Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir

DANISH MUSHTAQ
(2017-H-146-M)

Division of Entomology

Faculty of Horticulture

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

2020

Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir

DANISH MUSHTAQ
(2017-H-146-M)

Thesis
Submitted to

The Faculty of Horticulture

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir in partial fulfilment of requirement for the award of the degree of

Master of Science in Horticulture
(Entomology)
2020

TO…

My Beloved Parents, Family, friends and advisor for their love, endless support, encouragement & sacrifices,

Especially my brother who sacrificed his studies for my studies.

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Entomology Shalimar-192101

Certificate – I

This is to certify that the thesis entitled **"Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Entomology),** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Danish Mushtaq (Regd. No. 2017-H-146-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

Dr. Gh. Mohd. Lone
Chairman
Advisory committee

Endorsed

Head
Division of Entomology

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Entomology Shalimar-192101

Certificate– II

We, the members of the Advisory Committee of **Mr. Danish Mushtaq (Regd. No. 2017-H-146-M)**, a candidate for the degree of **Master of Science in Horticulture (Entomology)** have gone through the manuscript of the thesis entitled, **"Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. Gh. Mohd. Lone
Professor & Head, Division of Entomology,
Shalimar SKUAST-K

Members

Dr. F. A Zaki
Ex. Professor & Dean, FoH, Shalimar
SKUAST-K

Dr. Wali Mohd. Wani
Ex. Professor & Head, Division of Fruit
Science, Shalimar, SKUAST-K

Dr. Ali Anwar
Professor & Head, Division of Plant
Pathology, Shalimar,
SKUAST-K

Dr. Shakeel Ahmad Mir
Professor & Head, Division of Agri-statistics,
Shalimar, SKUAST-K

Dean's Nominee

Dr. Z. A Qadri
Ex. Professor, Division of FLA, Shalimar
SKUAST-K

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Entomology Shalimar-192101

Certificate – III

This is to certify that the thesis entitled, **"Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir"** submitted by **Mr. Danish Mushtaq (Regd. No. 2017-H-146-M)** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Entomology)** was examined and approved by the Advisory Committee and External Examiner on …….....

Chairman
Advisory Committee

External Examiner

Prof. & Head,
Division of Entomology

Dean,
Faculty of Horticulture, Shalimar
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Entomology, Faculty of Horticulture, Shalimar,
Srinagar- 192101

Name of the student : **Danish Mushtaq**

Registration No. : 2017-H-146-M

Major Subject : Entomology

Minor Subject : Plant Pathology / Fruit Science

Major Advisor : **Dr. Gh. Mohd. Lone**
Professor & Head
Division of Entomology
SKUAST-K, Shalimar

Title of the Thesis : **"Diversity of plant parasitic nematodes in high density apple plantation of Kashmir"**

ABSTRACT

The present investigation was carried out in Nematology Laboratory at Division of Entomology Faculty of Horticulture SKUAST-K, Shalimar during 2019 entitled "**Diversity of plant parasitic nematodes in high density apple plantation of Kashmir"**. Plant parasitic nematodes form an important component of soil ecosystem and present study revealed nine plant parasitic nematodes *viz., Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insigne, X. index, X. americanum, Longidorus elongatus and Hoplolaimus* sp., were found harbouring the rhizosphere of high density apple orchards in three districts (*viz;* Baramulla, Anantnag and Srinagar) of Kashmir valley. In all these three districts, most frequently occurring nematodes were *Helicotylenchus* sp*.,* (100%) *Pratylenchus* sp., (100%) and *Tylenchus* sp., (95.05 %) followed by *Tylenchorhynchus* sp., (91.34 %), *Xiphinema insigne* (86.41%), *X. index* (82.70%), *X. americanum* (81.47%)*, Hoplolaimus* sp., (74.06%) and *Longidorus elongatus* (72.83%). Highest population of *Helicotylenchus* sp., (120/250 cc soil), *Pratylenchus* sp., (100/250 cc soil) followed by *Tylenchus* sp., (75/250 cc soil) were recorded while it remained minimum for the *Hoplolaimus*

sp., (4/250 cc soil in district Baramulla). Among the above mentioned plant parasitic nematodes, *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchus* sp., ranked as 1st , 2nd and 3rd with average population range as 54.92-75.76**,** 33.73-53.79 and 21.29-41.85 per 250 cc soil at 95 per cent confidence interval and simultaneously their importance value in different districts were found as 16.78, 12.92 and 10.22 respectively. The absolute density of 56.20, 52.89 and 26.43 was found highest for *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchus* sp., with total biomass of 68.72, 67.53 and 42.52 for *X. index, Longidorus elongatus* and *Xiphinema insigne* respectively. Thus, it was revealed that *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., and *Tylenchorhynchus* sp., were the most frequent and dominant species associated with the rhizosphere of high density apple orchards of (*viz;* Baramulla, Anantnag and Srinagar) of Kashmir valley. The high population of these plant parasitic nematodes were encountered around the rhizosphere of high density apple plants and can be considered as a contributing factor in declining health of these apple plants and lowering the yield of apple in Kashmir valley. Besides, some plant parasitic nematodes *viz*; *Xiphinema* and *Longiodorus* act as vectors for transmission of virus in apple trees, thus needs future study.

Keywords: Absolute densities, Apple orchards, Kashmir valley, Plant Parasitic Nematodes, Rhizosphere.

Signature of student

Dated: _____

Signature of Major Advisor

Dated: _____

ACKNOWLEDGEMENT

"IN THE NAME OF ALMIGHTY, "ALLAH", THE MOST BENEFICENT AND MERCIFUL, PEACE AND BLESSINGS BE UPON HOLY PROPHET (SAW). I BOW IN REVERENCE TO ALMIGH TY FOR GIVING ME ENOUGH COURAGE, PATIENCE AND SUCCESS IN THIS VENTURE"

Research is an evolving concept. Any endeavour in this regard is challenging as well as exhilarating. It implies the testing of our nerves. It brings light to our patience, vigour and dedication. It needs the close cooperation and guidance of experts in the field to achieve something worthwile and substantial.

It is indeed a good honour and pleasure for me to express my deep sense of gratitude and indebtness to my major Advisor, Dr. Gh. Mohd. Lone (Professor & Head, Division of Entomology). His soft and sober attitude, inspiring guidance, whole hearted encouragement, facile suggestions and constructive criticism with a calm exposure, led this uphill task to its successful completion and shall remain a lifelong gifted memory for me.

I am highly grateful for constant and painstaking guidance, encouragement, suggestions and sustained efforts of the other members of my advisory committee viz., Dr. F.A.Zaki (Ex-Dean, FoH, SKUAST-K, Shalimar), Dr. Wali Mohd. Wani (Ex-Professor & Head, Division of Fruit Science, FoH, SKUAST-K, Shalimar), Dr. Shakeel Ahmad Mir (Professor & Head, Division of Agri-Statistics, SKUAST-K,, Shalimar), Dr. Ali Anwar (Professor & Head, Division of Plant Pathology, SKUAST-K,, Shalimar) and Dr. Z. A Qadri (Ex-Professor, Division of FLA, SKUAST-K, Shalimar).

It is a huge opportunity to offer my sincere thanks to Dr. Jamal (Professor, Division of Entomology, FOH, Shalimar, SKUAST-K), Dr. S.S. Pathania (Assistant Professor, Division of Entomology, FOH, Shalimar, SKUAST-K), Dr. A. A. Khan (Professor, Division of Entomology, FOH, Shalimar, SKUAST-K), Dr. Muneer Ahmed sofi (Assistant Professor, Division of Entomology, FoH, Shalimar, SKUAST-K), Dr. Abu Manzar (Associate Professor, Division of Entomology, FoH, Shalimar, SKUAST-K), Dr. Asma Sherwani (Assistant Professor Division of Entomology, FoH, Shalimar, SKUAST-K), Dr. Barkat (Associate professor, Division of Entomology, FoH, Shalimar, SKUAST-K), Dr. Sajad ahmed (Assistant Professor, Division of Entomology, FOH, Shalimar, SKUAST-K), Dr. Tauseef Ahmad Bhat (Assistant prof. Division of Agronomy, FoA, Wadura, SKUAST-K) and Dr. Fehim Jeelani

(Assistant Prof. Division of Statistics, FoA, Wadura, SKUAST-K) for their timely support, encouragement, suggestions, positive criticism, affection and morale uplift.

With utmost gratitude, I would like to place on record the help extended by the staff members of Division of Entomology, FOH Shalimar namely Mr. Naseer

ahmad, Mr.Bilal ahmed, Mr. Sajad ahmed, Mr. Reyaz ahmed, Mr. Arjumand, Mohd.Ayoub, Mr. Ghulam Rasool, Mohd Hafeez, Mr. Zahoor, Mr. Waseem, Mohd. Hussain and Mr. Khursheed.

My special thanks from the core of my heart to my seniors , Aejaz ahmed, Shahid Qayoom, Waheed- ul- Rehman, Irfan Gani, Tawseef ahmad baba,Owais Ahmed Khan, Suhail Fayaz, Naqeeb Raja, Shakeel Bhat, Syed Mazahir, Reyaz bhat and Juniors namely Aadil, Babar, Owais, Huzaifa, Azhaan, Asim, Nawaz, Zakir Amin.

Sincere thanks are due to Wajid Ashraf, Junaid Hussain Buchh, Aadil Gul, Ghulam Jeelani, Majid Rashid, Shayan showket, Tajamul Malik, Tajamul wani, Lateef ahmed, Zubair, Javaid, Ishfaq Ayoub, Mohd. Asif, Gulzar bhat, Hazik Shabir, Wasim Yousuf, Jasra, Insha, Batool, Wardah, Nelofar, Danishta and Masroora.

I also take this opportunity to express my gratitude to my parents, Abu and Ammi who put me above their own selves and taught me how to work hard by working hard themselves, my siblings, my brothers Mr. Khalid Mushtaq, Farhat Wani, Mohsin, Muheet and Sisters Adfar, Sadaf, Fozia, Anam whose love and affection for me surpassed all worldly definitions and made me feel at zenith of existence and my grandfather and grandmother who have always prayed for my safety and prosperity. My deep sense of gratitude to my better half Nawreen Mir for her continous support during my research work. May Allah protect you all.

Special thanks from the core of my heart goes to ARIS, Shalimar and Library staff members of SKUAST- K Shalimar for their timely guidance, support and encouragement.

Danish Mushtaq

Place: Shalimar
Dated:

CONTENTS

Chapter	Particular	Page No.
1	INTRODUCTION	1-3
2	REVIEW OF LITERATURE	4-17
	2.1 Identification/incidence	4
	2.2 Community analysis	10
3	MATERIALS AND METHODS	18-21
	3.1 Survey	18
	3.2 Collection of soil cum root sample	19
	3.3 Processing of the soil samples	19
	3.4 Killing and fixing of nematodes	19
	3.5 Staining of nematodes	19
	3.6 Identification of nematodes	20
	3.7 Counting of nematode population	20
	3.8 Photo micrograph of nematodes	20
	3.9 Statistical analysis	20
	3.10 Nematode diversity	21

4	EXPERIMENTAL FINDINGS		22-73
	4.1	Identification of plant parasitic nematodes in high density apple plantation of Kashmir	22
	4.2	Community analysis of predominant plant parasitic nematodes in high density apple plantation of Kashmir	26
5	DISCUSSION		74-77
6	SUMMARY AND CONCLUSION		78-80
	LITERATURE CITED		i-xi

LIST OF TABLES

Table No.	Particulars	Page No.
1.	Diversity of plant parasitic nematodes associated with high density apple orchards in village Ladoora (District Baramulla)	32
1.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Ladoora (District Baramulla).	33
2.	Diversity of plant parasitic nematodes associated with high density apple orchards in village Zangam (District Baramulla).	34
2.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Zangam (District Baramulla).	35
3.	Diversity of plant parasitic nematodes associated with high density apple orchards in village Arampora (District Baramulla)	36
3.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Arampora (District Baramulla).	37
4.	Diversity and population of plant parasitic nematodes associated with high density apple orchards in District Baramulla during the year 2019.	38
5.	Status and distribution of plant parasitic nematodes assosciated with different rootstocks of high density apple orchards in district Baramulla of Kashmir valley	39
6.	Diversity of plant parasitic nematodes associated with high density apple orchards in village Gopalpora (District Anantnag)	45

6.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Gopalpora (District Anantnag)	46
7	Diversity of plant parasitic nematodes associated with high density apple orchards in village Achabal (District Anantnag)	47
7.a	Community population of plant parasitic nematodes associated with high density apple orchards inAchabal (District Anantnag)	48
8	Diversity of plant parasitic nematodes associated with high density apple orchards in village Kokernag(District Anantnag)	49
8.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Kokernag (District Anantnag)	50
9.	Diversity and community population of plant parasitic nematodes associated with high density apple orchards in District Anantnag	51
10.	Status and distribution of plant parasitic nematodes assosciated with different rootstocks of high density apple orchards in district Anantnag of Kashmir valley	52
11.	Diversity of plant parasitic nematodes associated with high density apple orchards in SKUAST-K,Shalimar(District Srinagar)	60
11.a	Community population of plant parasitic nematodes associated with high density apple orchards inSKUAST-K,Shalimar (District Srinagar)	61
12	Diversity of plant parasitic nematodes associated with high density apple orchards in village Habak (District Srinagar)	62
12.a	Community population of plant parasitic nematodes associated with high density apple orchards in village Habak (District Srinagar).	63
13	Diversity of plant parasitic nematodes associated with high density apple orchards in village Zakura (District Srinagar).	64

13.a	Community population of plant parasitic nematodes associated with high density apple orchards in Zakura (District Srinagar).	65
14	Diversity and community structure of plant parasitic nematodes associated with high density apple orchards in District Srinagar.	66
15.	Status and distribution of plant parasitic nematodes assosciated with different rootstocks of high density apple orchards in district Srinagar of Kashmir valley	67
16.	Diversity and community population of plant parasitic nematodes associated with District Baramulla, Anantnag and Srinagar of Kashmir valley	68
17	Nematode measurement (µm) for the estimation of biomass of plant parasitic nematodes in district Baramulla, Anantnag and Srinagar of Kashmir valley	69
18	Diversity and community population including Relative Biomass and Importance value of plant parasitic nematodes associated with District Baramulla, Anantnag and Srinagar of Kashmir valley	70
19	Shannon Weiner density index measures (village wise) based on population abundance in district Baramulla, Anantnag and Srinagar of Kashmir valley	71
20	Shannon Weiner density index measures (District wise) based on population abundance in district Baramulla, Anantnag and Srinagar of Kashmir valley	72
21.	Overall mean population of plant parasitic nematodes in different rootstocks of high density apple orchards associated with district Baramulla, Anantnag and Srinagar of Kashmir valley.	73

LIST OF FIGURES

Fig. No.	Particulars	After page
1.	Population status of plant parasitic nematodes in district Baramulla	31
2.	Population status of plant parasitic nematodes in district Anantnag.	44
3.	Population status of plant parasitic nematodes in district Srinagar	55
4.	population status of plant parasitic nematodes in district Baramulla. Anantnag & Srinagar of Kashmir valley	58
5.	Overall mean population of plant parasitic nematodes in different apple rootstocks associated with district Baramulla. Anantnag & Srinagar of Kashmir valley	59

LIST OF PLATES

Plate No.	Particulars	After page
1.	Soil sampling in high density apple orchards	19
2.	Processes of nematode extractions	19
3	*Tylenchus* sp. Bastian, 1865	25
4	*Tylenchorhynchus* sp.Cobb, 1913	25
5	*Xiphinema index*, Thorne and Allen, 1950	25
6	*Longidorus elongatus,* Micoletzky, 1922	25
7	*Pratylenchus* sp. Filipjev, 1936	25
8	*Helicotylenchus* sp. Steiner, 1945	25
9	*Hoplolaimus* sp. Daday, 1905	25
10	*Xiphinema americanum,* Cobb, 1913	25
11	*Xiphinema insigne* loos, 1949	25

Chapter 1

INTRODUCTION

Apple (*Malus* × *domestica* Borkh.) is one of the most ubiquitous and well-adapted species of temperate fruit crops of the world grown particularly in North-Western Himalayas at an elevation range of 1,500 - 2,700 m above mean sea level.. It is known as the king of temperate fruits and is fourth among the most widely produced fruits in the world after banana, orange and grapes. Globally apple is grown in an area of area of 52 million hectares with an annual production of 89.3 metric tonnes (Anonymous, 2016a). In India, it is predominantly grown in Jammu and Kashmir, Himachal Pradesh and in some parts of Uttaranchal, Arunachal Pradesh and Nagaland. In India it is grown over an area of 2.77 lakh hectares with an annual production of 2.52 metric tonnes (Anonymous, 2016b). Nature has bestowed Kashmir valley with agro climatic conditions conducive for apple cultivation and a strong comparative advantage in its production and marketing. The area and production of apple in the Kashmir valley is 1, 46,327 hectares and 18, 51,723 Metric tonnes, respectively. The productivity is far below the average productivity of the developed and other developing countries of the world (Anonymous, 2019c). The fruit industry is the backbone of economy in Jammu and Kashmir State. Hence, it accounts 83% of the area and 60% of the total apple production in the country.

Owing to low productivity of Apple in India as compared to developed countries, various strategies have been framed to increase the productivity of Apple. Recently, in India, the high density planting (HDP) system has being conceived as an alternative production system with an aim to improve the potential of productivity and profitability. HDP technique is a modern method of fruit cultivation that involves planting of fruits trees densely, allowing small or dwarf trees with modified canopy for better light interception, distribution and ease of mechanized field operation. HDP gives higher yield as well as return/ unit

area as there are more number of trees/ unit area. High density plantation of newly established apple cultivars is now a days considered as one of the most economic and important planting systems in Kashmir after traditional plantation. Presently the continuing decline in the availability of cultivable land, rising energy and land costs together with mounting demand for horticultural produce has given thrust to the concept of high density planting (HDP). HDP aims to the combination of dwarfing root stocks and high density planting also provides faster return on investment through the initial costs tend to be somewhat on the higher side (Banday and Sharma, 2010)

Among the several Biotic and Abiotic factors that are responsible for low production of apple, plant parasitic nematodes constitute one of the constraints for reducing the quality and quantity of apple production in the country (Askary *et al.*, 2011).These parasitic nematodes represent a worldwide concern for apple growers due to their variable feeding habits and symptomatology. They are not distributed uniformly and their symptoms are often confused with pathological diseases or physiological distress and as the time advances and disease is recognized, the nematode has already done the damage. Proper attention has not yet been paid in the valley to know the detailed diversified status of plant parasitic nematodes with respect to their distribution, identification and pathological studies. The agro-climatic conditions of Kashmir and its surrounding, unexploited vast area, offers immense scope for development of various horticultural crops**.** In Kashmir, hundreds of hectares are under high density plantation and the area is increasing.

Among the various pests and diseases the information of nematodes parasitizing on apple trees and there debilitating role in fruit yield is scanty (Waliullah and Kaul, 1997).

Plant Nematology in Kashmir has now attained great importance as the persistence of high population buildup of plant parasitic nematodes due to global warming inflicts heavier damage in perennial crops. This can be judged from the

previous reviews of Fotedar and Mahajan (1974), Fotedar and Hando (1975, 1977), Mahajan (1973), Mahajan and Bijral (1973), Waliullah (1992 & 2005), Zaki and Mantoo (2003) and Lone *et al*. (2012a and 2012b). High density Apple plantation is likely to be more prone to the infestation and damage by the plant parasitic nematodes.

Therefore, the present research work was undertaken first time in high density apple orchards of Kashmir valley with an aim to fulfill the following objectives:

- To identify the plant parasitic nematodes associated with high density apple plantations of Kashmir.
- To determine the community analysis of predominant plant parasitic nematodes in high density apple plantation of Kashmir.

Chapter 2

REVIEW OF LITERATURE

2.1 Identification/incidence

Vrain and Rousselle (1980) surveyed apple orchards in southeastern Quebec in 1978, 351 soil samples were collected from 71 orchards in nine counties. Species in eight genera of plant-parasitic nematodes were found. Species of *Pratylenchus, Paratylenchus* and *Xiphinema* were detected most frequently. *Pratylenchus penetrans* or *Pratylenchus crenatus* were found in all 71 orchards, at densities greater than 33/100 cm^3 of soil in 58 per cent of infested samples. *Xiphinema americanum* was found in 88 per cent of the orchards.

Baqri (1999) studied the diversity in plant and soil nematodes of West Bengal .He listed various nematode species in the orders of Tylenchida (67 spp.), Aphelenchida (7 spp), Dorylaimida (81 spp.) and Monochida (15 spp.).

Mukherjee *et al.* (2000) reported high diversion of nematodes in 25-year-old rubber plantations in Tripura when calculated in relation to biomass and also observed a linear increase in the index of diversity (H) with increase in the age of plantations up to certain age group.

Pan *et al.,* (2000) made preliminary assessment of the occurrence of Longidorid and Tricodorid nematodes (Nematoda: Longidoridae and Trichodoridae) in Xiamen, Fujian province, of China. Longidorid nematodes were present in 16 of the 24 soil samples and 2 Trichodorids present in 2 samples. The results obtained provided new observation on the host range and geographical distribution of several of the species.

Rama and Dasgupta (2000) reported association of *X. insigne* with coconut and arecanut in Cooch Bihar and Jalpaiguri and also reported the association of *X.elongatum* with coconut in both the districts of West Bengal.

Ye and Robbins (2004a) identified and described two new parthogenetic species of Longidorus *viz*. *L. grandis* and *L. paralongicaudatus* in the Arkansas on the basis of characterized variations in offset head, guiding ring, odonto style length etc.

Barsi and Lamberti (2004) studied the morphometrics of *L.juvenilis* with brief descriptions, measurements and illustrations of the *L.aethaeus* and *L.moesicus*,which were recorded for the first time from Serbia .

Ye and Robbins (2004b) identified two new amphimictic species of Longidorus in Arkansas. *L.biformis* n.sp. was found in the rhizosphere of hardwood trees along streams in sandy soil in 14 Arkansas locations and the species was characterized by its long body (5.42-9.50 mm), wide expanded flattened head end, head width 20.0 to 26.0 micrometer, odontostyle 96 to 125 micrometer, guide ring 29 to 38 micrometer posterior to the anterior end, elongate conoid tail, and c'= 0.9-2.1 and *L. glycines* n.sp. was found in soyabean microplots at the main Research, Fayetteville, Arkansas and was characterized by its long body (6.14-8.31) wide offset flattened end, head width 20.3 to 23.3 micrometer, odontostyle 87.3 to 99.5 micrometer, guide ring 22.3 to 26.4 micrometer posterior to the anterior end, short conoid tail with rounded terminus , and c'=0.9-1.4.

Andret *et al.* (2004) reported that grapevine Fan Leaf Virus (GFLV) transmitted by *Xiphinema index* is responsible for most severe viral diseases of Grape vines worldwide. It reduces crop yield up to 80 per cent and affects fruit quality.

Chaudhury *et al*. (2004) while studying the diversity of nematodes in four districts of Assam, India during 2002-2003 computed on relative density, relative frequency, biomass, and prominence value and importance value. The association of 32 nematode species as they identified revealed that four belonged to Dorylaimidea and one to Triplonchidae. Based on the importance value among the

dorylaimids, *Xiphinema mammillocaudatum* ranked seventh and Trichodorus ranked 5th among all the nematodes.

Khan and Verma (2005) carried out a survey for assessing the incidence and distribution of Longidorid nematode species in temperate region of Himachal Pradesh especially the high-altitude zone of the state. It was revealed from the survey results that *Xiphinema slansis, Xiphinema inaequale, Xiphinema insigne, Xiphinema basiri*, *Longidorus citri*, *Longidorus brevicaudatus, Longidorus attenuatus, Paralongidorus microlaimus* and *Paralongidorus neoformis* were found in low to high number. Further, *Paralongidorus neoformis* was found in association with *Ficus carica* L. from Kullu.

Kumari *et al*. (2006) recorded *L.intermedius* in the Czech Republic for the first time in the rhizosphere of *Robinia pseudoacacia* at Dolni Bojanovice and *Carpinus betulus,Enonymus europaeus,* and *Quercus* sp. at Strazovice. The morphological and morphometrical and characteristics were also studied.

Roca-Fransisco (2006) collected specimens from various localities in Montenegro and Serbia which were previously described as *P. milanis* and *P. serbicus*, respectively. Both the species were having pore like amphidial apertures under SEM studies but not slit like as in the genus *Paralongidorus* and were therefore transferred to the *Longidorus.* It was further found that *L. serbicus* is morphologically identical to *L.moesicus*, small morphometric differences being attributed to intraspecific variations.

Adekuncle *et al*. (2006) conducted the survey for distribution and abundance of plant parasitic nematodes in fields grown to Lilium in Himachal Pradesh, India at Nagrota, Palampur, Sundernagar and Chail where moderate (101-500/200 cc soil) to high (501-1000/200 cc soil) populations of phytonematodes including the vectors for plant viruses (*Longidorus species* and *Xiphinema diversicaudatum*) were recorded. The highest incidence of virus vector

nematodes viz., *Xiphinema diversicaudatum, Longidorus* spp. and *Trichodorus* spp. were recorded at Palampur.

Tzortzakakis *et al.* (2006) during their survey study for presence of *Xiphinema* species in the viticulture areas of Tyrnavos, Thessally, Greece from existing grapevine fields and other cereal crops or under fallow, it was found that *Xiphinema index*, *Xiphinema italiae* and *Xiphinema pachtaicum* in 37 per cent of the samples with a prevalence of the last two species in uprooted fields. The occurrence of *Xiphinema italiae* in association with light sandy soils was discussed and compared with similar findings from other Greek grapevine areas.

Barsi *et al.* (2007) recorded *Paralongidorus rex* from Hungary for the first time since its description. Morphometrics and photomicrographs of a female and juveniles belonging to four developed stages were given together with short comments on their morphology. The head morphology of *P.maximus* was commented on, based on SEM photomicrographs.

Wasim (2007) recorded a new genus and three new and nine known species of Dorylaimida for the first time from Singapore. *Raffiesius singaporensis* gen. n. sp. n. was characterized by having a continuous lip region with amalgamated lips, labial papillae not protruding above labial *contour; slender, dorylaimoid odontostyle with aperture one third its* length; abrupt pharangial expansion; DO and DN far posterior to beginning of expansion; both pair of subventrals in the posterior third of expanded part; mono-opisthodelphic female genital system, and long filiform tail. *Oriverutus nusi* sp. n. was characterized by having 0.81-0.89µm long, slender body; offset lip region with distinct lips and labial papillae; 119-20µm long, attenuated odontostyle;amphidelphic female genital system, and elongate convoid tail with slightly dorsally bent tip: *Saevadorella microstylla* sp. n. is characterized by having 0.33-0.37µm long body; off lip region; 10.5-11.5µm long attenuated odontostyle; amphidelphic female genital system and short convoid, ventrally arcuate tail. S. parva sp. n. was characterized by having 0.37-0.54µm long body; distinctly offset lip region; 21.5-

22.5µm long attenuated odontostyle; amphidelphic genital system and short convoid, ventrally arcuate tail. *Mesodorylaimus flagellates, M. pusillus, Amphidorylaimus infecundus, Discolaimium clavatum, Labronerma nepalense, Oriverutus sundarus, O. parvus* and *O.asaccatus* were recorded for the first time from Singapore.

The nematodes *Pratylenchus penetrans* and *Helicotylenchus indicus* were found most frequent and dominant species in the entire nematode community associated with the rhizosphere of apple and pear in India (Singh *et al*., 2009).

Abbas and Waliullah (2010) reported occurrence of *X basri* .on gladiolus from three localities namely Chashmashahi, Shalimar and Chandpora of the Kashmir valley.

Sogut and Devran (2011) collected 120 soil and root samples from apple, cherry, pear, quince, apricot, peach and sour cherry plantations in the temperate fruit production region of Turkey. Seventy-eight populations of the root lesion 5 nematode were collected. Distribution ratios of the sampled root lesion nematode populations were 50%, 45%, 2.5% and 2.5% for *Pratylenchus thornei, Pratylenchus neglectus, Pratylenchus penetrans* and *Pratylenchus crenatus*, respectively. The study indicated that P. thornei and P. neglectus were widespread on temperate fruits in the West Mediterranean region of Turkey.

Zalpuri *et al.* (2013) carried out studies based on the survey conducted and assessment made by the frequency of occurrence of economically important plant parasitic nematodes associated with *Citrus* crop. Samples were collected from roots and soil rhizosphere from 10 localities representing 3 districts namely Samba, Kathua and Rajouri for the study of nematodes infestations. The frequency of occurrence and populations varied from place to place which issimply indicative of the fact that the studied area is highly infested with different varieties of nematode species which ultimately affect the *Citrus* plant species of high grade quality of Citrus plantations.

Vaid *et al*. (2014) studied the diversity of soil-inhabiting nematodes in Dera Ki Gali (DKG) forest of Poonch district in Jammu and Kashmir, India and concluded that a total of 43 nematode genera were recorded, with Rhabditida representing the highest percentage (34%), followed by Dorylaimida (20%) and Mononchida (15%). In terms of abundance, Rhabditida was the most dominant group (51%), followed by Dorylaimida (25%), Mononchida (9%), Monhysterida and Enoplida (2%). In terms of trophic groupings, the bacterivore genera representing the highest percentage (48%), followed by predators (20%), omnivores (18%) and plant parasites (11%).

Sigariova and Karpliyk (2015) reported the occurance of *Meloidogyne, Ditylenchus, Pratylenchus, Rotylenchus, Tylenchorynchus, Paratylenchus, Helicot -ylenchus* and *Heterodera* genera on Coleus, Begonia, Dahlia and Asparagus.

Sujata and sharma (2018) carried out an investigation during the year 2015-16. Soil samples were collected from the rhizosphere of the commercial vegetable crops (pea, potato and cabbage) and fruit crops (apple, apricot and almond) of the tribal district Kinnaur in Himachal Pradesh. All the three developmental blocks of the district (Kalpa, Pooh and Nichar) were covered under the study. Four nematodes *viz*., lesion nematode (*Pratylenchus coffeae*), stunt nematode (*Tylenchorhynchus mashhoodi*), spiral nematodes (*Helicotylenchus dihystera*) and juveniles (J2) of root knot nematode (*Meloidogyne* sp.) were found prevalent in the rhizosphere of all the vegetable and fruit crops, with their considerable population build up. Among fruit crops, apple orchards were found harbouring highest population of all the nematodes, followed by apricot and almond, with lesion nematode as most predominant both in terms of its frequency of occurrence (100 %) and population density (299-384/ 200 cc soil). Among vegetable crops, pea was found most sensitive to nematode infestation and was having a maximum population buildup of all the four nematodes (305,326, 252 and 244/ 200 cc soil, respectively). In all the three vegetables, maximum population density was recorded for stunt nematode (269-326/ 200 cc soil). All

the localities of Kalpa block were found having highest nematode populations in both fruits and vegetable crops rhizosphere.

2.2 Community analysis

Brown *et al*. (1994) during his ecological studies revealed that eight *Longidorus*, one *Paralongidorus* and seven *Trichodorus* species were natural vectors of nepoviruses and seven *Paratrichodorus Trichodorus* and four species were vectors of tobraviruses. They also observed that nematode transmitted viruses and their vector nematodes were restricted in their distribution to regions with mild temperature or Mediterranean climates with the natural distributions of the viruses reflecting that of their vectors. Specificity of transmission was indicative of a long association between viruses and nematode vectors which had been determined and maintained by the range of factors influencing the complex nematode-virus plant interactions. They further concluded that the influence of several ecological factors might have affected these interactions and the geographical distributions of the nematode/virus associations were reviewed and discussed accordingly.

Ten plant parasitic nematodes (*Tylenchus costatus*, *Tylenchorhynchus nudus*, *Helicotylenchus retusus*, *Pratylenchus zea*, *Xiphinema insigne*, *Criconemoides onoensis*, *Macroposthonia sp*., *Aphlenchoides sp*., *Hoplolaimus sp*., and *Cephalobus sp*.) were reported from the rhizosphere of temperate fruits (including apple) nurseries and orchards in Kashmir valley by Zaki and Mantoon (2003).

Sultan (2007) studied the populations of plant parasitic and non-parasitic (free-living) nematodes in the rhizosphere of apple nurseries in relation to organic matter. The observation indicated that as the organic matter content increased, the populations of free living nematodes also increased, whereas the plant parasitic nematode populations decreased. The populations of plant parasitic nematodes appeared at the highest level (more than 200 nematodes per 100 cc of soil sample)

in the soil with low organic matter content (0.19%-0.5%). The low levels of plant parasitic nematodes appeared in the soil with high organic matter content (2.67-3.39%).

Abbas Mohammad *et al.* (2008) carried out a survey in which 21 nematode species were found associated with 10 species of ornamentals cultivated in Mahallat, Iran. Among those 21 nematodes, *Aphelenchoides spp*., had 100 % frequency on Calla, *Helicotylenchus spp,* had 100 % frequency on Snapdragon, *Pratylenchus spp*., had 100 % frequency on Stock. While on tulip 5 nematodes with 100% frequency each were found viz. *Boleodorus spp., Helicotylenchus spp., Pratylenchus spp., P. thornei,* and *Zygotylenchus spp*.

Sen *et al.* (2008) studied the population fluctuation of Helicotylenchus in relation to soil temperature, moisture and pH in guava orchard of West Bengal and found that the maximum population densities of *Helicotylenchus* occurred in the month of June and July when the soil temperature, moisture and pH were ranging between 31-36°C, 15-30% and 5.6-5.8 respectively. Lowest population was found in September, April and May when the soil factors ranged between 31-37°C, 11.2-27.5% and 5.7-6.2 respectively.

Lone *et al*.(2009) investigated the status of plant parasitic Adenophoreans at Faculty of Agriculture, SKUAST-K, Wadura on apple locality wise in district Baramulla, to study the horizontal distribution of important adenophoreans around apple trees, their seasonal fluctuation and to record the report of known and new species (if any) and the observations revealed the following important information. Among the various identified plant parasitic Adenophoreans, the most important Adenophoreans were found as *Xiphinema insigne*, *Xiphinema index* and *Longidorus elongatus* in all the localities each with 100 per cent frequency. The study concludes with the findings that adenophoreans are cosmopolitan in apple at orchards of Baramulla district of Kashmir valley.

Nath *et al*. (2009) carried out survey on 15 -20 years old litchi plants and were sampled for qualitative and quantitative analysis of plant parasitic nematode communities. A total of nine species under seven genera were identified from soil and associated root samples of the litchi plants. Out of nine species, *Rotylenchulus reniformis*, *Helicotylenchus indicus*, *Tylenchorhynchus leviterminalis* and *Xiphinema* sp. were new records of association with litchi plants from Tripura state and also from north-east India. Results of the community analysis showed that out of nine plant parasitic nematode species, *Hemicriconemoides litchi, Rotylenchulus reniformis* and *Meloidogyne incognita* were the most abundant, frequent, prominent and important nematode species in all of the four litchi plantations in NorthTripura district. On the basis of total biomass of nematodes, these three species were also abundant and dominant in comparison to other six species. Out of four litchi plantations, Choraibari and Panisagar plantations in Dharmanagar sub-division showed highest species diversity followed by Nabincherra and Chantail plantation.

Matiyar *et al*. (2010) conducted a survey on plant and soil nematodes associated with banana plantations in different banana growing districts of West Bengal (India), revealed that the occurrence of the most economically important genera of plant parasitic nematodes were *Pratylenchus, Meloidogyne, Helicotylenchus, Tylenchorhynchus, Hoplolaimus, Rotylenchulus, Hirschmanniella, Criconemoides*. Altogether there were seventeen species of plant parasitic nematodes *viz*. *Pratylenchus coffeae, P. brachyurus, P. similis, Meloidogyne incognita, M. javanica, Hoplolaimus indicus, Rotylenchulus reniformis, Helicotylenchus multicinctus, H. abunaamai, H. incisus, H. gratus, H. dihystera, Tylenchorhynchus nudus, T. mashhoodi, T. coffeae, Hirschmanniella mucronata* and *Criconemoides* sp. Among the plant parasitic nematodes, *P. coffeae, P. brachyurus, M. incognita*, *H. multicinctus* and *R. reniformis* were found as serious pests of banana in West Bengal. Observation of the effects of some banana cultivars/types on the nematode fauna, showed that the cooking

banana type *Musa* (ABB) cv. Kanchakala and *Musa* (BBB) cv. Seed Banana supported a huge population of *M. incognita* which induced severe root galling symptoms. The lesion nematode, *P. coffeae* was found infesting all the cultivars/types.The rhizosphere of banana cultivar, Matti exhibited a high population of *H. multicinctus*. *R. reniformis* population was recorded in extremely high levels in the rhizosphere of all cultivars/types.

Lone *et al*. (2012a) described and illustrated *Xiphinema index*, the dagger nematode of order dorylaimida and superfamiy longideroidea from rhizosphere of neglected apple orchards of Baramulla, Kashmir India.

Askary *et al*. (2012) studied the population fluctuation of plant parasitic nematodes associated with Pome, stone and nut fruit nurseries (including apple) and concluded that the population fluctuation in nematodes may be due to the rise and fall in temperature as well as presence of moisture content. During the month of January-February, the temperature of the area came down to sub-zero (-7ºC) which proved lethal for nematode survival and therefore it hindered the nematode multiplication and activities. During April-May, the population of nematodes increased which may be due to sufficient soil moisture and an increase in environmental temperature (20-27ºC) which proved congenial for nematode multiplication and survival but again during the month of July-August the nematode population slightly came down which may be due to a rise in temperature (30-35°C) and low moisture content in soil which affected its activities.

Lone *et al*. (2012b) carried out a survey on the occurrence of virus vector nematodes in different eco-habitats of same age (25-30 years) apple trees and collected four composite soil samples from each of the disturbed (ploughed orchards or vegetative cultivable orchard), undisturbed (apple orchards not ploughed since last three years) and neglected orchards (unattended apple trees) having same altitude. Results revealed that maximum population of the virus vector nematodes per 250 cc soil was from neglected orchards (108.42), followed

by from undisturbed orchards (90.42) and comparatively low population (83.58) was recorded in disturbed orchards.

In Pakistan, occurrence of root-knot nematode (*Meloidogyne*) and dagger nematode (genus Xiphinema) in 100 percent root and soil samples, collected from apple orchards was reported by Nayba *et al*. (2012).

Zalpuri *et al.* (2013) inferred community analysis of plant nematodes is an important criterion for assessment of their pathogenic potential in a particular region. This investigation involved 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.*

Aasia *et al.* (2014) conducted a survey of ornamentals in Rajouri district of J&K and recorded the nematode community structure. Nine plant parasitic nematodes were isolated and identified from 217 soil samples collected from rhizosphere of plants. Out of these nine, the highest frequency of occurrence was recorded in *Meloidogyne spp*. (76.49%) followed *by Helicotylenchus* (54.83%), *Hoplolaimus* (37.32%), *Rotylenchus* (42.39%), *Tylenchorynchus* (25.03%), *Tylenchus* (19.81%), *Xiphinema* (16.58%), *Longidorus* (10.13%), and *Aphelenchoides* (8.75%).

Rashid *et al*. (2014) conducted a survey of ornamental plants in Rajouri district of J&K and recorded the nematode community structure. Nine plant parasitic nematodes viz; *Aphelenchoides* sp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Longidorus* sp., *Meloidogyne* sp., *Rotylenchulus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., and *Xiphinema* sp., were isolated and identified from 217 soil samples collected from the rhizosphere of ornamental plants. Out of these nematodes, the highest frequency of occurrence was recorded in *Meloidogyne* sp. (76.49%) followed by *Helicotylenchus* (54.83%), *Hoplolaimus* (37.32%),

Rotylenchulus (42.39%), *Tylenchorhynchus* (25.03%), *Tylenchus* (19.81%), *Xiphinema* (16.58%), *Longidorus* (10.13) and *Aphelenchoides* (8.75%).

Lone and Zaki (2014) carried out the survey in the neglected apple orchards of Kashmir valley and concluded that the nematodes *Xiphinema insigne* and *Longidorus elongatus* were found most frequent and dominant species in the entire nematode community associated with the rhizosphere of apple orchards.

Sharma and Sen (2015) reported ten plant parasitic nematodes viz., *Pratylenchus coffeae*, *Helicotylenchus dihystera*, *Tylenchorhynchus mashhoodi*, *Pratylenchus curvitatus, Meloidogyne sp*., *Meloidogyne xenoplax, Gracilacus peperpotti, Hoplolaimus indicus, Xiphinema sp.* and *Tylenchus sp*. harbouring the rhizosphere of apple orchards in Himachal Pradesh.

Deen *et al.* (2015) reported plant parasitic nematodes in rose at Taif governorate, KSA. The soil samples were collected from 3 localities. Among the samples collected, 4 genera viz. *Meloidogyne, Rotylenchus, Xiphinema* and *Pratylenchus* seemed to be the most prevalent ones occurring at rates of 120, 117, 66 and 45 times with percentage 30 %, 29.3%, 16.5% and 11.3% respectively.

Mir and Tanveer (2016) studied the community structure of soil inhabiting nematodes from a fifty year old apple orchard and concluded that ten randomly selected composite samples yielded 37 genera belonging to 8 orders. They were allotted different trophic groups on the basis of their feeding habits. Total nematode numbers extracted averaged 637/100 cc of soil. Of the total population, 43% were herbivores, 32.1% bacteriovores, 11% were predators, 7% omnivores and 6% fungivores.

Loukrakpam *et al. (*2016) carried out Study on ecology of plant parasitic as well as soil nematodes associated with mulberry plants in Manipur for consecutive period of three years i.e. 2006 - 2008. Sixteen different nematode genera were identified under four orders - Aphelenchida, Dorylaimida, Tylenchida

and Mononchida which spread over 12 families. During the present study, *Helicotylenchus* spp. showed as predominant nematode genera in all studied seasons followed by *Scutellonema* spp. from mulberry ecosystem of Government Silk farm, Wangbal, Thoubal District, Manipur. This may be due to the wide range physiological characteristics of the nematode group. *Helicotylenchus* spp. followed by *Scutellonema* spp., *Ditylenchus* spp.,*Caloosia* spp., *Criconemella* spp., *Aphelenchus* sp., *Paratylenchus* spp., *Basiria* spp. and *Tylenchus* spp. are most devastating nematodes of mulberry plantation in Manipur, India.

Nadia *et al.* (2016) identified stylet bearing nematodes associated with walnut (*Juglans regia* L.) in different localities namely Baghnotar, Nathiagali, Kakul, Bandi Pulah, Gulistan Colony, Sheikh ul Bandi and Jhangi of District Abbottabad, KPK, Pakistan . Soil samples were collected from the base of the walnut trees and were processed by using Bearmann funnel technique. Specimens collected were killed by heat, fixed in TAF and later transferred to 1.25glycerine for permanent mounting. Nine species of nematodes *Tylenchus sp., Psilenchus hilarulus, Meloidogyne larvae, Aphelenchus avenae, Tylenchus juveniles, Filenchus sheri, Pratylenchus thornei, Helicotylenchus pseudorobustus* and *Helicotylenchus dihyster*a have been identified from these localities. Most commonly found nematode species were *Aphelenchus avenae, Psilenchus hilarilus, Tylenchus sp.* and *Pratylenchus thornei.*

Kumar *et al.* (2019) conducted a systemic investigation to assess the diversity and community structure of plant parasitic nematodes from the soil rhizosphere of ten different citrus species grown at Citrus Research Station, Tinsukia, Assam. Four major plant parasitic nematode species *viz*., *Tylenchulus semipenetrans*, *Helicotylenchus dihystera*, *Hoplolaimus indicus* and *Tylenchorhynchus* spp were found prevalent in the rhizosphere of ten different citrus species. In addition to these, several Dorylaimid, Rhabditid and Predatory nematodes were also encountered. Amongst the plant parasitic nematodes, *T. semipenetrans* was highly abundant (100%) followed by *H. dihystera* (80%),

Tylenchorhynchus spp. (70%) and *H. indicus* (50%). Among, different citrus species, a higher population of *T. semipenetrans* was encountered on rough lemon and least number was encountered on trifoliate orange.

Chapter 3

MATERIALS AND METHODS

This aspect has been mentioned under different headings;

3.1 SURVEY

Survey studies of various high density apple orchards of Kashmir Valley were carried out to find out the prevalence of plant parasitic nematodes in the rhizosphere of the plants. Localities of the three apple growing districts of the state *viz*. Srinagar, Anantnag and Baramulla were surveyed and from each district twenty seven composite samples were collected. Selection of prominent locations with extensively apple cultivations were made, having same kind and same aged fruit plants. The most prominent fruit belts where intensive and extensive apple cultivation within the districts of Srinagar, Anantnag and Baramulla proposed for the survey were identified namely as:

a) Baramulla comprising villages (locations)

- Ladoora (with orchard locations L_1,L_2 and L_3)
- Zangam (with orchard locations Zg_1,Zg_2 and Zg_3)
- Arampora (with orchard locations Ap_1,Ap_2 and Ap_3)
- b) Anantnag comprising villages as
- Gopalpora (with orchard locations Gp_1, Gp_2 and Gp_3)
- Achabal (with orchard locations Ac_1, Ac_2 and Ac_3)
- Kokernag (with orchard locations Kn_1, Kn_2 and Kn_3)

c) Srinagar comprising villages

- SKUAST-K (with orchard locations SK_1, SK_2 and SK_3)
- Habak (with orchard locations Hb_1, Hb_2 and Hb_3)
- Zakura (with orchard locations Zk_1, Zk_2 and Zk_3)

3.2 Collection of soil cum root sample

About 500-1000 cc Soil samples were selected from each district from the feeder zone of apple orchards. Sampling was done during peak growing season (May to July).The samples were collected manually with the help of khurpi at a depth of 30-40 cm covering 60-90cm radius. The samples were collected in polybags and were tied with rubber band and the samples were labelled and stored in laboratory at a temperature of 7^{o}C.

3.3 Processing of the soil samples

To isolate the nematodes, from each thoroughly mixed composite soil sample only 250 cc fine soils was processed by modified Cobb's sieving and decanting technique (Cobb, 1918). For extraction of nematodes a set of sieves were used (18,60,100,200,300,400).Then the resultant suspension of each sieve with residue was separately spread on the double layer tissue paper placed on aluminum wire mesh and same was placed on petri-plates containing fresh water/distilled water.

3.4 Killing and Fixing of Nematodes

Nematode suspension from the beaker was taken in test tubes and these test tubes were dipped in metallic container filled with boiling water. Suspension was constantly shaken to apply uniform distribution of heat till all the nematodes were killed. Suspension was fixed with 4 per cent formaldehyde sol. and the volume was reduced to 20ml and then stored in McCartney vials inscribed with host, locality and date of collection.

3.5 Staining of Nematodes

The roots of High density apple plants were collected from each tree, cut into 2 to 3 cm pieces and mixed thoroughly. About 1g of root cutting was stained with 0.1 per cent acid fuchsin lacto phenol (Hooper, 1970) for 30 seconds for counting of Plant parasitic nematodes by using stereoscopic microscope (40 x).

Plate 1: Collection of soil sample in high density apple orchards

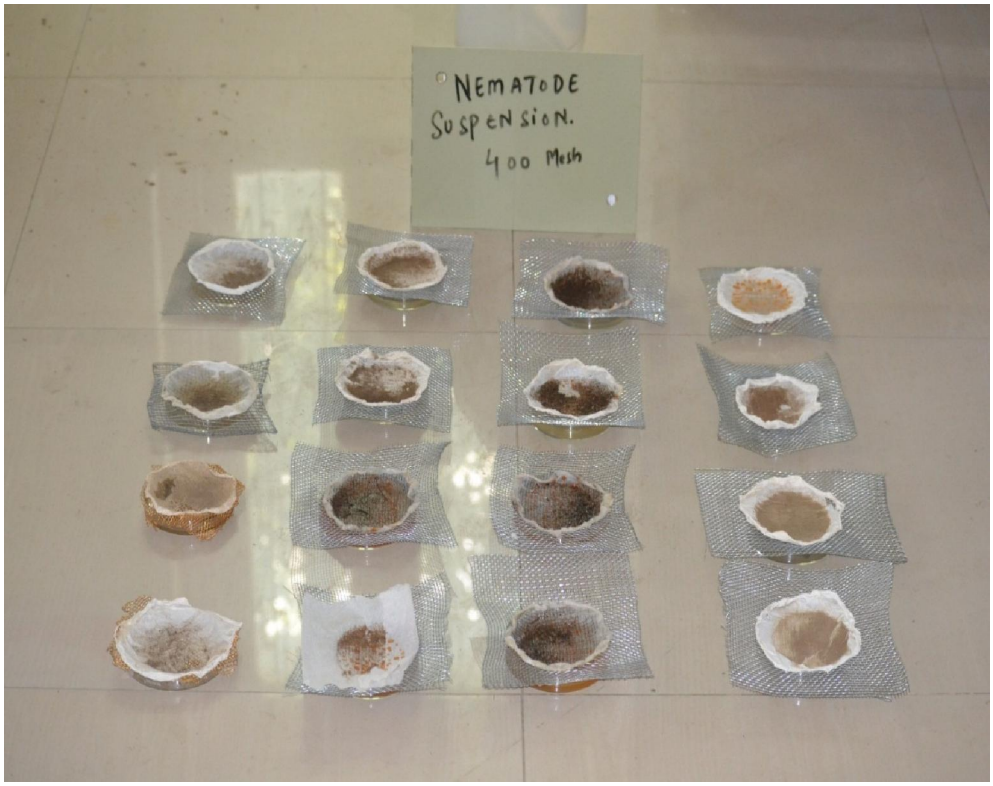

Plate 2: Processes of nematode extractions

3.6 Identification of Nematodes

The fixed nematodes were transferred to a small cavity block containing glycerine alcohol mixture (5 parts of glycerine and 95 parts of absolute alcohol) by picking them with the help of broom pick under zoom stereoscopic microscope. The cavity block was placed in desiccator at room temperature for slow dehydration for about 4-5 days. The nematodes were processed gradually into anhydrous glycerine and then were transferred from cavity block in to a drop of dehydrated glycerine on a glass slide and suitable glass wool support was given in the mount to prevent the pressure of cover slip on the specimens. The cover slip was sealed with glycel from the edges.

3.7 Counting of Nematode Population

The nematode suspension isolated from the sample was observed under zoom stereoscopic microscope in a counting dish for the identification of plant parasitic nematode genera and to count their population densities. The number of nematodes were counted in one ml of nematode suspension (after thorough bubbling) with the help of a counting dish and an average of five such counts were taken as the number of nematodes per ml. The volume of the suspension was multiplied with average count of nematodes per ml to estimate total number of nematodes per 250 cc of soil sample.

3.8 Photo micrograph of Nematodes

Photographs of nematodes from permanent slides were taken through leica microscope fitted with digital micrographic camera.

3.9 Statistical Analysis

Population density with range and frequency of occurrence of each nematode genus/ species was determined at each location and for total samples collected from the particular area. The Shannon Weiner density index formula was applied to find diversity of plant parasitic nematodes from locality to locality and from one belt to other belt.

$H = \sum^{s} i=1\ Pi \log_e Pi$

Where,

s = Number of species/ genus at each location,

Pi =Relative abundance of i^{th} species/ genus.

Nematodes communities were analyzed on having prominence value and importance value for each nematode genus/species (Norton, 1978; Waliullah, 1983). Biomass was determined on having the measurement on length and width of nematodes collected from each location/district.

3.10 Nematode Diversity

In order to study on the nematode community structure with reference to relative frequencies, relative densities, prominence value, biomass and importance value of nematodes, the formulae proposed by Norton (1978) is as under:

$$1.\ \text{Absolute frequency of sp./genus x} = \frac{\text{No. of samples containing species/genus}}{\text{No. of samples collected}} \times 100$$

$$2.\ \text{Relative frequency of sp./genus x} = \frac{\text{Frequency of species/ genus}}{\text{Sum of frequencies of all spp/genus present in samples}} \times 100$$

$$3.\ \text{Absolute density of sp./genus x} = \frac{\text{No. of individuals of x in a sample}}{\text{Volume or mass or unit of sample}} \times 100$$

$$4.\ \text{Relative density of sp./genus x} = \frac{\text{No. of individuals of sp. / genus in a sample}}{\text{Total no. of individuals of all spp/ genus. in a sample}} \times 100$$

5. Prominence value of sp. /genus x = Absolute density x √Frequency

6. Biomass of sp. /genus x = $a^2.b/16 \times 10^5$ µg.

(a = average greatest body width, b = average body length of a nematode in µm)

Chapter-4

EXPERIMENTAL FINDINGS

Results have been presented under the following headings:

4.1 Identification of plant parasitic nematodes in high density apple plantation of Kashmir

In all, nine nematode genera were isolated from the rhizosphere of high density apple orchards in the three districts of Kashmir valley *viz*., *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp.

4.1.1 Genus: *Helicotylenchus* Steiner, 1945

Description

Female: Body usually in the form of spiral. Lip region cup shaped with 3-4 indistinct annules. Cephalic framework well developed. Spear 25.01-29.6 µm in length. Median oesophageal bulb oval to round with distinct vulval apparatus. Excretory pore 121-125 µm from anterior end. Vulva a depressed slit, located at 58.6-64.04 % of the body. Ovaries paired, amphidelphic, outstretched. Tail curved dorsally with slight ventral projection, marked by 5-11 annules on the ventral side

4.1.2 Genus: *Pratylenchus* Filipjev, 1936

Description

Female: Female body almost straight anteriorly and slightly curved ventrally in posterior half when fixed. Lip region with two annules, offset by slight constriction. Cephalic framework well developed, strongly sclerotized, cup shaped. Stylet well developed with rounded basal knobs. Excretory pore 110-115µm from anterior end. Lateral field with 4 incisures. Oesophagus is

typically paratylenchoid type, oesophageal lobe overlapping the intestine ventrally for about two to two and half times widths long. Vulva located posteriorly 77-83 per cent from anterior end. Ovary single, prodelphic, stretched anteriorly and oocytes are arranged in single file. Spematheca broadly oval to nearly rounded, almost filled with sperms. Tail 27-40µm long with 18-23 annules. Shape of tail terminus smooth, broadly rounded to truncate annulate.

4.1.3 Genus:*Tylenchorhynchus* Cobb, 1913

Description

Female: Body cylindrical, slightly ventrally arcuate upon fixation. Lateral field with 4 incisures. Lip region continuous with body contour, marked by three annules. Spear 14.23-19.24 µm long, moderately developed, with rounded basal knobs. Median oesophageal bulb located at 52.80-55.80 per cent of oesophageal length from anterior end of body. Cardia present. Excretory pore located slightly anterior to basal oesophageal bulb. Vulva a transverse slit located at 52-58 per cent of the body. Ovaries amphidelphic, outstretched. Tail cylindrical, ending in broadly rounded. Tail annules 20-24 in numbers. Phasmid distinct located near middle of the tail.

4.1.4 Genus:*Hoplolaimus* Daday, 1905

Description

Female: Large sized nematodes 0.93-1.48mm in length, lip region offset high with prominent transverse and longitudinal striae. Head annules three. Cephalic framework strongly developed. Spear massive 34-37 µm in length with compact tulip shaped basal knobs. Excretory pore prominent 100-122µm distance from anterior end. Oesophagus well developed, oesophageal gland overlapping intestine dorsally and laterally. Vulva at 49.04-56 per cent of body length, ovaries two, outstretched anteriorly and posteriorly, spermtheca somewhat oval in shape.

4.1.5 Genus: *Xiphinema*

Species: *Xiphinema insigne* (Loos, 1949)

Description

Female: Body significant accurate, anteriorly tapering gradually from base of stylet, then more noticeable from a point four to five lip region widths behind oral opening. Posteriorly, body tapering evenly from anus to tail terminus. Lip region hemispherical set off from rest of body by slight constriction. Stylet almost straight, 25 µm long. Flanged portion of stylet 12 µm wide. Vulva non-protruding, vagina transverse. Tail uniformly elongate-conical, about five anal-body-widths in in length of 110 µm long.

4.1.6 Genus:*Xiphinema*

Species: *Xiphinema index* (Thorne and Allen, 1950)

Description

Female: Body long and slender with tapering anterior and rounded posterior extremity forming and open spiral with a greater curvature in the posterior half. Cuticle in two layers, inner one being thicker than the other one. Lip region rounded, slightly off set. Odontostylet long, odontophore nearly 1/1.6th of the odontostylet. Fixed guiding ring is about 8 labial-width from the oral aperture. Cardia short and conoid. Genital tract amphidelphic, each sexual branches consisting of a reflexed ovary, distal narrow and proximal convoluted portion of uterus. Vulva is at 38.4-39.8 per cent of the total body length from the anterior extremity. Tail short dorsally convex, ventrally almost straight or slightly convex with mamillate peg, about one anal body width long and provided with 2-3 papillae on each side.

4.1.7 Genus: *Xiphinema*

Species: *Xiphinema americanum* (Cobb, 1913)

Description

Female: Body 'C' shaped upon fixation with tapering ends. Cuticle finely striated transversely. Lip region rounded, off set from the rest of the body. Odontostylet long, odontophore 1/1.6th of the odontostylet length. Fixed guiding ring is at 6-8 labial widths from the oral aperture. Cardia short and conoid. Rectum about one anal body-width long. Ovaries amphidelphic. Vulva a transverse slit, about equatorial. Vagina at right angles to body axis. Tail conoid with a greater curvature dorsally, a hemispherical terminus.

4.1.8 Genus: *Longidorus*

Species: *Longidorus elongatus* (Micoletzky, 1922)

Description

Female: Body long and narrow slightly coiled when killed by heat. Lip region flattened anteriority. Odentostylet (spear) long and narrow with a simple junction. Odentostylet lacks basal flanges. Anterior part of oesophagus is long and coiled. Guiding ring is located in anterior half of odentostyle. Vulva a transverse slit present near mid-body. Ovaries are amphidelphic. Tail short and conoid, dorsally convex and ventrally flattened.

4.1.9 Genus: *Tylenchus* (Bastian, 1865)

Description

Female: Body long and tapering towards both the sides. Stylet with conus which is equal to shaft and having rounded basal knobs. Median oesophagal bulb is oval and muscular with basal bulb pyriform in shape. Cardia distinct. Tail filiform curved ventrally (hook-like). Vulva a tranverse slit, located at 60-65% of the body length.

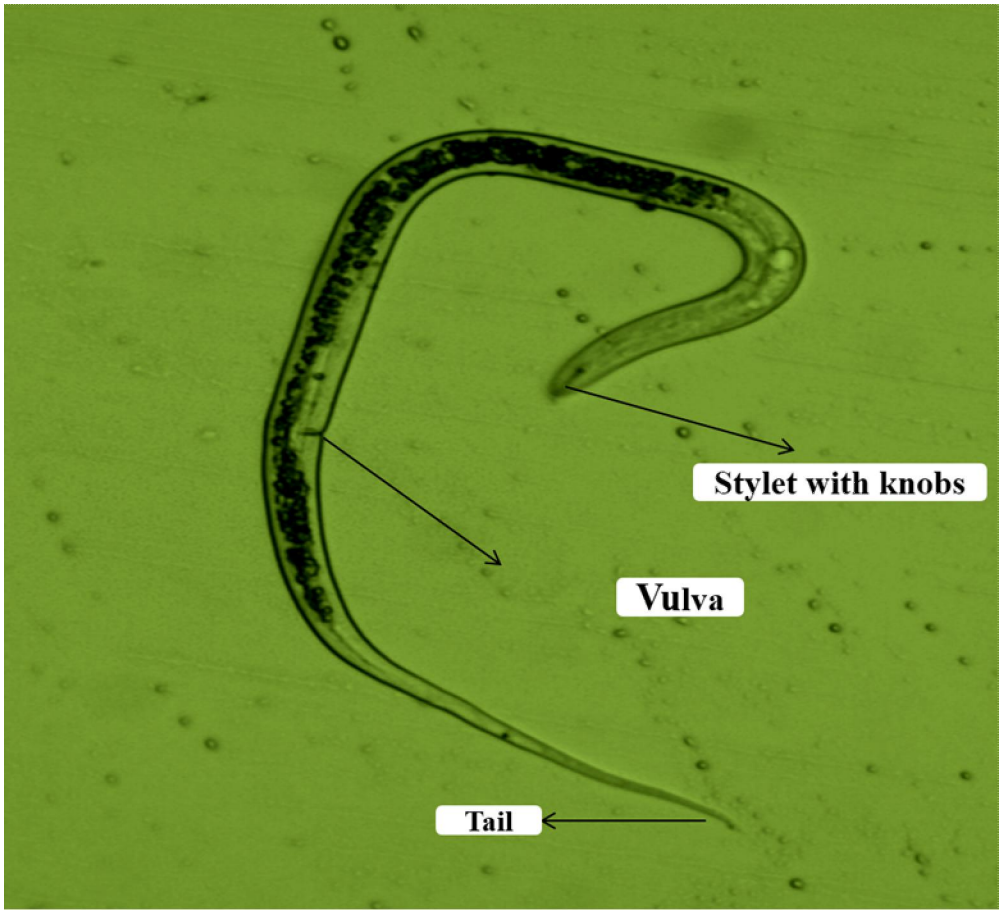

Plate 3. ***Tylenchus*** **sp. Bastian, 1865**

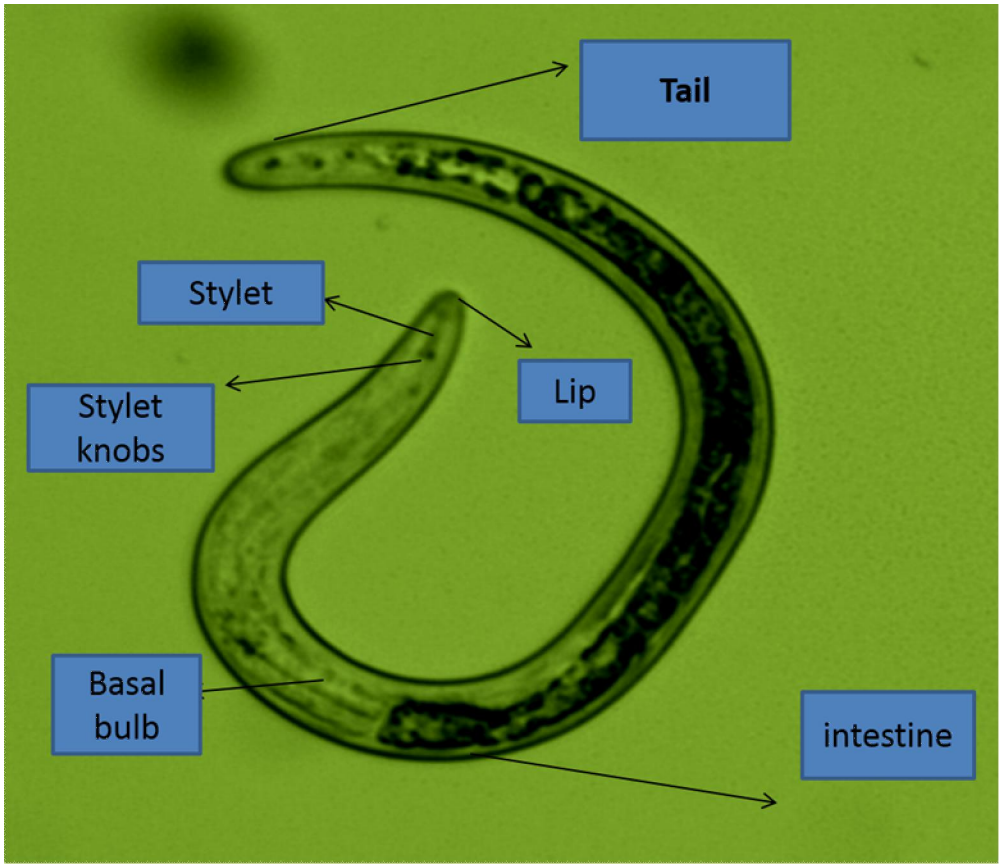

Plate 4 : ***Tylenchorhynchus*** **sp. Cobb, 1913**

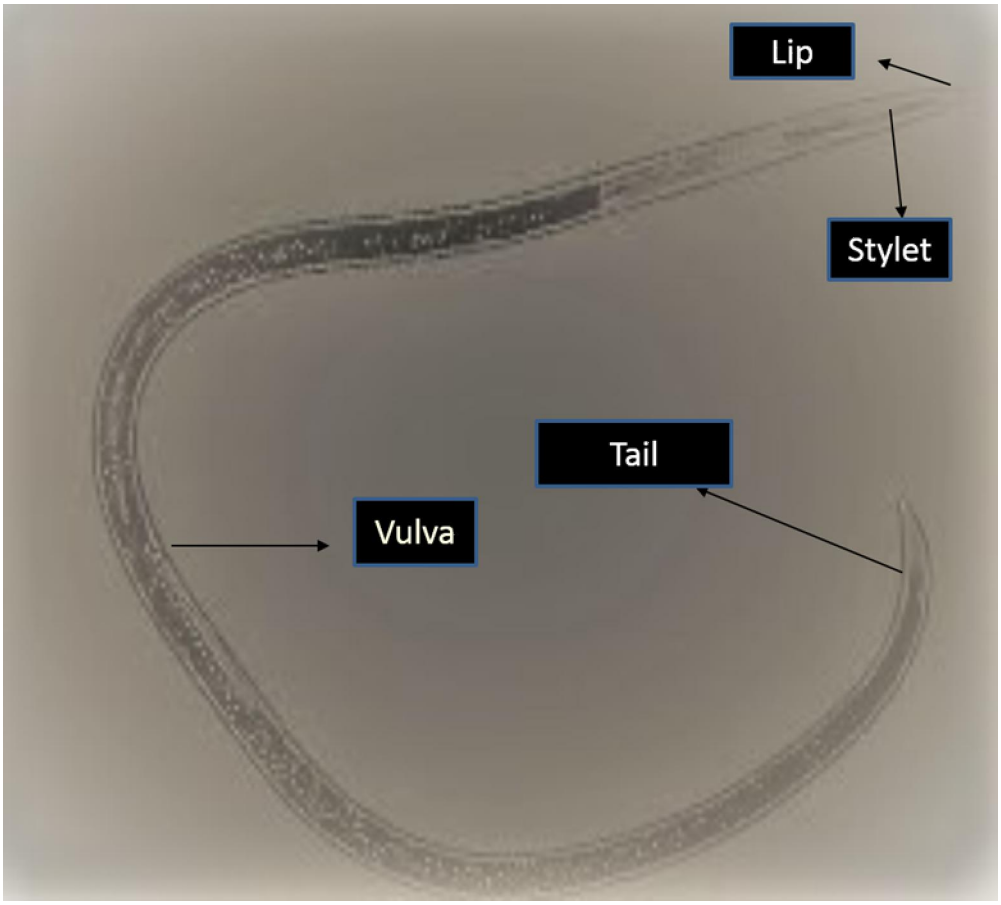

Plate 5: ***Xiphinema index*** **Thorne and Allen, 1950**

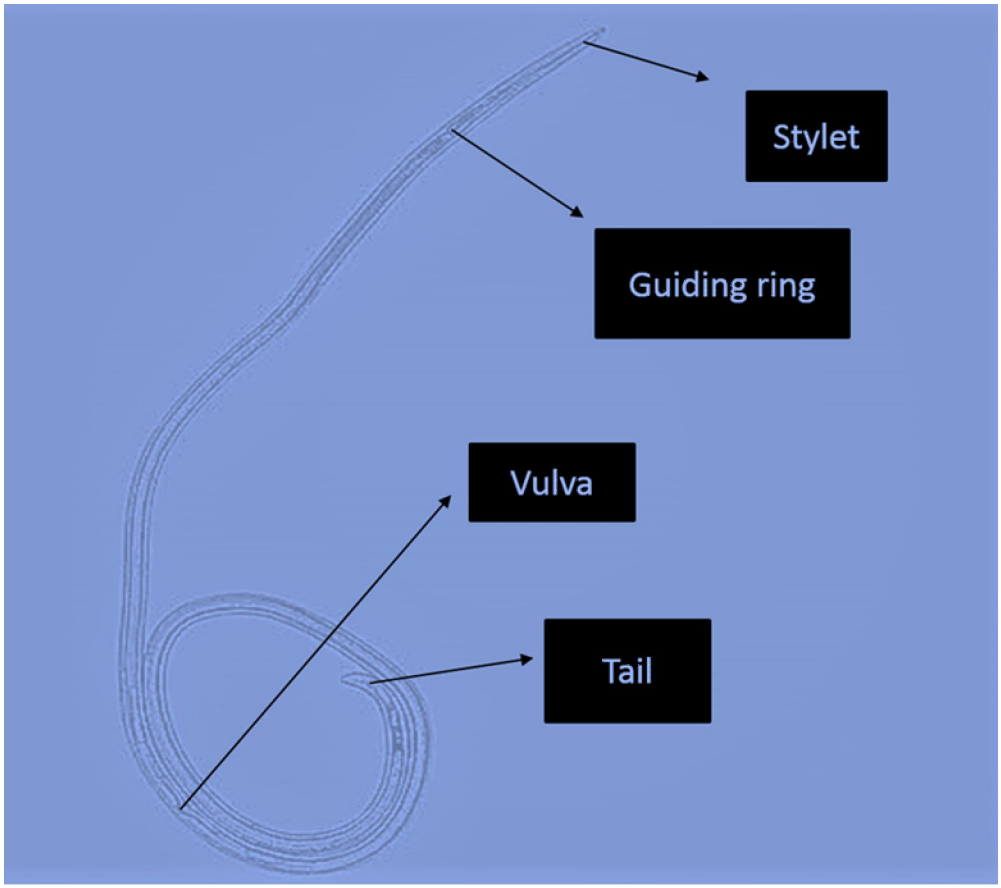

Plate 6: ***Longidorus elongatus*** **Micoletzky, 1922**

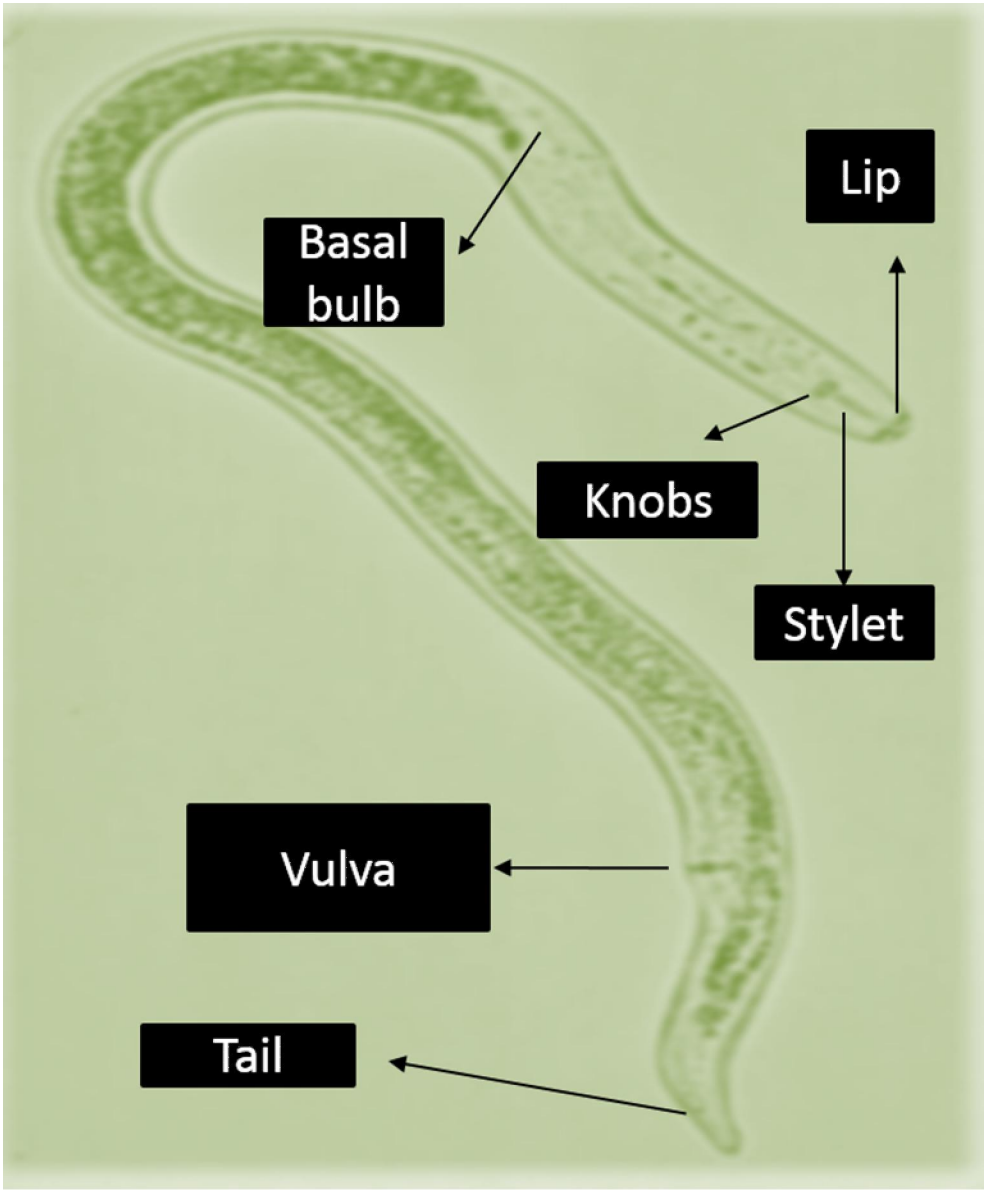

Plate 7: ***Pratylenchus*** **sp. Filipjev, 1936**

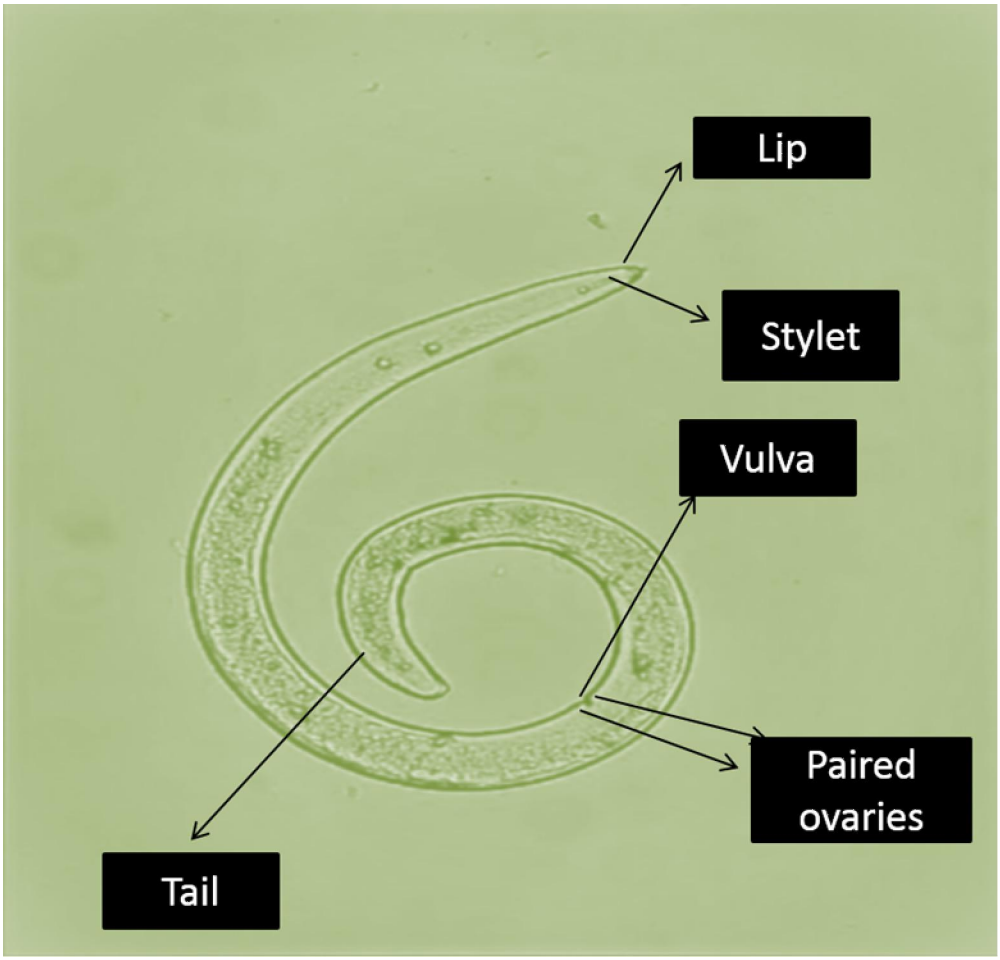

Plate 8: *Helicotylenchus* sp. Steiner, 1945

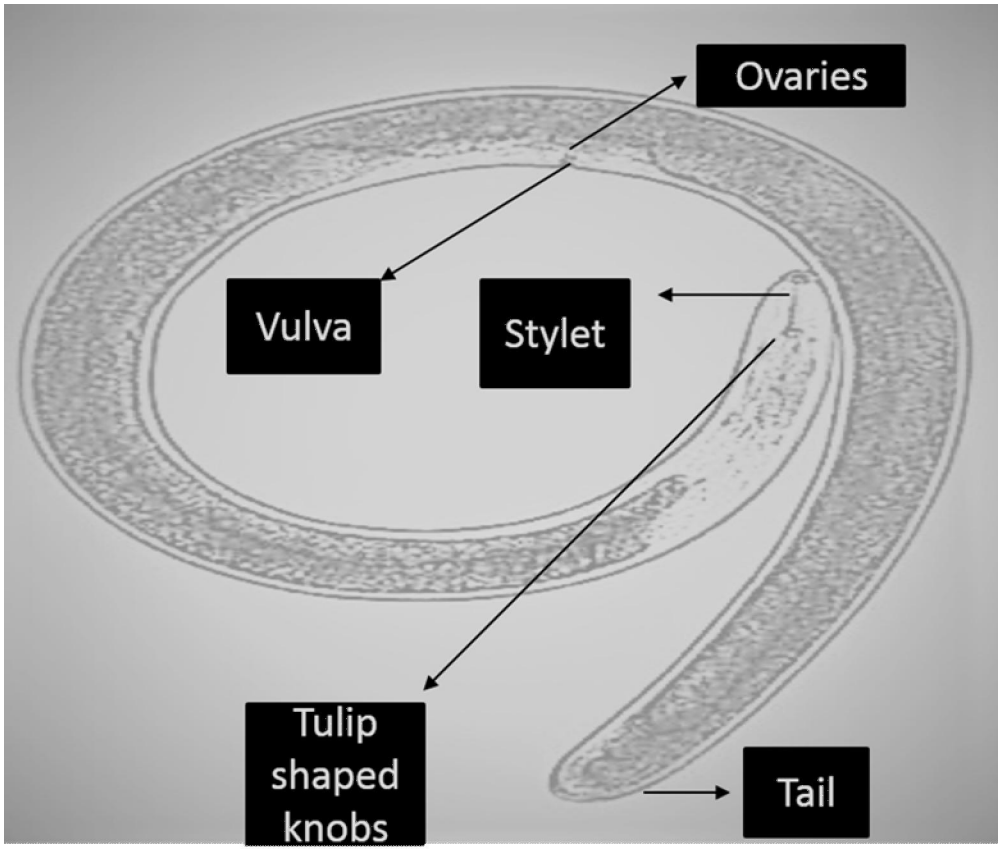

Plate 9: ***Hoplolaimus*** **sp. Daday, 1905**

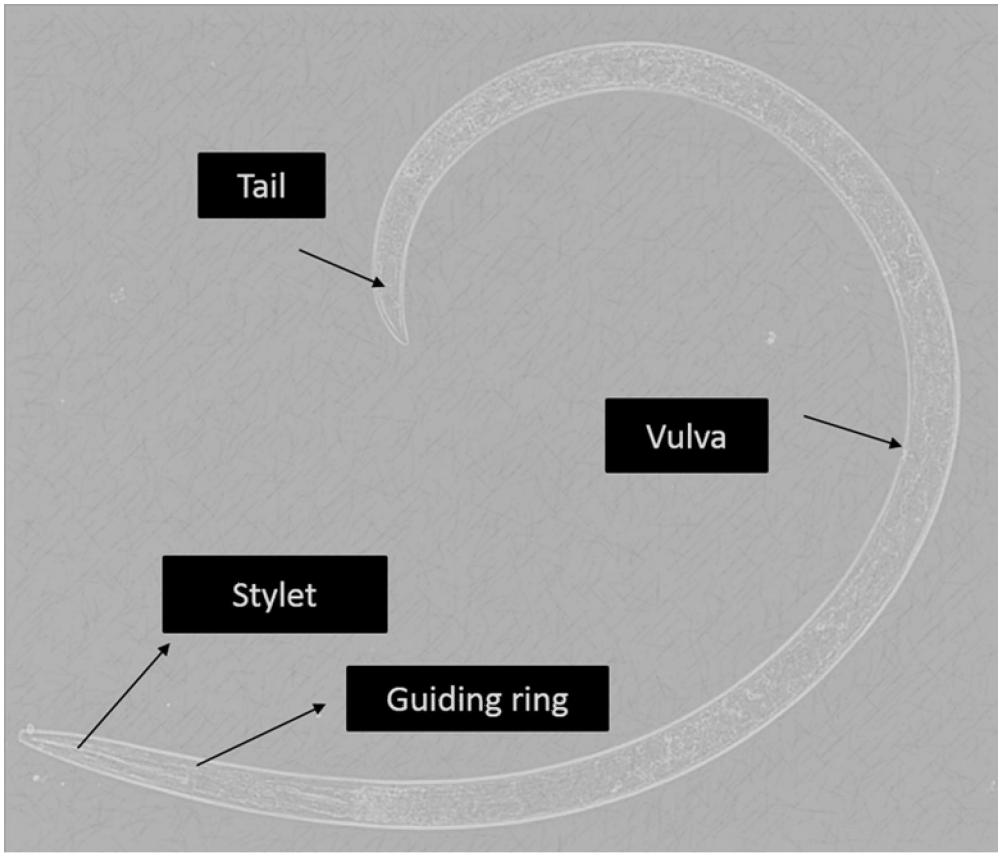

Plate 10: ***Xiphinema americanum*** **cobb, 1913**

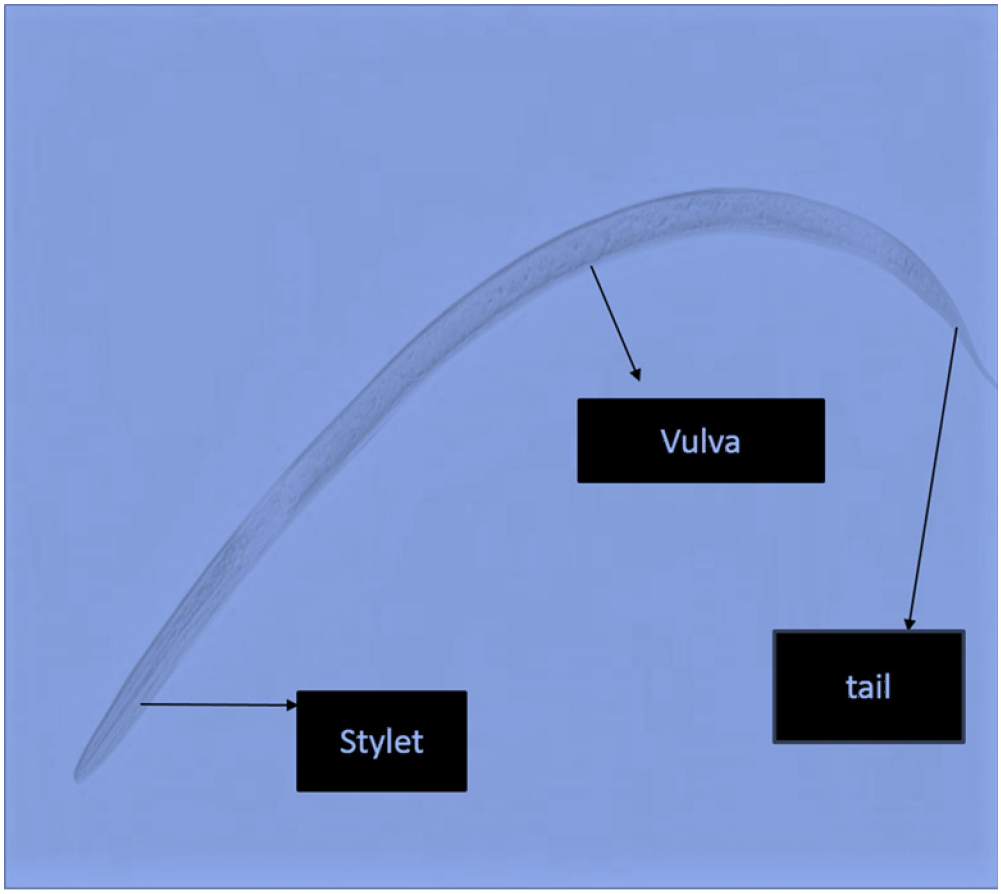

Plate 11: ***Xiphinema insigne*** **loos, 1949**

4.2 Community analysis of predominant plant parasitic nematodes in high density apple plantation of Kashmir

4.2.1 Plant parasitic nematodes in localities of district Baramulla

Ladoora (L)

The basic data of nine composite soil samples collected around the high density apple plants comprising of three composite soil samples from each of the three high density apple orchards in locality Ladoora are presented (Table 1). In all, nine nematode genera were found harbouring the high density apple orchard rhizosphere. The data revealed nematodes in nine groups with percent relative density per 250 cc soil as 31.41, 17.32, 9.50, 11.37, 9.12, 8.33, 5.80, 4.58 and 2.52 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp., respectively.

After species- wise analysis in the locality, the status position of plant parasitic nematodes are presented (Table 1a).The absolute population density per 250cc soil of *Helicotylenchus* sp. was recorded as 74.55 ranging from 64.13-84.97 at 95 per cent confidence interval with 100 per cent frequency in the locality. The per cent relative density of this species was recorded as 31.41 in comparison to other species with prominence value of 745.50 in entire locality.

The absolute population density of *Pratylenchus* sp., was computed to be as 41.11 ranging from 29.34-52.88 at 95 per cent confidence interval with 100 percent frequency in the locality. The per cent relative density and prominence value of this species were recorded as 17.32 and 17.32, respectively while *Tylenchorhynchus* sp. with absolute population density 22.55 ranging from 13.40-31.70 at 95 per cent confidence interval with 88.88 frequency. The per cent relative density and prominence value of this species were recorded as 9.50 and 212.42, respectively.

Absolute population density of *Tylenchu*s sp. was recorded as 27.00 ranging from 14.71-39.29 at 95 per cent confidence interval with 88.88 frequency. Its per cent relative density and prominence value were recorded as 11.37 and 254.34, respectively.

The status of *Xiphinema insigne* with respect to absolute population density was recorded as 21.66 ranging from 12.41-30.91 at 95 per cent confidence interval with 88.88 per cent frequency. Its per cent relative density and prominence value in comparison to other species were recorded as 9.12 and 204.03, respectively. The absolute population density of X. index was recorded as 19.77 ranging from 12.27-27.27 at 95 per cent confidence interval with 88.88 per cent frequency in the locality. The per cent relative density and prominence value of this species were recorded as 8.33 and 186.23, respectively. The absolute population density of *X. americanum* was recorded as 13.77 ranging from 6.71-20.83 at 95 per cent confidence interval with 88.88 per cent frequency. Its per cent relative density and prominence value were found as 5.80 and 129.71, respectively. Absolute population density of *Longidorus elongatus* and *Hoplolaimus* sp. were recorded as 10.88 and 6.00 ranging from 4.81-16.95 and 1.33-10.67 at 95 per cent confidence interval with per cent frequency of 77.77 and 66.66, respectively. Their per cent relative density was recorded as 4.58 and 2.52 with prominence values of 95.85 and 48.96, respectively and the diversity index of all the plant parasitic nematodes in locality was computed to be 1.954. In locality ladoora on the basis of prominence values *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchus* sp. were found as first, second and third important plant parasitic nematodes associated with high density apple orchards.

Zangam

The data from (Table 2) of locality zangam revealed the establishment of nematodes in the same way as that of found in locality ladoora in nine groups with percent relative density per 250cc soil as 26.45,19.32,9.70,15.72,9.27,6.92,4.91,4.10 and 3.50 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp.,

Tylenchus sp., *Xiphinema insine*., *X.index*., *X.americanum*., *Longidorus elongatus*., and *Hoplolaimus* sp., respectively.

Similarly the status of plant parasitic nematodes is presented in (Table 2a). Perusal of the data in (Table 2a) revealed the status of various plant parasitic nematodes as absolute population density with range at 95 per cent confidence interval and per cent frequency recorded as 68.77 (57.91-79.63) 100 per cent, 50.22 (33.74-66.70)100 per cent, 25.44 (18.60-32.28) 100 per cent, 40.89 (27.92-53.86) 100 per cent,24.12 (14.90-33.34) 88.88 per cent, 18.00 (10.13-25.87) 88.88 per cent, 12.7(7.11-18.45) 88.88 per cent, 10.67 (4.91-16.43) 77.77 per cent and 9.12 (3.37-14.87) 77.77 per cent for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*., *X.index*., *X. americanum*., *Longidorus elongatus*., and *Hoplolaimus* sp., respectively.Similarly their prominence value of 687.70, 502.20, 254.40,408.90, 227.21, 169.56, 120.38, 94.00 and 80.34 was recorded for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp., respectively. The diversity index of all the plant parasitic nematodes in the locality was recorded as 1.982. Among all the plant parasitic nematodes, *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchu*s sp., were recorded as first, second and third important plant parasitic nematodes in zangam locality.

Arampora

In locality Arampora the species of all the plant parasitic nematodes are presented in (Table 3). Perusal of the data in the (Table 3a) revealed per cent relative density of 26.49, 22.11, 10.41, 16.04, 8.05, 5.92, 4.16, 3.59 and 3.18 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp., respectively. The absolute density with range at 95 per cent confidence interval and per cent frequency were recorded as 78.55 (63.44-93.66) 100 per cent, 65.55 (51.93-79.17) 100 per cent, 30.88 (22.71-39.05) 100 per cent,

47.55 (35.63-59.47) 100 per cent, 23.88 (15.00-32.76) 88.88 per cent, 17.55 (9.88-25.22) 88.88 per cent, 12.34 (7.8-16.88) 88.88 per cent, 10.67 (4.15-17.19) 77.77 per cent and 9.40 (3.36- 15.44) 77.77 per cent for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*., *X.index*., *X.americanum*., *Longidorus elongatus*., and *Hoplolaimus* sp., respectively. Similarly their prominence value of 785.50, 655.50, 308.80, 475.50, 224.94, 165.32, 116.24, 94.00 and 82.81 was recorded for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp., respectively. The diversity index of all plant parasitic nematodes in the locality was recorded as 1.937. Among all the plant parasitic nematodes, *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchu*s sp., were recorded as first, second and third important plant parasitic nematodes in Arampora locality.

4.2.2 Status of plant parasitic nematodes in Baramulla fruit belt

After multiple comparison of twenty seven soil samples of district Baramulla comprising nine composite soil samples from each of the three localities, the status of plant parasitic nematodes are presented in Table 4. Perusal of the data (Table 4, Fig. 1) revealed that among the three localities viz; Ladoora, Zangam and Arampora, the maximum population of 78.55 for *Helicotylenchus* sp., was recorded in Arampora followed by 74.55 in Ladoora and 68.77 in Zangam. The mean population of *Helicotylenchus* sp., in district Baramulla was recorded as 73.95 ranging from 61.83-86.07 at 95 per cent confidence interval. The per cent relative frequency and per cent relative prominence value of *Helicotylenchus* sp., in the district Baramulla were recorded as 12.32 and 28.69, respectively and ranked as first dominant plant parasitic nematode in the entire district on the basis of population density and frequency of occurrence. *Pratylenchus* sp., the Lesion nematode was recorded as second dominant specie with mean population in the fruit belt as 52.29 ranging from 38.36-66.22 at 95 per cent confidence interval. Its per cent frequency in the belt was recorded at par

with *Helicotylenchus* sp., (100%). The maximum population per 250 cc soil was recorded in locality Arampora as 65.55 followed by absolute population of 50.22 in Zangam and 41.11 in Ladoora. The per cent relative frequency and per cent relative prominence value of *Pratylenchus* sp., in the district Baramulla were recorded as12.32 and 20.28, respectively. *Tylenchorhynchus* sp., the stunt nematode was recorded with a mean population of 26.29 ranging from 18.24-34.34 at 95 per cent confidence interval in district Baramulla with 96.29 frequency. The per cent relative frequency and per cent relative prominence value of *Tylenchorhynchus* sp., in the district Baramulla were recorded as 11.87 and 10.00, respectively. Similarly the mean population of *Tylenchus* sp., per 250 cc soil was recorded as 38.48 ranging from 26.09-50.87 at 95 per cent confidence interval with 96.29 frequency and was recorded as third dominant specie in the entire district. The maximum population per 250 cc soil was recorded in locality Arampora as 47.55 followed by population of 40.89 in Zangam and 27.00 in Ladoora .The per cent relative frequency and per cent relative prominence value of *Tylenchus* sp., in the district Baramulla were recorded as 11.87 and 14.64, respectively. The status of *Xiphinema insine*, *X.index*, and *X.americanum* with respect to mean population per 250 cc soil in the belt was recorded as 23.22 ranging from 14.11-32.33, 18.44 ranging from 10.76-26.12 and 12.96 ranging from 7.26-18.66 at 95 per cent confidence interval, respectively. Their per cent relative frequency and per cent relative prominence value were recorded as 10.95 and 8.48, 10.95 and 6.74 and 10.95 and 4.73, respectively. The data in the Table 4 revealed the status of *Longidorus elongatus* with its mean population per 250 cc soil as 10.74 ranging from 4.62-16.86 at 95 per cent confidence interval. Its per cent relative frequency was also recorded as 9.58 with relative prominence value of 3.67, respectively. *Hoplolaimus* sp., the lance nematode was recorded with low mean population of 8.17 ranging from 2.77-13.57 at 95 per cent confidence interval in the entire district with 74.07 frequency. Its per cent relative frequency and per cent relative prominence value in the belt were recorded as 9.13 and 2.72, respectively.

4.2.3 Status of plant parasitic nematodes associated with different rootstocks of high density apple orchards in district Baramulla

After analyzing different soil cum root samples, the data in the (Table 5) revealed that apple growth and yield response relationship with the population densities of plant parasitic nematodes most likely to cause damage were determined on the basis of their feeding habit. Population densities of *Pratylenchus sp.,* was detected at high levels at all sampling intervals followed by *Tylenchus sp.,* and *Helicotylenchus sp.,* while minimum population was detected for *Hoplolaimus sp*., (Table 5). After multiple comparison of different rootstocks, it was found that highest number of nematodes were present on M9 rootstock (153) followed by M4 (124) and M7 (86) while minimum population was found on MM-106 (47) (Table 5).

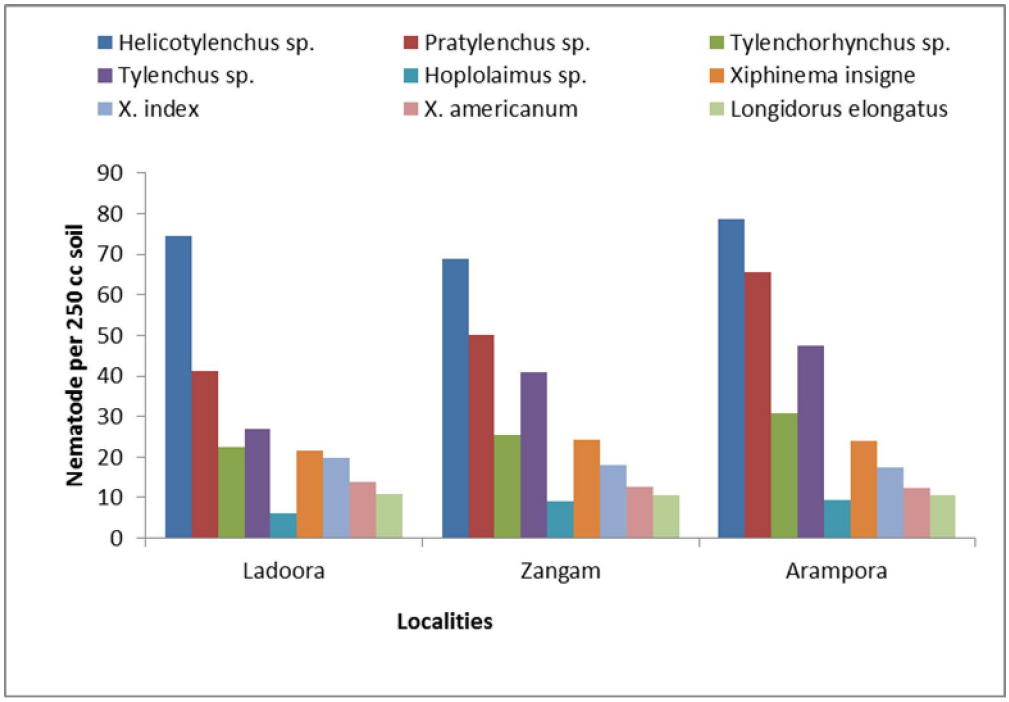

Fig. 1: Population status of plant parasitic nematodes in district Baramulla

Table 1: Diversity of plant parasitic nematodes associated with high density apple orchards in village Ladoora (District Baramulla)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		L_1			L_2			L_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	75	55	100	72	66	85	62	84	72	74.55	31.41
2	*Pratylenchus* sp.	50	30	40	45	35	55	12	38	65	41.11	17.32
3	*Tylenchorhynchus* sp.	40	22	20	35	28	20	0	12	26	22.55	9.50
4	*Tylenchus* sp.	38	40	55	0	22	28	20	14	26	27.00	11.37
5	*Hoplolaimus* sp.	12	6	4	18	0	8	0	6	0	6.00	2.52
6	*Xiphinema insigne*	35	22	34	24	0	32	26	12	10	21.66	9.12
7	*X. index*	24	16	22	12	0	18	32	30	24	19.77	8.33
8	*X. americanum*	12	22	24	10	0	28	8	14	6	13.77	5.80
9	*Longidorus elongatus*	10	16	24	12	0	0	10	18	8	10.88	4.58
No. of species per 250 cc soil		296	229	**323**	228	**151**	274	170	228	237		

L_1, L_2 and L_3 are orchards in village Ladoora (District Baramulla). S_1, S_2 and S_3 are sites where soil samples are extracted.
A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes.

Table 1a: Community population of plant parasitic nematodes associated with high density apple orchards in village Ladoora (District Baramulla)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	74.55	64.13- 84.97	31.41	100.00	12.67	745.50	32.58
2	*Pratylenchus* sp.	41.11	29.34-52.88	17.32	100.00	12.67	411.10	17.96
3	*Tylenchorhynchus* sp.	22.55	13.40-31.70	9.50	88.88	11.26	212.42	9.28
4	*Tylenchus* sp.	27.00	14.71-39.29	11.37	88.88	11.26	254.34	11.11
5	*Hoplolaimus* sp.	6.00	1.33-10.67	2.52	66.66	8.45	48.96	2.13
6	*Xiphinema insigne*	21.66	12.41-30.91	9.12	88.88	11.26	204.03	8.91
7	*X. index*	19.77	12.27-27.27	8.33	88.88	11.26	186.23	8.13
8	*X. americanum*	13.77	6.71-20.83	5.80	88.88	11.26	129.71	5.66
9	*Longidorus elongatus*	10.88	4.81-16.95	4.58	77.77	9.85	95.85	4.18
	S.W.I	**PA=237,**	**S=9,**	**D= 0.172,**	**1-D=0.828,**	**I/D =5.81,**	**H=1.954,**	**E=0.889**

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evennes

Table 2: **Diversity of plant parasitic nematodes associated with high density apple orchards in village Zangam (District Baramulla)**

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Zg_1			Zg_2			Zg_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	80	45	90	75	60	80	55	70	64	68.77	26.45
2	*Pratylenchus* sp.	50	37	40	80	55	90	38	28	34	50.22	19.32
3	*Tylenchorhynchus* sp.	32	42	18	26	30	19	28	12	22	25.44	09.70
4	*Tylenchus* sp.	40	38	24	24	34	26	48	64	70	40.89	15.72
5	*Hoplolaimus* sp.	14	6	0	8	12	16	0	22	4	09.12	03.50
6	*Xiphinema insigne*	24	22	10	0	28	34	33	30	36	24.12	09.27
7	*X. index*	20	28	8	14	0	12	28	30	22	18.00	06.92
8	*X. americanum*	12	22	8	0	6	11	16	20	20	12.78	04.91
9	*Longidorus elongatus*	10	14	22	15	9	0	0	18	8	10.67	04.10

Zg_1, Zg_2 and Zg_3 are orchards in village Zangam (District Baramulla). S_1, S_2 and S_3 are sites where soil samples are extracted.
A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes.

Table 2a: Community population of plant parasitic nematodes associated with high density apple orchards in village Zangam (District Baramulla)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	68.77	57.91-79.63	26.45	100.00	12.16	687.70	27.02
2	*Pratylenchus* sp.	50.22	33.74-66.70	19.32	100.00	12.16	502.20	19.73
3	*Tylenchorhynchus* sp.	25.44	18.60-32.28	09.70	100.00	12.16	254.40	9.99
4	*Tylenchus* sp.	40.89	27.92-53.86	15.72	100.00	12.16	408.90	16.06
5	*Hoplolaimus* sp.	09.12	03.37-14.87	03.50	77.77	09.45	80.34	3.15
6	*Xiphinema insigne*	24.12	14.90-33.34	09.27	88.88	10.81	227.21	8.92
7	*X. index*	18.00	10.13-25.87	06.92	88.88	10.81	169.56	6.66
8	*X. americanum*	12.78	07.11-18.45	04.91	88.88	10.81	120.38	4.73
9	*Longidorus elongatus*	10.67	04.91-16.43	04.10	77.77	09.45	94.00	3.69
S.W.I	**PA=260, S=9, D= 0.160, 1-D=0.840, I/D=6.25, H=1.982, E=0.902**							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evennes.

Table 3: Diversity of plant parasitic nematodes associated with high density apple orchards in village Arampora (District Baramulla)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Ap_1			Ap_2			Ap_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	120	98	75	80	70	64	80	62	58	78.55	26.49
2	*Pratylenchus* sp.	90	100	60	65	48	55	52	64	56	65.55	22.11
3	*Tylenchorhynchus* sp.	40	50	30	34	36	14	24	22	28	30.88	10.41
4	*Tylenchus* sp.	75	38	20	42	55	60	46	52	40	47.55	16.04
5	*Hoplolaimus* sp.	12	8	0	6	14	16	0	24	5	9.40	3.18
6	*Xiphinema insigne*	25	22	12	24	0	36	32	30	34	23.88	8.05
7	*X. index*	22	28	18	6	0	12	24	30	18	17.55	5.92
8	*X. americanum*	12	20	8	0	16	11	12	18	14	12.34	4.16
9	*Longidorus elongatus*	10	12	22	14	8	6	0	24	0	10.67	3.59
No. of species per 250 cc soil		**406**	376	**245**	271	247	274	270	326	253		

Ap_1, Ap_2 and Ap_3 are orchards in village Arampora (District Baramulla). S_1, S_2 and S_3 are sites where soil samples are extracted.
A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes.

Table 3a: Community population of plant parasitic nematodes associated with high density apple orchards in village Arampora (District Baramulla)

S.No	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	78.55	63.44-93.66	26.49	100.00	12.16	785.50	27.00
2	*Pratylenchus* sp.	65.55	51.93-79.17	22.11	100.00	12.16	655.50	22.53
3	*Tylenchorhynchus* sp.	30.88	22.71-39.05	10.41	100.00	12.16	308.80	10.61
4	*Tylenchus* sp.	47.55	35.63-59.47	16.04	100.00	12.16	475.50	16.34
5	*Hoplolaimus* sp.	9.40	3.36-15.44	3.18	77.77	9.45	82.81	2.84
6	*Xiphinema insigne*	23.88	15-32.76	8.05	88.88	10.81	224.94	7.73
7	*X. index*	17.55	9.88-25.22	5.92	88.88	10.81	165.32	5.68
8	*X. americanum*	12.34	7.8-16.88	4.16	88.88	10.81	116.24	3.99
9	*Longidorus elongatus*	10.67	4.15-17.19	3.59	77.77	9.45	94.00	3.23
S.W.I	**PA=296, S=9, D= 0.170, 1-D=0.830, I/D=5.88, H= 1.937, E=0.881**							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evennes.

Table 4: **Diversity and population of plant parasitic nematodes associated with high density apple orchards in District Baramulla during the year 2019**

S.No.	Nematodes	Absolute density/250 cc soil			Mean of A.D	95% C.I	Mean of F%	R.F	P.V	R.PV%
		Ladoora	Zangam	Arampora						
1	*Helicotylenchus* sp.	74.55	68.77	78.55	**73.95**	61.83-86.07	100.00	12.32	739.50	28.69
2	*Pratylenchus* sp.	41.11	50.22	65.55	**52.29**	38.36-66.22	100.00	12.32	522.90	20.28
3	*Tylenchorhynchus* sp.	22.55	25.44	30.88	**26.29**	18.24-34.34	96.29	11.87	257.90	10.00
4	*Tylenchus* sp.	27.00	40.89	47.55	**38.48**	26.09-50.87	96.29	11.87	377.48	14.64
5	*Hoplolaimus* sp.	6.00	09.12	9.40	**8.17**	2.77-13.57	74.07	9.13	70.26	2.72
6	*Xiphinema insigne*	21.66	24.12	23.88	**23.22**	14.11-32.33	88.88	10.95	218.73	8.48
7	*X. index*	19.77	18.00	17.55	**18.44**	10.76-26.12	88.88	10.95	173.70	6.74
8	*X. americanum*	13.77	12.78	12.34	**12.96**	7.26-18.66	88.88	10.95	122.08	4.73
9	*Longidorus elongatus*	10.88	10.67	10.67	**10.74**	4.62-16.86	77.77	9.58	94.61	3.67

A.D: Absolute density, **C.I:** Confidence interval, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value

Table 5: Status and distribution of plant parasitic nematodes associated with different rootstocks of High Density Apple orchards in district Baramulla of Kashmir valley

Nematode fauna		Rootstocks				
		M9	M4	M7	MM-106	Total
Ectoparasitic	*Xiphinema index*	10	88	77	40	25
	Xiphinema americanum	8	4	0	8	20
	Xiphinema insigne	10	8	0	0	18
	Longidorus elongatus	4	0	11	3	18
Endoparasitic	*Pratylenchus* sp.	56	49	47	15	167
	Tylenchus sp.	31	20	0	12	63
Semi-endoparasitic	*Helicotylenchus* sp.	20	14	7	9	50
	Hoplolaimus sp.	5	8	4	0	17
	Tylenchorynchus sp.	9	13	10	0	32
	Total	**153**	**124**	**86**	**47**	

Plant parasitic nematodes in localities of district Anantnag

Gopalpora

The basic data of nine composite soil samples collected around the high density apple plants comprising of three composite soil samples from each of the three high density apple orchards in locality Gopalpora are presented (Table 6). In the locality Gopal pora of district Anantnag fruit belt, eight nematode genera were isolated from the high density apple orchard rhizosphere. The plant parasitic nematodes comprised the species of *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchoruhnchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X. index*, *X.americanum* and *Longidorus elongatus* with per cent relative density of 31.56, 18.78, 10.43,

11.72, 9.84, 8.11, 5.26 and 4.27, respectively. After species wise analysis, the status of all the plant parasitic nematodes in the locality with respect to Frequency, Population density, Prominence value and Shannon wiener diversity index were recorded (Table 6a).

The absolute population density per 250 cc soil of *Pratylenchus* sp., was recorded to be 70.56 ranging from 60.03-81.09 at 95 per cent confidence interval. The frequency and prominence value was recorded as 100.00 per cent and 705.60. *Helicotylenchus* sp., with absolute density recorded to be 42.00 ranging from 33.68-50.32 at 95 per cent confidence interval with per cent frequency and prominence value as 100.00 and 420.00, respectively. *Tylenchoryhnchus* sp., with absolute population density as 23.34 ranging from 16.05-30.63 at 95 per cent confidence interval. The frequency and prominence value were recorded as 100.00 and 233.40, respectively. The absolute density per 250 cc soil of *Tylenchus* sp., was recorded to be 26.23 ranging from 15.08-37.38 at 95 per cent confidence interval, showing frequency and prominence value as 88.88 and 247.08, respectively.

Xiphinema insigne, X. index and X. americanum with absolute density of 22.00, 18.11 and 11.77 ranging from 13.38-30.62, 10.88-25.34 and 5.65-17.89 at 95 per cent confidence interval, respectively. The frequency and prominence value were recorded to be 88.88, 88.88, 77.77 and 207.24, 170.59 and 103.69, respectively. The absolute density of *Longidorus elongatus* was recorded as 9.55 ranging from 3.97-15.13 at 95 per cent confidence interval. The frequency and prominence value of this specie were recorded as 77.77 and 84.13, respectively. In Gopal pora apple orchards in terms of relative density, absolute frequency and prominence value, *Pratylenchus* sp., *Helicotylenchus* sp., and *Tylenchus* sp., ranked as first, second and third important plant parasitic nematodes in the entire fruit belt. Similarly after applying Shannon Weiner diversity formula on all populations, the diversity index of all the plant parasitic nematodes in the locality gopal pora was recorded to be 1.880.

Achabal

The data from (Table 7) of locality Achabal reveals the population of plant parasitic nematodes in eight groups with percent relative density per 250cc soil as 32.89, 19.94, 10.18, 11.29, 9.76, 6.36, 5.57 and 3.97 for *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus* and similarly the status of plant parasitic nematodes is presented in (Table 7a). Perusal of the data in (Table 7a) revealed the status of various plant parasitic nematodes as absolute population density with range at 95 per cent confidence interval and per cent frequency recorded as 68.89 (58.96-78.82) 100.00 per cent, 41.78 (32.74-50.82) 100.00 per cent, 21.34 (13.03-29.65) 88.88 per cent, 23.67 (13.88-33.46) 88.88 per cent, 20.44 (11.79-29.09) 88.88 per cent, 13.34 (6.43-20.25) 77.77 per cent, 11.67 (5.62-17.72) 77.77 per cent and 8.34 (3.36-13.32) 77.77 per cent for *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus*, respectively. Similarly their prominence value of 688.90, 417.80, 201.02, 222.97, 192.54, 117.52, 102.81 and 73.47 was recorded for *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus*, respectively. The diversity index of all the plant parasitic nematodes in the locality was recorded as 1.849. Among all the plant parasitic nematodes, *Pratylenchus* sp., *Helicotylenchus* sp., and *Tylenchus* sp., were recorded as first, second and third important plant parasitic nematodes in Achabal locality.

Kokernag

In locality Kokernag of Anantnag fruit belt, the Table 8 revealed the relative per cent population density in the ratio of 31.69, 19.35, 10.32, 12.64, 10.42, 6.35, 5.67 and 3.51 for the plant parasitic nematodes viz; *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus*, respectively. After analysis the community population status are presented in Table 8a. Perusal of the data

(Table 8a) revealed the absolute population density per 250 cc soil with range at 95 per cent confidence interval and per cent frequency as 68.23 (60.23-76.23) 100.00 per cent, 41.67 (34.07-49.27) 100.00 per cent, 22.23 (14.23-30.23) 88.88 per cent, 27.23 (16.33-38.13) 88.88 per cent, 22.45 (14.08-30.82) 88.88 per cent, 13.67 (7.04-20.30) 77.77 per cent, 12.23 (5.74-18.72) 77.77 per cent and 7.56 (1.88-13.24) 66.66 per cent for *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus,* respectively. Similarly their prominence value of 682.30, 416.70, 209.40, 256.50, 211.47, 120.43, 107.74 and 61.68 was recorded for *Pratylenchus* sp., *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, and *Longidorus elongatus,* respectively. The diversity index of all plant parasitic nematodes in the locality was recorded as 1.863. Among all the plant parasitic nematodes, *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchu*s sp., were recorded as first, second and third important plant parasitic nematodes in Kokernag locality of district Anantnag.

Status of plant parasitic nematodes in Anantnag fruit belt

After multiple comparison of twenty seven soil samples of district Anantnag comprising nine composite soil samples from each of the three localities, the status of plant parasitic nematodes are presented in Table 9, Fig. 2. Perusal of the data in Table 9 revealed that among the three localities viz; Gopalpora, Achabal and Kokernag, the maximum population of 70.56 for *Pratylenchus* sp., was recorded in Gopalpora followed by 68.89 in Achabal and 68.23 in Kokernag. The mean population of *Pratylenchus* sp., in district Anantnag was recorded as 69.22 ranging from 59.74-78.70 at 95 per cent confidence interval. The per cent relative frequency and per cent relative prominence value of *Pratylenchus* sp., in the district Anantnag were recorded as 14.21 and 33.21, respectively and ranked as first dominant plant parasitic nematode in the entire district on the basis of population density and frequency of occurrence. *Helicotylenchus* sp., the Spiral nematode was recorded as second dominant specie

with mean population in the fruit belt as 41.81 ranging from 33.49-50.13 at 95 per cent confidence interval. Its per cent frequency in the belt was recorded at par with *Pratylenchus* sp., (100%). The maximum population per 250 cc soil was recorded in locality Gopalpora as 42.00 followed by absolute population of 41.78 in Achabal and 41.67 in Kokernag. The per cent relative frequency and per cent relative prominence value of *Helicotylenchus* sp., in the district Anantnag were recorded as 14.21 and 20.06, respectively. *Tylenchorhynchus* sp., the stunt nematode was recorded with a mean population of 22.31 ranging from 14.51-30.11 at 95 per cent confidence interval in district Anantnag with 92.59 frequency. The per cent relative frequency and per cent relative prominence value of *Tylenchorhynchus* sp., in the district Anantnag were recorded as 13.15 and 10.29, respectively. Similarly the mean population of *Tylenchus* sp., per 250 cc soil was recorded as 25.71 ranging from 15.10-36.32 at 95 per cent confidence interval with 88.88 frequency and was recorded as third dominant specie in the entire district. The maximum population per 250 cc soil was recorded in locality Kokernag as 27.23 followed by population of 26.23 in Gopalpora and 23.67 in Achabal. The per cent relative frequency and per cent relative prominence value of *Tylenchus* sp., in the district Anantnag were recorded as 12.63 and 11.62, respectively. The status of *Xiphinema insine*, *X.index* and *X.americanum* with respect to mean population per 250 cc soil in the belt was recorded as 21.63 ranging from 13.09-30.17, 15.04 ranging from 8.12- 21.96 and 11.89 ranging from 5.67-18.11 at 95 per cent confidence interval, respectively. Their per cent relative frequency and per cent relative prominence value were recorded as 12.63 and 9.77, 11.57 and 6.50 and 11.05 and 5.02, respectively. The data in the Table 9 revealed the status of *Longidorus elongatus* with its low mean population per 250 cc soil as 8.48 ranging from 3.07-13.89 at 95 per cent confidence interval in the entire district with 74.07 frequency. Its per cent relative frequency was also recorded as 10.52 with relative prominence value of 3.49, respectively.

Status of plant parasitic nematodes associated with different rootstocks of high density apple orchards in district Anantnag

Although recent research indicates that several plant parasitic nematodes are associated with the different rootstocks of high density apple orchards (Table 10). The basic data revealed that *Pratylenchus sp.,* was found highest at all locations followed by *Longidorus elongatus* and *Tylenchus sp.,* (Table 10). After multiple comparison of different rootstocks, it was found that highest number of nematodes were present on M9 rootstock (85) followed by MM-111 (64) and M4 (57) while minimum population was found on MM-106(32) (Table 10).

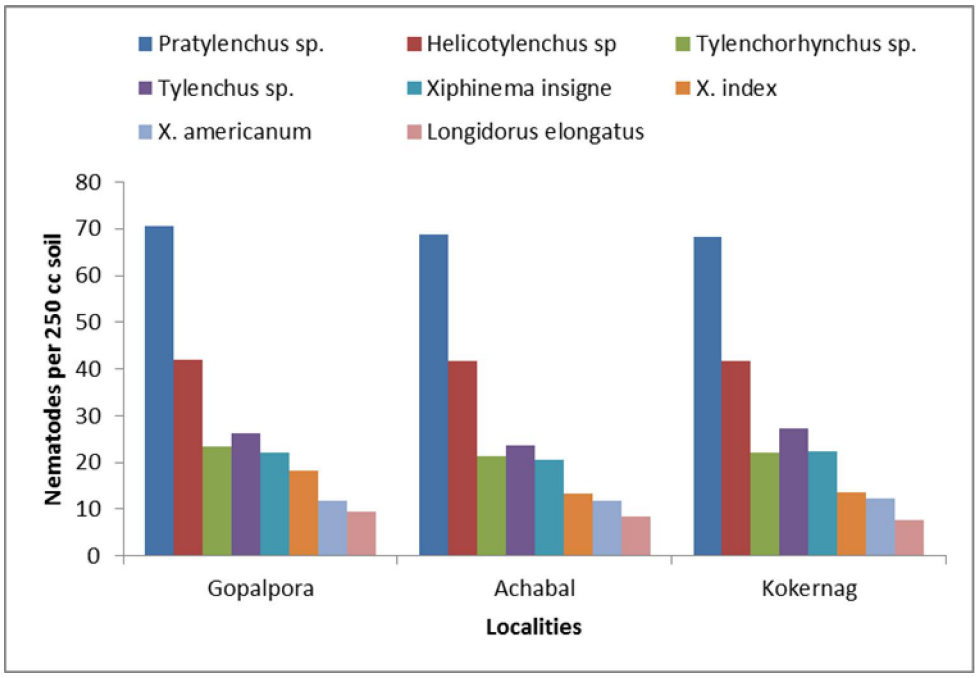

Fig. 2: Population status of plant parasitic nematodes in district Anantnag

Table 6: Diversity of plant parasitic nematodes associated with high density apple orchards in village Gopalpora (District Anantnag)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Gp_1			Gp_2			Gp_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Pratylenchus* sp.	70	50	98	74	60	75	62	80	66	70.56	31.56
2	*Helicotylenchus* sp	50	40	34	45	38	55	22	38	56	42.00	18.78
3	*Tylenchorhynchus* sp.	38	22	24	30	28	18	12	8	30	23.34	10.43
4	*Tylenchus* sp.	34	38	52	0	24	26	22	16	24	26.23	11.72
5	*Xiphinema insigne*	34	24	32	26	0	32	18	22	10	22.00	9.84
6	*X. index*	22	16	17	14	0	28	32	12	22	18.11	8.11
7	*X. americanum*	14	20	22	12	0	0	18	12	8	11.77	5.26
8	*Longidorus elongatus*	12	14	20	10	0	0	8	18	4	9.55	4.27
No. of species per 250 cc soil		274	224	**299**	211	**150**	234	194	206	220		

Gp_1, Gp_2 and Gp_3 are orchards in Gopalpora (District Anantnag)

S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes.

R.D: Relative density of plant parasitic nematodes

Table 6a: Community population of plant parasitic nematodes associated with high density apple orchards in village Gopalpora (District Anantnag)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Pratylenchus* sp.	70.56	60.03-81.09	31.56	100.00	13.84	705.60	32.48
2	*Helicotylenchus* sp	42.00	33.68-50.32	18.78	100.00	13.84	420.00	19.33
3	*Tylenchorhynchus* sp.	23.34	16.05-30.63	10.43	100.00	13.84	233.40	10.74
4	*Tylenchus* sp.	26.23	15.08-37.38	11.72	88.88	12.31	247.08	11.37
5	*Xiphinema insigne*	22.00	13.38-30.62	9.84	88.88	12.31	207.24	9.54
6	*X. index*	18.11	10.88-25.34	8.11	88.88	12.31	170.59	7.85
7	*X. americanum*	11.77	5.65-17.89	5.26	77.77	10.76	103.69	4.77
8	*Longidorus elongatus*	9.55	3.97-15.13	4.27	77.77	10.76	84.13	3.87

S.W.I PA=223, S=8, D=0.181, 1-D= 0.819, I/D= 5.52, H=1.880, E=0.904

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

.

Table 7: Diversity of plant parasitic nematodes associated with high density apple orchards in village Achabal (District Anantnag)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Ac_1			Ac_2			Ac_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Pratylenchus* sp.	68	48	92	76	58	74	60	78	66	68.89	32.89
2	*Helicotylenchus* sp	50	48	32	44	36	54	24	30	58	41.78	19.94
3	*Tylenchorhynchus* sp.	36	24	24	32	26	22	16	12	0	21.34	10.18
4	*Tylenchus* sp.	32	34	44	0	23	28	16	16	20	23.67	11.29
5	*Xiphinema insigne*	32	22	30	26	0	34	14	12	14	20.44	9.76
6	*X. index*	20	14	16	12	0	24	24	10	0	13.34	6.36
7	*X. americanum*	16	18	22	14	0	13	16	0	6	11.67	5.57
8	*Longidorus elongatus*	18	10	15	8	0	6	4	14	0	8.34	3.97
No. of species per 250 cc soil		272	218	**275**	212	143	255	174	172	**164**		

Ac_1, Ac_2 and Ac_3 are orchards in Achabal (District Anantnag). S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes

Table 7a: Community population of plant parasitic nematodes associated with high density apple orchards in Achabal (District Anantnag)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Pratylenchus* sp.	68.89	58.96-78.82	32.89	100.00	14.28	688.90	34.15
2	*Helicotylenchus* sp	41.78	32.74-50.82	19.94	100.00	14.28	417.80	20.71
3	*Tylenchorhynchus* sp.	21.34	13.03-29.65	10.18	88.88	12.69	201.02	9.96
4	*Tylenchus* sp.	23.67	13.88-33.46	11.29	88.88	12.69	222.97	11.05
5	*Xiphinema insigne*	20.44	11.79-29.09	9.76	88.88	12.69	192.54	9.54
6	*X. index*	13.34	6.43-20.25	6.36	77.77	11.12	117.52	5.82
7	*X. americanum*	11.67	5.62-17.72	5.57	77.77	11.12	102.81	5.09
8	*Longidorus elongatus*	8.34	3.36-13.32	3.97	77.77	11.12	73.47	3.64
S.W.I	**PA=209, S=8, D= 0.190, 1-D=0.810, I/D= 5.26, H=1.849, E=0.889**							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

Table 8: Diversity of plant parasitic nematodes associated with high density apple orchards in village Kokernag (District Anantnag)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Kn_1			Kn_2			Kn_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Pratylenchus* sp.	78	56	88	68	54	70	64	70	66	68.23	31.69
2	*Helicotylenchus* sp	52	46	38	40	38	50	26	30	55	41.67	19.35
3	*Tylenchorhynchus* sp.	34	28	24	26	24	32	0	14	18	22.23	10.32
4	*Tylenchus* sp.	42	33	42	18	34	38	0	16	22	27.23	12.64
5	*Xiphinema insigne*	30	22	32	24	0	36	24	22	12	22.45	10.42
6	*X. index*	18	16	16	14	26	0	20	13	0	13.67	6.35
7	*X. americanum*	18	20	24	10	0	16	14	0	8	12.23	5.67
8	*Longidorus elongatus*	16	20	12	6	4	0	10	0	0	7.56	3.51
No. of species per 250 cc soil		**288**	241	276	206	180	242	**158**	165	181		

Kn_1, Kn_2 and Kn_3 are orchards in Kokernag(District Anantnag). S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes.

Table8a: Community population of plant parasitic nematodes associated with high density apple orchards in village Kokernag (District Anantnag)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Pratylenchus* sp.	68.23	60.23-76.23	31.69	100.00	14.51	682.30	33.02
2	*Helicotylenchus* sp	41.67	34.07-49.27	19.35	100.00	14.51	416.70	20.16
3	*Tylenchorhynchus* sp.	22.23	14.23-30.23	10.32	88.88	12.91	209.40	10.13
4	*Tylenchus* sp.	27.23	16.33-38.13	12.64	88.88	12.91	256.50	12.41
5	*Xiphinema insigne*	22.45	14.08-30.82	10.42	88.88	12.91	211.47	10.23
6	*X. index*	13.67	7.04-20.30	6.35	77.77	11.29	120.43	5.82
7	*X. americanum*	12.23	5.74-18.72	5.67	77.77	11.29	107.74	5.21
8	*Longidorus elongatus*	7.56	1.88-13.24	3.51	66.66	9.67	61.68	2.98
S.W.I	**PA=215, S=8, D= 0.184, 1-D= 0.816, I/D= 5.43, H=1.863, E=0.896**							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

.

Table 9: Diversity and community population of plant parasitic nematodes associated with high density apple orchards in District Anantnag

S.No.	Nematodes	Absolute density/250 cc soil			Mean of A.D	95% C.I	Mean of F%	R.F	P.V	R.PV%
		Gopalpora	Achabal	Kokernag						
1	*Pratylenchus* sp.	70.56	68.89	68.23	**69.22**	59.74-78.70	100.00	14.21	692.20	33.21
2	*Helicotylenchus* sp	42.00	41.78	41.67	**41.81**	33.49-50.13	100.00	14.21	418.10	20.06
3	*Tylenchorhynchus* sp.	23.34	21.34	22.23	**22.31**	14.51-30.11	92.59	13.15	214.62	10.29
4	*Tylenchus* sp.	26.23	23.67	27.23	**25.71**	15.10-36.32	88.88	12.63	242.18	11.62
5	*Xiphinema insigne*	22.00	20.44	22.45	**21.63**	13.09-30.17	88.88	12.63	203.75	9.77
6	*X. index*	18.11	13.34	13.67	**15.04**	8.12-21.96	81.48	11.57	135.66	6.50
7	*X. americanum*	11.77	11.67	12.23	**11.89**	5.67-18.11	77.77	11.05	104.75	5.02
8	*Longidorus elongatus*	9.55	8.34	7.56	**8.48**	3.07-13.89	74.07	10.52	72.92	3.49

A.D: Absolute density, **C.I:** Confidence interval, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value

Table 10: Status and distribution of plant parasitic nematodes associated with different rootstocks of High Density Apple orchards in district Anantnag of Kashmir

Nematode fauna		Rootstocks					
		M9	M4	M7	MM-106	MM-111	Total
Ectoparasitic	*Xiphinema index*	6	2	4	0	4	**16**
	Xiphinema americanum	3	1	3	0	5	**12**
	Xiphinema insigne	7	5	4	0	0	**16**
	Longidorus elongatus	10	6	0	3	5	**24**
Endoparasitic	*Pratylenchus* sp.	32	27	22	25	24	**130**
Semi-endoparasitic	*Tylenchus* sp.	7	2	0	4	9	**22**
	Helicotylenchus sp.	4	3	0	0	8	**15**
	Hoplolaimus sp.	5	5	4	0	4	**18**
	Tylenchorynchus sp.	11	6	0	0	5	**22**
	Total	**85**	**57**	**37**	**32**	**64**	

Plant parasitic nematodes in localities of district Srinagar

SKUAST-K, Shalimar

The basic data of nine composite soil samples collected around the high density apple plants comprising of three composite soil samples from each of the three high density apple orchards in locality SKUAST-K, Shalimar are presented (Table 11). In the locality SKUAST-K, Shalimar of district Srinagar fruit belt, eight nematode genera were isolated from the high density apple orchard rhizosphere. The present study (Table 11) reveals the per cent relative density of

plant parasitic nematodes as 29.05, 21.06, 9.02, 11.92, 10.18, 7.53, 5.92 and 5.28 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus*. After species wise analysis, the data (Table 11) revealed the absolute population density per 250 cc soil of *Helicotylenchus* sp., as 50.12 ranging from 42.72-57.52 at 95 per cent confidence interval with 100 per cent frequency. Similarly the absolute population density per 250 cc soil with range at 95 per cent confidence interval and frequency was recorded to be 36.34 (31.30-41.38) 100.00 per cent, 15.56 (8.20-22.92) 77.77 per cent, 20.56 (14.67-26.45) 100.00 per cent, 17.56 (9.37-25.75) 77.77 per cent, 13.00 (6.17- 19.83) 77.77 per cent, 10.23 (4.56-15.90) 77.77 per cent and 9.11 (2.59-15.63) 66.66 per cent for *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus,* respectively. The prominence value of 501.20, 363.40, 137.08, 205.60, 154.70, 114.53, 90.12 and 74.33 was also recorded for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus,* respectively.The diversity index of 1.901 was also recorded for all the nematode species present in the entire locality.

Habak

The status of plant parasitic nematodes in the locality Habak in district Srinagar revealed the presence of eight plant parasitic nematodes with per cent relative density per 250 cc soil as 29.10, 20.06, 7.64, 18.79, 8.25, 6.31, 5.26 and 4.54 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus,* respectively (Table12).

The species wise analysis of plant parasitic nematodes are presented (Table 12a). Perusal of the data (Table 12a) revealed the absolute population density per 250 cc soil with range at 95 per cent confidence interval and average

frequency for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus* as 58.33 (50.02-66.64) 100.00 per cent, 40.22 (31.97-48.47) 100.00 per cent, 15.33 (9.33-21.33) 88.88 per cent, 37.56 (28.32-47.00) 100.00 per cent, 16.55 (7.24-25.86) 77.77 per cent, 12.66 (5.83-19.49) 77.77 per cent, 10.55 (4.76-16.34) 77.77 per cent and 9.11 (2.59-15.63) 66.66 per cent, respectively. The prominence value was also recorded in the entire locality with the values as 583.30, 402.20, 144.40, 376.60, 145.80, 111.53, 92.94 and 74.33 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus* respectively. The diversity index of all the species in the locality was recorded to be 1.85.

Zakura

The population status with respect to per cent relative density of plant parasitic nematodes were recorded (Table 13) as 28.13, 19.65, 8.11, 18.71, 8.61, 6.36, 6.23 and 4.17 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus***,** respectively. The detailed status of *Helicotylenchus* sp., (Table 13a) on analysis revealed absolute population density with range at 95 per cent confidence interval and average frequency as 50.12 (36.86-63.38) 100.00 per cent. The same parametric status are put on the records as 35.00 (24.75-45.25) 100.00 per cent, 14.45 (8.51-20.39) 88.88 per cent, 33.34 (25.01-41.67) 100.00 per cent, 15.34 (8.09-22.59) 88.88 per cent, 11.34 (5.34-17.34) 77.77 per cent, 11.11 (5.01-17.21) 77.77 per cent and 7.45 (1.95-12.95) 66.66 for *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus elongatus* (Table 13a), respectively. The prominence value was also recorded in the entire locality with the values as 501.20, 350.00, 136.12, 333.40, 144.50, 99.91, 97.88 and 60.79 for *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum* and *Longidorus*

elongatus, respectively. The diversity index of all the species in the locality was recorded to be 1.681.

Status of plant parasitic nematodes in Srinagar fruit belt

The overall status of plant parasitic nematodes in the entire district, locality wise is presented Table 14 Fig. 3. Perusal of the data Table 14 revealed the absolute density mean per 250 cc soil for *Helicotylenchus* sp., in the belt as 52.84 with range as 43.19-62.50 at 95 per cent confidence interval with 100.00 per cent frequency and thus indicating this specie as first dominant plant parasitic nematode among other plant parasitic nematodes in the entire Srinagar district. Maximum population of this specie was recorded in Habak (58.33) followed by SKUAST-K (50.12) and minimum population was recorded in Zakura (50.08). The second and third important plant parasitic nematodes were registered as *Pratylenchus* sp., and *Tylenchorhynchus* sp., having absolute density mean with range at 95 per cent confidence interval recoded as 37.18 (29.33-45.02) and 30.52 (22.66-38.37) with per cent frequencies as 100.00 and 100.00. Their maximum and minimum population densities in the belt were recorded in Habak (40.22) and Zakura (35.00) and Habak (37.66) and SKUAST-K (20.56), respectively. The absolute population density mean with range at 95 per cent confidence interval for *Tylenchus* sp., were recorded as 15.11 (8.67-21.54) with a frequency of 85.18 per cent. Similarly, the absolute density mean for the species *Xiphinema insine*, *X.index*, and *X.americanum* were recorded as 16.48, 12.33 and 10.63 with range at 95 per cent confidence interval as 8.23-24.73, 5.77-18.88 and 4.77-16.48, respectively. The data in the Table 14 revealed the status of *Longidorus elongatus* withits low mean population density per 250 cc soil as 8.55 ranging from 2.37-14.73 at 95 per cent confidence interval in the entire district with 66.66 frequency. Similarly, the per cent relative prominence value of *Helicotylenchus* sp., and other species were recorded as 22.93, 21.06, 7.89, 17.29, 8.42, 6.15, 5.30 and 3.95 with per cent relative frequencies as 14.51, 14.51, 12.36, 14.51, 11.82, 11.29, 11.29 and 9.67, respectively.

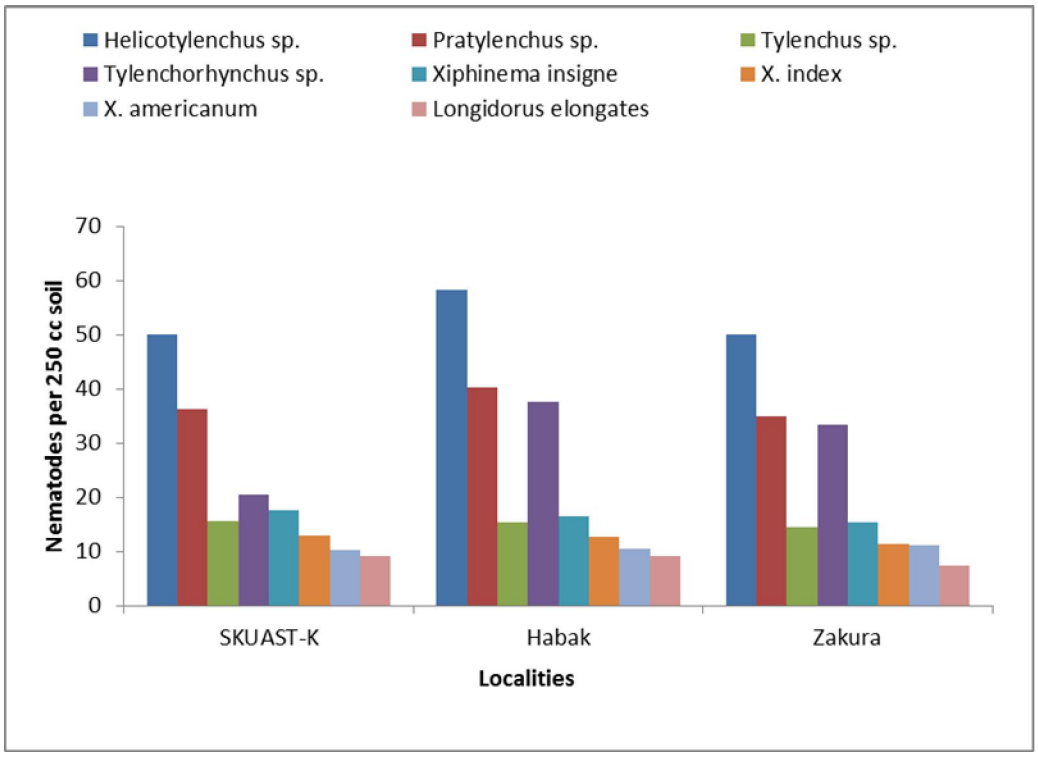

Fig. 3: Population status of plant parasitic nematodes in district Srinagar

Status of plant parasitic nematodes associated with different rootstocks of high density apple orchards in district Srinagar

This district comprises of variable number of rootstocks among all other districts (Baramulla and Srinagar) of Kashmir valley. The analyzed data (Table 15) revealed that different plant parasitic nematodes attack roots of high density apple orchards amongst which *Pratylenchus sp.,* stands first followed by *Tylenchus sp.,* and *Longidorus elongatus* while it remained lowest for *Xiphinema americanum*. However, upon analysis of data (Table 15), it was confirmed that most of the nematodes were present on M9 (40) followed by M4 (32) and M7 (31) while it remained minimum for MM-111 (22).

Population status of plant parasitic nematodes associated with different Districts namely Baramulla, Anantnag and Srinagar of Kashmir valley:

The analyzed data of eighty one composite soil samples of all the three districts namely Baramulla, Anantnag and Srinagar of Kashmir valley comprising nine localities revealed that *Helicotylenchus* sp., stands first dominant plant parasitic nematode with absolute population density mean (Table 18) per 250 cc soil as 56.20 ranging from 54.92-75.26 at 95 per cent confidence interval with frequency 100.00 per cent in all the three districts (Baramulla, Anantnag and Srinagar) of Kashmir valley. The maximum population was recorded in the high density apple orchards at Baramulla (73.95) followed by Srinagar (52.85) and minimum population at orchards of Anantnag (41.81). The status of other plant parasitic nematodes with respect to absolute population density, their range, frequency, maximum and minimum population in the districts are presented (Table 18 Fig. 4). Perusal of the data (Table 18) revealed the mean absolute population of *Pratylenchus* sp., in these districts as 52.89 ranging from 33.73-53.79 at 95 per cent confidence interval with 100 per cent frequency. The maximum population of *Pratylenchus* sp., was recorded in Anantnag (69.22) followed by Baramulla (52.29) and minimum population was recorded in District Srinagar (37.18). The status of *Tylenchorhynchus* sp., with respect to absolute

population density mean per 250 cc soil around the high density apple plants was recorded as 26.37 ranging from 13.80- 28.66 at 95 per cent confidence interval. The per cent frequency of this specie was recorded as 91.34 per cent in different districts (Baramulla, Anantnag and Srinagar) of Kashmir valley with maximum population in Srinagar (30.52) followed by Baramulla (26.29) and minimum population in the district Anantnag (22.31), respectively. The data in the (Table 18) also revealed *Tylenchus* sp., with absolute population density mean of 26.43 ranging from 21.29-41.85 at 95 per cent confidence interval and average per cent frequency 95.05 in different districts (Baramulla, Anantnag and Srinagar) of Kashmir valley with maximum population in Baramulla (38.48) followed by Anantnag (25.71) and having a minimum population in district Srinagar (15.11), respectively. The absolute population density with range at 95 per cent confidence interval and frequency for *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp., were recorded as 20.44 (11.81-29.07) 86.41 per cent, 15.27 (8.22-22.32) 82.70 per cent, 11.82 (5.90-17.74) 81.47 per cent, 9.25 (3.35-15.15) 72.83 per cent and 8.17 (2.77-13.57) 74.06 (only in district Baramulla), respectively.

The Tables 16, 17 and 18 reveal *Helicotylenchus* sp., *Pratylenchus* sp., and *Tylenchus* sp., stand first, second and third predominant plant parasitic nematodes on the basis of absolute density (56.20, 52.89 and 26.43), per cent relative density (29.63, 19.72 and 14.24), and prominence value (562.00, 528.90 and 257.42), respectively, but on the basis of total biomass and relative biomass in all districtsnamely Baramulla, Anantnag and Srinagar, *Xiphinema index* stands first (68.72 and 26.83), *Longidorus elongatus* stands second (67.53 and 26.36) and *Xiphinema insigne* stands third (42.52 and 16.60) while as *Hoplolaimus* sp., remains minimum in terms of total biomass (7.19) and relative biomass (2.81) among other plant parasitic nematodes in different districts (Baramulla, Anantnag and Srinagar) of Kashmir valley. The data from the Table 16 also revealed the rank of rest of the plant parasitic nematodes according to pathogenic significance

rank in descending order of absolute population density of each specie in all districts (Baramulla, Anantnag and Srinagar) of Kashmir valley as *Helicotylenchus* sp., (56.20), *Pratylenchus* sp., (52.89) and *Tylenchus* sp., (26.43), respectively while as *Hoplolaimus* sp., stands at last rank among other plant parasitic nematodes with absolute density mean as 8.17. On the basis of importance value of all plant parasitic nematodes in all districts namely Baramulla, Anantnag and Srinagar, *Helicotylenchus* sp., stands first (16.78), *Xiphinema index* stands second (15.00) and *Longidorus elongatus* stands third (13.50). The importance value of other plant parasitic nematodes in descending order were recorded as *Pratylenchus* sp., (12.92), *Xiphinema insigne* (12.56), *Tylenchus* sp., (10.22), *Tylenchorhynchus* sp.,(8.89), *Xiphinema americanum* (7.80) and *Hoplolaimus* sp., (5.00), respectively (Table 18). The values in the Tables 19 and 20 revealed that when all the plant parasitic nematodes were measured on the basis of population abundance by Shannon Weiner density formula, the diversity index in fruit belts ranged from 1.937 (Arampora) to 1.982 (Zangam) with a difference of 0.045 at district Baramulla. Similarly from 1.849 (Achabal) to 1.880 (Gopalpora) with a difference of 0.031 at district Anantnag and from 1.681 (Zakura) to 1.901 (SKUAST-K) with a difference of 0.220 at district Srinagar. In all the three districts namely; Baramulla, Anantnag and Srinagar on the basis of population abundance the data (Table 20) revealed that the diversity index ranged from 1.813 (Srinagar) to 1.957 (Baramulla) with the difference in energy flow of 0.144 which is almost nearer to the diversity index at Anantnag (1.864) fruit belt**.**

Overall mean population of plant parasitic nematodes in different rootstocks of high density apple orchards associated with district Baramulla, Anantnag and Srinagar of Kashmir valley

After multiple comparison of overall rootstocks of all the districts (Baramulla, Anantnag and Srinagar) of Kashmir valley comprising nine localities revealed that M9 rootstock stand first with mean nematode population (92.66) in

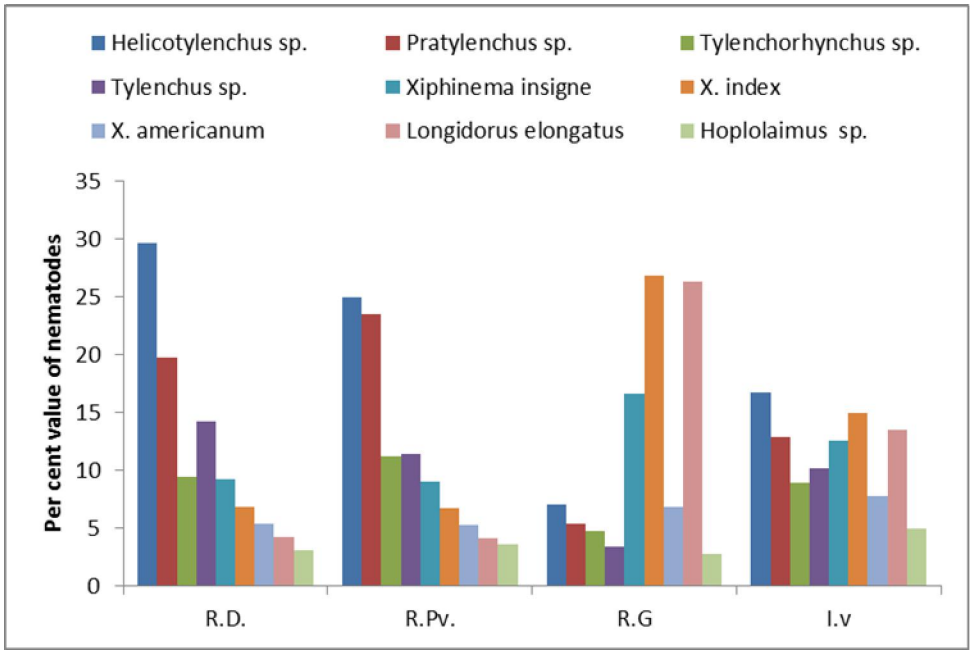

Fig. 4: Population status of plant parasitic nematodes in district Baramulla, Anantnag and Srinagar of Kashmir Valley

all the three districts (Baramulla, Anantnag and Srinagar) of Kashmir valley (Table 21, Fig. 5). The maximum population of nematodes on M9 rootstock (Table 21) was recorded in the high density apple orchards at Baramulla (153) followed by Anantnag (85) and minimum population at orchards of Srinagar (40). The status of other rootstocks with respect to overall mean population of nematodes in all the districts is presented (Table 21). Perusal of the data (Table 21) revealed M4 rootstock having mean nematode population (70.33) in all the districts (Baramulla, Anantnag and Srinagar) of Kashmir valley and stand second rootstock after M9 on the basis of overall nematode population in the Kashmir valley. The maximum population was recorded in Baramulla (124) and minimum population at orchards of Srinagar (30). The data in the (Table) also revealed that M7 stands third rootstock having mean nematode population (52.00) followed by MM-106 (34.33) in all the three districts (Baramulla, Anantnag and Srinagar) of Kashmir valley. Similarly, the data in the (Table 21) revealed that MM-111 and M9-T337 showed less mean nematode population of (28.66) and (10.33) respectively, with MM-111 rootstock found only at orchards of districts of Anantnag and Srinagar while M9-T337 found only at orchards of district Srinagar.

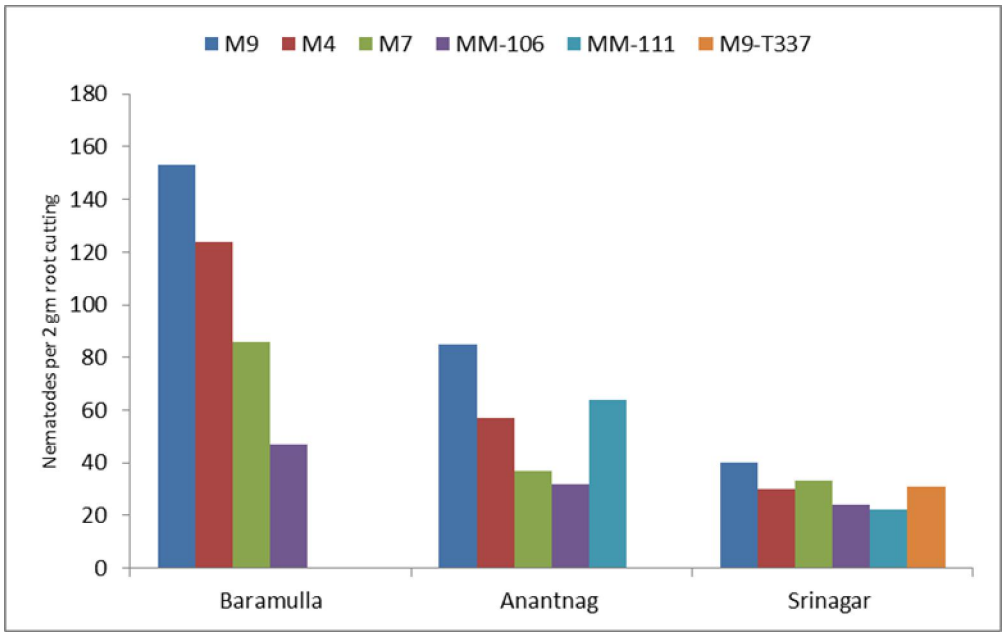

Fig. 5: Overall mean population of plant parasitic nematodes in different apple rootstocks associated with district Baramulla, Anantnag & Srinagar of Kashmir valley

Table 11: Diversity of plant parasitic nematodes associated with high density apple orchards in SKUAST-K, Shalimar (District Srinagar)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Sk_1			Sk_2			Sk_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	44	54	56	65	40	44	63	40	45	50.12	29.05
2	*Pratylenchus* sp.	38	31	36	44	30	38	34	28	48	36.34	21.06
3	*Tylenchus* sp.	18	16	20	0	22	0	14	24	26	15.56	9.02
4	*Tylenchorhynchus* sp.	20	8	22	14	26	12	28	25	30	20.56	11.92
5	*Xiphinema insigne*	18	20	30	22	0	0	26	24	18	17.56	10.18
6	*X. index*	20	12	8	0	14	0	22	17	24	13.00	7.53
7	*X. americanum*	18	14	0	10	8	0	16	6	20	10.23	5.92
8	*Longidorus elongatus*	15	18	10	0	23	5	0	11	0	9.11	5.28
No. of species per 250 cc soil		191	173	182	155	163	**99**	203	175	**211**		

Sk_1, Sk_2 and Sk_3 are orchards in SKUAST-K,Shalimar(District Srinagar). S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes

Table 11a: Community population of plant parasitic nematodes associated with high density apple orchards in SKUAST-K, Shalimar (District Srinagar)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	50.12	42.72-57.52	29.05	100.00	14.75	501.20	30.54
2	*Pratylenchus* sp.	36.34	31.3-41.38	21.06	100.00	14.74	363.40	22.14
3	*Tylenchus* sp.	15.56	8.20-22.92	9.02	77.77	11.47	137.08	8.35
4	*Tylenchorhynchus* sp.	20.56	14.67-26.45	11.92	100.00	14.75	205.60	12.52
5	*Xiphinema insigne*	17.56	9.37-25.75	10.18	77.77	11.47	154.70	9.42
6	*X. index*	13.00	6.17-19.83	7.53	77.77	11.47	114.53	6.97
7	*X. americanum*	10.23	4.56-15.90	5.92	77.77	11.47	90.12	5.49
8	*Longidorus elongatus*	9.11	2.59-15.63	5.28	66.66	9.83	74.33	4.53
	S.W.I PA=172, S=8, D= 0.174, 1-D= 0.826, I/D= 5.74, H= 1.901, E=0.914							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

Table 12: Diversity of plant parasitic nematodes associated with high density apple orchards in village Habak (District Srinagar)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Hb_1			Hb_2			Hb_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	66	70	56	45	63	75	55	50	45	58.33	29.10
2	*Pratylenchus* sp.	50	48	56	20	38	44	36	38	32	40.22	20.06
3	*Tylenchus* sp.	16	18	22	12	0	8	16	20	26	15.33	7.64
4	*Tylenchorhynchus* sp.	42	35	48	43	38	40	55	22	16	37.66	18.79
5	*Xiphinema insigne*	14	18	28	20	0	8	0	28	33	16.55	8.25
6	*X. index*	22	18	6	0	12	0	24	16	16	12.66	6.31
7	*X. americanum*	20	16	12	0	6	14	0	19	8	10.55	5.26
8	*Longidorus elongatus*	15	18	10	0	23	5	0	11	0	9.11	4.54
No. of species per 250 cc soil		**245**	241	238	**140**	180	194	186	204	176		

Hb_1, Hb_2 and Hb_3 are orchards in Habak (District Srinagar). S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes

Table 12a: Community population of plant parasitic nematodes associated with high density apple orchards in village Habak (District Srinagar)

S.No.	Nematodes	A.D	95% C.I	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	58.33	50.02-66.64	29.10	100.00	14.51	583.30	30.20
2	*Pratylenchus* sp.	40.22	31.97-48.47	20.06	100.00	14.51	402.20	20.82
3	*Tylenchus* sp.	15.33	9.33-21.33	7.64	88.88	12.9	144.40	7.47
4	*Tylenchorhynchus* sp.	37.66	28.32-47.00	18.79	100.00	14.51	376.60	19.50
5	*Xiphinema insigne*	16.55	7.24-25.86	8.25	77.77	11.29	145.80	7.55
6	*X. index*	12.66	5.83-19.49	6.31	77.77	11.29	111.53	5.77
7	*X. americanum*	10.55	4.76-16.34	5.26	77.77	11.29	92.94	4.81
8	*Longidorus elongatus*	9.11	2.59-15.63	4.54	66.66	9.67	74.33	3.84
	S.W.I PA=200, S=8, D= 0.182, 1-D=0.818, I/D= 5.49, H= 1.857, E=0.893							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

Table 13: Diversity of plant parasitic nematodes associated with high density apple orchards in village Zakura (District Srinagar)

S.No.	Nematodes	No. of Nematodes /250 cc soil									A.D	R.D%
		Zk_1			Zk_2			Zk_3				
		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
1	*Helicotylenchus* sp.	65	70	55	72	45	30	24	38	52	50.12	28.13
2	*Pratylenchus* sp.	55	50	30	52	24	28	22	24	30	35.00	19.65
3	*Tylenchus* sp.	14	18	20	10	0	6	18	20	24	14.45	8.11
4	*Tylenchorhynchus* sp.	44	38	50	40	38	42	50	24	18	33.34	18.71
5	*Xiphinema insigne*	16	8	24	22	6	0	22	12	28	15.34	8.61
6	*X. index*	20	16	8	12	0	0	22	14	10	11.34	6.36
7	*X. americanum*	18	18	10	0	16	14	20	0	4	11.11	6.23
8	*Longidorus elongatus*	10	12	0	22	0	9	6	0	8	7.45	4.17
No. of species per 250 cc soil		**242**	230	197	230	**129**	129	184	132	174		

Zk_1, Zk_2 and Zk_3 are orchards in Zakura (District Srinagar). S_1, S_2 and S_3 are sites where soil samples are extracted.

A.D: Absolute density of plant parasitic nematodes. R.D: Relative density of plant parasitic nematodes

Table 13a: Community population of plant parasitic nematodes associated with high density apple orchards in Zakura (District Srinagar)

S.No.	Nematodes	A.D	95% CI	R.D%	A.F%	R.F%	P.V	R.PV%
1	*Helicotylenchus* sp.	50.12	36.86-63.38	28.13	100.00	14.28	501.20	29.08
2	*Pratylenchus* sp.	35.00	24.75-45.25	19.65	100.00	14.28	350.00	20.30
3	*Tylenchus* sp.	14.45	8.51-20.39	8.11	88.88	12.69	136.12	7.90
4	*Tylenchorhynchus* sp.	33.34	25.01-41.67	18.71	100.00	14.28	333.40	19.34
5	*Xiphinema insigne*	15.34	8.09-22.59	8.61	88.88	12.69	144.50	8.38
6	*X. index*	11.34	5.34-17.34	6.36	77.77	11.12	99.91	5.80
7	*X. americanum*	11.11	5.01-17.21	6.23	77.77	11.12	97.88	5.68
8	*Longidorus elongatus*	7.45	1.95-12.95	4.17	66.66	9.52	60.79	3.53
S.W.I	**PA=178, S=8, D=0.176, 1-D=0.824, I/D= 5.68, H= 1.681, E=0.808**							

A.D: Absolute density, **C.I:** Confidence interval, **R.D:** Relative density, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **S.W.I:** Shannon wiener density information, **P.A:** Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon wiener index, **E:** Evenness.

.

Table 14: Diversity and community structure of plant parasitic nematodes associated with high density apple orchards in District Srinagar

S.No.	Nematodes	Absolute density/250 cc soil			Mean of A.D	95% C.I	Mean of F%	R.F	P.V	R.PV%
		SKUAST-K	Habak	Zakura						
1	*Helicotylenchus* sp.	50.12	58.33	50.12	**52.85**	43.19-62.50	100.00	14.51	528.50	29.93
2	*Pratylenchus* sp.	36.34	40.22	35.00	**37.18**	29.33-45.02	100.00	14.51	371.80	21.06
3	*Tylenchus* sp.	15.56	15.33	14.45	**15.11**	8.67-21.54	85.18	12.36	139.31	7.89
4	*Tylenchorhynchus* sp.	20.56	37.66	33.34	**30.52**	22.66-38.37	100.00	14.51	305.20	17.29
5	*Xiphinema insigne*	17.56	16.55	15.34	**16.48**	8.23-24.73	81.48	11.82	148.65	8.42
6	*X. index*	13.00	12.66	11.34	**12.33**	5.77-18.88	77.77	11.29	108.63	6.15
7	*X. americanum*	10.23	10.55	11.11	**10.63**	4.77-16.48	77.77	11.29	93.65	5.30
8	*Longidorus elongatus*	9.11	9.11	7.45	**8.55**	2.37-14.73	66.66	9.67	69.77	3.95

A.D: Absolute density, **C.I:** Confidence interval, **A.F:** Absolute frequency, **R.F:** Relative frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value.

Table 15: Status and distribution of plant parasitic nematodes associated with different rootstocks of high density apple orchards in district Srinagar of Kashmir valley

Nematode fauna		Rootstocks						Total
		M9	M4	M7	MM-106	MM-111	M9-T337	
Ectoparasitic	*Xiphinema index*	2	1	4	3	0	7	17
	Xiphinema americanum	1	0	2	1	1	1	6
	Xiphinema insigne	1	2	1	3	0	0	7
	Longidorus elongates	4	3	2	2	1	5	17
Endoparasitic	*Pratylenchus* sp.	15	13	11	10	7	8	64
Semi-endoparasitic	*Tylenchus* sp.	7	6	2	4	1	7	27
	Helicotylenchus sp.	2	5	3	1	5	0	16
	Hoplolaimus sp.	3	1	1	0	3	3	11
	Tylenchorynchus sp.	5	1	5	0	4	0	15
	Total	40	32	31	24	22	31	

Table 16: Diversity and community population of plant parasitic nematodes associated with District Baramulla, Anantnag and Srinagar of Kashmir valley

S.No.	Nematodes	Baramulla				Anantnag				Srinagar				Mean	Rank
		A.D	R.D%	A.F%	P.V	A.D	R.D%	A.F%	P.V	A.D	R.D%	A.F%	P.V	of A.D	
1	*Helicotylenchus* sp.	73.95	28.11	100.00	739.50	41.81	32.04	100.00	418.10	52.85	28.76	100.00	528.50	**56.20**	**1**
2	*Pratylenchus* sp.	52.29	19.58	100.00	522.90	69.22	19.35	100.00	692.20	37.18	20.25	100.00	371.80	52.89	2
3	*Tylenchorhynchus* sp.	26.29	9.87	96.29	257.90	22.31	10.31	92.58	214.62	30.52	8.25	85.17	281.39	26.37	4
4	*Tylenchus* sp.	38.48	14.37	96.29	377.49	25.71	11.88	88.88	242.18	15.11	16.47	100.00	151.10	26.43	3
5	*Xiphinema insigne*	23.22	8.81	88.88	218.73	21.63	10.00	88.88	203.75	16.48	9.01	81.47	148.65	20.44	5
6	*X. index*	18.44	7.05	88.88	173.70	15.04	6.94	81.47	135.66	12.33	6.73	77.77	108.63	15.27	6
7	*X. americanum*	12.96	4.95	88.88	122.08	11.89	5.50	77.77	104.75	10.63	5.80	77.77	93.65	11.82	7
8	*Longidorus elongatus*	10.74	4.09	77.77	94.62	8.48	3.91	74.06	72.93	8.55	4.66	66.66	69.77	9.25	8
9	*Hoplolaimus* sp.	8.17	3.06	74.06	70.26	-	-	-	-	-	-	-	-	**8.17**	**9**

A.D: Absolute density, **R.D:** Relative density**, A. F:** Absolute frequency, **P. V:** Prominence value

Table 17: Nematode measurement (µm) for the estimation of biomass of plant parasitic nematodes in district Baramulla, Anantnag and Srinagar of Kashmir valley

Species	Area	1	2	3	4	5	6	7	8	9	10	11	12	Mean
X.insigne	**L**	2488.56	2450	2484	2440	2548	2468.10	2350	2254	2420	2466	2340	2497	**2433**
	W	38.65	38.34	37.22	39.45	36.20	40.16	38.96	38.22	37.66	39.59	34.28	36.50	**37**
X.index	**L**	2866	2733	3234	2745	2840	3255	2710	2988	2733	2850	2855	2755	**2880**
	W	50.77	54.66	49.90	50.94	51.32	49.55	52.93	48.54	49.90	50	48	49	**50**
X.americanum	**L**	2050.40	2020.42	2295	2284	2156	2255	2230	2190	2188.56	1745	1645.54	1775.45	**2069**
	W	36.34	38.55	36.20	32.45	34.55	36.26	37.40	35.40	32.60	34.45	25.20	35.45	**34**
L.elongatus	**L**	3860	3714	4094	5145.23	4556	4234	3980	4244	3998	4156	4034	4034	**4170**
	W	56.50	52.34	50.94	56.78	53.23	53.32	53.44	54.69	52.22	53.90	52.65	53.56	**53**
***Helicotylenchus* sp.**	**L**	1250.56	1145	1232.45	1115	1139.56	1234	1132.55	1154.08	1266	1123	1186.55	1228	**1183**
	W	22.32	22.38	22.56	18.19	21.45	19.22	20.01	22.56	22.68	18.08	22.60	22.97	**21**
***Pratylenchus* sp.**	**L**	834	734.15	845	750.34	823	845	784.44	810.45	876	834	789	834	**813**
	W	24.32	22.44	24.54	24.45	23.48	23.01	22.09	25.50	24.66	23.88	22.33	20.09	**23**
***Tylenchorhyncus* sp.**	**L**	1256	1350.45	1355	1350.12	1234.33	1255	1288	1345	1323	1350	1256	`1350	**1196**
	W	24.45	28.55	26.45	26.66	24.56	25.55	24.53	25.56	23.45	28.86	24.88	24.76	**25**
***Tylenchus* sp.**	**L**	890	1234	1232	1055.24	1054.13	1055.33	1155.46	883	1288	870.3	1045.12	1043	**1067**
	W	20.12	21.72	20.25	22.62	21.23	23.08	24.55	20.44	23.76	23.88	20.55	23.88	**22**
***Hoplolaimus* sp.**	**L**	1890	1989	1980	1955.56	1990.30	1956.45	1934.55	1844.23	1967.54	1987	1966	1956	**1951**
	W	24.44	28.89	29.90	28.42	28.41	28.88	27.56	25.65	26.43	26.64	26.33	26.44	**27**

L: Length of nematodes, **W:** Width of nematodes

Table 18: Diversity and community population including Relative Biomass and Importance value of plant parasitic nematodes associated with District Baramulla, Anantnag and Srinagar of Kashmir valley

S.No.	Nematodes	Districts			A.D (mean)	Cumulative mean for all the districts								
		A.D				R.D%	95% C.I	A.F%	P.V	R.PV %	G/Nem (µg)	T.G (µg)	R.G	I.V %
		Baramulla	Anantnag	Srinagar										
1	*Helicotylenchus* sp.	73.95	41.81	52.85	**56.20**	29.63	54.92-75.76	100.00	562.00	24.98	0.32	17.98	7.02	16.78
2	*Pratylenchus* sp.	52.29	69.22	37.18	52.89	19.72	33.73-53.79	100.00	528.90	23.51	**0.26**	13.75	5.37	12.92
3	*Tylenchorhynchus* sp.	26.29	22.31	30.52	26.37	9.47	13.80-28.66	91.34	251.83	11.19	0.46	12.13	4.74	8.89
4	*Tylenchus* sp.	38.48	25.71	15.11	26.43	14.24	21.29-41.85	95.05	257.42	11.44	0.33	8.72	3.41	10.22
5	*Xiphinema insigne*	23.22	21.63	16.48	20.44	9.27	11.81-29.07	86.41	204.4	9.09	2.08	42.52	16.60	12.56
6	*X. index*	18.44	15.04	12.33	15.27	6.9	8.22-22.32	82.70	152.7	6.79	4.50	68.72	26.83	15.00
7	*X. americanum*	12.96	11.89	10.63	11.82	5.41	5.90-17.74	81.47	118.2	5.25	1.49	17.61	6.88	7.80
8	*Longidorus elongatus*	10.74	8.48	8.55	9.25	4.22	3.35-15.15	72.83	92.5	4.11	**7.30**	67.53	26.36	13.50
9	*Hoplolaimus* sp.	8.17	-	-	**8.17**	3.06	2.77-13.57	74.06	81.7	3.63	0.88	7.19	2.81	5.00

A.D: Absolute mean, **R.D:** Relative density, **C.I:** Confidence interval**, A.F:** Absolute frequency, **P.V:** Prominence value, **R.PV:** Relative prominence value, **G:** Biomass of nematodes, **T.G:** Total Biomass, **R.G:** Relative Biomass, **I.V:** Importance value

Table 19: Shannon Weiner density index measures (village wise) based on population abundance in district Baramulla, Anantnag and Srinagar of Kashmir valley

S.No.	District	Village	P.A	S	D	1-D	1/D	H	E
1	Baramulla	Ladoora	237	09	0.172	0.828	5.813	1.954	0.889
		Zangam	260	09	0.160	0.840	6.251	1.982	0.902
		Arampora	296	09	0.170	0.830	5.881	1.937	0.881
2	Anantnag	Gopalpora	223	08	0.181	0.819	5.525	1.880	0.904
		Achabal	209	08	0.190	0.810	5.263	1.849	0.889
		Kokernag	215	08	0.184	0.816	5.432	1.863	0.896
3	Srinagar	SKUAST-K	172	08	0.174	0.826	5.745	1.901	0.914
		Habak	200	08	0.182	0.818	5.491	1.857	0.893
		Zakura	178	08	0.176	0.824	5.680	1.681	0.808

P.A: Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon Wiener index, **E:** Evenness.

Table 20: Shannon Weiner density index measures (District wise) based on population abundance in district Baramulla, Anantnag and Srinagar of Kashmir valley

S.No.	District	P.A	S	D	1-D	1/D	H	E	Remarks
1	Baramulla	264	09	0.167	0.833	5.98	1.957	0.890	Based on population abundance per 250 cc soil
2	Anantnag	215	08	0.185	0.815	5.40	1.864	0.896	
3	Srinagar	183	08	0.177	0.823	5.63	1.813	0.871	
Mean		**220.00**	**8.33**	**0.167**	**0.823**	**5.67**	**1.878**	**0.885**	

P.A: Population abundance, **S:** Species richness, **D:** Simpson's index, **1-D:** Simpson's index of diversity, **1/D:** Simpson's reciprocal index, **H:** Shannon Wiener index, **E:** Evenness.

.

Table 21: Overall mean population of plant parasitic nematodes in different rootstocks of high density apple orchards associated with district Baramulla, Anantnag and Srinagar of Kashmir valley

S.No	Rootstock	Districts			Total nematodes	Mean
		Baramulla	Anantnag	Srinagar		
1	M9	153	85	40	278	92.66
2	M4	124	57	30	211	70.33
3	M7	86	37	33	156	52.00
4	MM-106	47	32	24	103	34.33
5	MM-111	-	64	22	86	28.66
6	M9-T337	-	-	31	31	10.33

Chapter-5

DISCUSSION

The results so gathered under the present study have been discussed below under appropriate headings:

5.1 Identification of plant parasitic nematodes in high density Apple plantation of Kashmir

A large number of plant parasitic nematodes feed on the roots of fruit trees and other plants causing direct damage while many species of different plant parasitic nematodes have also been found responsible for transmission of serious viral diseases from one plant to another in various countries. These virus vector nematodes cause damage to many economically important crops both by direct feeding on the roots (Christie and Perry, 1951) and by vectoring plant diseases (Hewitt *et al*., 1958).

The most severe nematode problems occur where good host crops are grown too frequently for too long time on the same land. Gregarious feeding by various ectoparasitic and endoparasitic nematodes cause a decline in root growth by feeding on root tips stopping growth by transmission of root tips into terminal grafts and by formation of root galls respectively. Kashmir valley is covered by thousands of hectares of fruit crops especially apple orchards in Baramulla district and that is why it was found necessary to reveal the status of plant parasitic nematodes on these constant woody perennial hosts and open a new refreshed chapter for further studies in future.

In the present study nine plant parasitic nematodes *viz*. *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp., *Tylenchorhynchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp. were isolated from the rhizosphere of high density apple orchards in all the three districts (Baramulla, Anantnag and Srinagar). Among the major nematodes found during study the *Helicotylenchus* sp. was having the maximum number followed by

Pratylenchus sp., *Tylenchus* sp., *Tylenchorhynchus* sp.Similar results were obtained by Sharma and Kaur, 1985. The results obtained for identification of major nematodes in our study are in close conformity with the results of Hoestra 1967; McElory, 1972; Kiryanova and krall, 1980. The nematode genera *Helicotylenchus*, *Pratylenchus*, *Tylenchorhynchus* and *Hoplolaimus* as recovered from the high density apple orchards of Kashmir valley (Baramulla, Anantnag and Srinagar) in the present study have also been isolated from the apple orchards in different parts of the world (Wallace and MacDonald, 1979; Kaul, 1985; Khan *et al.,* 1997; Lone *et al*., 2012 and Lane, 1993). Maqbool & Quasim (1988) and Tan & Kilic (2012) also confirmed that high frequency of *Pratylenchus* and *Helicotylenchus* species occurs in apple orchards of different parts of the world. However, the *Hoplolaimus* nematode was found only in orchards of Baramulla district of Kashmir valley. The results of our studies are also supported by the findings of Khan and Sharma, 1990.

5.2 Community analysis of predominant plant parasitic nematodes in high density apple plantation of Kashmir valley

The parameters, *viz.,* absolute frequency, relative frequency, absolute density, relative density, prominence value, Shannon Wiener density index and biomass of different genera of nematodes were studied during the present investigation. Eighty one composite soil samples of all the three districts namely Baramulla, Anantnag and Srinagar of Kashmir valley comprising nine localities revealed that among all the nematodes found during the present study, the maximum absolute density was recorded for *Helicotylenchus* sp. followed by *Pratylenchus* sp., *Tylenchus* sp. and *Tylenchorhynchus* sp. Similarly the mean performance of relative density, 95 per cent confidence interval, absolute frequency, prominence value and relative prominence value followed the same trend as that of absolute density in all the three districts under study. These results are supported by the findings of Maqbool and Quasim, 1988 and Tan and Kilic, 2012. However, the mean biomass showed maximum value for *Longidorus*

elongatus followed by *Xiphinema index*, *Xiphinema insigne* and *Xiphinema americanum. Xiphinema index* was having the highest mean total biomass followed by *Longidorus elongatus, Xiphinema insigne* and *Helicotylenchus* sp. The mean relative biomass followed the same trend as that of mean total biomass. The importance value showed maximum value for *Helicotylenchus* sp. followed by *Xiphinema index, Longidorus elongatus* and *Pratylenchus* sp. the results of our study are in close conformity with the findings of Rashid *et al*., 2014 and Mir and Tanveer, 2016. The mean performance of different parameters for community analysis is presented in Table 18. A comparison of plant parasitic nematode density and their population abundance on the basis of number and biomass per 250 cc soil, the Shannon Weiner Density Index revealed that no significant difference in energy flow of plant parasitic nematodes was found from locality to locality and from district to district. The highest Shannon Weiner Density Index was recorded for district Baramulla followed by Anantnag and Srinagar presented in Table 20. Population abundance in all the three districts *viz.* Baramulla, Anantnag and Srinagar revealed that the diversity index ranged from 1.813 (Srinagar) to 1.957 (Baramulla) with the difference in energy flow of 0.144 which is almost nearer to the diversity index at Anantnag (1.864) fruit belt**.** The results obtained for Shannon Weiner Density Index are supported by studies of Taylor and Brown, 1976.

The data on nematode population associated with apple rootstock revealed that apple growth and yield response relationship with the population densities of plant parasitic nematodes is most likely to cause damage as determined on the basis of their feeding habit. A large number of plant parasitic nematodes feed on the roots of fruit trees and other plants causing direct damage while many species of different plant parasitic nematodes have also been found responsible for transmission of serious viral diseases from one plant to another in various countries and thus virus vector nematodes cause damage to many economically important crops both by direct feeding on the roots (Christie and Perry, 1951) and

by vectoring plant diseases (Hewitt *et al*., 1958). Plant parasitic nematodes may be endoparasitic (remaining and feeding inside the cell), semi-endo or semi-ecto parasitic (body half inside and half outside the plant surface), and/or ectoparasitic (remaining and feeding from outside the plant cell). Nematodes occupy a key position in the soil food web and are suitable indicators of soil quality (Yeates *et al.,* 1993). They preferably move toward the root zone for resources. A few of the plant-parasitic species invade roots resulting in crop losses, and therefore are well studied (Jones *et al.,* 2013).

In the present study different plant parasitic nematodes were isolated from the roots of high density apple orchards of three districts of Kashmir valley. Among the rootstocks studied, the rootstock M9 was having the maximum number of *Pratylenchus* sp., which is a known serious pest of apple trees (Zaki and Mantoo, 2003; Colbran 1953; Bosher and Newton 1957; Decker 1959; Goss 1961; Palmiter and Braun 1962), followed by M4 and M7. The results obtained in our study are in close conformity with the results of Mai and Abawi, 1978 and Jaffee *et al.,* 1982; Mai *et al.,* 1994. Also it was revealed that *Pratylenchus* sp., was found highest in all the rootstocks of high density apple orchards followed by *Tylenchus* sp., in the districts Baramulla and Srinagar while *Longidorus* sp., in the district Anantnag. The mean nematode population was found to be highest for M9 rootstock followed by M4 and M7 rootstock while as lowest mean was obtained for M9-T337 rootstock (Table 21). In the present findings, it was found that M9 clonal rootstock of apple is most susceptible to nematode infestation. The results are in close conformity with the facts published by Wolfe *et al.,* 2019; under the heading "Rootstocks for Kentucky Fruit Trees" University of Kentucky, college of Agriculture, Food and Environment.

Chapter-6

SUMMARY AND CONCLUSION

Apple is among the pioneer temperate fruit crops of the world. Apple occupies a significant place in the horticultural wealth of Kashmir valley known worldwide for its production and quality of high grade apples. In recent times most of the submerged lands have been mostly transformed into apple orchards. The various types of nematodes are encountered in apple orchards which not only reduces apple production but also makes it difficult for growers in most of the times. To study the incidence of different plant parasitic nematodes and their diversity for various apple growing locations is very much important in order to study their biodiversity and ecology with constant woody apple hosts and open a new chapter and challenge in the subject of Nematology.

The present study entitled as "Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir" was carried out to study the identification and community analysis of plant parasitic nematodes in high density apple orchards in different districts, *viz.,* Baramulla, Anantnag and Srinagar of Kashmir valley. In all, nine nematode genera were isolated from the rhizosphere of high density apple orchards in all the three districts under study *viz., Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp., *Xiphinema insine*, *X.index*, *X.americanum*, *Longidorus elongatus* and *Hoplolaimus* sp. encountered in and around the rhizosphere of apple grown under the high density pattern of the orchard where in only some of them show greater strength in their population density, frequency etc. and were ascertained as most predominant plant parasitic nematodes in the above mentioned districts of Kashmir valley. Community analysis of predominant plant parasitic nematodes in high density apple plantation of Kashmir valley on various parameters revealed that *Helicotylenchus* sp. followed by *Pratylenchus* sp., *Tylenchus* sp. and *Tylenchorhynchus* sp. showed highest mean absolute density in all the three districts. The mean performance of parameters, *viz.,* relative frequency, relative

density and prominence value also showed similar trend as that of the mean absolute density. The highest mean biomass was found in *Longidorus elongatus* while as *Xiphinema index* showed highest mean total biomass and mean relative biomass. Shannon Weiner Density Index revealed that no significant difference in energy flow of plant parasitic nematodes was found from locality to locality and from district to district. The district Baramulla recorded highest Shannon Weiner Density Index followed by Anantnag and Srinagar.

Conclusion

Nine species of plant parasitic nematodes were found in all the three district *viz*; Baramulla, Anantnag and Srinagar of Kashmir valley.

The present community analysis revealed that *Helicotylenchus* sp., *Pratylenchus* sp., *Tylenchus* sp. and *Tylenchorhynchus* sp. were the most frequent and dominant species associated with the rhizosphere of high density apple orchards of Baramulla, Anantnag and Srinagar respectively.

The high population of these plant parasitic nematodes were encountered around the rhizosphere of high density apple plants and can be considered as a contributing factor in declining health of these apple plants and lowering the yield of apple in Kashmir valley.

The present study concluded that plant parasitic nematodes are cosmopolitan in apple orchards of all the three districts of Kashmir valley. However, their role in apple orchard ecosystem as far as the crop health and its productivity is concerned a detailed long term experimentation on the molecular characterization of the nematode viruses occurring in fruit orchards needs to be conducted in order to work out damaging potential of these vectors of viruses and simultaneously their eco-friendly management could be taken up to enhance the fruit production.

The present study also concludes that M9 rootstock is more susceptible to nematode attack than other rootstocks.

From the overall results, it can be inferred that lesion nematode (*Pratylenchus* sp.,) which is a major nematode of economic importance globally is a widespread plant parasitic nematode on apple rootstock particularly M9 and is responsible for apple decline and replant problem worldwide, has also been found as a one of the predominant plant parasitic nematode in the High density apple orchards of the state. Besides, Spiral nematode (*Helicotylenchus* sp.,) and Stunt nematode (*Tylenchorhynchus* sp.,) which are among the important plant parasitic nematodes in the high density apple orchards of Kashmir valley are also of global importance in apple cultivation. Other nematodes of economic importance *viz;* Dagger nematode (*Xiphinema* spp.), Lance nematode (*Hoplolaimus* spp.), Citrus nematode (*Tylenchus* spp.) and Needle nematode (*Longidorus elongatus*) have also been found in the high density apple orchards of the valley.

Due to meager information, diversity among the species of phyto-nematodes could not be compared; however, it may be assumed that diversity varies considerably with habitat, area and the number of individuals. However, the nematode population of different sexes and stages, relative virulence of a particular species, its host specificity and tolerance level in host, needs to be investigated for assessing the role of these ecological parameters in the management of plant parasitic nematodes. The screening of the various cultivars of high density plantation against the plant parasitic nematodes locality wise with the climate change is need of the hour. To our knowledge, this is probably the first record to assess diversity of plant parasitic nematodes in high density apple plantation of Kashmir.

In view of the above findings, monitoring of nematode populations in the apple nurseries/orchards in the valley is required at regular intervals so that timely preventive management strategies may be adopted. Apart from that breeding prog -rams aimed at developing nematode resistant clonal rootstocks in apple will be facilitative.

LITERATURE CITED

Aasia, R., Azad, S. A. and Umar, F. 2014. Community analysis of plant parasitic nematodes associated with ornamental plants in Rajouri district (J&K), India. *International Journal of Current Microbiology and Applied Sciences* **3**(1):194-197

Abbas, A. and Waliullah, M. I. S. 2010. Prevalence of plant paristic nematodes in *Gladiolus hostulaus* L. in and around Srinagar, Kashmir. *Indian Journal of Nematology* **40**: 179-183.

Adekuncle, O. K., Kulshrestha, S., Prasad, R., Hallam, V., Raikhy, G., Varma, N., Ram, R., Kumar, S. and Zaidi, A. A. 2006. Plant Parasitic and Vector nematodes associated with Asiatic and Oriental and Hybrid Lilies. *Bioresource Technology* **97**(3):364-371.

Andret-Link., Laporte, P., Valal, L., Ritzenthaler, C., Demangeat, G., Vigne, E., Laval, V., Pfeiffer, P., Stussi-Garaud, C. and Fuchs, M. 2004. Grapevine Fan Leaf Virus., Still a major threat to the Grapevine Industry. *Journal of Plant Pathology* **86**: 183-195.

Anonymous, 2016a. FOASTAT Database 2015-2016.

Anonymous, 2016b. Indian Horticulture Database 2015-16, National Horticulture Board, Ministry of Agriculture, Govt. of India.

Anonymous, 2019c. Area and production statement for the year 2018-2019. Department of Horticulture, Jammu and Kashmir Govt., Srinagar.

Askary, T. H., Banday, S. A., Umer, I., Khan, A. A., Mir, M. M. and Waliullah, M. I. S. 2011. Plant parasitic nematode diversity in pome, stone and nut fruits, In: Agroecology and Strategies for Climate Change. (Ed. Lichtfouse, E.), Springer, Heidelberg, Germany. pp. 237-268.

Askary, T. H., Waliullah M. I. S. and Gupta, S. 2012. Population fluctuation of plant parasitic nematodes associated with pome, stone and nut fruit nurseries. *Annals of Plant Protection Sciences* **20**(1): 265-267.

Banday, F. A. and Sharma, M. K. 2010. Advances in temperate fruit production Kalyani publishers

Baqri, Q. H. 1999. Diversity in plant and soil nematodes of West Bengal, India. An over view. Proceeding of the Indian National Science Academy. Part B, Reviews and Tracts. *Biological Sciences* **65**(1-2):1-4

Barsi, L. and Lamberti, F. 2004. Morphometrics of Longidorus juvenilis and first record of *L. aetnaeus* and *L .moesicus* (Nematoda: Dorylaimida) from Serbia. *Nematologia Mediterranea* **32**(1): 5-14.

Barsi, L. Lambert, F. and Deluca, F. 2007. Morphological and molecular characterization of *Longidorus danuvii* sp. n. and *L. silvae* Roca, 1993 (Nematoda: Dorylaimida) from Serbia. *Nematology* **9**(4):585-598.

Bastian, H. C. 1865. Monograph on the Anguillutidae, or Free Nematoids, Marine, land and fresh water, with descriptions of 100 new species. *Transactions of the Linnean Society* **25**:73-180.

Bosher, J. E., Newton, W. 1957. *Pratylenchus penetrans* in clonal apple stocks. *Phytopathology* **47**(1): 4.

Brown, D. J. F., Halbrendt, J. M., Jones, A. T., Taylor, C. E. and Lamberti, F. 1994. An appraisal of some aspects of the ecology of nematode vectors of plant viruses. *Nematologia Mediterranea* **22**(2):253-263.

Chanu, L. B. and Meitei, N. M. 2016. Community analysis of soil and plant parasitic nematodes associated with Mulberry plants form Manipur. *Biological Forum- An International Journal* **8**(2): 65-72.

Choudhury, B. N., Rahman, M. F. and Bora, A. 2004. Diversity of nematodes in four districts of Assam. *Indian Journal of Nematology* **34**(2): 222-224.

Christie, J. R. and Perry, V. G. 1951. Removing nematodes from soil. *Proceedings of Helminth. Society Washington* **18:** 106-108.

Cobb, N. A. 1913. New nematode genera found inhabiting fresh water and non-brackish soils. *Journal of Washington Academy of Sciences,* Washington **36(**4): 432-444.

Cobb, N. A. 1918. Estimating the nematode population of soil with special reference to sugarbeet and root gall nemas *Heterodera schachtii* Schmidt and *Heterodera radicicola* (Greef) Mullar and with a description of *Tylencholaimus aequalis* n.sp. USDA *Agriculture Technical Circular Bur. Pt. Ind. U.S. Department of Agriculture* **1**: 1-48.

Colbran, R. C. 1953. Problems of tree replacement. **I**. The root lesion nematode *P.coffeae* Zimmerman as a factor in the growth of replant trees in apple orchards. *Aust. J.A. Res.* **4:** 384-9.

Daday, E. V. 1905. *Untersuchungen iiber die Susserwasser-Mikrofauna Paraguays Zoologica*, Stuttgart **18**: 1-349.

Decker. J. 1959. *Pratylenchus penetreans* als Ursache von "Mudiakeitser-scheinungen" in Baumschulen der DDR. *Nematologica Suppl*. **2**:68-78.

Deimi, A. M., Chitambar, J. J. and Maafi, Z. T. 2008. Nematodes associated with flowering ornamental plants in Mahallat, Iran. *Nematologia Meditertranea* **36**(2): 122-127.

Ei-Deen, N. A., Hadeer, D. Y., El-Ghamdi, A. A. and Samra, B. N.2015. Evaluating the Pathogenicity of Nematodes Infecting Roses at Taif

Governorate, KSA. *Research Journal of Pharmaceutical Biological and Chemical Sciences* **6**(2):1562-1569.

Filipzev, I. N. 1936. On the classification of the Tylenchinae. *Proceedings of Helminthology Society of Washington* **3**:80-82.

Fotedar, D. N. and Hando. Z. A. 1977. *Aerotylenchus safroni* n. gen., n. sp. (Nematoda: Tylenchida) from Kashmir. *Indian Journal of Nematology* **7**: 141-147.

Fotedar, D. N. and Mahajan, R. 1974. Four new species of the genus *Helicotylenchus Steiner*, 1945 (Nematoda: Hoplolaimida) from India. *Rivista Parasitologia,* **35**(2):119-124.

Goss, O. M. 1961. The relationship of root-lesion nematodes to premature decline and die back of apples and replant difficulties in Western Australia. *Proc. Pl. Path. Conf.* **1**(36):2.

Hewitt, W. B., Raski, D. J. and Goheen, A. C. 1958. Nematode vector of soil-borne fanleaf virus of grape vines. *Phytopathology* **48**: 586-595.

Hoestra, H. 1967. Specific apple replant disease: problems and prospects. *Meded Rijsksfac Landb Wwt Gent* **32**: 427-432.

Hooper, D. J. 1970. Handling, fixing, staining and mounting nematodes. **In**: J.F. Southey (Ed). Laboratory methods for work with plant and soil nematodes. *Tech. Bull. Minist. Agric.Fish.Fd 2, (5th edition). London, H.M.S* pp. 39-54.

Jones, J. T., Haegeman, A., Danchin, E. G. J., Gaur, H. S., Helder, J., Jones, M. G. K. (2013). Top 10 plant-parasitic nematodes in molecular plant pathology. *Mol. Plant Pathol.* **14:** 946-961.

Kaul V. 1985. Seasonal fluctuations of phytonematodes in two fruit nurseries in Kashmir. *Indian Journal of Heiminthology* **37**(1): 4-11.

Khan, A., Shaukat, S. S. and Islam, S. 1997. Influence of soil temperature and moisture on seasonal variation of three plant-parasitic nematodes associated with apple in Swat, Pakistan. *International Journal of Nematology* **7**(1): 26- 29.

Khan, M. L. and Sharma, G. C. 1990. Effect of temperature and moisture on population fluctation of nematodes in an apple orchard. *Indian Journal of Nematology* **2**: 1-13.

Khan, M. L. and Verma, A. K. 2005. Occurrence of longidorid nematode species from the high altitude zone of Himachal Pradesh with description of *Paralongidorus neoformis sp*.n. *National Symposium on Recent Advances and Research Priorities in Indian Nematology*. IARI, New Delhi, December **63**:9-10.

Khan, M. R. and Hasan, M. A. 2010. Nematode diversity in banana Rhizosphere from West Bengal, India. *Journal of Plant Protection Research* **50**(3): 263-268.

Kiryanova. E. S. and Krall, E. L. 1980. Plant parasitic nematode and their control (Book) Amerind publishing Co. **2**: 731.

Kumar, K. K. and Das, A. K. 2019. Diversity and community analysis of plant parasitic nematodes associated with citrus at citrus research station, Tinsukia, Assam. *Journal of Entomology and Zoology Studies* **7**(3): 187-192.

Kumari, S., Chaloupkova, M. and Jokes, M. 2006. First record of *Longidorus intermedius* Kozlowska and Seinhorst, 1979 (Nematoda:Longidoridae) from the Czech Republic. *Helminthologia Bratislava* **43**(2):122-124.

Lan, Q. Y. 1993. The identification of plant nematodes around rhizosphere of apple trees. *Sichuan Fruit Trees* **1**: 4-7.

Lone, G. M. and Zaki, F. A. 2014. Report of *Xiphinema insigne* (Loos, 1949) and Longidorus elongatus (deMan, 1876; Thorne and Swanger, 1936 (Dorylaimida: Longidoroidea) from Rhizosphere of Neglected Apple Trees of Kashmir, India. *Indian Journal of Nematology* **44**(2): 232-237.

Lone, G. M., Waliullah M. I. S., Zaki, F. A., Ali, A. and Mir, S. A. 2012b. Occurrence of virus vector nematodes in disturbed, undisturbed and neglected apple ecosystems of Kashmir, India. *Indian Journal of Nematology* **42**(1): 92-94.

Lone, G. M., Zaki, F. A. and Waliullah, M. I. S. 2012a. Report of *Xiphinema index* Thorne and Allen, 1950 (Dorylaimida: Longidoroidea) associated with neglected apple orchards of Baramulla, Kashmir. *Indian Journal of Nematology* **42**: 71-74.

Loos, C. A. 1949. Notes on free-living and plant parasitic nematodes of Ceylon. No. 5. *Journal of Zoological Society of India* **1**:23-29.

Mahajan, R. 1973. Two new nematodes, *Tylenchus kashmirensis* n. sp. and *Dorylaimoids pari* n. sp. from Kashmir. *Revista Parasitologia* **34**(3): 201-204.

Mahajan, R. and Bijral, S. 1973. Studies on the criconematidae (Nematoda: Tylenchida) from India with descriptions of two new species. *Leipzig* **191**(3): 199-205.

Maqbool, M. A. and Quasim, M. 1988. Control of plant parasitic nematodes associated with apple and pistachio trees in Baluchistan. *Advances in Plant Nematology* pp. 271-274

McElory, F. D. 1972. Nematodes of tree fruits and small fruits. (In*) Economic Nematology* (Book). Academic *Proceedings of the Ohio State Horticultural Society* **125**: 91-94

Micoletzky, H. 1922. *Proceedings of Helminthology Society of Washington* **29**:189-207.

Mir, R. A. and Tanveer, S. 2016. Community structure of soil inhabiting nematodes in an apple orchard at Bandipore, Kashmir, India. *Journal of Entomology and Zoology Studies* **4**(2): 200-206.

Mukherjee, B., Nath, R. C. and Dasgupta, M. K. 2000. Plant parasitic nematode communities in rubber nurseries and plantations in Tripura. *Indian Journal of Nematology* **30**(2): 170-174.

Nath, R. C., Sinha, B. C., Mukherjee, B. and Dasgupta, M. K. 2009. Community analysis and diversity of plant parasitic nematodes associated with litchi plantations in North Tripura District. *Pest Management in Horticultural Ecosystems* **15**(1): 51-59.

Nayba, J. N., Khan, S. A., Ullah, Z. and Khan, H. U. 2012. Estimation of prevalence and population densities of plant parasitic nematodes associated with twelve fruit in Pakistan. *Pakistan Journal of Phytopathology* **24**(1): 63-68.

Norton, D. C. 1978. Ecology of plant parasitic nematodes John Wiley and sons, **Inc**: New York USA pp. 263

Palmiter, D. H., Braun, A. J. 1962. Apple tree decline associated with nematodes. *Phytopathology* **52**:926.

Pan, C. S., Zheng, J., Zhoux., Neilson, R. and Brown, DJF. 2000. Preliminary assessment of the occurrence of Longidorid and Trichodorid nematodes in Xiamen, Fujian Province, China. *Russian Journal of Nematology* **8**(2): 153-159.

Rama, K. and Dasgupta, M. K. 2000. Population ecology and community structure of plant parasitic nematodes associated with coconut and areca

nut in northern West Bengal. *Indian Journal of Nematology* **30**(2): 175-182.

Rashid, A., Azad, A. S. and Farooq, U. 2014. Community analysis of plant parasitic nematodes associated with ornamental plants in Rajouri district (J&K), India. *International Journal of Current microbiology and Applied Science* **3**(1): 194-197.

Roca, Fransisco. 2006. On the identity of two *Paralongidorus* species (Nematoda:Longidoridae) described from Montegro and Serbia. *Nematology* **8(**5):781-785.

Saeed, N., Khan, M. S., Khan, A., Kiran, A. and Zada, S. 2016. Stylet bearing nematodes associated with walnut (*Juglans regia* L.) in District Abbottabad. *International Journal of Scientific & Engineering Research* **7**(2):1296.

Sen, D., Chatterjee, A. and Manna, B. 2008. Population fluctuation of Helicotylenchus Steiner, 1945 in relation to soil temperature, moisture and pH in guava orchard at South 24 Parganas, West Bengal, India. *Records of the Zoological Survey of India* **108**(2): 75-81.

Sharma, G. C. and Sen, S. 2015. Status of plant parasitic nematodes in apple orchards of Himachal Pradesh. *International Journal of Farm Sciences* **5**(3): 171-178.

Sharma, N. K. and Kaur, D. J. 1985. Nematodes associated with temperate fruit crop in Himachal Pradesh. (In) *Advance Research in Temperate fruits*, (Chadha T R, Bhutani V P and Kaul J L, Eds.) UHF, Solan (India).

Sigariova, D. D. and Karpliyk, V. G. 2015. Parasitic nematodes in flowering and ornamental plants: effect of parasites on the plants and response of the plants to the presence of nematodes. *Vestnik zoologii* **49**(5): 427-432.

Singh, S., Tyagi, S. and Prasad, D. 2009. Distribution pattern of plant parasitic nematodes infesting sunflower. *Annual Plant Protection Science* **17**: 443-446.

Sogut, M. A. and Devran Z. 2011. Distribution and Molecular Identification of Root Lesion Nematodes in Temperate Fruit Orchards of Turkey. *Nematropica* **41**: 91-99.

Steiner, G. 1945. *Helicotylenchus*, a new genus of plant parasitic nematodes and Its relationship to *Rotylenchus* Filipjev. *Proceedings of Helminthology Society of Wash*ington **12**: 34-38.

Sujata and Sharma, G. C. 2018. Status of phyto-parasitic nematodes in major fruits and vegetable crops of the tribal belt Kinnaur in Himachal Pradesh. *Journal of Entomology and Zoology Studies* **6**(2): 3069-3072.

Sultan, Abdul, Jawwad, Anwar and Wahbeh 2007. Survey of plant parasitic nematodes associated with the rhizosphere of plants in nurseries and intensive agriculture in the West Bank. M. Sc. Thesis Faculty of Graduate Studies. Habron University, Palestine. 86.

Tan, A. N. and Kilic, M. 2012. Plant parasitic nematode associated with vegetable growing green house in South Eastern Anatolia region, Turkey. *African Journal of Agriculture Research* **7**(18): 2777-2790.

Taylor, C. E. and Brown, D. J. F. 1976. The geographical distribution of *Xiphinema* and *Longidorous* in the British Isles and Ireland. *Annals of Applied Biology* **84**: 383-402.

Thorne, G. and Allen, M.W.1950. *Paratylenchus hamatus* n. sp. and *Xiphinema index* n. sp., two nematodes associated with fig roots, with a note on *Paratylenchus anceps* Cobb. *Proceedings Helminthology Society*, Washington **17**: 27-25.

Tzortzakakis, F. A., Pateras, D. and Charoulis, A. 2006. Occurrence of *Xiphinema* species in grapevine areas of Tyrnavos with comments on the distribution of *Xiphinema italiae* in Greece. *Helminthologia Bratislava* **3**(3): 186-187.

Vaid, S., Shah, A. A., Ahmad, R. and Hussain, A. 2014. Diversity of soil inhabiting nematodes in Dera Ki Gali forest of Poonch district, Jammu and Kashmir, India. *International Journal of Nematology* **24**(1): 97-102.

Vrain, T. C and Rouselle, G. L. 1980.Distribution of plant parasitic nematodes in Quebec apple orchards. *Plant Disease* **64**: 582.583.

Walilullah, M. I. S. and Kaul, V. 1997. Nematodes associated with cherry plants in Kashmir valley India. *Indian Journal of Nematology* **27**: 237-239.

Waliullah, M. I. S. 1992. Nematodes associated with vegetable crops in Kashmir valley. *Nematologica Mediterranea* **20**: 47-48.

Waliullah, M. I. S. 2005. Nematodes associated with Kiwi (*Actinidia deliciosa* Chev.) in Kashmir valley. *Indian Journal of Nematology* **35**(2): 227.

Wallace, M. K. and Mac-Donald, D. H. 1979. Plant-parasitic nematodes in Minnesota apple orchards. *Plant Disease Reporters* **63**(12): 1063-1067.

Wasim, A. 2007. New and known species of Dorylaimoidea (Nematoda: Dorylaimida) from Singapore. *Nematology* **9**(2): 215-229.

Wolfe, D. E., Strang, J., Becker, D. and Wright, S. 2019. Rootstocks for Kentucky Fruit Trees. University of Kentucky College of Agriculture, Food and Environment.

Ye, W. and Robbins, R. T. 2004a .Cluster analysis of Longidorus species (Nematoda: Longidoridae), a new approach in species identification. *Journal of Nematology* **36**(30): 207-219.

Ye, W. and Robbins, R. T. 2004b. Distribution and morphology of *Longidorus braviannulatus* Norton and Hoffman, 1975 and *Longidorus fragilis*

Thorne, 1974. (Nematoda: Longidoridae) from North America. *Journal of Nematology* **36**(3):220-231.

Yeates, G. W., Bongers, T., Goede, R. G. M., de Freckman, D. W., and Georgieva, S. S. 1993. Feeding habits in soil nematode families and genera - an outline for soil ecologists. *Journal of Nematology* **25**: 315-331.

Zaki, F. A. and Mantoon, M. A. 2003. Plant parasitic nematode associated with temperate fruit in Kashmir valley, India. *Pest Management and Economic Zoology* **2**: 97-101.

Zalpuri, L., Tara, J. S. and Singh, V. K. 2013a. Plant and Soil Nematodes: Diversity and Interactions. *Global Journal of Biology, Agriculture and Health Sciences* **2**(2): 123-124.

Zalpuri, L., Tara, J. S. and Singh, V. K. 2013b. Prevalence of Plant Parasitic Nematodes (Citrus Species) in Various Villages of Jammu Region. *International Journal of Scientific and Research Publications* **3**(6): 1-3.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Entomology,
Shalimar Campus, Srinagar – 190 025

C E R T I F I C A T E

Certified that all the corrections/amendments as suggested by External Examiner **Dr. M. A. Ansar Ali,** Scientist-C, (Entomology) Spices Board India, Lal Mandi, Wazir Bagh Srinagar, Kashmir during Viva-Voce examination held on **02-03-2020** have been incorporated in the manuscript entitled **"Diversity of Plant Parasitic Nematodes in High Density Apple Plantation of Kashmir"** submitted by **Mr. Danish Mushtaq (Regd. No. 2017-H-146-M)**

(Dr. Gh. Mohd. Lone)
Chairman
Advisory Committee