STUDIES ON THE STUNT NEMATODE, *Tylenchorhynchus mashhoodi* SIDDIQI AND BASIR ON MAIZE CROP

By

SANTHOSH G

DEPARTMENT OF NEMATOLOGY

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA (SAMASTIPUR)-848 125

2019

STUDIES ON THE STUNT NEMATODE, *Tylenchorhynchus mashhoodi* SIDDIQI AND BASIR ON MAIZE CROP

By

SANTHOSH G

A THESIS SUBMITTED TO
THE DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA IN PARTIAL FULLFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE (AGRICULTURE)

IN

DEPARTMENT OF NEMATOLOGY

DR. RAJENDRAPRASAD CENTRAL AGRICULTURAL UNIVERSITY,
BIHAR, PUSA (SAMASTIPUR) -848 125

Regd. No. M/NEMA/164/2017-18 of DRPCAU, Pusa

2019

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA (SAMASTIPUR) -848 125

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA (SAMASTIPUR) -848 125

Dr. Uma Shankar Singh
Associate. Prof-cum-Senior Scientist

Department of Nematology
DRPCAU Pusa, Bihar 848125

Dated 27/06/2019

Certificate

This is to certify that the work recorded in this thesis entitled **"STUDIES ON THE STUNT NEMATODE, *Tylenchorhynchus mashhoodi* SIDDIQI AND BASIR ON MAIZE CROP"** submitted in partial fulfillment of the requirements for the award of the degree **Master of Science (Agriculture) in Nematology** of the faculty of post graduate studies, Dr. Rajendra Prasad Central Agricultural University, Bihar is a genuine record of bona fide research work carried out by **Mr. Santhosh G** under my guidance and supervision.

The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of this investigation and sources of literature have been fully acknowledged.

27/06/2019

Uma Shankar Singh
Chairman
Advisory Committee

ENDORSED

27/06/2019

K.N Pathak
Head
Department of Nematology,
DRPCAU, Bihar
Pusa (Samastipur)-848 125

Certificate

We, the under designed, members of the advisory committee of **Mr. Santhosh G,** a candidate for the degree of **Master of Science (Agriculture) in Nematology,** have gonethrough the manuscript of the thesis and agree that the thesis entitled **"STUDIES ON THE STUNT NEMATODE, *Tylenchorhynchus mashhoodi* SIDDIQI AND BASIR ON MAIZE CROP"** may be submitted by him in partial fulfillment of the requirements for the award of the degree.

27/06/2019

Uma Shankar Singh
Chairman
Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

27/06/2019

1. **K. N. Pathak**
Professor
Department of Nematology

27.06.2019

2. **A. K. Rai**
Professor
Department of Entomology

SP Singh 27/6/19

3. **S. P. Singh**
Professor
Department of Entomology
Director Education (Nominee)

Certificate

This is to certify that thesis entitled **"STUDIES ON THE STUNT NEMATODE, *Tylenchorhynchus mashhoodi* SIDDIQI AND BASIR ON MAIZE CROP"** submitted by **Mr. Santhosh G** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture) in Nematology** of the Faculty of Post graduate Studies, Dr. Rajendra Prasad Central Agricultural University, Bihar, Pusa (Samastipur) was examined and approved on 20./.7./.2019

EXTERNAL EXAMINER

Uma Shankar Singh
Chairman
Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

1. **K. N. Pathak**
Professor
Department of Nematology

2. **A. K. Rai**
Professor
Department of Entomology

3. **S. P. Singh**
Professor
Department of Entomology
Director Education (Nominee)

ENDORSED

K N Pathak
Head
Department of Nematology
DRPCAU, Bihar
Pusa (Samastipur)-848 125

Acknowledgement

Even a small achievement remains mere event till the helping hands behind that never get remembered. I don't want to miss this opportunity to thanks all those who have directly or indirectly helped me for successful completion of this work.

I feel extremely honoured for getting an opportunity to work under expert guidance of ***Dr.Uma Shankar Singh****, Associate Professor-cum-Senior Scientist, Department of Nematology, Dr. Rajendra Prasad Central Agricultural University, Bihar -848125. I extremely thankful to him for suggesting an interesting problem, his scholastic guidance and constructive criticism during the course of this investigation.*

I am very thankful and Grateful to ***Dr. R. C. Shrivastav****, Honorable Vice-Chancellor ,Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, and* ***Dr.K.N.Pathak****, Head, Department of Nematology Dr. Rajendra Prasad Central Agricultural University. Pusa, Bihar, for providing all the facilities during the course of investigation and whole hearted co-operation.*

I am also thankful to my advisory committee members ***Dr.A.K. Rai****, Professor-cum-chief Scientist, Department of Entomology, DRPCAU, Pusa* ***Dr. S.P. Singh****, Professor-cum-Chief Scientist, Head of the Department of Entomology , RPCAU, Pusa, for their valuable suggestions and keen interest showed during the course of the investigation.*

I wish to express my heartful thanks to ***Dr. Nishi Keshari****, Department of Nematology RPCAU, Pusa and staff members of Department of Nematology, RPCAU, Pusa for their valuable help and encouragement throughout the course of study.*

I express my regards to Prof. R.C. Sharma, University Librarian, RPCAU, Pusa, for their kind co-operation during the course of my post graduate study. I take this opportunity to record my gratitude to other thanks Farm superintendent and field labourness for providing me necessary facilities required for the research work.

I express my sincere gratitude to my seniors and friends, who all the way co-operated during the course of studies and acknowledge the moral and material help extended to me by all my friends.

My family is my strength and source of motivation behind me. I have no words to express my feelings in fathomable depths which springs in the very core of

my heart. It seems one uses the choice would to measure the boundless love and fireless sacrifice of some one. I find no much measure in adequate quantity, for all that my beloved father ***G. Venkata chalapathi*** *and mother* ***Smt. S.Padmavathi*** *have done for me, whose love and affection, moral support has no equivalent and as everlasting source throughout my life. I am grateful to all my family members for their love and care.*

Life is in general and my research in particular would have remained a "cipher space" if not the tremendous encouragement genuine, faith and love bestowed on me by my seniors ***P. Nagarjuna, Mounica, Vinod and Nithinkumar*** *and my friends* ***Karthik, Papa p sushee, Usaa, Varalupinni, Lavanya, Kiran, Nishmitha, Venkat, Ashish, Alekya, Abhinay, Mahesh Naik, Karthika, AdiLaxmi, Nithyashree, Mohan babu, Sudhamini, Satya, G.Naresh, Ashok, Sanjeev*** *and my lovely juniors special thanks to my seniors*

I am extremely fortunate to have such friends who always stand by me and with whom a true time I hold that drive off all my worries.

I place on record my sincere thanks to all those who helped me directly or indirectly in making of this work successful.

Last but not least, I thanks to Dr. Rajendra Prasad Central Agricultural University. Pusa, Bihar, for providing me an opportunity to undertake the post-graduation studies.

Place : RPCAU, Pusa
Date : 27/06/ 2019

(Santhosh G)

◈◈◈

Dr. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA (SAMASTIPUR) -848 125

Name of the Student	:	Santhosh G
Registration number	:	M/Nema/164/2017-18
Degree to be awarded	:	Master of Science in Agriculture
Department	:	Nematology
Major Subject	:	Nematology
Minor Subject	:	Entomology
Major Advisor	:	Dr Uma Shankar Singh
Number of Pages	:	43+i-v (References)
Year	:	2019
Title of Thesis	:	**"Studies on the stunt nematode, *Tylenchorhynchus mashhoodi* Siddiqi and Basir on maize crop"**

ABSTRACT

Studies on the stunt nematode, *Tylenchorhynchus mashhoodi* Siddiqi and Basir on maize crop were conducted to know i) intensity and frequency of distribution of plant parasitic nematodes in general and stunt nematode, *Tylenchorhynchus* spp. In particular in maize growing fields around Pusa-Dholi. ii) Pathogenicity of stunt nematode, *Tylenchorhynchus mashhoodi* on maize cv. Dewaki to determine threshold level in terms of plant growth characters, nematode reproduction, quantum root index, yellowing index and effects of stunt nematode infection on chlorophyll a, b and total chlorophyll contents of leaf, iii) Screening of different maize varieties/lines for source(s) of resistance against stunt nematode *T. mashhoodi* during 2018-2019. The salient findings are as under.

i) Important plant parasitic nematodes namely species of *Tylenchorhynchus, Pratylenchus, Rotylenchulus, Helicotylenchus, Hoplolaimus* were found in dominating population around the rhizosphere of maize in Pusa-Dholi area. Frequency of occurrence was found to be higher in Garhia and Harpur village of Samastipur District.

ii) An inoculums level of 100 nematodes and above /plant proved detrimental to the growth and development of maize cv. Dewaki. The nematode population/ plant significantly increased progressively with an increase in nematode inoculums from 10 to 10,000 nematode/ plant. Nematode reproduction rate was maximum (88.5 times) at 10 nematodes/ plant and minimum (9.5 times) at 10,000/ plant. Chlorophyll a, b and total chlorophyll contents significantly reduced with an increase in inoculums levels from 100 to 10,000 nematodes/ plant. Un-inoculated plants had significantly more chlorophyll contents over other treatments.

iii) Screening of 8 maize varieties/ lines namely Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Laxmi, Dewaki, Ganga safed-2 against *T. mashhoodi* indicated that none of variety/ line was resistant. All the varieties tested were categorized as susceptible to *T. mashhoodi.*

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER - I

INTRODUCTION

INTRODUCTION

Maize (*Zea mays* L.), also recognized as "Queen of Cereals or Miracle Crop," has the highest productivity per day and is flexible in nature compared to other cereal crops. Maize acts as the main crop for food safety owing to enormous demographic growth with reducing soil and water supplies. Even after attaining self-sufficiency in food and grain production, about 50% of kids are struggling with malnutrition. Globally, it provides nearly 30% of the food calories to more than 4.5 billions peoples in 94 developing countries and the demand of maize is expected to double worldwide by 2050 to meet this rising demand and thus higher maize production is need of hour (Srinivasan *et al.*,2004).

Maize has the enormous capacity to satisfy the requirements of food, feed and fodder as a source of 4500 products including specific maize such as QPM (Quality Protein Maize), as a quality feed for livestock, poultry and as a basic raw material for thousands of industrial goods such as starch oil, protein, alcoholic drinks, food sweeteners, pharmaceuticals, cosmetics, textiles, gum package and paper. Maize is also possibly utilized in the manufacturing of ethanol, a bio fuel that can reduce reliance on oil imports and have a significant effect on rural economy and agricultural production. This made its significance not only as a food crop, but also in the healthy growth of the agri-business value chain in our nation. In addition to these, maize contributes to exports to many nations such as Nepal, Malaysia, Bangladesh, etc. Thus, India will compete with the US, Brazil, Argentina, and Ukraine at the bottom.

Globally, maize is the third most significant crop of food grains after rice and wheat. India ranks fourth in maize-growing nations with an area of 9.75 million hectares (Indian Agristat., 2017) with total production of 26.88 million tons and productivity of 26.9 q / ha (Agri coop., 2018). Maize has the ability to grow in a broad spectrum of environments i.e. severe semi-arid to sub-humid and humid regions that have given way to the production environment traditional maize-growing areas such as Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh and non-traditional maize-growing areas are Karnataka and Andhra Pradesh.

Bihar has such capacity that maize can grow throughout the year. In India, it ranks 7^{th} with an area of 0.24 million hectares with output of 0.62 million tons during

the *Kharif* season and an area of 0.28 million hectares with output of 2.13 million tons during the *rabi* season and an area of 0.19 million hectares with output of 1.08 million tons during the summer (DES, 2017).

A number of biotic and abiotic stresses affect maize crop. The most significant diseases affecting maize are Fusarium stalk rot caused by *Fusarium moniliforme*, Pythium stalk rot caused by *Pythium aphanidermatum Fitz*., late wilt by *Cephalosporium maydis* (Samara, Sabet and Hingorani), charcoal rot caused by *Macrophomina phaseolina*, black bundle illness caused by *Cephalosporium acermonium*, further leaf blight caused by *Helminthpsporium maydis* (Nasik &Miy) and northern leaf blight caused by *Helminthosporium maydis* (Anon, 1973). Besides these, disease induced by plant parasite nematodes is also of financial significance.

Nematodes are widespread in distribution and found in soil, fresh water and salt water wherever organic matter exists, from oceans to mountains, from arctic's to tropics and are said to be "Ubiquitous' (Thorne, 1961). The parasitic forms are important in the health of human being and animals and in the efficiency of agriculture. The free living forms are known to be present in enormous number in soil and fresh water and undoubtedly have major roles in maintaining the natural ecological balance. The role of the marine forms is almost entirely unexplored. Rarely any crop is free from the attack. They are so numerous that Cobb (1914) suitably remarked "... if all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable". We would find it in mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes. Out of total known species of nematodes, about 50% are marine, 25% free living, 10% plant parasitic and 15% animal parasitic forms (Ayoub, 1980). Plant parasitic and free living forms are grouped as soil and fresh water nematodes. More than forty nematode species are associated with maize but significant ones belong to the genera cyst nematodes (*Heterodera zeae*), lesion nematodes (*Pratylenchus* spp.), root knot nematodes (*Meloidogyne incognita* and *M. javanica*), stunt nematode (*Tylenchorhynchus mashhoodi),* spiral nematode (*Helicotylenchus* spp.) and so on (Kornobis, 1983; Norton, 1984; Patel *et al.,* 2000) and are accountable for crop losses of 10.2 percent (Sasser and Freckman, 1987). Nematodes, apart from causing damage, interact with other disease causing agents and adversely effect the quality and quantity of maize production. Bihar's preliminary study indicates that this crop is

dreadfully assaulted with other plant parasitic nematodes like spiral nematode, *Helicotylenchus dihystera*, *H. indicus*, *H. Pseudobustus*, Its population ranges from 33 to 656/100g.soil (Haider and Nath, 1992). *T. vulgaris* population (Singh *et al.,* 1997) varied from 0 to 5080 nematodes / 200 g soil from Panchmahal district of middle Gujarat, . Maize cyst nematode was noted in several Bihar maize growing areas (Anon., 1987-90).

The review of the literature on this subject shows that very meagre study has been carried out on plant parasite nematodes, including especially on the effect of stunt nematode on Maize in comparison to pests and diseases attacking maize crop in Bihar. It is therefore suggested to explore the role of *Tylenchorhynchus mashhoodi,* the most prevalent species of stunt nematode in this locality on maize crop with the following objectives.

1. To know the intensity of infestation and frequency of distribution of stunt nematode, *Tylenchorhynchus* spp. in maize growing fields around Pusa-Dholi campus of University.
2. To study the pathogenicity of *Tylenchorhynchus mashhoodi* on maize crop.
3. To screen different maize cultivars/hybrids to locate resistance source against *Tylenchorhynchus mashhoodi.*

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Introduction

The genus *Tylenchorhynchus,* stunt or stylet nematode and a migratory ectoparasite, was created by N. A. Cobb in 1913. The first record of the parasitism of stunt nematode, *Tylenchorhynchus claytoni* was by Steiner (1937) on Virginia tobacco roots from North Carolina and was given common name "Stylet nematode".. Some species like *T. claytoni,* were observed to induce marked typical stunting of affected plants and hence another common name "Stunt nematode" was added that has become more popular. Thorne, (1961) was first person who described *T. cylindricus* from southern California. Allen (1955) in his generic monograph on stunt nematodes described 34 different species of this genus. By 1959, there were 50 species which rose to more than 100 species of *Tylenchorhynchus* by 1970 Thorne, (1961)

Handoo (2000) reported the stunt nematodes (*Tylenchorhynchus* spp.) which are economically important plant pathogens and contain 111 valid species that parasitize a wide variety of plants. Handoo (2000) and Handoo *et al.* (2007) proposed the history of the genus and the taxonomic changes to stunt nematodes. In July 2007, one new species and an occurrence of a rare, known species of the genus *Tylenchorhynchus* was found during a survey of rice (*Oryza sativa L.*) fields and coconut (*Cocos nucifera L.*) plantations in the Sindh region of Pakistan, The damaging symptoms of infected plants by nematode are root and stem discoloration, bark damage and chlorosis of leaves Musarrat Ramzan *et al.* (2008)

Tylenchorhynchus swarupi can be distinguished from others by its smaller body size, 0.42-0.54 mm long, set off head with 5-6 indistinct annules, long post-anal sac and smaller rectum. Incisures four, inner two incisures fuse at phasmid and continue as one incisure thereafter. Tail annules very fine. Tail terminus conoid and striated Singh and Khera (1978) reported *T. mashhoodi* from rhizosphere of tomato, egg-plant and okra from various localities around Calcutta.

Sitaramaiah (1984) listed 35 species of which 22 were new species described from India between 1959 and 1981. Nematode spp. those which have relatively large

host range are *T. brassicae, T. brevilineatus , T. dubidus, T. mashhoodi, T. phaseoli, T. vulgaris* and *T. zeae*. Crops like okra, groundnut, pigeon pea, chickpea, rice, wheat, barley, *Brassica* spp., citrus, cotton, pearl millet, sorghum, maize, sugarcane, radish, brinjal, cowpea, cucurbits, turmeric, coconut, mango, guava and banana are important hosts of these species Singh and Sitaramaiah (1994).

Stunt nematode, *T. claytoni,* infect various crops such as golf green turfs (Troll and Tarjan,1954); Sudan grass, corn, wheat (Krusberg,1956); Strawberry, sugarcane, camellia, sweat potato and rice (Martin and Birchfield 1955; Nelson, 1956) and rye grass (Khera and Zuckerman, 1963). Oostenbrink (1966) observed complex of *Pratylenchus crenatus, T. dubius* and *Rotylenchus robustus* resulted in poor growth of crop attacked by nematode in a field trail. Cabbage and cauliflower were attacked by *T. brassicae* (Siddiqi *et al.*, 1972).

Stunt nematode, *T. vulgaris*, was first reported from Delhi, India by Upadhyay and Swarup (1972) which was predominantly associated with maize plant,. Patel *et al.* (1962) reported the occurrence of stunt nematode on bidi tobacco from Jakhla village of Kheda district in Gujarat. Sharma (1971) and Upadhyay and Swarup (1972) studied the life cycle of *T. dubius* and *T. vulgaris*, respectively. In these species females feed on host roots before laying eggs. A female lays eggs near roots. A female can lay about 12 eggs at the rate of two to three eggs / day. The first stage larva hatches in about 72-96 hrs. after egg laying. Second stage larva is formed within the egg membrane. Eggs hatch within four to five days after they are deposited. Host feeding is essential for development of second stage larvae. Within 20-25 days, three molts occur and larva becomes an adult either male or female. The entire life cycle is completed in about 25-28 days (Siyanand *et al*.,1982).

Vanden Berg *et al.* (2001) identified 17 species of plant-parasitic nematodes belonging to ten genera from maize–bean intercropping systems in the western highlands of Kenya, *viz.*, *Ditylenchus* spp., *Helicotylenchs dihystera, H. pseudorobustus, Hemicriconemoides snoecki, Meloidogyne incognita, M. javanica, Paratrichodorous minor, Pratylenchus brachyurus, P. zeae, Rotylenchulus borealis, Scutellonema brachyurus, S. clathricaudatum, S. magniphasmum, Tylenchorhynchus* spp., *Xiphinema elongatum, X. Setariae and X. pinoides.* These species are discussed in relation to their occurrence in some neighbouring countries.

2.2 Survey of maize growing fields around Pusa – Dholi to know the intensity of infestation and frequency of distribution of plat parasitic nematodes in general and stunt nematode *Tylenchorynchus* spp. in particular

The population densities of phytonematodes changes every time so it is important for the study of nematode population behaviour, their interactions with the environment, crop performance and the success of any nematode control/ management approach. In basic and applied research, nematode numbers provide an excellent parameters because of the relative ease in estimation, slow reproduction and limited mobility. Survey of stunt nematode, *Tylenchorhynchus* spp. on different crops carried by different workers are reviewed here after.

Hassan *et al*. (2009) reported that in Kashmir valley a number of *Tylenchids* were found associated with *Zea mays* such as *Pratylenchus sativus* (Kaul, 1985), *Aphelenchoides srinagrensis* and *Tylenchorhynchus zeae*, Sethi and Swarup (1968).

A few populations of nematodes belonging to two species of the genus *Tylenchorhynchus* Cobb, 1913 were collected during the course of intensive survey of vegetable crop fields near Calcutta and environs, by the first author. One of the species has been identified as *Tylenchorhynchus mashhoodi* Siddiqi & Basir, 1959 and the other is new to science (Singh and Khera, 1978).

In a preliminary survey, Haider and Nath(1992) found that lesion nematode, *Pratylenchus zeae* is the most encountered species of plant parasitic nematodes around maize rhizosphere in Bihar. They reported that the infected plants exhibits stunted and unhealthy plant growth.

Landi and Manachini (2005) reported some phytophagous genera which where common pest of maize crop. The genus *Rhabditis, Pratylenchus,Helichotylenchus* and *Acrobeloides* made up more than 70% of the total nematode collected.The dominant trophic group was the bacterial feeders (61%) in particular *Rhabditis* , that was the most abundant and often the dominant one. Phytophagous represented in almost all fields more than 30% of the total nematodes.

Nombela *et al*. (1998) found that among them *Helicotylenchus, Pratylenchus* and *Filenchus* were most abundant, where as *Tylenchorhynchus, Hoplolaimus* and *Heterodera* were found in low percentages. Damage by increasing densities of

Tylenchorhynchus mashhoodi on maize was demonstrated in India (Mahapatra and Das, 1984).

Soil samples taken from a pomegranate orchard showing symptoms of severe decline, in Wadi Dhulail, Jordan, showed that it had large numbers of *Helicotylenchus pseudorobustus*, *Tylenchorhynchus clarus*, *Longidorus* spp. and a few larvae of *Meloidogyne* spp. were also present. Hashim (1983) did sampling in various districts of northwest Jordan and revealed 23 plant-parasitic nematode species in the rhizosphere of pomegranate.

A survey conducted for identification plant parasitic nematodes affecting various vegetable crops growing in three hilly districts surrounding Kathmandu Valley, Nepal, five species of order *Tylenchidae* were reported for the first time from Nepal. The nematode species were *Tylenchorhynchus mashhoodi*, *Hoplolaimus indicus*, *Helicotylenchus indicus*, *Microposthonia paraxestis* and *Hemicriconemoides cocophilus*. All the species described with their morphometric data and also illustrated with line diagrams along with localities and host plants (Keshari and Gupta, 2016).

2.3 Pathogenicity of stunt nematode *Tylenchorynchus mashhoodi* on maize CV. Dewaki to determine threshold level in terms of plant growth characters, nematode reproduction and effects of stunt nematode infection on chlorophyll a, b and total chlorophyll contents of leaf.

The pathogenic behaviour of nematodes varies from nematode to nematode as their habits of parasitism are variable due to differences in habits of nematode parasitism, the intensity of nematode damage to the host also will vary. As a result, the number of nematodes required to cause economic damage to the host will also vary based on type of nematode and even host plants. Studies on the pathogenic behaviour of stunt nematode on maize and other crops carried by different workers are reviewed here after.

Upadhyay and Swarup (1981) reported that there was reduction in shoot and root weights of maize with an increase in inoculum levels of *T. vulgaris*, at 100 and 10,000 nematodes / plant. Initial inoculum level of 1,000 nematodes / kg soil appeared to be marginal threshold for plant growth and development. Jain, (1982) reported that when maize plants inoculated with 10, 100, 1,000 and 10,000 *T. vulgaris* / pot / 10 kg

soil showed a reduction in shoot length and fresh & dry shoot weights. The greatest reductions occurred at the highest inoculum level of 10,000 nematodes / pot.

Mahapatra and Das (1984) observed infection of *T. mashhoodi* resulted in significant reduction in plant growth characters like plant height, shoot and root weights of maize cv. BMC 20. They also reported that increase in final nematode population with an increase in initial inoculum levels after 60 days. The highest rate of nematode multiplication (78.7 times) was recorded in the inoculum level of 10 nematodes/plant and lowest (8.5 times) in the inoculum level of 10,000 nematodes /plant. Inoculum level of 100 *T. mashhoodi* adult &. larvae and above /750 g soil reduced the potential plant growth of young 20 days old maize plants.

Graham (1954) proved the pathogenicity of *T. claytoni*, on tobacco. He observed that there was stunted top growth and a much retarded root system. Affected roots were shrivelled and sparsely developed and did not elongate normally.

Thakar (I969) reported that increase the height and shoot weight of tobacco, bajra and brinjal crops by inoculation of stunt nematode, *T. brassicae* Siddiqi. after 45 days of inoculation, the average height of tobacco plants and shoot weight with the inoculum levels of 10 and 100 nematodes per pot was significantly greater over that of the check plants. When such observations when recorded after 60 days of inoculation though showed an increase in height but it was found not significant.

Stunt nematode (*Tylenchorynchus* spp.) have been reported to cause chlorosis, stunting and malformed roots. *Tylenchorynchus mashhoodi* and *Tylenchorynchus vulgaris* produced significant stunting, weight reduction and discolouration of maize in pots at an inoculum level of 100 nematodes/pot or more (Jenkins *et al*., 1957; Mahapatra and Das, 1984; Singh *et al*,1997*).*

Joshi and Hollis (1976) reported significant reduction in root length and root dry weight with stunted and chlorotic growth in two-week old seedlings of rice cultivar 'Saturn' and 'Zenith' grown in pots containing 5,000 nematodes (*T. martini*) /pint of soil in U.S.A. Gill and Swarup (1977) inoculated the gram seedlings (*Cicer arietinum)* with *T. vulgaris* and found the reduction in plant growth characters (shoot weight and root length and weight) significantly with increasing levels of inoculums.

Vaishnav and Sethi (1979) found that increase in the inoculum level of *T. vulgaris* adults and larvae 1,000 per 500 g soil significantly reduced the growth of 10 days old plants of bajra.

Jain (1982) noticed reduction in shoot and root length and fresh and dry shoot weights when maize plants inoculated with *T. vulgaris* per pot of 1 kg soil and showed reductions, the greatest reduction occurring at the highest inoculum level of 10,000 nematodes.

Chhabra and Mahjan (1976) controlled *Tylenchorhynchus mashhoodi* Siddiqi et Basir in vineyards by three granular nematicides, fensulfothion (Dasanit 5G) at 10 and 15 kg a.i./ha, aldicarb (Temik 10G) at 3 and 4 kg a.i./ha and carbofuran (Furadan 3G) at 1 and 1.5 kg a.i./ha. Four months after the application of the granules, all the treatments except fensulfothion at 10 kg a.i./ha were equally effective and significantly better than the control.

2.4 Screening of different maize varieties/hybrids for source (s) of resistance against stunt nematode, *T. mashhoodi.*

Singh and Patel (1999) reported only one variety / hybrid, IWC9403 as resistant by evaluating different maize varieties / hybrids against *Tylenchorhynchus valgaris* .

Moradia (1991) stated that application of huge amount of nematicides for management of nematodes becomes the limiting factor for farming community not only due to their very high cost but also they are hazardous and destroy natural enemies of nematodes in nature leaving residual toxicity in crop produce as well in the soil.

Patel (1987) mentioned the cheapest and effective nematode management practice from farmer's view point by use of resistant/tolerant crop cultivars against nematodes. The stunt nematodes being migratory ectoparasites and polyphagous in feeding habit can be easily managed through crop rotation and use of resistant cultivars. The special cells like giant cells or nurse cells may not be formed in resistant varieties and necrotic zone around the nematode head may be formed which do not allow the nematode to feed and multiply and ultimately leading to nematode death. Efforts to control nematodes in few cases with resistant varieties have been made and reviewed below with special reference to *Tylenchorhynchus* spp.

Kumar (2001) reported screening of five maize varieties against the spiral nematode *Helicotylenchus indicus* with inoculation of 2000 nematodes. Data revealed that all five varieties *viz*., Shaktiman-1, Pusa early hybrid-1, Suwan, Deoki and Laxmi were susceptible.

Nelson (1956) Reported that various hybrids, inbreeds and single crosses of maize for their in infested soil filled in pots for screening of susceptibility of *T. Claytoni* by results revealed that twenty-one inbreeds and 11 single crosses showed decrease in shoot and root weights when exposed to high nematode population. Nine inbreeds exhibited some resistance to nematode attack and had shoot and root weights similar to those of controlled and un inoculated.

Upadhyay and Swarup (1976) carried out screening of 17 different maize varieties by inoculating the 1,000 *T. vulgaris* in the rhizosphere of 10 days old seedlings in pots. Nematode population was estimated after 90 days of inoculation. Findings revealed that three varieties viz; Kisan, Hi-starch and Ganga 5 had nematode population build up of 11,000 to 12,000 nematodes / plant while varieties viz. Ganga 101, Vijay and VL 54 having higher population build up over 40,000 nematodes /plant. It was also noticed that nematodes showed different preferences for feeding on different maize varieties. The maximum nematode multiplication occurred in Ganga 101 which may be considered as most preferred variety, whereas it was least in Ganga 5. Varieties viz., VL 54, EH 2356, C 2, Vijay Him 123, Sona and Vikram were as good as Ganga 101 supporting more number of nematodes.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Introduction

The present study on i) Survey of Maize fields in and around Pusa – Dholi to know the infestation intensity and distribution frequency of plant parasitic nematodes in general and stunt nematode *Tylenchorhynchus* spp. in particular and the effect of stunt nematode, *T. mashhoodi*, on maize cv, Dewaki, with respect to ii) the pathogenicity of *T. mashhoodi* to determine the threshold level in terms of plant growth, characters, nematode reproduction and effect of stunt nematode infection on chlorophyll a, b and total chlorophyll content, iii) screening of different available maize varieties/lines for source (s) of resistance against stunt nematode, *T. mashhoodi*, were carried out at the Department of Nematology, Dr. Rajendra Prasad Central Agricultural University, Bihar, Pusa, Samastipur district during 2018- 2019.

3.2 Maintaining pure culture of *Tylenchorhynchus mashhoodi*

Pure culture of stunt nematode, *Tylenchorhynchus mashhoodi* is maintained in pots of diameter 30cm at Department of Nematology, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar was multiplied by giving nematode susceptible maize cv. Ganga Safed-2 with regular watering and required care as and when needed. The nematode culture maintained by above method on host in pots was used for conducting subsequent research studies.

3.3 Soil sterilization

Soil that is loamy in texture is collected from nearby fields and is mixed with sand and FYM in the ratio 2:1:1 and sieved through 2mm sieve to remove bigger size stones and other matters. After sieving soil is autoclaved at 20 psi for 4 hours. Thus obtained soil was spread over a polythene sheet for aeration for days. This sterilized soil was used for conducting various research experiments.

3.4 Disinfestations of pots

The pots of diameter 15cm for 1Kg soil and 16cm for 1.5 Kg soil were used. Firstly they were washed with water and then disinfected with 4% formalin (40 EC) solution and were exposed nearly 15 minutes to evaporate excess formalin. These disinfected pots were used for research studies.

3.5 Extraction of stunt nematode *T. mashhoodi*

To obtain the stunt nematode, *T. mashhoodi*, soil from the nematode maintained pure culture pots was collected from the rhizosphere of susceptible maize crop and processed for extracting nematodes using Cobb's sieving and decanting method (Cobb, 1918). Nematodes, thus obtained were used for inoculums in different future studies.

3.6 Estimation of nematode population

After standardizing the nematode suspension to a constant volume of 25ml and placing in 100 ml beaker, the population uniformly distributed by blowing through a pipette. 5ml of this suspension was taken with the help of pipette into nematode counting dish and placed under a stereoscopic binocular microscope for counting of nematodes and counted with the help of hand tally counter. For each suspension five such counts were taken. The total population of the sample was derived by multiplying the calculated average with volume factor.

3.7 Inoculation of nematode

With the help of a spatula the feeder roots of the plant were exposed and poured the nematode suspension of nearly 10ml uniformly over them. A light irrigation was given and similar procedure was followed to uninoculated control plants but instead of nematode suspension pure tap water was used.

3.8 Measurement of plant growth parameter

3.8.1 Plant height was measured by taking shoot as well as root length

3.8.2 Shoot length in cm

At the end of experiment, each plant was cut at the base and then shoot length was measured from the base of plant to tip of the leaf.

3.8.3 Root Length in cm

Each pot was inverted and tapped gently so that the entire soil of the pot along with root system came out as an unbroken mould. This was put into a can containing tap water and allowed to soak for some time to free the roots of adhering soil particles. The root length was measured from the base of the plant to the tip of the longest rootlet.

3.8.4 Fresh and Dry weight

3.8.4.1 Shoot weight in gram

Fresh shoot along with leaf, were cut into pieces and weighed on electronic balance. After taking fresh shoot weight, the shoot were kept in incubator at 60^0C in a brown paper bag till drying and weighed on electric balance.

3.8.4.2 Root weight in gram

Roots after measuring the length were weighed for fresh weight. Roots were kept in incubator at 60^0C in a brown paper bag till drying. Dried roots were weighed on electronic balance.

3.9 Estimation of yellowing index (YI)

Yellowing index estimated on visual scoring using 0-5 scale. The scale was as followed:

Scale	Description
0-1	No yellowing
1-2	Mild yellowing
2-3	Moderate yellowing
3-4	Severe yellowing
4-5	Very severe yellowing

3.10 Estimation of quantum root index

Quantum root index estimated on visual scoring using 1-5 scale. The score allotted for minimum rooting was 1 and for maximum rooting 5.

3.11 Estimation of chlorophyll a, b and total chlorophyll from leaf

The chlorophyll content was determined by method of Hiscox and Israelstam, (1979). 50 mg of fresh leaf of various treatments such as 0, 10, 100 and 1,000 and 5,000 and 10,000 *T. mashhoodi /* plant under pathogenicity test study were collected and chopped into small pieces then placed into test tube containing, 10 ml of Dimethyl Sulfoxide (DMSO) extra pure AR (Sisco Research Lab). The tubes containing leaf tissues + DMSO were kept in oven adjusted at 65^0C temperature for about 3 hours. During the incubation period the tubes were shaken gently. Chlorophyll was extracted into fluid, then transferred to graduated tube and made up

to 10 ml volume by adding DMSO. This extract nearly 3ml was transferred to a cuvette and absorbance was measured as the optical density value (OD) at 663 and 645 nm. using Backman spectrophotometer. Chlorophyll a, b and total chlorophyll (a+b) content was calculated by the equations of Arnon (1949) and expressed as mg/g fresh leaf weight.

Chlorophyll a = 12.7 E 663 _ 2.63 E 645

Chlorophyll b = 22.9 E 645 _ 4.68 E 663

Total Chlorophyll = 22.2 E 645 + 8.02 E 663

Where E 663 and E 645 were the absorbance value (OD) at 663 and 645 nm respectively.

3.12 Experiments

3.12.1 Survey of maize growing fields around Pusa, Dholi to know the infestation intensity and distribution frequency of plant parasitic nematodes in general and stunt nematode, *T. mashhoodi* particular

3.12.1.1 Experimentation

A survey was carried out during the year 2018-2019 around Pusa-Dholi to find out the infestation intensity and distribution frequency of plant parasitic nematodes in general and stunt nematode, *T. mashhoodi* in particular, associated with maize crop. Six villages were selected on random basis for conducting the survey. Samples of both healthy and uneven or patchy plants were collected from these selected places. Sub-sample of nearly 500 g of soil from the rhizosphere of the plant after digging to a depth of 15-20 cm using a Khurpi was also collected. From each plot 10 such sub samples were collected and mixed properly and approximately 500 g of soil from each field was stored as a representative sample in a polythene bag and the samples were brought to the laboratory after proper labelling for nematode isolation and counting.

3.12.1.2 Procedure

The soil samples along with the roots were spread on polythene sheet, lumps were broken and mixed thoroughly by cone and quartering method. 100g of it was taken in a plastic pan and submerged well with sufficient water. Stones were removed and soil lumps if any were broken after soaking for few minutes. The suspension was

mixed well and processed according to Cobb's sieving and decanting method (Cobb, 1918). The residue from 325 mesh sieve was transferred to double layer tissue paper placed on aluminium screen. This was rested on 10 cm Petri dish containing sufficient amount of tap water touching the surface of tissue paper and placed in a room for 24 hours. After the stipulated time the water was collected in 250 ml beaker and left undisturbed for few hours to allow the nematodes to settle down. The supernatant excess water was decanted and suspension was examined under stereoscopic binocular microscope in an observation disc.

3.12.1.3 Observation

Observations were recorded on nematode population in each sample as per section 3.6.

Lastly, the infestation intensity and distribution frequency of Stunt nematode, *T. mashhoodi* along with other plant parasitic nematodes tabulated after necessary calculation.

$$\text{Frequency} = \frac{\text{No of samples containing a given species}}{\text{No. of samples collected}} \times 100$$

3.12.2 Pathogenicity of stunt nematode, *T. mashhoodi* on maize cv. Dewaki to determine threshold level in terms of plant growth characters, nematode reproduction and effects of stunt nematode infection on chlorophyll a, b and total chlorophyll contents of leaf.

3.12.2.1 Experimentation

The experimentation was conducted during *rabi* season 2018 to study the pathogenic effects of different inoculum levels of stunt nematode, *T. mashhoodi*, with respect to plant growth and development, nematode reproduction and effect on Chlorophyll a, b and total chlorophyll contents of leaf in earthen pots of 16 cm diameter in net house at 24 – 34^0 C temperature using Complete Randomized Design (CRD). Inoculum levels of 0, 10, 100 and 1,000 and 5,000 and 10,000 were subjected to maize cv. Dewaki, susceptible to stunt nematode, *T. Mashhoodi*. Each inoculatum level was replicated three times.

3.12.2.2 Procedure

The earthen pots of 16 cm diameter were disinfected as mentioned under section 3.4 and filled with sterilized soil @ 1.5 kg/pot as per section 3.3. Three seeds of maize cv. Dewaki were sown in centre of each pot. On germination (2-3 cm height), plants were thinned down to one/pot. After 10 days of seeding, nematode extracted under section 3.5 were inoculated in the rhizosphere of plants after making a ring around the plant stem in each case as per the treatments under 3.10.2.1. Two to four sprays of mancozeb (Diethane M-45 @ 2 g/l water) and Dimethoate (Roger @ 2ml/l water) were done to protect the plants from insect pests and diseases. The plants were watered as and when required. For proper plant growth 1% urea solution was given according to requirement. Plants were depotted carefully and roots were washed free of soil with water after 90 days of nematode inoculation.

3.12.2.3 Observations

Observations on

a) Plant height in cm, fresh weight, dry weight of shoot and root in g
b) Final nematode population in soil/plant and reproduction factor (pf/pi)and
c) Quantum root index (QRI)scale 1-5
d) Yellowing index(YI)scale 0-5
e) Chlorophyll a, b and total chlorophyll from the leaves (Hicox and Israelstam, 1979).

Finally, after necessary calculations the data was subjected to statistical analysis using appropriate procedures.

3.12.3. Screening of different available maize varieties / lines against stunt nematode, *Tylenchorhynchus mashhoodi*

3.12.3.1 Experimentation

Seeds of 8 maize varieties namely, Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Laxmi, Dewaki and Ganga safed-2 received from T.C.A., Dholi, Dr. Rajendra Prasad Central Agricultural University, Bihar, Pusa, were evaluated for their reactions to stunt nematode, using Completely Randomized Design (CRD) with 5 replications in net house at 8 – 29^{0}C temperature during *rabi* season 2018-2019.

3.12.3.2 Procedure

Three seeds of 8 maize varieties were seeded in 15 cm diameter earthen pots previously disinfested with 4 % formaldehyde (formalin 40 EC) solution and filled with 1kg sterilized soil as per section 3.3. Ten days after seeding, seedlings were thinned down to one/pot. Out of 10 pots five plants were inoculated with 2000 nematodes in the rhizosphere of seedlings by making ring surrounding the stem with spatula. After inoculation, ring was covered with same sterilized soil. Remaining 5 un inoculated plants served as check for comparison purpose. Regular watering and after cares were taken. Plants were depotted carefully and roots were washed with tap water after 90 days of inoculation. Cobb's sieving and decanting method wais utilised for estimating final nematode population by from processing 100 g soil sample collected from each inoculated pot

3.12.3.3 Observations

Observations were recorded on plant height (cm), fresh shoot and root weight (g) and final nematode population in each pot.

Data were statistically analysed using appropriate statistical methods.

CHAPTER - IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

This deals with the study related to i) survey of maize grown around Pusa-Dholi to know the infestation intensity and distributional frequency of plant parasitic nematodes in general and Stunt nematode *Tylenchorhynchus spp.* in particular and the effect of *T. mashhoodi,* on maize cv. Dewaki, ii) To know the pathogenicity of *T. mashhoodi* and to determine the threshold level in terms of plant growth characters, reproduction of nematodes, quantum root index, yellowing index and also about the effect of infection on chlorophyll a, b and total chlorophyll contents of leaf.iii) screening of various maize varieties/lines available for source(s) of resistance against *T. mashhoodi,* were conducted at the Department of Nematology, Dr.Rajendra Prasad Central Agricultural University, Pusa, Bihar during 2018-2019. The obtained experimental findings are given below in sections.

4.1 Experiments

4.1.1 Survey of maize fields around Pusa-Dholi to know the infestation intensity and distributional frequency of plant parasitic nematodes in general and stunt nematode *Tylenchorhynchus* spp. in particular.

A total of 70 soil samples along with the roots were collected from rhizosphere of maize plants from 7 villages around Pusa-Dholi and analysed in laboratory for estimation of nematode under section 3.12.1.2 and 3.6. The population of different nematodes at different places are furnished in table 1. Species of *Helicotylenhus, Hoplolaimus, Tylenchorhynchus, Pratylenchus and Rotylenchulus* were found in almost all the places surveyed in various populations. Frequency of *Tylenchorhynchus* varied from 60 to 100% recording with maximum at Garhia and Harpur while minimum at Basantpur. *Hoplolaimus* varied from 60-80% with maximum at Dholi farm and minimum at Harpur and BISA. *Helicotylenchus* varied from 70-100% with maximum recorded in Garhia and Harpur and minimum in Pusa farm, *Pratylenchus* varied from 40 to 80% with maximum in Garhia and minimum in Basantpur, *Rotylenchulus* varied from 20 to 50% maximum was found at Garhia and minimum in Basantpur. *Meloidogyne* was found only in Harpur with 30% frequency whereas,

Table 1: Distribution of plant parasitic nematodes in maize fields around Pusa-Dholi

(Nematode population / 100g soil)

Sl. No	Location	No. of samples analysed	*Tylench orhynchus spp.*	*Hoplo laimus* spp.	*Helico Tylenhus* spp.	*Praty lenchus* spp.	*Heter odera* spp.	*Melido gyne* spp.	*Rotyle nchulus* spp.	*Hemicrico nemoides* spp.	*Tyle nchus* spp.	Saproz-oic and others	TOTAL	Frequeny of *Tylench Orhynchus* spp. (%)
1	Garhia	10 A R F	359 112-825 (100)	140 59-522 (70)	274 122-525 (100)	41 11-120 (80)	23 14-92 (40)	-	35 26-145 (50)	21 3-17 (30)	53 142-239 (30)	255 122-352 (100)	1148 469-2598 (600)	31.34
2	Harpur	10 A R F	382 139-701 (100)	133 129-352 (60)	221 119-447 (100)	18 7-51 (60)	8 7-43 (30)	10 21-152 (30)	100 37-410 (50)	4 6-32 (20)	39 21-239 (30)	185 137-225 (100)	1100 616-2610 (580)	34.79
3	BISA	10 A R F	214 127-678 (70)	168 48-521 (60)	212 151-401 (80)	25 11-73 (60)	-	-	40 27-134 (50)	-	-	151 101-225 (100)	810 465-2033 (420)	26.41
4	Pusa Farm	10 A R F	267 47-559 (90)	202 135-525 (70)	116 112-257 (70)	53 21-152 (60)	-	-	37 15-152 (50)	-	-	139 91-182 (100)	815 349-1827 (440)	32.52
5	Dholi Farm	10 A R F	209 120-602 (90)	124 46-437 (80)	84 62-185 (80)	57 32-185 (60)	-	-	13 5-89 (30)	-	14 9-102 (40)	131 113-166 (100)	640 387-1618 (480)	32.70
6	Birauli chowk	10 A R F	107 77-280 (80)	118 15-258 (70)	132 21-323 (80)	19 7-87 (50)	-	-	10 9-62 (30)	-	18 12-98 (30)	166 67-184 (100)	570 208-1298 (440)	18.70
7	Basantpur	10 A R F	37 22-110 (60)	49 33-132 (70)	60 31-127 (80)	14 21-77 (40)	-	-	6 13-47 (20)	-	-	134 55-212 (100)	302 175-706 (370)	12.25

A-Average; R-Range; F-Frequency
Figures in parenthesis indicate percent frequency of occurrence

Heterodera and *Hemicriconemoides* were found at 30-40% and 20-30% frequency, respectively in Garhia and Harpur. Other identified nematodes were *Tylenchus* and saprozoic. Average percent frequency of *Tylenchorhynchus* spp. over other nematodes ranged from12.25 to 34.79%. Minimum average percent frequency was found in Basantpur and maximum in Harpur.

Common symptoms were stunted growth, blunt malformed and reduced root systems bore lesions while heavy infestation results in wilting and dying of plants before harvest. Such plants produced shorter cobs compared to healthy plants.

6.1.2 Pathogenicity of *T. mashhoodi* and to determine the threshold level in terms of plant growth characters, reproduction of nematodes, quantum root index, yellowing index and also about the effect of infection on chlorophyll a, b and total chlorophyll contents of leaf.

The experiment was performed in *kharif* season. Time to time observations were taken and they depicted that plants inoculated with 10 nematodes were same as the un inoculated plants from the beginning and plants inoculated with 100; 1,000; 5,000; and 10,000; of individuals per 1500g of soil showed gradual reduction in growth at all stages. Stunted growth with yellow and sticky appearance was noticed in plants inoculated with 1,000; 5,000; and 10,000 nematodes per 1500g of soil. Plants inoculated with 5,000; and 10,000 nematodes per 1500g of soil showed smaller leaves with dried tips when compared to plants inoculated with lesser number of nematodes. Such plants also possessed thin sparse, poor, stunted and smaller roots, bore lesions when compared to un inoculated plants.

All plant growth characteristics viz., Plant height, fresh and dry weight of shoot and roots, quantum root index, yellowing index, chlorophyll contents as well as nematode population build up due to different inoculum levels. Table2 showed significant differences. Progressive decrease in plant height, fresh and dry shoot and root weights, chlorophyll contents of leaves was noticed with corresponding increase increase in nematode inoculums.

Plant height was decreased significantly in 100 *T. mashhoodi* /plant and subsequently decreased significantly with an increase in nematode inoculum levels. In un inoculated control maximum plant height was recorded whereas minimum in 10,000 nematodes per plant. There wais an average reduction of 1.8% to 69.06% in plant height over un inoculated control.

Table 2: Effect of different inoculum levels of stunt nematode *Tylenchorhynchus mashhoodi on* growth, development, quantum root index, yellowing index and chlorophyll contents of maize cv. Dewaki and nematode multiplication

Inoculum Level	Growth Character and Chlorophyll Content								Quantum root Index (1-5)	Yellowing index (0-5) $\sqrt{x+0.5}$trans	Nematode Population Log x + 1 trans	Reproduction Rf = Pf/Pi
	Plant height (cm)	Fresh Weight (g)		Dry Weight (g)		Chlorophyll Content (mg/g)						
		Shoot	Root	Shoot	Root	A	b	Total				
0	103	44.67	21.03	18.80	6.07	7.59	3.31	13.10	4.57	0.7	0	0
10	101.60 (1.8)	42.53 (4.79)	19.90 (5.37)	18.53 (1.14)	5.83 (3.95)	7.33 (3.4)	5.23 (5.08)	12.63 (3.58)	4.30 (5.9)	0.97 *(0.4)	2.47 *(885)	88.5%
100	90.80 (12.29)	38.63 (13.52)	16.73 (20.44)	11.67 (37.92)	3.93 (35.25)	5.99 (21.08)	3.92 (28.85)	9.91 (24.35)	3.77 (17.50)	1.40 *(2.1)	3.41 *(7753)	77.5%
1,000	78.37 (24.30)	31.43 (29.63)	11.90 (43.41)	10.17 (45.90)	2.07 (65.89)	5.39 (28.98)	3.36 (39.01)	8.74 (33.28)	3.10 (32.16)	2.25 *(3.0)	4.24 *(51805)	51.80%
5,000	48 (53.63)	15.07 (66.26)	7.20 (65.76)	7.33 (61.01)	1.60 (73.64)	3.20 (57.83)	2.62 (52.45)	5.82 (55.57)	2.27 (50.32)	2.33 *(3.6)	4.40 *(74117)	14.82%
10,000	32.03 (69.06)	8.33 (81.35)	4.15 (80.17)	4.33 (76.96)	1.07 (82.37)	2.34 (69.16)	1.79 (67.5)	4.13 (68.47)	1.23 (73.08)	2.54 *(4.2)	4.52 *(95.208)	9.51%
SEm ±	0.77	0.61	0.20	0.23	0.80	0.07	0.12	0.10	0.13	0.10	0.01	
CD (P=0.05)	2.37	1.86	0.63	0.72	0.24	0.20	0.39	0.31	0.41	0.34	0.06	
CV %	1.77	3.52	2.68	3.49	4.07	2.49	5.92	1.94	7.37	11.98	1.08	

Rf – Reproduction Factor; Pf – Final Population; Pi- Initial Population; QRI- Quantum root index (1-5),1=minimum rooting 5=maximum rooting ; YI yellowing index 0-5, * 0-1 = No yellowing,1-2 = Mild yellowing, 2-3 = Moderate yellowing, 3-4 = Severe yellowing, 4-5 = Very Severe yellowing. Figures in parentheses indicate percent reduction over un inoculated control
*Figures in parenthesis are retransformed

SHOOT GROWTH

ROOT GROWTH

Plate 1: Effect of different inoculum levels of Stunt nematode*Tylenchorhynchus mashhoodi on* growth, development of maize cv. Dewaki

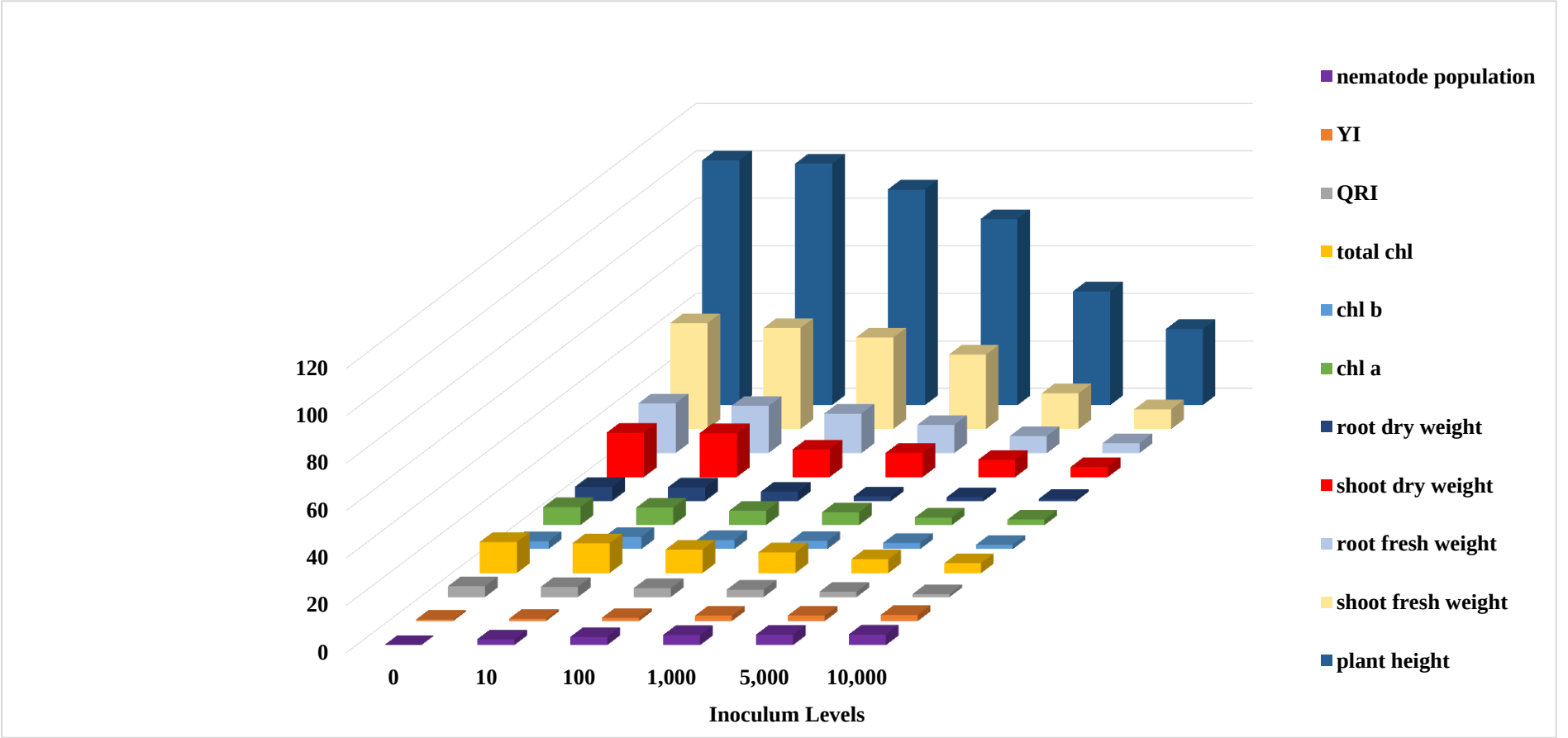


Fig 1: Effect of different inoculum levels of stunt nematode *Tylenchorhynchus mashhoodi* on plant growth, development, nematode reproduction, quantum root index, yellowing index and chlorophyll contents on mazie cv Dewaki

Table 2(a): Effect of different inoculum levels of stunt nematode, *T. mashhoodi* on plant height (cm) of maize cv. Dewaki.

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over control
0	102.5	104.8	103.3	103.53	-
10	103.1	100.5	101.2	101.60	1.8
100	92.1	91.5	93.3	90.80	12.29
1,000	79.7	78.9	76.5	78.37	24.30
5,000	49.5	47.6	46.9	48.00	53.63
10,000	31.5	31.9	32.7	32.03	69.06
SEm ±				0.77	
CD (P=0.05)				2.37	
CV %				1.77	

Similar to plant height there was a significant decrease in fresh shoot weight when inoculum levels were increased from 100 nematodes and above / plant. The un inoculated control recorded maximum fresh shoot weight of 44.67g and was at par with 10 nematodes per plant and plants inoculated with 10,000 nematodes recorded a minimum weight of 8.33 g. Average reduction of weight were furnished in Table 2b.

Table 2(b):Effect of different inoculum levels of stunt nematode, *T. mashhoodi* on fresh shoot weight (g /plant) of maize cv. Dewaki

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	43.7	45.6	42.9	44.67	-
10	42.8	39.5	41.2	42.53	4.79
100	37.9	39.5	36.7	38.63	13.52
1,000	32.4	31.2	30.7	31.43	29.63
5,000	14.3	15.7	15.2	15.07	66.26
10,000	9.7	8.6	8.2	8.33	81.35
SEm ±				0.61	
CD (P=0.05)				1.86	
CV %				3.52	

For dry shoot weight also same trend was seen Table 2c

Table 2(c): Effect of different inoculum levels of stunt nematode, *T.mashhoodi* on dry shoot weight (g/plant) of maize cv. Dewaki

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	18.9	18.3	19.2	18.80	-
10	18.1	18.4	19.1	18.53	1.43
100	12.1	11.7	11.2	11.67	37.92
1,000	10.2	9.8	10.5	10.17	45.90
5,000	6.9	7.4	7.7	7.33	61.01
10,000	3.9	4.5	4.6	4.33	76.96
S Em ±				0.23	
CD (P=0.05)				0.72	
CV %				3.49	

Plants inoculated with 10,000; 5,000; 1,000 and100 nematodes differed significantly with each other in terms of fresh root weight. Fresh root weight was significantly less in the inoculum level of 10,000 nematodes/plant than remaining inoculum. Un inoculated control had maximum fresh root weight of 21.03g followed by 10 nematodes per plant and at par with each other and differing significantly over other inoculum levels. Average reduction in root fresh weight over the un inoculated control was varied from 5.37 to 80.17% (Table 2d).

Table 2(d):Effect of different inoculum levels of stunt nematode, *T. mashhoodi* on fresh root weight (g /plant) of maize cv. Dewaki.

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	20.4	21.5	21.2	21.03	-
10	19.6	20.2	19.9	19.90	5.37
100	16.4	16.7	17.1	16.73	20.44
1,000	11.8	12.3	11.6	11.90	43.41
5,000	7.5	6.9	7.2	7.20	65.76
10,000	4.5	4.1	3.9	4.15	80.17
S Em ±				0.20	
CD (P=0.05)				0.63	
CV %				2.68	

For dry root weight, the treatment differences were significant among various inoculum levels. Un inoculated plants recorded significantly more dry weight i.e., 6.07 g followed by 10 nematode per plants which was at par with each other. 10000 nematodes per plant produced least dry weight i.e., 1.07 g followed by 5,000 nematodes per plant being statistically at par with each other. However 1,000 and 100 nematode/plant had medium effect on dry root weight (Table 2e). Average reductions in dry root weights recorded were 3.3 to 82%.

Table 2(e): Effect of different inoculum levels of stunt nematode, *T. mashhoodi* on dry root weight (g /plant) of maize cv. Dewaki.

Inoculum Level	R_1	R_2	R_3	MEAN	% reduction over Control
0	6.1	5.9	6.2	6.07	-
10	5.8	6.0	5.7	5.83	3.95
100	3.9	4.1	3.8	3.93	35.25
1,000	2.1	1.9	2.2	2.07	65.89
5,000	1.7	1.6	1.5	1.60	73.64
10,000	0.9	1.1	1.2	1.07	82.37
S Em ±				0.80	
CD (P=0.05)				0.24	
CV %				4.07	

With regards to *T. mashhoodi* reproduction on maize cv. Dewaki, significant differences for nematode population build up/plants were obtained due to various levels of inoculum (Table 2f). There was a progressive increase in nematode population with the linear increase in inoculum levels from 10 to 10,000 nematodes for plant and indicated positive correlation with different inoculum levels.

Nematode population per plant was significantly low in 10 nematodes/plant followed by 100; 1,000 and 5,000 nematodes/plant, and varies significantly. Maximum population was recorded in 10,000 nematodes per plant inoculums (Table 2f).

Data depicted the decrease in reproduction rate with an increase in the level of inoculum. Reproduction rate was recorded maximum of 88.5 times in the level of nematodes / plant followed by 77.53, 51.80, 14.82 in the levels of 100; 1,000; 5000 inoculum level respectively while it is minimum 9.51% in highest inoculum level of 10,000 nematodes per plant depicting inverse relation of reproduction rate and inoculum levels.

Table 2(f): Multiplication of stunt nematode, *T. mashhoodi* at different inoculum levels on maize cv. Dewaki.

Inoculum Level	Nematode population/plant/ pot (log x + 1 trans)			Mean	Reproduction Factor Rf= Pf/Pi
	R_1	R_2	R_3		
0	0	0	0	0	-
10	2.46	2.42	2.51	2.47 (885)	88.5
100	3.14	3.42	3.40	3.41 (7753)	77.53
1,000	4.25	4.19	4.25	4.24 (51805)	51.80
5,000	4.46	4.37	4.34	4.40 (74,117)	14.82
10,000	4.51	4.50	4.48	4.52 (95,208)	9.51
S Em ±				0.01	
CD (P=0.05)				0.06	
CV %				1.08	

Figures in parenthesis are retransformed values

Rf – Reproduction Factor; Pf – Final Population; Pi- Initial Population

In quantum root index QRI(1-5) 1= Minimum rooting,5= Maximum rooting it was observed that it decreased with an increase in nematode inoculum levels. Inoculum level of 10,000 nematodes/plant had minimum QRI 1.23 fallowed by 5,000,and 1,000 nematodes/plant, Un inoculated (control) plants recorded maximum QRI 4.57 followed by 10 and 100 nematodes/plant and were statistically at par with each other (Table 2g).

Table 2(g): Effect of different inoculum levels of stunt nematode, *T. mashhoodi on* Quantum root index (1-5) of maize cv. Dewaki

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	4.40	4.60	4.70	4.57	-
10	4.30	4.20	4.40	4.30	5.9
100	3.40	4.10	3.80	3.77	17.50
1,000	3.10	3.20	3.00	3.10	32.16
5,000	1.80	2.60	2.40	2.27	50.32
10,000	1.20	1.40	1.10	1.23	73.08
SEm ±				0.13	
CD (P=0.05)				0.41	
CV %				7.37	

Quantum root index scale1= minimum rooting, 5=maximum rooting.

For yellowing index(0-5) significant differences were observed (Table 2h) among various inoculum levels. It was significantly less 0.70 in control plants over other inoculum levels. Significantly more 2.54 yellowing index was recorded in 10,000 nematodes / plant followed by 5,000 and 1,000 nematode / plant

Table 2(h): Effect of different inoculum levels of stunt nematode, *T. mashhoodi on* Yellowing index (0-5) of maize cv. Dewaki.

InoculumLevel	R_1	R_2	R_3	MEAN
0	0.70	0.70	0.70	0.70
10	0.91	1.02	0.97	0.97 (0.4)
100	1.37	1.44	1.4	1.40 (2.1)
1,000	2.25	2.26	2.23	2.25 (3.0)
5,000	2.52	2.32	2.32	2.33 (3.6)
10,000	2.48	2.61	2.54	2.54 (4.2)
S Em ±				0.10
CD (P=0.05)				0.34
CV %				11.98

* 0-1 = No yellowing1-2 = Mild yellowing 2-3 = Moderate yellowing

3-4 = Severe yellowing 4-5 = Very Severe yellowing

Figures in parentheses are $\sqrt{x + 0.5}$ transformations

Chlorophyll contents of the leaf showed significant differences with varying inoculum levels (Table 2i, 2j, 2k). There was a progressive reduction of chlorophyll content of leaves with increasing level of inoculum levels from 100 to 10,000 nematodes per plant on maize cv Dewaki. The un inoculated control and 10 nematodes per plant showed relatively more chlorophyll content than other inoculum levels.

Effect of different levels of inoculum on chlorophyll contents of leaf are furnished in the Table 2i. Maximum chlorophyll content was noticed in un inoculated control 7.59 and was at par with 10 nematodes per plant and 10,000 nematodes per plant recorded lowest content 2.34

Table (2i):Effect of different inoculum levels of stunt nematode, *T. mashhoodi on* chlorophyll-a content(mg/g) in maize cv. Dewaki

Inoculum Level	R_1	R_2	R_3	MEAN	% reduction over Control
0	7.48	7.80	7.50	7.59	-
10	7.36	7.22	7.40	7.33	3.4
100	6.13	6.06	5.78	5.99	21.08
1,000	5.53	5.34	5.29	5.39	28.98
5,000	3.20	3.32	3.09	3.20	57.83
10,000	2.40	2.36	2.24	2.34	69.16
S Em ±				0.07	
CD (P=0.05)				0.23	
CV %				2.49	

Chlorophyll b also followed the same trend (Table 2 j). Maximum chlorophyll content was noticed in un inoculated control and was at par with 10 nematodes per plant and 10,000 nematodes per plant recorded lowest content. Average chlorophyll b content reduction varied from 5.08 to 67.51%.

Table 2(j): Effect of different inoculum levels of stunt nematode, *T. mashhoodi on* chlorophyll- b content (mg/g) in maize cv. Dewaki

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	5.29	5.54	5.69	3.31	-
10	5.09	5.06	5.01	5.23	5.08
100	3.92	3.62	4.21	3.92	28.85
1,000	3.12	3.39	3.52	3.36	39.01
5,000	2.78	2.47	2.61	2.62	52.45
10,000	1.69	1.75	1.93	1.79	67.51
SEm ±				0.12	
CD (P=0.05)				0.39	
CV %				5.92	

The total chlorophyll content also showed a similar trend with maximum content in un inoculated control followed by 10 nematodes per plant and was at par with each other and statistically differing from other inoculum levels. The values reduced from 100 to 10,000 nematodes per plant inoculums and average reduction ranged from 3.58 to 68.47%

Table 2(k):Effect of different inoculum levels of stunt nematode, *T. mashhoodi on* total chlorophyll content (mg/g) in maize cv. Dewaki

Inoculum level	R_1	R_2	R_3	MEAN	% reduction over Control
0	12.77	13.34	13.19	13.10	-
10	12.65	12.82	12.41	12.63	3.58
100	10.05	9.68	9.99	9.91	24.35
1,000	8.65	8.73	8.85	8.74	33.2
5,000	5.98	5.79	5.70	5.82	55.57
10,000	4.12	4.11	4.17	4.13	68.47
S Em ±				0.10	
CD(P=0.05)				0.31	
CV %				1.94	

4.1.3 Screening of various maize varieties/lines available for source(s) of resistance against *T. mashhoodi*

To locate the source(s) of resistance to *T. mashhoodi* an experiment was conducted in pots. To evaluate their reaction towards *T. mashoodi* eight different maize varieties or strains are subjected to experimentation.

1. Plant height

There was a significant decrease in plant height due to inoculation of 2,000 *T .mashhoodi* nematodes per plant in all 8 varieties viz., Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Laxmi, Dewaki, Gaga safed-2 as against their un inoculated control (Table 3) Average reduction in plant height over control were observed maximum reduction in varieties Shaktiman-4 51.1% and followed by Laxmi- 50.6% and minimum reduction in varieties Shaktiman-5 30.86%and followed by Ganga safed-2.

2. Fresh shoot weight

All 8 varieties showed significant reduction in fresh shoot weight. Average reduction in fresh shoot weight over un inoculated control were 52.56%, 49.55%, 45.11%, 44%, 42% , 39.79%, 32.09%, 31.9% in followingShaktiman-4, Shaktiman-1, Laxmi, Shaktiman-3, Shaktiman-2, Dewaki, Ganga safed-2, Shaktiman-5, respectively.

3. Fresh root weight

Similarly significant reduction was observed in fresh root weight. Average reduction in fresh root weight over un inoculated control were 52.30%, 48.05%, 47.92%, 46.44%, 41.76%, 39.22%, 39.2%, 31.79%, in following varieties Shaktiman-4, Laxmi, Shaktiman-3, Shaktiman-5, Shaktiman-2, Dewaki, Shaktiman-1, Ganga safed-2, respectively.

4. Nematode reproduction

Final nematode population increase per pot varied from 24,336 (Variety Shaktiman-2) to 36,893 (Variety Shaktiman-4), it showed that variable nematode reproduction encouraged by different maize varieties under screening test. All varieties Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Laxmi,

Dewaki, Ganga safed-2 were having nematode population of more than 9,000 nematodes / plant indicating good nematode reproduction. All the varieties showed susceptible reaction. Reproduction factor was observed maximum in Shaktiman-4 18.4% followed by Laxmi 15.4% varieties and least reproduction factor observed in varieties Shaktiman-1 11.69% and Shaktiman-2 12.18%.

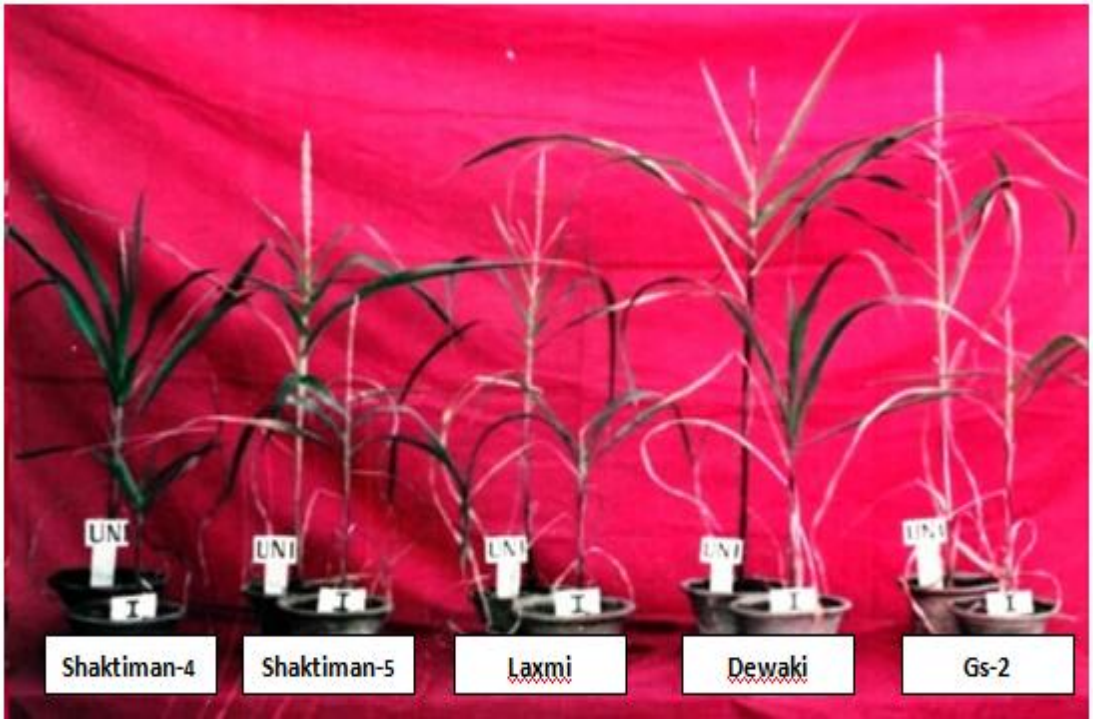
Table 3: Screening of maize varieties against stunt nematode *Tylenchorhynchus mashhoodi*

Sl. No.	Variety/ Lines	Treatment	Plant Height (cm)	Fresh shoot Wt.(g)	Fresh root Wt.(g)	% reduction over Un inoculated control	Nematode Population (Log x + 1 trans) Reproduction			Reaction
							Final	Reproduction factor Rf = Pf/Pi	Reproduction good (G) or Poor (P)	
1	Shaktiman 1	I UNI	36 (38.98) 59	9.70 (49.55) 19.23	9.13 (39.2) 15.03	41.20%	4.446 *(27963)	11.69	G	S
2	Shaktiman 2	I UNI	33.7 (48.39) 65.3	10.67 (42) 18.43	8.27 (41.76) 14.20	46.24%	4.386 *(24369)	12.18	G	S
3	Shaktiman 3	I UNI	32.1 (37.79) 51.6	10.20 (44) 18.27	8.40 (47.92) 16.13	42.20%	4.427 *(26759)	13.3	G	S
4	Shaktiman 4	I UNI	22.4 (51.1) 45.9	7.40 (52.56) 15.6	4.87 (52.30) 10.21	51.65%	4.566 *(36893)	18.4	G	S
5	Shaktiman 5	I UNI	41 (30.86) 59.3	12.33 (31.99) 18.13	8.17 (46.44) 15.23	33.74%	4.450 *(28210)	14.10	G	S
6	Laxmi	I UNI	19.9 (50.6) 40.3	8.93 (45.11) 16.27	5.73 (48.05) 11.03	49%	4.418 *(30289)	15.4	G	S
7	Dewaki	I UNI	32..1 (41.87) 55.23	11 (39.79) 18.27	7.70 (39.22) 12.67	41.01%	4.414 *(25987)	12.99	G	S
8	Ganga safed 2	I UNI	36.3 (36.86) 57.5	11.70 (32.09) 17.23	8.00 (31.79) 11.73	35.23%	4.452 *(28321)	14.16	G	S

	Character		SEm ±	CD(P=0.05)	SEm ±	CD (P=0.05)	SEm±	CD (P=0.05)		SEm ±	CD(P=0.05)		
	Variety		0.32	0.85	0.09	0.27	0.07	0.20		0.02	0.08		
	Treatment		0.15	0.42	0.04	0.13	0.37	0.10		0.10	0.04		
	V × T		0.42	1.21	0.13	0.39	0.10	0.29		0.03	0.11		
	CV%		2.23		2.21		2.26			4.09			

Nematode reproduction: G – Good (more than 9000 nematodes per plant); P- Poor (less than 9000 nematodes per plant) Rf – Reproduction Factor; Pf – Final Population; Pi- Initial Population; I-Inoculated; UNI-Un inoculated; S- Susceptible .Figures in parentheses indicate percent reduction over un inoculated control *Figures in parenthesis are retransformed values.

Shoot growth

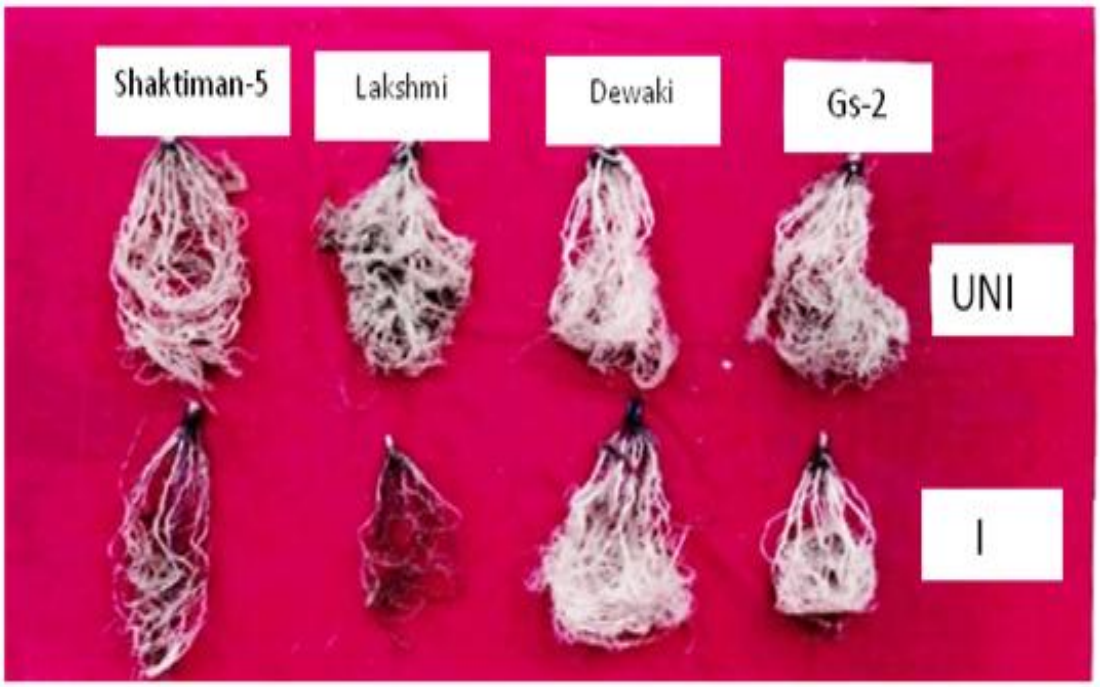


Shoot growth

Plate 2: Screening maize varieties against stunt nematode *Tylenchorhynchus mashhoodi*

I = Inoculated, UNI = Un inoculated

Root growth



Root Growth

Plate 3: Screening maize varieties against stunt nematode *Tylenchorhynchus mashhoodi*

I = Inoculated, UNI = Un inoculated

CHAPTER -V

DISCUSSION

DISCUSSION

Most of the plant parasitic nematodes spend at least a part of their life time in soil phase, although it may be intermittent and survival of such population depends on their ability to detect host from distance. The soil phase, although it may be intermittent and may vary in duration, plays a vital role in the life history of plant feeding nematodes (Jones, 1959). Being obligate parasites nematodes grow and reproduce in close association with their hosts, but soil is a major principal arena for population studies. In generally, plant parasites exist in communities comprised population of different species. Oostenbrink (1966) concluded that dispersal efficiency, polyphagy, weak inter-specific competition and great persistence are probably response for prevalence of poly-specific nematode communities is likely to be responsible. Many species have a wide range of hosts. Even though, these associations provide opportunities for different types of interaction between species sharing the same host.

Nematological survey provides a comprehensive picture of nematode infestations and a complex population character. At the same time, it reveals the influence of cultivated crops and soil type. Quantitative figures are often off-direct as a basis for advisory work and the experience gained from this work helps the opinion on the importance of nematode infestation (Oosternbrink, 1960).

The results of the survey during the present investigations clearly showed that maize crops could be attacked by several species of plant parasitic nematodes, namely *Helicotylenchus, Hoplolaimous, Tylenchorhynchus, Pratylenchus, Heterodera, Meloidogyne, Rotylenchulus, Hemicriconemoides, Tylenchus* and others. These nematodes were also recorded as parasites of maize and other crops by several workers (Jenkins et al, 1957; Singh, 1960; Handoo, 2007; Musarrat Ramzan *et al*., 2008; Singh and Khera , 1978; Sitaramaiah, 1984; Siddiqi *et al*, 1972.;Troll and Tarjan., 1954; Krusberg, 1956; Martin and Birchfield, 1955; Nelson, 1956; Zuckerman, 1971; Siyanand *et al.*, 1982; Upadhyay and Swarup, 1972; Patel *et al.*, 1962; Vanden Berg *et al*., 2001; Hassan *et al*., 2009; Sethi and Swarup, 1968;; Landi and Manachini, 2005; Mukhopadhyaya and Haque, 1974; Hashim, 1983; Keshari and Gupta, 2016).

Maize is the cereal crop of a poor man and mostly grown in marginal land of most parts of this state. Stunt nematode (*Tylenchorhynchus* spp.*),* spiral nematode *(Helicotylenchus* spp.*),* lesion nematode (*Pratylenchus* spp.) and reniform nematode *(Rotylenchulus* spp.) have been clearly shown to be associated with maize crop and it appears that the cultivation of this crop in Bihar is a major pest and potential threat. High populations of these nematodes in stunted and poorly cultivated fields gave a clear idea of crop damage. The combination of these nematodes with this crop may be a good and resonant cause to reduce crop growth. Several workers reported association of these nematodes with maize and damage they caused. (Upadhyay and Swarup,1981; Mahapatra and Das, 1984; Jenkins *et al*., 1957; Singh *et al* .,1997*)*; Jain, 1982; Haider and Nath, 1992; Patel et al., 1995; Kumar, 2001). A literature persuasion showed that no systematic work was undertaken in Bihar on the distribution and pathogenicity of ectoparasitic stunt nematode. The observation during the survey of frequent association of ectoparastic nematodes with maize was informative and indicated the desirability of sustained work on these nematodes.

Pathogenic effects are directly correlated with initial nematode population of soil (Oostenbrink,1966). As nematode population increased there was subsequent reduction in the growth and yield of the crop. Significant damage occured only when nematode population crossed certain limit. According Jain (1982) reported that when maize plants inoculated with 10, 100, 1,000 and 10,000 *T. vulgaris* / pot / 10 Kg soil showed a reduction in shoot, length, fresh and dry shoot weights. The greatest reductions occurred at the highest inoculum level of 10,000 nematodes/pot and Kumar (2001) also reported that when maize plants inoculated 10, 100, and 1,000, 5,000 and 10,000 *Helicotylenchus indicus*/ pot. It showed that significantly decreased with an increase in inoculum levels. Nematode reproduction rate decreased with corresponding increase in inoculum levels.

Results obtained from the study are in confirmation with those reported by Upadhyay and Swarup (1981), who also reported significant reduction in the development of maize seedlings and plant growth due to 1,000 nematodes / plant and above with maximum reduction at 10,000 nematodes / plant. Similar results were reported by Jain, (1982) which corroborate with the present findings. Inoculation of maize plants with 10, 100, and 1,000 and 10,000 *T. vulgaris* / plant / kg soil decreased

shoot length and root length and fresh, dry shoot weights. At the highest inoculum level of 10,000 nematodes / plant, the greatest reduction occurred.

Mahapatra and Das (1984) recorded reduction in potential growth of 20-day maize cv plants. BMC 20 with inoculum level of 100 and above adult *T. mashhoodi*/ larvae in 750 g soil. At an initial inoculum level of 100 nematodes and above, the test nematode could produce significant stunting effect. They also reported that there were 11.57, 27.82, and 46.31 percent average reduction in height of shoot; 12.74, 29.96, 45.35 % reduction in root length, 12.00, 28.96, 47.16 % reduction in dry shoot weight and 12.19, 27.74, 49.52 percent, root dry weight reduction of plants corresponding to 100, 1,000 and 10,000 nematodes / plant treatments, respectively.

Singh (1997) reported quantum root index (QRI) during1994-95 that it was decreased with an increase in nematode inoculum levels. Inoculum level of 10,000 nematodes / plant had minimum QRI followed by 5,000, 2,000and 1,000 nematodes / plant, each differed significantly from each other except for 1,000 nematodes / plant which was at par with 2,000 nematodes / plant. Uninoculated (control) plants recorded maximum QRI followed by 10 and 100 nematodes/ plant and were statistically at par with each other. Yellowing index recorded during 1994-95 showed significant differences among various inoculum levels. It was significantly less in control plants over other inoculum levels. Significantly more yellowing index was recorded in 10,000 nematodes / plant followed by 5,000, 2,000 and 1,000 nematode / plant. Yellowing index at inoculums levels of 0, 10 and 100 nematodes /plant were statistically at par with each other.. However, 100 nematodes / plant had mediocre effect on yellowing of foliage and differed significantly from other inoculum levels.

Vaishnav and Sethi., (1979) found that increase in the inoculum level of 1,000 *T. vulgaris* adults and larvae per 500 g soil significantly reduced the growth of 10 days old plants of bajra and also Graham (1954) proved the pathogenicity of *T. clavtoni* on tobacco. He observed there was stunted top growth and a much retarded root system. Affected roots were shrivelled and sparsely developed and did not elongate normally.

Jenkins *et al*, 1957; Mahapatra and Das, 1984; Singh *et al*,1997 reported that Stunt nematode (*Tylenchorynchus* spp.) caused chlorosis, stunting and malformed roots..*Tylenchorynchus mashhoodi* and *Tylenchorynchus vulgaris* produced

significant stunting, weight reduction and discoloration of maize in pots at an inoculum level of 100 nematodes/pot or more.

Singh (1997) also reported that an inoculum level of 1,000 stunt nematode *T. vulgaris* and above /plant proved detrimental to the growth and development of maize cv. Farm Sameri.

Overall multiplication of stunt nematode depended on density, it is usually acknowledged that inter generic and to some extent inter specific competition may not be very high within the soil population, but there is a lot of inter specific competition (Oosterbrink, 1966).Although in total the maximum population was in inoculum level of 10,000 nematodes/plant while taking into account the multiplication factor, the highest reproduction factor (88.5%) was in inoculum level of 10 nematodes and the minimum reproduction factor (9.5%) was in inoculum level of 10,000 nematodes / plant . Our results corroborate with the earliesr reports. Padhi and Das (1984) also reported the maximum multiplication of *Helicotylenchus abunaamai* in the growing rice plant 9.95% at a lower level of nematodes in 100 g soil.

Patel and Thakar (1989) found maximum *T. vulgaris,* multiplication rate at the initial inoculum level of 100 nematodes/plant on wheat variety J-24. Singh (1997) also recorded the rate of reproduction being inversely proportional to the *T. Vulgaris* inoculum concentrations, with a peak of 61.7 times at the smallest inoculum level of 10 nematodes / plant and a minimum of 7.2 times at the largest inoculum level of 10,000 nematodes plant in maize cv. Farm Sameri.

In the current research on effect of *T. mashhoodi* on leaf chlorophyll contents of maize cv. Dewaki disclosed that a substantial decrease in leaves chlorophyll a, b and complete chlorophyll content started from 100 nematodes and above / plant over uninoculated and 10 nematodes / plant. Because study data relating to effect of *T. mashhoodi* on leaf chlorophyll contents of maize or other related cereals could not be traced from scanned literature. However, these findings are consistent with the outcomes achieved by some workers on distinct crops and other nematodes.

Joshi and Hollis (1976) reported significant reduction in root length and root dry weight with stunted and chlorotic growth in two-week old seedlings of rice cultivar 'Saturn' and 'Zenith' grown in pots containing 5,000 nematodes (*T. martini*) /pint of soil in U.S.A. Gill and Swarup (1977) inoculated the gram seedlings (*Cicer arietinum)* with *T. vulgaris* and found the reduction in plant growth characters (shoot

weight and root length and weight) significantly with increasing levels of inoculums. Singh (1997) also reported a substantial decrease of 18.89, 25.75 and 18.75 percent, respectively in leaf chlorophyll a, b and total chlorophyll content in maize cv Farm Sameri due to 2000 *T. vulgaris* / kg soil over control...

The most significant and readily adopted control technique for nematode control is the cultivation of resistant plant variants. As such, attempts have been produced here to monitor various maize types to locate sources of resistance to stunt nematode, *T. mashhoodi*. Only few researchers Singh and Patel (1999) ; Moradia, (1991) ; Patel (1987) ; Singh and Patel (1999) have identified sources of resistance to *T. vulgaris* and *T. claytoni* in maize and Tobacco and other crops but there seems to be no reference to *T. mashhoodi* for maize and other crops. Nearly all of the varieties studied during the current inquiries indicated comparable sort of response. Upadhyay and Swarup (1976) carried out screening of 17 different maize varieties by inoculating 1,000 *T. vulgaris* in the rhizosphere of 10 days old seedlings in pots. Nematode population was estimated after 90 days of inoculation. Findings revealed that three varieties viz., Kisan, Hi-starch and Ganga 5 had nematode population build up of 11,000 to 12,000 nematodes / plant while varieties viz., Ganga 101, Vijay and VL 54 having higher population build up over 40,000 nematodes / plant. It was also noticed that nematodes showed different preferences for feeding on different maize varieties. The maximum nematode multiplication occurred in Ganga 101 which may be considered as most preferred variety, whereas it was least in Ganga 5. Varieties viz., VL 54, EH 2356, C 2, Vijay Him 123, Sona and Vikram were as good as Ganga 101 supporting more number of nematodes Similarly, 20 bajra varieties / lines were assessed against *T. vulgaris* by Moradia and Patel (1992) and only GHB 183 was projected to be resistant, while GHB 27258 and NSC 179 reported maize varieties IWC 9402, IYC 9411, IYC 9408, GM1, IYC 9409, IWC 9401, IWC 9404, FS, GM2, IYC 9407, IYC 9410, ITC 9405, CHM 520A, CHM 501, CHM 633, SH 1 and SWT vulnerable and IWC 9403 resistant to *Tylenchorhynchus vulgaris.*

Nelson (1956) grew various hybrids, inbreeds and single crosses of maize in infested soil filled in pots for screening of susceptibility to *T. Claytoni.* Results revealed that twenty-one inbreeds and 11 single crosses showed decrease in shoot and root weights when exposed to high nematode population. Nine inbreeds exhibited

some resistance to nematode attack and had shoot and root weights similar to those of controlled and un inoculated plants.

Kumar (2001) reported that screening of maize varieties against the spiral nematode *Helicotylenchus indicus* in five varieties with 2000 inoculation of *H. indicus*. Data revelled that all the five varieties viz., Shaktiman-1, Pusa early hybrid-1,Suwan, Deoki and Lakshmi were categorized as a susceptible.

Singh (1997) reported that based on plant growth development and nematode reproduction variety IWC 9403 was labeled as resistant variety, while remaining 17 varieties viz., IWC 9402, lYC 9411, lYC 9408, GM 1, lYC 9409, IWC 9401., IWC 9404, FS, GM 2, lYC 9407, lYC 9410, lYC 9405, CHM 520A, CHM 501, CHM 633, SH 1 and SWT were categorized as susceptible to *T. vulgaris*.

From the above debate, it is found that resistance in maize against actoparasitic nematodes is very less. In our results also all maize varieties, Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Dewaki, Laxmi, Ganga Safed-2 screened were susceptible to *T. mashhoodi.* Therefore, there is an urgent need to monitor quite a large amount of maize varieties / accessions / hybrids to find sources of *T. mashhoodi* resistance. Even after that, if resistance sources are not available, tolerant varieties / lines should be exposed to chemical mutations to create genetic variability to search for resistance to nematodes and breeding programmes to incorporate resistance sources into the evolving agronomically suitable cultivars of nematode resistance.

As *T. mashhoodi* is a fresh evolving main nematode restricting the profitable cultivation of maize in light as well as heavy (clay) soils and no data is accessible on the management aspects of this maize nematode. Therefore, study work on practically feasible and economically viable management strategies through crop rotation, soil solarisation, use of resistant varieties and bio agents, cultural methods, nematicides / fungicides, etc. should be scheduled in an incorporated manner in the future.

CHAPTER -VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Studies on i) Survey of maize growing fields around Pusa-Dholi to determine frequency of distribution and the intensity of infestation of plant parasite nematodes in general and stunt nematode in particular. Especially *Tylenchorhynchus* spp. ii) Pathogenicity of stunt nematode, *Tylenchorhynchus mashhoodi* to determine threshold levels in terms of plant growth characteristics such as plant height, fresh root and shoot weight, dry root and shoot weight, quantum root index, yellowing index, nematode reproduction and stunt nematode impact on chlorophyll a, b and total leaf chlorophyll content, iii) Testing of various maize varieties / lines for sources of stunt nematode (*Tylenchorhynchus mashhoodi*) resistence.

A random study was conducted in maize crop fields around Pusa-Dholi revealing the existence of plant pest nematode, namely species of *Tylenchorhynchus, pratylenchus, Helicotylenchus, Hoplolaimus, Tylenchus, Heterodera, Meloidogyne, Hemicriconemoids,* along with saprozoic and others. *Tylenchorhynchus, Helicotylenchus, and Hoplolaimus* species were dominant among ectoparasites. *Tylenchorhynchus* spp. incidence frequency ranges from 60 to 100% recording maximum at Garhia and Harpur while minimum at Basantpur. *Hoplolaimus* varied from 60-80% maximum at Dholi farm and minimum at Harpur and BISA. *Helicotylenchus* varies from 70-100% maximum recorded in Garhia and Harpur and minimum in Pusa farm, *Pratylenchus* varies from 40 to 80% maximum in Garhia and minimum in Basantpur, *Rotylenchulus* varies from 20 to 50% maximum was found at Garhia and minimum in Basantpur. *Meloidogyne* was found only in Harpur with 30% frequency whereas, *Heterodera* and *Hemicriconemoides* were found at 30-40% and 20-30% frequency respectively in Garhia and Harpur. Other identified nematodes were *Tylenchus* and saprozoic. Average percent frequency of *Tylenchorhynchus* spp. over other nematodes ranged from12.25 to 34.79%. Minimum average percent frequency was found in Basantpur and maximum in Harpur.

Study of the pathogenic impact of stunt nematode, *Tylenchorhynchus mashhoodi* on maize cv. Dewaki shows that crop inoculated with 100 and above nematodes / plant has a substantial decrease in root and shoot, plant height, fresh and dry weight. Significant variations in the quantum root index and yellowing index were

also noted. There were small important variations in plant height, fresh and dry shoot and root weights between 0 and 10 levels of nematode inoculum.

Therefore, an inoculum level of 100 nematode and above / plant had a negative impact on plant growth and development of cv. maize Dewaki.

With regard to the build-up / plant nematode population, significant variations were achieved due to distinct levels of nematode inoculums. In general, the nematode population increase gradually with a increase in inoculum levels from 10 to 10,000 nematodes / plant.

It was considerably higher in the level of 10,000 nematodes / plant accompanied by 5,000 nematodes / plant being on par with each other. Nematode reproduction rate reduced with an increase in inoculum level it was maximum at level of 10 nematodes / plant (88.5 percent), while it was minimum at level of 10,000 nematodes / plant (9.5 percent).

Significant variations were also noted in leaf chlorophyll a, b, and total chlorophyll content at distinct levels of nematode inoculums. The chlorophyll content reduced with increase in nematode inoculum from 100 to 10000 nematodes / plant. chlorophyll content was considerably more at inoculum level of 10 nematodes / plant and un inoculated control..

Screening of various maize varieties / lines showed that all eight varieties / lines studied, namely Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, Laxmi, Dewaki, Ganga safed-2 were susceptible to stunt nematode *Tylenchorhynchus mashhoodi*.

REFERENCES

REFERENCES

Agri. Coop. (2018). Department of Agriculture Cooperation & Farmers Welfare. Agricoop.nic.in

Allen., M. W. (1955). A review of nematode genus *Tylenchorhynchus*. University of California Publications in Zoology. **61**:129-166.

Anonymous.,(1987-90). Annual report of PL-480 on corn cyst nematode (*Heteroderadera zeae)* Rajendra Agricultural University, Pusa.

Arnon, D.I. (1949). Copper enzymes isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant physiol. **24**: 1-15.

Ayoub, S.M. (1980). "Plant Nematology-An Agricultural Training Aid". Nema Aid Publication, Sacramento, California, USA.

Chhabra, H. K. and Mahajan, R. (1976). Control of *Tylenchorhynchus mashhoodi* Siddiqi and Basir in vineyards by granular nematicides. *Nematol.medit*.**4**: 243-244.

Cobb, N. A. (1913). New nematode genera found inhibiting fresh water and non-brackish soils. *J. Wash. Acad. Sci*. **3**: 432-444.

Cobb, N.A. (1914). "Nematodes and their Relationships".U.S. Dept. Agr. Yearbook, 1914: 457-490.

Cobb, N.A. (1918). Estimating the nematode population of the soil. *Agricultural Technology Circular Bureau*, Plant Industry U.S. Department of Agriculture 48 p.

DES,(2017). Bihar Agricultural Statistics, Directorate of Economics and Statistics, 2016-2017.

Gill, J.S. and Swarup, G. (1977). Pathogenic effect of *Tylenchorhynchus vulgaris* on gram, *Indian J. Nematol*.**7**:155-56.

Graham, T.W.(1954). The tobacco stunt nematode in South Carolina. *Phytopathology* **44**: 332.

Haider, M.G. and Nath R.P. (1992) Distribution of plant parasitic nematodes in maize fields and seasonal variation of *Hoplolaimus indicus*. *Current Nematology* **3**: 173-178.

Handoo, Z. A. (2000). A key and diagnostic compendium to the species of the genus *Tylenchorhynchus* Cobb, 1913 (Nematoda*: Belonolaimidae*). *Journal of Nematology* **32**:20–34.

Handoo, Z. A., Khan, A., and Islam, S. (2007). A key and diagnostic compendium to the species of the genus *Merlinius* Siddiqi, 1970 (Nematoda: *Tylenchida)* with description of *Merlinius khuzdarensisn*. sp. associated with date palm. *Nematology*. **9**:251–260.

Hashim, Z. (1983). Plant parasitic nematodes associated with pomegranate (*Punicagranatum L*.) in Jordan and an attempt to chemical control. *Nematologia Mediterranean* 11(2): 199-200.

Hassan, J., Chishti, M.Z., Rasheed, M., Ahmad, I., Ahmad, F. and Lone, B. A. (2009). Nematodes associated with *Zea mays* and their control through organic soil amendments. *International Journal of Plant Production* **3**: 71-75.

Hiscox, J.D. and Israelstam, G.F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* **57**: 1332-1334.

Indian Agristat. (2017). Indian Agristat, State Wise Area under food grain crops in India 2016-2017.www.indiaagristat.com

Jain, R. K, (1982). Pathogenicity of *T. vulgaris* Upadhyay et al. 1972 to maize. Aqric. Sci. Digest, **2**: 29-31.

Jenkins, W.R. Taylor, D.P., Rhode, R.A. and Coursen, B.W. (1957). Univ. Md. Agric. Exp. Sta. bull. A-89:25.

Jones, F.G.W.(1959). Nematology Department report of Rothamsted Exp. Stat. F 1958, pp. 112-116.

Joshi, M.M. and Hollis, J.P.(1976). Pathogenicityof *Tylenchorhynchus martini* Swarmers to rice. *Nematologica* **22**:123-24.

Kaul, V. (1985).Studies on the plant parasitic nematodes of Kashmir.Ph.D thesis submitted to Department of Zoology, University of Kashmir, Srinagar.

Keshari, A.K., Gupta, R. (2016). Five Species of Plant Parasitic Nematodes (Order: *Tylenchidae*) Affecting Vegetable Crops of Nepal. *Inte. J. Life Sci.* **10(1)**: 10-16.

Khera, S. and Zuckerman,B. M.(1963). In vitro studies of host-parasite relationships of some plant parasitic nematodes. *Nematologica.***7** : 1-6.

Kornobis, S. (1983). Nematode on maize crops Wilkopolska. *Zeszyty Problemowe Postapowalluk Rolniczych*, **278**: 139-148.

Krusberg, L. R. (1956). Studies on the tessellate stylet nematode (Abstra). Phytopathology **46**: 18.

Kumar, D. (2001). Studies on the spiral nematode, *Helicotylenchusindicus* infesting maize crop. Msc thesis submitted to department of nematology, Rajendra agricultural university, Bihar, Pusa (Samastipur).

Landi, S. and Manachini, B. (2005). Nematodes associated with the rhizosphere of corn (*Zea mays* L.). *Comm. Appl. Biol. Sci*, Ghent University **70**: 937-944.

Mahapatra, S.N. and Das, S.N. (1984). Pathogenicity of *Tylenchorhynchus mashhoodi* on maize (*Zea mays*). *Journal of Research*, Assam Agricultural University **5**: 119-121.

Martin, W. J. and W. Birchfield. (1955). Notes on plant parasitic nematodes in Louisiana. *Plant. Dis. Reptr*. **39**: 3-4.

Mohandas, C. and Prabhoo, N.R, (1979). Studies on the distribution of nematodes in kerala. (Abstract). *Indian J. Nematol*. **9**: 75-76.

Moradia, A. M. (1991), Studies on stunt nematode, *Tylenchorhynchus vulgaris*. Upadhyay et al,.1972, on bajra. M. Sc.(Agri.) thesis submitted to Gujarat Agricultural University, Sardar Krushinagar, Gujarat.

Moradia, A. M. and D. J. Patel (1992), Evaluation of Bajra varieties / lines against . *Tylenchorhynchus vulgaris*. *Current Nematol*. **3**(2):207.

Mukhopadhyay, M.C. and Haque M.S. (1974). Nematodes associated with field crops, fruits and fodder crops in West Bengal. *Indian J. Nematol* **4**: 104-107.

Musarrat Ramzan,. Handoo Z.A , Shahina Fayyaz. (2008). Description of *Tylenchorhynchus qasimii* sp. with a New Report of *T. kegasawai* Minagawa, 1995 from Pakistan. *Journal of Nematology* **40(1):**20–25.

Nelson, R. R, (1956). Resistant to stunt nematode in corn. *Plant Pis.Reptr*. **40** : 635-639.

Nombela, G., Navas, A. and Bello, A. (1998). Effects of crop rotation of cereals with vetch and fallow on soil nematofauna in central Spain. *Nematologica* **44**: 63-80.

Norton, D.C.(1984). Nematode parasites of corn. In: Plant and Insect Nematodes (Ed. by Nickle, W.R.), New York, USA, Marul Dekker, Inc. 61-94.

Oostenbrink, M. (1960). Organisation of a nematology Program 21-32. In Nematology, fundamentals and recent advance with emphasis on plant parasitic and siol forms. Eds. Sasser and Jenkins, Eurasia publishing house (p.) Ltd., New Delhi.

Oostenbrink, M.(1966). Major characteristics of Relation between Nematodes and Plants.Publi. H. Veenmanand Zonen N. V, Wageningen, The Netherlands, pp. 7-8.

Padhi, N.N. and Das, S.N.(1984). Some aspects of ecological behavior of *Helicotylenchus abumaamai* siddiqi, 1972.*Indian J. Nematol*.**14(1**): 25-29.

Patel, A.S. (1989). Stunt nematode, *Tylenchorhynchus vulgaris* Upadhyay et al., 1972 On Bidi tobacco. M.Sc.(Agri.) thesis submitted to Gujarat Agricultural University, Anand campus, Anand.

Patel, B. A., Singh, U. S., Patel, D. J. Patel, and Gohil, V. A.. (1995). Out break of *Tylenchorhynchus vulgaris* on maize in Panchmahals district of Gujrat State. *Current Nematol*.**6** (1): 101-102.

Patel, J. Desai M.V and Shah H.M. (1962). Stunt nematodes on tobacco in Gujarat, India. *Plant. Dis. Reptr*.**46**: 173-174.

Patel, N. B., Patel, R. G., Patel, A. D., Patel, H. V., Patel, B. A. and Patel, D. J,. (2000). Occurrence and distribution of *Tylenchorhynchus vulgaris* and *Pratylenchuzeae* in maize growing areas of Panchmahal district of Gujrat. *Indian J. Nematol*.**30**: 95-96.

Patel, P. N. (1987). Effect of the stunt nematode, *Tylenchorhynchus vulgaris*. Upadhyay *et al.,* 1972, on wheat and its control. M.Sc.(Agri.) thesis submitted to Gujarat Agricultural University, Sardar Krushinagar, Gujarat.

Patel, P.N. and Thakar, N.A. (1989). Damaging threshold level of stunt Nematode, *Tylenchorhynchus vulgaris*, on wheat variety. J. 24. *Indian J. Nematol*. **19**:78-79.

Rajendran, G. Naganathan, T.G. and Vadivelu, S. (1979). Studies on banana nematodes. *Indian J. Nematol*. **9**: 54.

Sasser, J.N. and Freckman, D.W. (1987). A world perspective on nematology- The role of the society. In: Vistas on Nematology. (Eds J.A. Veech and D.W Dickson).The Society of Nematologists, Inc., Maryland, USA. pp. 7-15

Sethi, C.L. and Swarup, G.(1968). Plant parasitic Nematodes of North western India. *Nematologica* **14**: 77-88.

Sharma, R. D. (1971). Studies on plant parasitic nematode, *Tylenchorhynchus dubius*. *Meded. Landb. Hoogesch Wageningen*. **71** : 1-154.

Siddiqi, Z. A. Khan A. M. and Saxena S. K. (1972). Host range and varietal resistance of certain crucifers against *Tylenchorhynchus brassicae. Indian Phytopath*. **25**: 275-281

Singh, K. (1960). Suspected plant parasitic nematodes in certain sugarcane soils of Madras state. *Indian Phytopath*. **13**: 151-152

Singh, R. S. and Sitaramaiah, K. (1994). Plant Pathogens the Plant Parasitic Nematodes. Oxford and IBH Publishing Co. Pvt. Ltd., 66 Janpath, New Delhi. pp. 233-235.

Singh, R. V. and Khera, S. (1978). plant parasitic nematodes from the rhizosphere of vegetable crops around Calcutta.- 2. Family *Tylenchorhynchidae*. Bull. zool. Surv. India, i **(1);** 25-28,

Singh, U.S. (1997) Stunt nematode, *Tvlenchorhynchusvulgaris*Upadhyay et al., 1972, On Maize. P.hd thesis submitted to Gujarat Agricultural University, Anand campus, Anand.

Singh, U.S. and Patel, D.J.(1999). Evaluation of maize varieties/ hybrids against stunt nematode, *Tylenchorhynchus vulgaris*. *Indian J. Nematol* **29(1**): 84-85.

Singh, U.S., Patel, B.A., Patel, N.B. and Patel, D\S.J.(1997). Occurrence and spread of *Tylenchorhynchus vulgaris* in maize growing area of Panchamahals districts Gujarat and its pathogenicity on maize cv. Farm sameri. Indian Phytopathological Society-golden jubilee International conference onIntegrated pest disease management for sustainable Agriculture. 10-15 Nov. 1997, New Delhi, India.

Sitaramaiah, K. (1984). Plant Parasitic Nematodes of India. Today and Tomorrow Publishers, New Delhi, pp.233-235.

Sitaramaiah, K., Singh, R.S., Singh, K.P. and Sikora, R.A.(1971). Plant parasitic and soil nematodes of India Uttar Pradesh Agricultural University, Pant nagar, Experimental Sta. Bull., **3**: 70 pp.

Siyanand, A. R. Seshadri and Das Gupta, D. R.(1982), Investigation on the life cycles of *Tylenchorhynchus vulgaris*, *Praty1enchus thornei* and *Hoplolaimus indicus* individually and in combined infestation in maize. *Indian J . Nematol* .**12** : 272-276.

Srinivasan, G., Zaidi, P. H., Prasanna, B. M., Gonzale, F. and Lesnick, K,. (2004). Proceeding of 8th Asian Regional Maize Workshop New Technologies for the New Millenium Bangkok, Thailand, 5-8 August, 2002, CIMMYT Mexico DF.

Steiner, G.(1937). Opusculamiscelanea nematolgica.V. I. *Tylenchorhynchus c1aytonin. sp*. an apparently rare nemic parasite of the tobacco plant. *Proc. He 1. Soc. Wash.4* : pp. 33-38.

Thakar, N.A. (1969). Effect of root-knot and stunt nematodes on some important crops. M.Sc.Thesis submitted to the Sardar Patel University, Vallabh Vidhyanagar.

Thorne, G.(1961). Principles of Nematology.McGraw Hill Book Company, Inc., New York. pp. 101-106.

Troll, J. and A. C. Tarjan,. (1954). Wide spread occurrence of root parasitic nematodes in golf course greens in Rhode Island. *Plant Pis.Reptr*.**38** : 342-344.

Upadhyay, K. D. and Swarup, G. (1972). Culturing, host range and factors affecting multiplication of *Tylenchorhynchus vulgaris* on maize. *Indian .J. Nematol* .**2** : 139-145.

Upadhyay, K. D. and Swarup, G. (1976). Reaction of some maize varieties against *Ty1enchorhynchus vulgaris*, *Indian J.Nematol*,**6** : 105-106,

Upadhyay, K. D. and Swarup, G. (1981). Growth of maize plants in the presence of *Tylenchorhynchus vulgaris.* Upadhyay *et al*., 1972, singly and in combination with *Pratylenchus zeae* (Graham,) 1951 and *Fusarium moniliforme* (Sheld.). *Indian. J. Nematol*. **11** :29-34.

Vaishnav,M.U. and Sethi, C.L. (1979). Pathogenicity of *Meloidogyne incognita* and *Tylenchorhynchus vulgaris* on bajra and their interrelationship. *Indian J.Nematol*.**8**:1-8.

Vanden Berg E., Marais, M., Kandji S., Mounport, D.N., Diaye, B. and Cadet, P. (2001). Plant-parasitic nematodes associated with maize-bean intercropping systems in Kenya. *African Plant Protection*.**7(2):** 81-84.

Zuckerman, B. M. ; W. F. Mai and R. A. Rohde. (1971).Plant Parasitic nematodes , vol. II. Academic Press, New York, San Francisco, London. Pp. 139-141.