (40%) and Relative frequency(8.5%) was recorded in *Aphelenchus avenae*. In context to Relative density, *Dorylaimids* occupied the highest position (33.58%) followed by *Tylenchorhynchus mashhoodi*(19.5%), *Rhabditids* (17.47%) and *Rotylenchulus reniformis* (15.77%). The lowest relative density was found in case of *Aphelenchus avenae*(2.42%). In consideration to Prominence value, *Dorylaimids* was adjudged as the most prominent nematode(85.93) with the succeeding nematodes in descending order as *Rhabditids*(44.69), *Tylenchorhynchus mashhoodi*(43.76) and *Rotylenchulus reniformis*(33.56).But *Aphelenchus avenae* was noticed as the least important species.

#### 4.3.2. Guava

It was evident from the data quoted in Table-11 that there was highest record of 10 plant parasitic and 3 free living nematodes in guava than other fruit crops. *Dorylaimids* exhibited highest occurrence of frequency (15) with Absolute frequency (100%) and Relative frequency (15.96%) followed by *Rhabditids* with frequency of occurrence (13), Absolute frequency (86.67%) and Relative frequency (13.83%). This was followed by *Rotylenchulus reniformis* with frequency of occurrence (11), Absolute frequency (73.33%) and Relative frequency (11.7%). The lowest frequency of occurrence (2), Absolute frequency (13.33%) and Relative frequency (2.13%) was recorded in case of *Hemicriconemoides mangiferae*. So far as absolute density is concerned, *Rotylenchulus reniformis* excelled all other nematodes attaining Absolute density(211.63) and Relative density(47.22%) followed by

Table no.10 Community analysis of nematodes associated with cashewnut

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	15	6	40.00	8.5	6.66	2.42	4.21
2	<i>Hoplolaimus indicus</i>	15	7	46.67	9.9	15.71	5.72	10.73
3	<i>Rotylenchulus reniformis</i>	15	9	60.00	12.7	43.33	15.77	33.56
4	<i>Tylenchorhynchus mashhoodi</i>	15	10	66.67	14.1	53.6	19.50	43.76
5	<i>Dorylaimids</i>	15	13	86.67	18.3	92.3	33.58	85.93
6	<i>Mononchids</i>	15	13	86.67	18.3	15.23	5.54	14.18
7	<i>Rhabditids</i>	15	13	86.67	18.3	48	17.47	44.69
				473.33	100	274.83	100.00	

Table no.11 Community analysis of nematodes associated with guava

SL. NO	NEMATOPDE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	15	5	33.33	5.32	11.20	2.50	6.47
2	<i>Caloosia heterocephala</i>	15	3	20.00	3.19	20.00	4.46	8.94
3	<i>Helicotylenchus dihystrera</i>	15	5	33.33	5.32	23.20	5.18	13.39
4	<i>Hemicriconemoides mangiferae</i>	15	2	13.33	2.13	4.00	0.89	1.46
5	<i>Hoplolaimus indicus</i>	15	4	26.67	4.26	14.25	3.18	7.36
6	<i>Meloidogyne spp.</i>	15	5	33.33	5.32	40.60	9.06	23.44
7	<i>Pratylenchus coffeae</i>	15	9	60.00	9.57	11.11	2.48	8.61
8	<i>Rotylenchulus reniformis</i>	15	11	73.33	11.70	211.63	47.22	181.23
9	<i>Tylenchorhynchus mashhoodi</i>	15	7	46.67	7.45	24.85	5.54	16.98
10	<i>Xiphinema insigne</i>	15	5	33.33	5.32	18.80	4.19	10.85
11	<i>Dorylaimids</i>	15	15	100.00	15.96	41.46	9.25	41.46
12	<i>Mononchids</i>	15	10	66.67	10.64	12.00	2.68	9.80
13	<i>Rhabditids</i>	15	13	86.67	13.83	15.07	3.36	14.03
				626.67	100.00	448.17	100.00	

*Dorylaimids* with Absolute density (41.46) and Relative density (9.25%). This was followed by *Meloidogyne sp.* with Absolute density (40.6) and Relative density (9.06%). The lowest Absolute density (4) and Relative density(0.89%) was recorded in *Hemicriconemoides mangiferae*. In context to Prominence value it was noticed that *Rotylenchulus reniformis* was considered the most prominent species (181.23) followed by in descending order as *Dorylaimids* (41.46), *Meloidogyne sp.*(23.44), *Rhabditids*(14.03) and *Helicotylenchus dihystra* (13.39). *Hemicriconemoides mangiferae* was adjudged as the least important species(1.46).

#### 4.3.3. Jackfruit

Data presented in Table-12 indicated that *Hoplolaimus indicus* and *Dorylaimids* occupied highest occurrence of frequency(15) with Absolute frequency(100%) and Relative frequency(16.85%) followed by *Mononchids* and *Rhabditids* possessing frequency of occurrence(13), Absolute frequency (86.67%) and Relative frequency (14.61%).This was followed by *Tylenchorhynchus mashhoodi* having frequency of occurrence (12), Absolute frequency(80%) and Relative frequency (13.48%).The lowest frequency of occurrence (3), Absolute frequency (20%) and Relative frequency (3.37%) was noticed in *Helicotylenchus dihystra*. Pertaining to Absolute density *Hoplolaimus indicus* and *Dorylaimids* registered Absolute density (39.2) and Relative density (8.93%). But maximum Absolute density (251) and Relative density (57.2%) was noticed in case of *Tylenchorhynchus mashhoodi*, the minimum density being 10 and Relative density (2.28%) in case of *Rhabditids*. In consideration to Prominence value, *Tylenchorhynchus mashhoodi* was treated as the most promising species having Prominence value (224.50) followed by *Hoplolaimus indicus* and *Dorylaimids* (39.2), *Mononchids* (27.64), but the least promising nematode was *Rhabditids* (9.31).

#### 4.3.4. Lime

Presentable data in Table-14 indicated that *Dorylaimids* and *Rhabditids* registered highest frequency of occurrence (15) with Absolute frequency (100%) and Relative frequency (17.24%) followed by *Rotylenchulus reniformis* having frequency

of occurrence (14) with Absolute frequency (93.33%) and Relative frequency (16.09%). The lowest frequency of occurrence (4) with Absolute frequency (26.67%) and Relative frequency (4.6%) was recorded in case of *Caloosia heterocephala* and *Pratylenchus coffeae*. In connection to density of nematode, *Rotylenchulus reniformis* showed highest Absolute density (246.57) and Relative density (48.76%) followed by *Rhabditids* having Absolute density (55.06) and Relative density (10.89%). *Xiphinema insigne* was found to have lowest Absolute density (1) and Relative density (1.38%). So far as the Prominence value of nematodes in lime concerned, *Rotylenchulus reniformis* was found to be the most promising species (238.21) followed by *Rhabditids* (55.06), *Dorylaimids* (46.4), *Mononchid* (44.86), *Hoplolaimus indicus* (24.39). *Xiphinema insigne* was treated as the least prominent nematode (3.61).

#### 4.3.5 Litchi

Community structure of nematodes in Litchi reflected on Table-13 revealed that *Dorylaimids* exhibited highest frequency of occurrence (15) with Absolute frequency (100%) and Relative frequency (17.24%) followed by *Mononchids* and *Rhabditids* having frequency of occurrence (12), Absolute frequency (80%) and Relative frequency (13.79%). But plant parasitic nematodes have comparatively lower frequency of occurrence (10) with Absolute frequency (66.67%) and Relative frequency (11.49%) noticed in case of *Hemicriconemoides mangiferae* and *Tylenchorhynchus mashhoodi* followed by *Rotylenchulus reniformis* and *Hoplolaimus indicus* having frequency of occurrence (9) with Absolute frequency (60%) and Relative frequency (10.34%). The lowest frequency of occurrence (4) with Absolute frequency (26.67%) and Relative frequency (4.6%) was recorded in *Aphelenchus avenae*. In context to density of nematode per 200cc soil, *Rotylenchulus reniformis* indicated highest Absolute density (52.66%) and Relative density (20.24%) followed by *Hemicriconemoides mangiferae* possessing Absolute density (51.4%) and Relative density (19.76%). Next to plant parasitic nematodes, *Dorylaimids* have Absolute density (39.46%) and Relative density (15.17%). The lowest Absolute density (7) and Relative density (2.69%) was recorded in case of *Aphelenchus avenae*. As regards to Prominence value, *Hemicriconemoides mangiferae* was adjudged as the most prominent species (41.97) followed by

Table no.12 Community analysis of nematodes associated with jackfruit

SL. NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Helicotylenchus dithystra</i>	15	3	20	3.37	28	6.38	12.52
2	<i>Hoplalaimus indicus</i>	15	15	100	16.85	39.2	8.93	39.20
3	<i>Rotylenchulus reniformis</i>	15	11	73.33	12.36	21.45	4.89	18.37
4	<i>Tylenchorhynchus mashhoodi</i>	15	12	80	13.48	251	57.20	224.50
5	<i>Xiphinema insigne</i>	15	7	46.67	7.87	20.28	4.62	13.85
6	<i>Dorylaimids</i>	15	15	100	16.85	39.2	8.93	39.20
7	<i>Mononchids</i>	15	13	86.67	14.61	29.69	6.77	27.64
8	<i>Rhabditids</i>	15	13	86.67	14.61	10	2.28	9.31
				593.33	100.00	438.82	100.00	

Table no.13 Community analysis of nematodes associated with lime

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Caloosia heterocephala</i>	15	4	26.67	4.60	9.5	1.88	4.91
2	<i>Helicotylenchus dityastera</i>	15	6	40.00	6.90	20.66	4.09	13.07
3	<i>Hemicriconemoides mangiferae</i>	15	6	40.00	6.90	18.66	3.69	11.80
4	<i>Hoplolaimus indicus</i>	15	7	46.67	8.05	35.71	7.06	24.39
5	<i>Pratylenchus coffeae</i>	15	4	26.67	4.60	16	3.16	8.26
6	<i>Rotylenchulus reniformis</i>	15	14	93.33	16.09	246.57	48.76	238.21
7	<i>Xiphinema insigne</i>	15	4	26.67	4.60	7	1.38	3.61
8	<i>Dorylaimids</i>	15	15	100.00	17.24	46.4	9.18	46.40
9	<i>Mononchids</i>	15	12	80.00	13.79	50.16	9.92	44.86
10	<i>Rhabditids</i>	15	15	100.00	17.24	55.06	10.89	55.06
				580.00	100.00	505.72	100.00	

**Table no.14 Community analysis of nematodes associated with litchi**

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	15	4	26.67	4.60	7	2.69	3.61
2	<i>Helicotylenchus dihystera</i>	15	6	40.00	6.90	16	6.15	10.12
3	<i>Hemicriconemoides mangiferae</i>	15	10	66.67	11.49	51.4	19.76	41.97
4	<i>Hoplolaimus indicus</i>	15	9	60.00	10.34	33.55	12.90	25.99
5	<i>Rotylenchulus reniformis</i>	15	9	60.00	10.34	52.66	20.24	40.79
6	<i>Tylenchorhynchus mashhoodi</i>	15	10	66.67	11.49	25.4	9.76	20.74
7	<i>Dorylaimids</i>	15	15	100.00	17.24	39.46	15.17	39.46
8	<i>Mononchids</i>	15	12	80.00	13.79	21.5	8.27	19.23
9	<i>Rhabditids</i>	15	12	80.00	13.79	13.16	5.06	11.77
				580.00	100.00	260.13	100.00	

*Rotylenchulus reniformis* (40.79) and *Dorylaimids* (39.46). But *Aphelenchus avenae* was found to be the least prominent species (3.61).

#### 4.3.6. Mango

Perusal of data in table-15 reflected highest frequency of occurrence (15) with Absolute frequency (100%) and Relative frequency (15.79%) in case of *Dorylaimids* followed by *Rotylenchulus reniformis*, *Mononchids*, *Rhabditids* each have equal frequency of occurrence (13) with Absolute frequency (86.67%) and Relative frequency (13.68%). But *Aphelenchus avenae* were found to have lowest frequency of occurrence (4) with Absolute frequency (26.67%) and relative frequency (4.21%). In context to density of nematode, *Rotylenchulus reniformis* exhibited the highest Absolute density (291.07) and Relative density (48.49%) followed by in descending orders in case of *Tylenchorhynchus mashhoodi* having Absolute density (110.44) and Relative density (18.4%) and *Dorylaimids* having Absolute density (66.6) & Relative density (11.10%). The lowest Absolute density (7.5) and Relative density (1.25%) was recorded in *Aphelenchus avenae*. With regard to Prominence value of nematodes, the most prominent species happened to be *Rotylenchulus reniformis* (270.97) followed by *Tylenchorhynchus mashhoodi* (85.55), *Dorylaimids* (66.6) and *Hoplolaimus indicus* (13.66). However, *Aphelenchus avenae* was found to be the least prominent nematode (3.87).

#### 4.3.7. Papaya

It was quite apparent from table-16 that *Rotylenchulus reniformis*, *Dorylaimids* and *Rhabditids* possessed equal frequency of occurrence (15) with Absolute frequency (100%) and Relative frequency (16.66%) followed by *Mononchids* having frequency of occurrence (13) with Absolute frequency (86.67%) and Relative frequency (14.44%). But *Caloosia hetrocephala*, *Tylenchorhynchus mashhoodi* and *Xiphinema insigne* equally registered the lowest frequency of occurrence (4) with Absolute frequency (26.67%) and Relative frequency (4.44%). In context to the density of nematodes, *Rotylenchulus reniformis* was found to have the highest Absolute density (340) and Relative density (52.82%) followed by *Helicotylenchus dihystra* showing Absolute density (112.22%) and Relative density (17.43%). The lowest Absolute density (8) and Relative density (1.24%) was recorded in *Xiphinema insigne*. While considering Prominence value of nematodes in papaya, it

was appeared that *Rotylenchulus reniformis* happened to be the most prominent species (340.0) followed by in descending order in case of *Helicotylenchus dihystra* (86.93), *Dorylaimids* (35.86) and *Hoplolaimus indicus*(33.23). However, *Xiphinema insigne* was considered the least prominent species having prominence value (4.13).

#### 4.3.8. Sapota

While observing the data on table-17, it was found that there was highest frequency of occurrence (15) with Absolute frequency (100%) and Relative frequency (20%) reported in case of *Dorylaimids* followed by the succeeding nematodes in descending order as *Rhabditids* with frequency of occurrence (14), Absolute frequency (93.33%), Relative frequency (18.67%) and *Tylenchorhynchus mashhoodi* having frequency of occurrence (10), Absolute frequency (66.67%) and Relative frequency (13.33%). The lowest frequency of occurrence (3), Absolute frequency (20%) and Relative frequency (4%) was recorded in case of *Aphelenchus avenae*. In consideration to density of nematodes, *Hoplolaimus indicus* was found to have highest Absolute density (59.14) and Relative density (24.94%) followed by *Dorylaimids* with Absolute density (54) and Relative density (20.77%). But *Aphelenchus avenae* exhibited the lowest Absolute density (1.69). With regards to prominence value of nematodes, *Dorylaimids* was considered the most prominent nematode having the prominence value of (54) followed by *Hoplolaimus indicus* (40.4), *Mononchids* (34.22). However, the least prominent species was reported in case of *Aphelenchus avenae*(1.79).

Table no.15 Community analysis of nematodes associated with mango

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	15	4	26.67	4.21	7.5	1.25	3.87
2	<i>Caloosia heterocephala</i>	15	5	33.33	5.26	11.6	1.93	6.70
3	<i>Hemicriconemoides mangiferae</i>	15	7	46.67	7.37	20	3.33	13.66
4	<i>Hoplolaimus indicus</i>	15	11	73.33	11.58	37.09	6.18	31.76
5	<i>Rotylenchulus reniformis</i>	15	13	86.67	13.68	291.07	48.49	270.97
6	<i>Tylenchorhynchus mashhoodi</i>	15	9	60.00	9.47	110.44	18.40	85.55
7	<i>Xiphinema insigne</i>	15	5	33.33	5.26	13.2	2.20	7.62
8	<i>Dorylaimids</i>	15	15	100.00	15.79	66.6	11.10	66.60
9	<i>Mononchids</i>	15	13	86.67	13.68	31.23	5.20	29.07
10	<i>Rhabditids</i>	15	13	86.67	13.68	11.53	1.92	10.73
				633.33	100.00	600.26	100.00	

Table no.16 Community analysis of nematodes associated with papaya

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Caloosia</i>	15	4	26.67	4.44	33	5.13	17.04
2	<i>Helicotylenchus dihystrera</i>	15	9	60.00	10.00	112.22	17.43	86.93
3	<i>Hemicriconemoides mangiferae</i>	15	3	20.00	3.33	10	1.55	4.47
4	<i>Hoplolaimus indicus</i>	15	8	53.33	8.89	45.5	7.07	33.23
5	<i>Rotylenchulus reniformis</i>	15	15	100.00	16.67	340	52.82	340.00
6	<i>Tylenchorhynchus</i>	15	4	26.67	4.44	15	2.33	7.75
7	<i>Xiphinema</i>	15	4	26.67	4.44	8	1.24	4.13
8	<i>Dorylaimids</i>	15	15	100.00	16.67	35.86	5.57	35.86
9	<i>Mononchids</i>	15	13	86.67	14.44	17.07	2.65	15.89
10	<i>Rhabditids</i>	15	15	100.00	16.67	27.06	4.20	27.06
				600.00	100.00	643.71	100.00	

**Table no.17 Community analysis of nematodes associated with sapota**

SL.NO	NEMATODE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	15	3	20	4	4	1.69	1.79
2	<i>Caloosia</i>	15	5	33.33	6.67	10	4.22	5.77
3	<i>Hemicriconemoides</i>	15	4	26.67	5.33	5	2.11	2.58
4	<i>Hoplolaimus indicus</i>	15	7	46.67	9.33	59.14	24.94	40.40
5	<i>Pratylenchus</i>	15	5	33.33	6.67	7.2	3.04	4.16
6	<i>Rotylenchulus</i>	15	5	33.33	6.67	18	7.59	10.39
7	<i>Tylenchorhynchus</i>	15	10	66.67	13.33	20.8	8.77	16.98
8	<i>Dorylaimids</i>	15	15	100	20	54	22.77	54.00
9	<i>Mononchids</i>	15	14	93.33	18.67	35.42	14.94	34.22
10	<i>Rhabditids</i>	15	7	46.67	9.33	23.57	9.94	16.10
				500.00	100	237.13	100.00	

#### 4.4 Community structure of nematodes associated with fruit crops as a whole

Analysis of data of entire nematode community associated with fruit crops as a whole with the record of pooled data on table-18 revealed that free living nematodes exhibited comparatively higher frequency of occurrence, Absolute frequency and Relative frequency than parasitic nematodes with the record of highest frequency of occurrence (118), Absolute frequency (98.33%) and Relative frequency (17.15%) in case of *Dorylaimids* followed by *Rhabditids* and *Mononchids* in descending order as frequency of occurrence (101 & 100), Absolute frequency (84.17%, 83.33%) and Relative frequency (14.68% & 14.53%) respectively. But among plant parasitic nematodes, *Rotylenchulus reniformis* exhibited highest frequency of occurrence (87) with Absolute frequency (72.5%) and Relative frequency (12.65%) followed by the succeeding nematodes in descending orders as *Hoplolaimus indicus* having frequency of occurrence (68), Absolute frequency (56.67%), Relative frequency (9.88%) and *Tylenchorhynchus mashhoodi* with the frequency of occurrence (62), Absolute frequency (51.67%) and Relative frequency (9.01%). But the lowest frequency of occurrence (5), Absolute frequency (4.17%) and Relative frequency (0.73%) was reported in case of *Melodogyne sp.* associated with guava crop only. In context to density of nematodes, *Rotylenchulus reniformis* registered the highest Absolute density (182.22) and Relative density (31.27%) followed by *Tylenchorhynchus mashhoodi* with Absolute density (84.48), Relative density (14.5%) and *Dorylaimids* with Absolute density (61.52) and Relative density (10.56%). The least Absolute density (7.54) and Relative density (1.29%) was reported in *Aphelenchus avenae*. In consideration to Prominence value of nematodes, *Rotylenchulus reniformis* was adjudged as the most promising species having Prominence value (155.15) followed by *Dorylaimids* (61.01), *Tylenchorhynchus mashhoodi*(60.72) and *Hoplolaimus indicus* (27.60). But *Aphelenchus avenae* was treated as the least prominent species having prominence value (3.23).

Table -18 Community analysis of nematodes with fruit crops in Bhubaneswar

SL.NO	NEMATOPDE SPECIES	TOTAL NO.OF SAMPLES COLLECTED	NO.OF SAMPLES CONTAINING THE SPECIES	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY	ABSOLUTE DENSITY	RELATIVE DENSITY	PROMINANCE VALUE
1	<i>Aphelenchus avenae</i>	120	22	18.33	3.20	7.54	1.29	3.23
2	<i>Caloosia heterocephala</i>	120	21	17.50	3.05	16.09	2.76	6.73
3	<i>Helicotylenchus dihystra</i>	120	29	24.17	4.22	49.31	8.46	24.24
4	<i>Hemicriconemoides mangiferae</i>	120	32	26.67	4.65	25.75	4.42	13.30
5	<i>Hoplolaimus indicus</i>	120	68	56.67	9.88	36.66	6.29	27.60
6	<i>Meloidogyne spp.</i>	120	5	4.17	0.73	40.4	6.93	8.25
7	<i>Pratylenchus coffeae</i>	120	18	15.00	2.62	11.11	1.91	4.30
8	<i>Rotylenchulus reniformis</i>	120	87	72.50	12.65	182.22	31.27	155.15
9	<i>Tylenchorhynchus mashhoodi</i>	120	62	51.67	9.01	84.48	14.50	60.72
10	<i>Xiphinema insigne</i>	120	25	20.83	3.63	14.48	2.48	6.61
11	<i>Dorylaimids</i>	120	118	98.33	17.15	61.52	10.56	61.01
12	<i>Mononchids</i>	120	100	83.33	14.53	26.88	4.61	24.54
13	<i>Rhabditids</i>	120	101	84.17	14.68	26.28	4.51	24.11
				573.33	100.00	582.72	100.00	

## **CHAPTER-5**

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### **DISCUSSION**

## DISCUSSION

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Our country attains second highest share in the world production of fruits next to China. Different variety of fruits grown in various states of the country are harvested at different times, so that round the year different variety of fruits are available in the market and there is great scope for export of surplus produce to abroad earning huge foreign exchange. Though fruit crops are one of the profitable enterprises, yet the production of various fruits are very low because of non availability of quality seeds or healthy planting materials, poor nutrient management, inadequate care and maintenance, huge post harvest losses and risks of pests and diseases. Among various pests and diseases, the role of plant parasitic nematodes in limiting production and yield of fruit crops cannot be ruled out. Moreover, the changing climate scenario have tremendous impact on natural micro flora and fauna resulting emergence of some minor pests in to alarming proportion as well as extinct of a few major pests. So keeping in view the prospects of commercial fruit crops on one side and effect of nematodes in decreasing the quality production of fruit crops on the other side, it was imperative to select out the thesis topic entitled “Association of nematodes with fruit crops in Bhubaneswar” with the objectives to locate prevalence of various nematode genera with estimation of their population in the rhizosphere of fruit crops and also to compute community analysis of various nematodes associated with 8 fruit crops in Bhubaneswar.

Results on survey of nematodes in Bhubaneswar collecting 120 samples from the rhizosphere of 8 fruit crops during Kharif and Rabi 2016-17 revealed the presence of 10 plant parasitic nematodes and 3 groups of free living nematodes. Among plant parasitic nematodes, *Aphelenchus avenae*, *Caloosia heterocephala*, *Hemicriconemoides mangiferae*, *Hoplolaimus indicus*, *Helicotylenchus dihystra*, *Meloidogyne sp.*, *Pratylenchus coffeae*, *Rotylenchulus reniformis*, *Tylenchorhynchus mashhoodi*, *Xiphinema insigne* as well as free living nematodes- *Dorylaimids*, *Mononchids* and *Rhabditids* were encountered.

As regards to cashewnut, *Aphelenchus avenae*, *Hoplolaimus indicus*, *Rotylenchulus reniformis*, *Tylenchorhynchus mashhoodi* as plant parasitic nematodes and *Dorylaimids*, *Mononchids* and *Rhabditids* as free living nematodes were reported. Among them, *Dorylaimids* was the most prominent species followed by *Rhabditids*

and *Tylenchorhynchus mashhoodi*. But Orisajo (2012) while surveying seven locations in North Central Nigeria found ten plant parasitic nematodes where *Meloidogyne sp.*, *Helicotylenchus coffeae* and *Radopholus sp.* were wide spread in all locations and *Rotylenchulus reniformis* in three locations. But *Rotylenchulus reniformis* in cashew nut as per the current result was found in nine locations. The variation might be due to various edaphic factors.

So far as association of nematodes in guava was concerned, guava was the only fruit crop where all ten plant parasitic and three free living *Dorylaimids*, *Mononchids* and *Rhabditids* were reported. This corroborates the findings of Khan *et al.* 2007 who also reported ten plant parasitic nematodes. Moreover, *Rotylenchulus reniformis* was adjudged as the most prominent species (PV=181.23) followed by *Dorylaimids* (41.46) and *Meloidogyne sp.* (23.44). But the present results contradicts to Ansari and Khan (2012) who made extensive survey of plant parasitic nematodes in 14 localities of Aligarh and found *Meloidogyne sp.* as the most prominent species followed by *Hoplolaimus sp.* Climate of Aligarh and the variety of guava different from the Odisha climate and the variety of guava might have contributed variation in prominence of different plant parasitic nematodes.

In consideration to the study of nematodes in jackfruit, five plant parasitic nematodes and three free living groups altogether 8 genera were reported. This finding is in agreement with Mukherjee *et al.* 2001 reporting the same 8 genera in jackfruit, but they have not studied the community analysis. So the present result on community analysis revealed that *Tylenchorhynchus mashhoodi* exhibited highest Absolute density (251) and was considered the most prominent species (PV=224.5), the least being recorded in case of *Rhabditids*.

With respect to nematode diversity in lime, seven plant parasitic nematodes and 3 groups free living nematodes altogether ten genera were recorded. This is in consonance with the results of Vyas *et al.* 2008, who also surveyed lime crop reporting 8 genera of nematodes. Moreover the present result depicted that *Rotylenchulus reniformis* was found to have highest Absolute density (246.57) and was treated the most prominent species (238.21), the least nematode species being recorded as *Xiphinema insigne* (3.61). The present report contradicts the results of Ganguly (1988) who found high density of *Xiphinema basiri* and moderate population of

*Rotylenchulus reniformis*. This might have resulted because *Rotylenchulus reniformis* is more adapted than *Xiphinema* in Odisha, but in Northern state *Xiphinema* might be more adopted compared to *R. reniformis*.

In context to litchi crop, it was evident that six plant parasitic and 3 free living group nematodes were associated with litchi where *Hemicriconemoides mangiferae* was the most prominent species (PV=41.97) followed by *Rotylenchulus reniformis* (40.79). This result is in agreement with the findings of Mc Sorley (1992), Nath *et al.* (2008) and Daneel (2017).

While studying the association of nematodes in mango, it was noticed that 7 plant parasitic and 3 free living nematodes were associated with mango. *Rotylenchulus reniformis* recorded the maximum Absolute density (291.07) and was adjudged as the most prominent nematode (PV=270.97) followed by *Tylenchorhynchus mashhoodi* (85.55). David *et al.* 1990 and Anwar *et al.* 2017 also reported very high population of *Rotylenchulus reniformis* and *Hemicriconemoides mangiferae* in mango crop.

In context to association of nematodes in papaya, it was observed that seven plant parasitic and 3 groups of free living nematodes were found in the rhizosphere of papaya. *Rotylenchulus reniformis* obtained 100% Absolute frequency, highest density (340) considering this species as the most prominent nematode (PV=340) followed by *Helicotylenchus dihystra* (PV=86.93), the least prominent nematode being *Xiphinema insigne* (PV=4.13), *Rotylenchulus reniformis* as the most prominent species was also reported by Mc Sorley (1992), Castillo and Barcina (1993), Ganguly *et al.* (1995) and Sayeed *et al.* (2008).

Nematodes associated with the rhizosphere of sapota indicated that seven plant parasitic and three groups of free living nematodes were associated with sapota. Free living *Dorylaimids* happened to be the most prominent species (PV=54) followed by *Hoplolaimus indicus* (PV=40.4). *Aphelenchus avenae* was found the least nematode species (1.79). Since there was no reference available, so report of nematodes associated with sapota is the new record.

Community analysis of nematodes in 120 soil samples collected from the rhizosphere of 8 fruit crops as a whole indicated that *Dorylaimids* registered the

highest Absolute frequency (98.33%), but *Rotylenchulus reniformis* yielded highest Absolute density (180.22), with the lowest density recorded in *Aphelenchus avenae* (7.54). So far as the Prominence value was concerned, *Rotylenchulus reniformis* was adjudged as the most prominent nematode (PV=155.15) followed by in descending order as *Dorylaimids* (PV=61.01), *Tylenchorhynchus mashhoodi* (60.72) and *Hoplolaimus indicus* (27.60). The least nematode species recorded was *Aphelenchus avenae* (PV=3.23). This study of community analysis is also found a new record reporting plant parasitic and free living nematodes in 8 fruit crops.

However, this preliminary investigation provides a wealth of information pertaining to endo parasitic nematode, *Meloidogyne sp.* reported only in guava and semi endo parasitic nematodes *Rotylenchulus reniformis* in all 8 fruit crops in order to undergo further study on host parasitic relationship to explore the pathogenicity. Moreover, *Meloidogyne sp.* recorded in Guava needs further investigation to identify the correct species.

## **CHAPTER-6**

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### **SUMMARY & CONCLUSION**

## SUMMARY AND CONCLUSION

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Investigation on diversity of nematodes associated with 8 fruit crops was carried out in Bhubaneswar by collecting 120 soil samples from the rhizosphere of fruit crops during Kharif and Rabi, 2016-17. Volumetrically measured 200cc soil was processed for each sample by Cobb's Sieving and decanting technique followed by Modified Baermann technique to obtain clear nematode suspension. Killing and fixing of nematodes was immediately done for each sample in order to wet preserve the nematodes as well as to examine the fixed specimens for counting nematodes in order to assess the density of nematode populations. Simultaneously, processing of fixed nematode specimens in Seinhorst's solution and permanent mounting of nematodes on slide was performed for easy identification for various plant parasitic and free living nematodes associated fruit crops such as cashewnut, guava, jackfruit, lime, litchi, mango, papaya and sapota. Upon examination of various nematodes in 120 soil samples, it was ascertained that ten plant parasitic nematodes and three groups of free living nematodes were associated with 8 fruit crops. Among plant parasitic nematodes, *Rotylenchulus reniformis* and *Hoplolaimus indicus* were found associated with all 8 fruit crops. *Tylenchorhynchus mashhoodi* was encountered with all fruit crops except lime. *Meloidogyne sp.* was only recorded in guava, while *Pratylenchus coffeae* was in guava, lime and sapota. Barring cashewnut and jackfruit, *Hemicriconemoides mangiferae* was reported in other six fruit crops. *Xiphinema insigne* was associated with five fruit crops except cashewnut, litchi and sapota. Similarly *Helicotylenchus dihystra*, *Caloosia heterocephala* and *Aphelenchus avenae* were each associated with five fruit crops except in order of cashewnut, mango, sapota; cashewnut, jackfruit, litchi and jackfruit, lime, papaya. In context to free living nematode groups such as *Dorylaimids*, *Mononchids* and *Rhabditids* were each encountered with 8 fruit crops. Guava is the only fruit crop found associated all 10 plant parasitic and 3 free living nematodes.

Community analysis of nematodes in individual fruit crops studied revealed that *Rotylenchulus reniformis*, *Rhabditids* and *Dorylaimids* exhibited highest frequency of occurrence (15) and 100% Absolute frequency in papaya. *Hoplolaimus indicus* and *Dorylaimids* were each having maximum frequency of occurrence (15) and Absolute frequency (100%) in jackfruit. Similarly *Rhabditids* in lime and

*Dorylaimids* in guava, litchi, lime, mango and sapota registered highest frequency of occurrence (15) and Absolute density (100%). *Dorylaimids*, *Rhabditids* and *Mononchids* showed highest frequency of occurrence (13) with 86.67% Absolute frequency in cashewnut. In contrast, *Aphelenchus avenae* in cashewnut, litchi, mango, sapota, *Hemicriconemoides mangiferae* in guava, *Helicotylenchus dihystra* in jackfruit. *Tylenchorhynchus mashhoodi* in papaya, *Caloosia heterocephala* in lime, papaya and *Xiphinema insigne* in papaya exhibited the lowest frequency of occurrence as well as Absolute frequency.

With respect to density of nematodes in fruit crops, highest Absolute density of *Rotylenchulus reniformis* in guava (211.63), litchi (52.66), lime (246.57), mango (291.07), papaya (340); *Tylenchorhynchus mashhoodi* in jackfruit (251); *Hoplolaimus indicus* in sapota (59.14) and *Dorylaimids* in cashewnut (33.58) were recorded. But *Aphelenchus avenae* in cashewnut, litchi, mango and sapota; *Hemicriconemoides mangiferae* in guava; *Caloosia heterocephala* in lime and papaya and *Rhabditids* in jackfruit indicated the lowest Absolute and Relative density.

In consideration to Prominence value of nematodes in 8 fruit crops, maximum Prominence value of *Rotylenchulus reniformis* in guava (181.23), lime (238.21), mango (270.97), papaya (340); *Tylenchorhynchus mashhoodi* in jackfruit (224.5); *Hemicriconemoides mangiferae* in litchi (41.97) and *Dorylaimids* in cashewnut (85.93) and sapota (54) were reported. In contrast, lowest Prominence value of *Hemicriconemoides mangiferae* in guava; *Xiphinema insigne* in lime and papaya; *Rhabditids* in jackfruit; *Aphelenchus avenae* in cashewnut, litchi, mango, sapota were recorded. So far as the Community analysis of nematodes in 120 samples of 8 fruit crops as a whole was concerned, *Dorylaimids* exhibited highest frequency of occurrence (118) with 98.33% Absolute density, the lowest being in *Meloidogyne* sp.(5). Maximum density was noticed in *Rotylenchulus reniformis* (182.22) with the lowest density in *Aphelenchus avenae* (7.54). Similarly highest Prominence value was recorded in *Rotylenchulus reniformis*(155.15) with the lowest Prominence value (3.23) in *Aphelenchus avenae*.

So *Rotylenchulus reniformis* was adjudged as the most prominent species in guava, lime, mango and papaya; *Tylenchorhynchus mashhoodi* in jackfruit; *Hemicriconemoides mangiferae* in litchi and *Dorylaimids* in sapota and cashewnut ,

while *Rotylenchulus reniformis* was considered as the most prominent species as a whole in all 8 fruit crops. Similarly least prominent species was recorded as *Hemicriconemoides mangiferae* in guava; *Xiphinema insigne* in lime and papaya; *Aphelenchus avenae* in cashewnut, litchi, mango, sapota and in jackfruit but, all together in 8 fruit crops. *Aphelenchus avenae* was considered as the least prominent species.

Th-4996