CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood,1949 ON BAWCHI, *Psoralea corylifolia* L.

By

Miss. Kshirsagar Priyanka Prakash

(Reg. No. 2020/145)

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.
2023

CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood,1949 on Bawchi, *Psoralea corylifolia* L.

By

Miss. Kshirsagar Priyanka Prakash

(Reg. No. 2020/145)

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

APPROVED BY

Prof. B. Y. Pawar
(Chairman and Research Guide)

Dr. S. T. Aghav
(Committee Member)

Dr. P. R. Palande
(Committee Member)

Dr. R. T. Gaikwad
(Committee Member)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.

2023

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

Place: MPKV, Rahuri

Date : / / 2023 **(P. P. Kshirsagar)**

Prof. B.Y. Pawar
Assistant Professor,
AICRP on MAP & Betelvine,
Department of Agril. Entomology,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722, Dist. Ahmednagar
Maharashtra State, INDIA

CERTIFICATE

This is to certify that the thesis entitled, "**CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (KOFOID AND WHITE, 1919) CHITWOOD, 1949 ON BAWCHI, *Psoralea corylifolia* L.**" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** embodies the results of a piece of *bonafide* research work carried out by **Miss. KSHIRSAGAR PRIYANKA PRAKASH ,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place: MPKV, Rahuri **(B.Y. Pawar)**

Date: / /2023 (Research Guide)

Dr. C.S. Patil
Head,
Department of Agricultural Entomology,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra State, INDIA

CERTIFICATE

This is to certify that the thesis entitled, "**CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (KOFOID AND WHITE, 1919) CHITWOOD, 1949 ON BAWCHI, *Psoralea corylifolia* L.**" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** embodies the results of a piece of *bonafide* research work carried out by**, Miss. KSHIRSAGAR PRIYANKA PRAKASH,** under the guidance and supervision of **Prof. B.Y. PAWAR,** Assistant Professor, AICRP on MAP & Betelvine, Department of Agril. Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of this thesis has been submitted for any other degree or diploma.

Place: MPKV, Rahuri (C.S. Patil)

Date: / /2023

Dr. S. A. Ranpise
Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra State, INDIA

CERTIFICATE

This is to certify that the thesis entitled, "**CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (KOFOID AND WHITE, 1919) CHITWOOD, 1949 ON BAWCHI, *Psoralea corylifolia* L.**" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** embodies the results of a piece of *bonafide* research work carried out by **Miss. KSHIRSAGAR PRIYANKA PRAKASH,** under the guidance and supervision of **Prof. B.Y. PAWAR,** Assistant Professor, AICRP on MAP & Betelvine, Department of Agril. Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of this thesis has been submitted for any other degree or diploma.

Place: MPKV, Rahuri (**S. A. Ranpise**)

Date: / /2023

ACKNOWLEDGEMENT

It gives me great pleasure to express my deep sense of gratitude and sincere thanks to my research guide and chairman of advisory committee ***Prof. B. Y. Pawar****, Assistant Professor, AICRP on MAP & Betelvine, Department of Agril. Entomology, MPKV, Rahuri. I owe to him for his constant inspiration and well versed advice and keen criticism, prompt suggestions regarding research problems, constant encouragement and sympathetic attitude throughout the course of investigation and the completion of thesis.*

It is proud privilege to express my sincere and whole hearted thanks to the respectable members of advisory committee, ***Dr. R. T. Gaikwad*** *Associate Professor, AICRP on MAP & B Department Plant Pathology, MPKV, Rahuri,* ***Dr. S. T. Aghav*** *Assistant Professor, Department of Agril. Entomology, PGI, MPKV, Rahuri,* ***Dr. P. R. Palande*** *Assistant Professor & Academic Incharge, Department of Agril. Entomology, PGI, MPKV, Rahuri for their valuable suggestions and guidance during the investigations and correcting the manuscript.*

I am highly obliged to ***Dr. Prashant Kumar Patil****, Hon. Vice Chancellor, MPKV, Rahuri, for providing necessary facilities during the entire course of study.*

I sincerely thank to ***Dr. S. A. Ranpise****, Dean, Faculty of Agriculture and Director of Instruction, Post Graduate Institute, M.P.K.V., Rahuri for providing necessary facilities for successful completion of my research work.*

My sincere and heartfelt gratitude to ***Dr. C.S. Patil****, Head, Department of Entomology and Director of Extension, MPKV, Rahuri for their inspiring guidance during the course of investigation.*

I am very thankful to ***Mrs. Chemate, Mr. Bhusari*** *and other non-teaching staff of Department of Agricultural Entomology MPKV, Rahuri for their immense help during the conduct of this research work.*

I have no words to express my feelings towards my family but I make a mention of my father ***Mr. Prakash Uttam Kshirsagar****, my loving mother* ***Mrs. Padmini Prakash Kshirsagar****. I would like to express special thanks to my brother* ***Mr. Swapnil Prakash Kshirsagar****, as he always there for me in any situation and his words of motivation makes me enthusiastic. I express my deep sense of appreciation towards my seniors Mr. Suraj Daware, Atul Kakade and Miss. Pushplatha M their constant encouragement and blessings and eternal moral support which have brought my educational carrier to this stage.*

I express my sincere thanks to my beloved friends Miss. Kiran Ghanwat, Durgeshwari Ekatpure, Anupama Patil, Kiran Khomane, Amruta Todkar, Durgesh Narwade, Tushar Chavan, Shivsandeep Rankhamb, Atul Shintre, Pratik Phadtare, Priya, Shubham and for supporting me and encouraging me.

I am also obliged to all authors past and present whose literatures have been cited in this manuscript.

At the end I wish to thank all those who directly or indirectly played pivotal role in successful completion of my post-graduation. Any omission in this brief acknowledgement does not mean lack of gratitude.

Place : M.P.K.V., Rahuri
Date**:** / /2023 (P. P. Kshirsagar)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
/	:	Per
@	:	At the rate of
+	:	Plus
x	:	Multiply
C.D.	:	Critical difference
cm	:	Centimetre (s)
cm^2	:	Square centimetre (s)
cm^3	:	Cubic centimetre
e.g.	:	Exempli gratia, For example
et al.	:	And others (et alli)
etc.	:	*Et cetera*, and so on
FYM	:	Farm Yard Manure
g	:	Gram (s)
ha	:	Hectare (s)
hr	:	Hour (s)
i.e.	:	Id est, That is
IPM	:	Integrated Pest Management
kg	:	Kilogram (s)
l	:	Litre (s)
m	:	Metre (s)
m^2	:	Square metre
Mg	:	Milligram (s)
NSE	:	Neem Seed Extract
Q	:	Quintal (s)
No.	:	Number
S.E.	:	Standard error
Rs.	:	Rupee (s)
RKN	:	Root knot nematode
T	:	Tones
viz.,	:	Videlicet (Namely)
Cfu	:	Colony forming units
J_2	:	Juvenile stage 2
Ml	:	Millilitre
^0C	:	Degree Celsius
WP	:	Wettable Powder
spp.	:	Species
PPN	:	Plant Parasitic Nematodes
RKI	:	Root Knot Index

ABSTRACT

CROP LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood,1949 ON BAWCHI, *Psoralea corylifolia* L.

By

Miss. Priyanka Prakash Kshirsagar

A candidate for the degree
of
MASTER OF SCIENCE (AGRICULTURE)
in
AGRICULTURAL ENTOMOLOGY

Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722
2023

Research Guide	:	**Prof. B.Y. Pawar**
Department	:	**Agricultural Entomology**

An experiment entitled "Crop loss assessment and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 on Bawchi, *Psoralea corylifolia* L." was conducted at 'All India Co-ordinated Research Project' on Medicinal, Aromatic plant & Betelvine project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist: Ahmednagar (Maharashtra) during *Kharif* 2021. During the course of study, the efficacy of treatment of application of neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha were evaluated over untreated control with Paired plot design for assessing the avoidable yield losses owing to *M. incognita* in *Psoralea corylifolia* L. with ten replications. The observations on soil nematode population per plot, number of root galls, egg masses per 5 g roots and yield per plot at initial, intermediate and termination stage of the experiment were recorded. The average yield loss in plot treated with neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha over untreated plot was 51.10 per cent. The average output from treated and untreated Bawchi plot was recorded as 13.84 and 6.72 q/ha, respectively.

The studies on assessing the effect of different treatments *viz*., nematicides, bioagents and antagonist crop for management of *M. incognita* infesting Bawchi plot cultivated at AICRP on MAP & Betelvine MPKV, Rahuri was evaluated with Randomized Block Design with three replications and nine treatments for control of *M. incognita* in *Psoralea corylifolia* L. The initial, intermediate and termination observations on population of *M. incognita* per 200 cm^3 soil, root galls and egg masses/5 g roots were recorded. The treatment with Neem cake @ 2 ton/ha was observed significantly superior in reducing *M. incognita* population, root galls and egg masses at intermediate and termination stage which is at par with *Trichoderma* plus @ 20 kg per ha.

Abstract contd…. **Miss. Kshirsagar Priyanka Prakash**

Impact of different strategies on management of root-knot nematode showed that the treatment with Neem cake @ 2 ton/ha with highest net return was observed than all other treatment. The next promising treatment was of *Trichoderma viride* (2×10^{6} cfu/g) @ 20 kg/ha, *Purpureocillium lilacinum* ((2×10^{8} cfu/g) @ 20 kg/ha and *Pseudomonas fluorescens* (1 x 10^{9} cfu / ml) @ 20 kg/ha in reducing root-knot nematode population at intermediate stage. However, the next promising treatment was Karanj cake application @ 2 ton/ha followed by Intercropping of *Tagetes* spp. @ 3:1 proportion which found equally effective and at par with groundnut cake application @ 2 ton/ha.

Pages 1 to 39

1. INTRODUCTION

Psoralea corylifolia L. (Family - Leguminosae) is a well-known traditional medicinal plant used from ancient times for treatment of various ailments. The word Psoralea originates from the Greek *psoraleos*, which stands for “affected with the itch or with leprosy”. Also known as “Kushtanashini” (leprosy destroyer) in Ayurveda. Psoralea is also known by various names ‘Purple flame’ in English, ‘Karkoli’ in Malayalam, ‘Banchige’ in Kannada and ‘Bavanchalu’ in Telgu language. The seeds of Psoralea have white streaks inside hence got the name Somaraji. In India, it is found as a wild weed in cold weather of the Himalayas. It is found in Bombay, Bengal, Uttar Pradesh and Rajasthan, in valley of Karnataka, Bihar and Deccan. This plant is also widely distributed in the tropical and subtropical regions of the world. (Khushboo *et al*., 2010).

P. corylifolia grows annually and is an erect herb. The plant can survive in acid, basic and neutral environment. The fruit cannot survive in freezing weather. The fruit normally has no odour but when chewed, it produces pungency. The taste of the fruit is bitter, acrid and unpleasant. The size of the flowers is small and shaped like red clover. It is widely distributed and an important part of therapeutics in Ayurveda. Interestingly, its medicinal usage is reported in Indian pharmaceutical codex, Chinese, British and the American pharmacopoeias and in different traditional system of medicines such as Ayurveda, Unani and Siddha. (Khan *et al*., 2015).

In Ayurvedic literature, the properties of Bakuchi plant are documented as the sanskrit shloka states the use of Bakuchi in various Ayurvedic treatments as in Kushtha (skin disorders); Keshya and Tvchya (skin and hair treatments); Krumi (as a germicidal); Shwasa & Kasa (Bronchial asthama and cough); Pandu (Anaemia) and Shotha (Oedema). It has cardio tonic, vasodilator, pigmentor, antitumor, antibacterial, cytotoxic and anti-helminthic properties and locally used for alopecia areata, hair loss, leprosy, inflammation, leukodermapsoriasis and eczema. There have been hundreds of bioactive compounds isolated from seeds and fruits and most important compounds identified belongs to coumarins, flavonoids and meroterpenes groups (Prasad *et al*., 2004). The root of *P. corylifolia* has shown its effectiveness in dental caries. The fruits are aphrodisiac and have purgative effect and the leaves are anti-diarrheal. The roots of *P. corylifolia* have been investigated for bioactive compounds. It was found that psoralen and isopsoralen isolated from seeds are regarded therapeutically active constituent (Shadab and Shamsi, 2019). The above deliberation about phytochemical investigation of different parts of *P. corylifolia* clearly indicates that this plant is a very useful source of variety of bioactive constituents including flavonoids, terpenes, glycosides, alkaloids, coumarins and others. *P. corylifolia* is a widely used herb and have many diverse ethno pharmacological and medicinal applications. The many chemical and pharmacological researches that have been carried out have resulted in the isolation of the diverse bioactive compounds. Nematodes are establishing limitation in the cultivation of many medicinal, aromatic, and spice plant. However, there is very finite information available regarding the nature and extent of nematode disease problems in Bawchi. The host range of root-knot nematodes is large and more than two thousand plant species have been reported as hosts for this nematode (Sasser, 1980).

Meloidogyne spp. is sedentary endoparasites of roots, feeding and developing within galls. Infection can also make plants more susceptible to soil-borne, root-infecting diseases. Disease resistance can also be broken by nematodes. Chemical control approaches are now used to control plant parasitic nematodes. In the face of the dangers posed by chemical control approaches, resistant cultivars and biopesticides can be crucial components of integrated nematode management. Bio insecticides are becoming more popular because they are environmentally safe and cost effective, and they prevent nematodes from evolving into new races or biotypes (Sultan *et al*., 2010).

Meloidogyne spp. produces root galls or root knots which cause slow fragility of the root in its function of nutrients and water uptake and its translocation. Plants with above ground symptom may be with dwarfed foliage, yellowish in colour with fewer fruits. These symptoms are constantly misdiagnosed as macro and micronutrient deficiency or moisture stress. Apart from the plant damage, root-knot nematodes are known for disease complexes involving fungi, bacteria, virus, mycoplasma, insects, and other nematodes. Nodules of Rhizobium spp. may easily be recognised from root-knot nematode galls. Most legume roots have spherical nodules caused by nitrogen-fixing bacteria and the nodules are easily detached, whereas nematode galls are the swelling and integral part of the root which cannot be removed without causing root damage.

Meloidogyne spp. and its races have always been difficult to identify due to morphological similarities between species, life stages in different habitat, variable host ranges, poorly defined species boundaries, intraspecific variability, potential hybrid origin and polyploidy (Blok and Powers, 2009). Estimating crop losses has been conducted based on data published by AICRP on nematodes over the years. Phytonematode cause 21.3 per cent crop losses totalling Rs. 102,039.79 million per year; losses in 19 horticultural crops were estimated to be Rs. 50,224.98 million, while losses in 11 field crops were estimated to be Rs. 51,814.81 million (Kumar *et al*., 2020).

Consequently, it has become increasingly vital to hunt for new environment friendly solutions for the management of phytonematodes. The utilisation of resistant cultivars and biocontrol agents may become essential components of integrated nematode management in the face of hazards posed by chemical control methods. Biocontrol of Phytonematodes with microbial substances is becoming increasingly popular because of its environmentally favourable and economically viable approach that does not allow nematodes to evolve into new races.

Meloidogyne incognita is harmful to *Psoralea corylifolia* L. by root infestation and reducing yield due to hampered growth. Only few attempts have been made so far to manage this melody. As a result, there is an urgent need to conduct research on this important nematode that infests *Psoralea corylifolia* L. In view of the above facts and data, the current study was taken up with an emphasis to develop an appropriate management package for saving the Bawchi plant from root knot nematode attack. The specific objectives of this investigation are:

1. To study the avoidable yield losses due to root-knot nematode, *Meloidogyne incognita* on Bawchi, *Psoralea corylifolia* L.

2. To study eco-friendly management of root-knot nematode infesting Bawchi, *Psoralea corylifolia* L.

2. REVIEW OF LITERATURE

The root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949, is one of the most damaging plant parasitic nematode linked with the crop plants and capable of attacking a wide range of crop plants as well as weed species. As a result, it has received substantial global research. It is evident to control the nematode population when taking into account the financial damages brought on by nematodes.

2.1 Assessment of Avoidable Yield Losses Due to Root-Knot Nematodes, *Meloidogyne incognita* Infesting Bawchi, *Psoralea corylifolia* L.

Oka *et al*. (2000) observed that root-knot nematodes (*Meloidogyne* spp.) are the most widely distributed nematode in agriculture, attacking over 2,000 different plant species, including cultivated crops and wild plants, causing an estimated monetary loss of $100 billion per annum worldwide. Plant parasitic nematodes, especially root-knot nematodes (*Meloidogyne* spp.), cause serious yield losses in vegetables, ornamental and medicinal plants and horticultural crops around the world.

Karssen and Moens (2006) recorded more than 100 *Meloidogyne* species have been described of which four species namely; *Meloidogyne javanica*, *Meloidogyne arenaria*, *Meloidogyne hapla* and *M. incognita* are responsible for approximately 90% of the nematode damages in tropical and subtropical environments.

Hisamuddin and Robab (2010) at Aligarh Muslim University reported that the impairment in growth of *P. Corylifolia* caused by *M. incognita* might be due to one or more or all of the following reasons like obstruction in proper translocation of water and mineral elements from the roots to the shoots due to abnormalities in the galled roots. Departure in translocation path of metabolites. Deceleration in the rate of synthesis of metabolites as a result of scarcity of water and nutrients in the leaves, Withdrawal and consumption of metabolites in significant amount diverted towards giant cells by few nematode.

Khan *et al*. (2014) at National Bureau of Plant Genetic Resources, New Delhi estimated that *Meloidogyne incognita* has also been found associated with *P. corylifolia*. He observed severe infestation of root-knot nematode, *M. incognita* on *P. corylifolia* plant cultivated at NBPGR, New Delhi, India. Roots of infected plants were heavily galled, and soil sample collected from the rhizosphere of affected plant yielded 536-845 second-stage juveniles (J2)/200 cm3 soil. The severe root galling and presence of high population density of J2 in soil around symptomatic plant indicates that RKN can be a potentially damaging pest of *P. corylifolia*. These findings will assist in recognizing RKN as an economic threat to the crop and should increase grower’s awareness of the need to take soil samples from field.

Sumita and Das (2014) carried out to study efficacy of different bio-agents (*Trichoderma viride*, *T. harzianum*, Biofor-pf and neem cake) against root-knot nematode, *Meloidogyne incognita* in green gram (*Vigna radiata*) revealed that soil application of neem cake @ 2 tones/ ha significantly increased the shoot length, fresh and dry weight of shoot of green gram, followed by soil application of *T. viride* @ 2.5 kg/ha as compared to untreated control. The present study revealed that all bio-agents significantly reduced the number of galls per root system, number of egg masses per root system and final nematode population as compared to untreated control. Among the bio-agents, maximum reduction in galls and egg masses per root system, and final nematode population was obtained in Biofor-pf @ 100 kg/ ha followed by neem cake @ 2 t/ha. Siddiqui and Shaukat (2004) reported that combined application of *Psudomonas fluorescens* and *Trichoderma harzianum* reduces galls and egg masses on tomato plant infested by *M. javanica*.

Danish M *et al.* (2018) at Botanical Garden of Aligarh Muslim University reported that Bawchi (*P. corylifolia*) was highly susceptible towards *Meloidogyne incognita*. The nematode not only caused stunting of the plant growth but also changes in biochemical parameters. It was found that the plant growth parameters like shoot and root lengths, fresh and dry weights of the bawchi plants infected with *M. incognita* were adversely affected as the inoculums level increased from 100 to 2,000 J2 per plant. The damage caused to the plants on infection by *Meloidogyne incognita* involves several mechanisms.

2.2 Management of Root-knot Nematodes, *Meloidogyne incognita* Infesting Bawchi, *Psoralea corylifolia* L.

Pandey R. (2007) stated that plant parasitic nematode are major pests of large number of agricultural crops, including medicinal and aromatic plants, causing heavy yield losses and considerably reducing farm income of the growers. It is therefore, important to recognize the nematode infestation problems at an early and initiate appropriate eco-friendly control measures. Due to ill-effect of chemicals, biological nematode management tactics are becoming increasingly popular. The biological control of plant parasitic nematodes is considered as one of the safest, eco-friendly and effective management tactic to keep nematode population under control. In these method different types of organic and biological inputs like various botanicals and microbes like fungi, bacteria, nematodes etc. are presently used at commercial scale to keep PPN population below the damaging level for enhancing the crop yield.

2.2.1 Application of bioagents

Nematicides, which are available today are generally very expensive, less effective and have toxic hazards. In case of chemical method, environmental health hazard, non availability and high cost discourage their use. In view of the cost and problems in use of nematicides, it is necessary that some alternative methods need to be tried. Among such methods bio-control fungal formulation and soil amendments with organic matters may prove promising in nematode control.

Jatala and Alam (1990) reported that considerable range of fungi colonizes the eggs of cyst and root-knot nematodes. The egg and female parasitic (also grouped as opportunistic fungi) fungi are promising groups for control of various nematodes. Most promising ones are *Purpureocillium lilacinum.* Under field conditions in over 60 countries, *P.lilacinum* gave good control of *M. incognita, M. arenaria, Tylenchulus semipenetrans, Rotylenchulus reniformis* and *Globodera pallida.*

Windham *et al*. (1989) reported that the filamentous fungi, *Trichoderma* spp. has been an effective bioagent for the management of root-knot nematodes infesting vegetable and other crops obtained reduced root galling on tomato by *M. javanica*.

Khair and Nagdi (2008) evaluated four bioagents *viz. B. subtilis, Pseudomonas fluorescens***,** *Trichoderma harzianum* and *Trichoderma viride* against root knot nematode on brinjal in-vitro and in the greenhouse in comparison with the nematicide, oxamyl. In-vitro, culture filtrates of *B. subtilis, P. fluorescens, T. harzianum* and *T. viride* at 10 per cent concentration caused nematode mortality of 100, 99, 98 and 96 per cent, respectively after 72 hours exposure to the filtrates.

Rao (2008) conducted field experiment to evaluate the efficacy of *P. lilacinum* (10^6 cfu/g) and *P. fluorescens* (10^8 cfu/g) singly, in combination and with the addition of neem seed cakes for the management of root-knot nematode, *M. javanica* on acid lime. Application of *P. lilacinum* and *P. fluorescens* at 10 g and neem cake at 20 kg/ha reduced the population of the nematode and increased the yield of crops.

Muthulakshmi *et al*. (2010) reported that the population of the root-knot nematode, *M. graminicola* was significantly lower in rice roots when treated with *P. fluorescens*. There was 46% reduction in the nematode population 12 days after sowing in the *P. fluorescens* treated plants. Earlier reports have proved the effectiveness of *P. fluorescens* in suppression of economically important plant diseases and plant parasitic nematodes. Significant reduction in root and soil population of the rice root nematode was obtained with *P. fluorescens*.

Pawar *et al*. (2013) found that the treatment of *Pseudomonas fluorescens* applied @ 20 kg/ ha was most efficient in reducing the *M. incognita* population (31.28 %), root galls / 5 g root (29.28 %) and increasing pomegranate yield (18.99 %) with B:C ratio of 1:2.37. Next superior treatment was of *Trichoderma viride* @ 20 kg/ha. The reduction in nematode population, root galls/ 5 g roots and increase in the yield reported in them were 23.28 and 29.81; 23.90 and 25.07; with 1: 2.33 B:C ratio, respectively.

Walunj (2013) found that split application of bioagents, Phule *Trichoderma* plus (10 kg/ha each at bahar of tree and 90 days after "bahar") for management of *M. incognita* with better persistence of cfu/g in soil was up to 150 days. Next superior treatment was *P. chlamydosporium* over single application. The treatment of phorate 10G and Phule *Trichoderma* plus were most effective in reducing the *M. incognita* population of 24.3 and 31.4 per cent, root galls of 14.10 and 37.53 per cent and egg mass of 9.23 and 22.86 per cent and increasing the pomegranate yield by 58.49 and 57.77 per cent, respectively. These treatments recorded 1:3.51 and 1:3.48 B:C ratio and 1: 24.68 and 1: 24.20 ICBR, respectively.

Walunj and Mhase (2015) found that the persistence of Phule *Trichoderma* plus in soil was reported better at 30 to 60 DAT and recorded 12.0 to 10.6 cfu/g of soil than the other bioagents. The Phule *Trichoderma* plus and nematicide, phorate 10 G gave effective control from *M. incognita* infesting pomegranate.

Niranjana and Dhan (2018) carried out a pot experiment for management of *M. incognita* in turmeric using bioagents, botanicals and chemicals. The maximum plant height (68.75 cm), fresh rhizome weight (308.25 g), dry rhizome weight (62.13 g), least number of galls (26.25) and lowest nematode population (201.75/ 200 cc) was reported in carbofuran 3G among different treatments and was better over individual treatments and control. Next superior treatment was *Trichoderma viride* and neem cake. In combination treatments neem cake + *Purpureocillium lilacinum* performed best with maximum plant height (72.00 cm), fresh rhizome weight (325.00 g), dry rhizome weight (65.00 g), minimum galls (23.50) and lowest *M. incognita* population (153.25/ 200 cc) which was equally effective with consortium of Neem cake + *Trichoderma viride* when compared with untreated control.

2.2.2 Application of organic amendments (cake application)

Goswami and Swarup (1971) have recorded appreciable reduction of *Meloidogyne* spp. population after application of cakes besides general improvements in growth characters. In case of oil cakes treatments, all the cakes caused a reduction in galling. The cake was found most effective in reducing the galls of the root–knot nematodes. The efficacy of oil cakes as a manure may be attributed to the fact that decomposition of organic matter in soil encouraged the predatory nematodes and fungi.

Darekar, *et al*. (1990) reported that Neem (*Azadirachta indica*), karanj (*Pongamia glabra* (*P. pinnata*) and castor (*Ricinus communis*) oilseed cakes were tested in a field experiment in furrows and spots for control of *Meloidogyne incognita* on tomato. All treatments at 400 kg/ha reduced *M. incognita* populations and gall index, with neem and karanj cake being most effective. Spot applications were superior to in-furrow applications.

Rao, *et al*. (1997) reported that significant increase in plant growth and reduction in root galling and final population of *M. incognita* were observed in tomato seedlings transplanted in neem cake-amended soil incorporated with *T. harzianum.*

Nagesh, *et al*. (2001) noticed that neem was the better substrate for *P. lilacinum* in terms of amounts and duration of mycelial growth and sporulation. Further, the application of inorganic fertilizer along with oil cakes was beneficial to the endozoic antagonistic fungus (*P. lilacinum*), plant host (tomato) and also enhanced the antagonistic potential of *P. lilacinum* against root-knot nematode under nursery conditions.

Khan and Rathi (2001) reported that neem cake is the best non-chemical alternative for the management of root knot nematode in tomato.

Ploeg (2002) reported that it is necessary to develop eco-friendly methods to not only control the nematode populations, but also to ensure productivity, quality of plants and to reduce environmental pollution. Bio-active substances from neem cake extracted solutions were evaluated for their potential to control the root-knot nematodes. In these study different concentrations of the solution extracted from neem cake.

Javed, *et al.* (2007) reported that two types of neem formulations, crude and refined, were tested. The crude form was neem leaves and neem cakes (a by-product left after the extraction of oil from neem seed) and one of the neem-refined products was “aza”. The protective and curative soil application of these formulations significantly reduced the number of egg masses and eggs per egg mass on tomato roots. Protective application of neem crude formulations (leaves and cake) did not reduce the invasion of juveniles whereas aza at 0.1% w/w did. Curative application of neem formulations significantly reduced the number of egg masses and eggs per egg mass as compared with the control.

Sharma and Pandey (2009) estimated the efficiency of the potential biocontrol agents in the management of root-knot nematode and assessed from the reduction in root galling expressed in terms of Root Knot Index (RKI) at Central Institute of Medicinal and Aromatic Plants (CIMAP-CSIR) Lucknow, India.

Muthulakshmi, *et al*. (2010) conducted experiment and the evaluation of efficacy of biocontrol agents viz., *Pseudomonas fluorescens* and *Trichoderma viride*, against root-knot nematode, *Meloidogyne incognita* in mulberry (V1 variety) revealed that soil application of both *P. fluorescens* and *T. viride* alone or in combination was able to control the nematode population and improve the mulberry leaf yield and nutritional standards. Combined soil application of *P. fluorescens* (@ 10 g/plant) + *T. viride* (@ 10 g/plant) as soil application was effective to check the root-knot nematode disease and to improve growth of mulberry with increased leaf yield and reduced nematode population.

Chormule, *et al*. (2017) conducted the experiment and results of field trial revealed that efficacy of bioagents viz., *Pseudomonas fluorescens*, *Purpureocillium lilacinum*, *Phule Trichoderma plus*, *Trichoderma viride* and *Pochonia chlamydosporia* @ 20 kg/ha and organic amendment, neem cake @ 2 t/ha were effective in reducing the root-knot nematode population, number of root galls and egg masses and increasing the yield at termination.

Baheti, *et al*. (2019) showed in this investigation that neem, karanj and mustard oil-cakes have been tested for the management of root-knot nematode, *M. incognita* infecting okra on farmer's field naturally infested with test nematode. The observations on number of galls/plant, egg masses/plant, eggs and larvae/egg mass, final nematode population/100 cc soil and yield were recorded. Results showed that neem cake @ 6 q/ha was proved to be most effective for the management of *M. incognita* on okra while karanj cake @ 6 q/ha was found best to enhanced crop yield (49.18-53.51 per cent) followed by neem cake @ 6 q/ha (40.98-45.61 per cent) and karanj cake @ 4 q/ha (39.34-43.86 per cent) over untreated control.

2.2.3 Intercropping

Gommers, *et al*. (1980) studied that inter-cropping of marigold with adversely affected root-knot nematodes and observed reduced galling in brinjal when it was planted in association with marigold. Crop rotation with non-host crops is often adequate by itself to restrict the build-up of nematode populations. Under AICRP-Nematodes, demonstration trials have been conducted at farmer's field to demonstrate that inclusion of non-host crops such as onion/cluster bean/mustard or resistant varieties (Hisar Lalit of tomato/cowpea GC-1) in reducing root-knot nematode populations significantly and enhancing the yield of susceptible crops grown in plots.

Choudhary (1981) reported that Marigold (*Tagetes* spp.) is a nematode antagonistic crop and its root exudates in the form of α-terthienyl have been found to have nematicidal value. Ploeg (1999) observed certain marigolds (*Tagetes* spp.) suppress nematodes when included in crop rotation. Marigold cultivars of *Tagetes patula*, *T. erecta*, *T. signata* and *Tagetes* hybrid are effective against root knot nematode. Effect of selected marigold varieties on root-knot nematode also enhancing yields of tomato and melon. Disease as tested against the second stage juveniles of the plant parasitic nematode *Meloidogyne* spp.

Mali, *et al*. (2019) concluded that french marigold *Tagetes patula* caused significant reduction in the number of root galls (8 / plant), root knot nematode population (29.80 / 8 galls) and soil nematode population (150.25 / 50 ml) with a remarkable growth of tomato plant at College of Agriculture, Nagpur. Considering the eco-friendliness, it can be stated that the planting of antagonistic plant like French marigold *Tagetes patula* instead of chemical nematicides effectively reduces the root galls and nematode multiplication with healthy plant growth. Hence, these marigold cultivars can be included in nematode management without any adverse effect on agroecosystem.

3. MATERIALS AND METHODS

The pure culture of root-knot nematode was maintained in earthen pots in glasshouse as well as in the field of AICRP on Nematodes, Department of Agril. Entomology, M.P.K.V., Rahuri. The Bawchi Plant was grown in such earthen pots and field to maintain and multiply the nematodes. This maintained culture was used for comparing the field populations of root- knot nematodes. The experiment on management of root-knot nematode was conducted in field during *Kharif* 2021, at research plot of AICRP on MAP & Betel vine, MPKV, Rahuri. This chapter presents the materials and methods employed in these experiments.

3.1 Materials

3.1.1 Earthen pots

Earthen pots having 20 cm diameter were used for maintaining the pure culture of root-knot nematode, *M. incognita*. The earthen pots were washed with water and disinfect with 4 per cent formaldehyde. The formaldehyde was allowed to get evaporated before using such pots for maintaining the pure culture. Before using these pots for cultivating differential host’s plants, formaldehyde was allowed to evaporate.

3.1.2. Soil and soil sterilization

Medium black soil was collected from the nearby field of the AICRP on Nematodes, Department of Agricultural Entomology, M.P.K.V., Rahuri and mixed with FYM in 3:1 proportion and the mixture after sieving were steam sterilize at the pressure of 6.75 kg/cm^2 for four hours in a soil sterilizer with boiler. Such a sterilized soil used for maintaining the pure culture of root- knot nematode in earthen pots in glasshouse.

3.1.3 Extraction of nematode

Whenever, soil population of nematodes were needed, the soil from the root zone of plant was grown continuously in earthen pots as well as in the field for pure culture was taken and processed by Cobb's Decanting and Sieving Method (Cobb, 1918).

3.1.4. Extraction of egg masses

The root samples collected from the feeder root zone of bawchi plant and under running tap water lightly cleansed and egg masses were removed from them. Second stage juveniles were obtained from eggs by incubating them in distilled water at 25^{0}C for 48 hours and collecting them using a modified Bareman's funnel technique. The number of J_2 in suspension was standardised by counting them in 1 ml of suspension. The average number was used to represent J_2/ml in suspension.

3.1.5. Nematode inoculation

For inoculation, the collection of nematodes was done as per sections 3.1.3 and 3.1.4 was used. Prior to the inoculation, number of nematodes per millilitre of suspension was determined and the desired number of nematodes was introduced in pots by making small holes in the soil.

3.1.6. Seeds and seedlings

The Bawchi plant selected as planting material and collected from AICRP on MAP & Betel vine MPKV, Rahuri. The seedlings of Bawchi were collected during Kharif, 2021, at research plot of AICRP on MAP & Betelvine MPKV, Rahuri for estimating avoidable yield losses due to root-knot nematode.

3.1.7 Bionematicide/ Nematicide

The following bionematicides, nematicide and fungicide in the study on assessment of yield losses and management of root-knot nematode infesting Bawchi under field conditions.

Table No. 3.1. List of Bionematicide

Sr. No.	Bionematicides	Available Conc.	Trade names	Biological strain/ Chemical name
1.	*Pseudomonas fluorescens*	1 x 10^9 cfu / ml	Phule Sufluero 1.15% WP	*Pseudomonas fluorescens*
2.	*Trichoderma viride*	2 x 10^6 cfu / ml	*Trichoderma* 1.0 % WP	*Trichoderma viride*
3.	*Paecilomyces lilacinus*	2×10^8 cfu /g	1.0 WP	*Purpureocillium lilacinum*

Note: Bionematicide applied by mixing with FYM@ 100 kg FYM/ha.

3.1.8 Others

Farm Yard Manure, neem cake and fertilizers were provided by the AICRP on MAP & Betel vine, Department of Plant Pathology, M.P.K.V., Rahuri. Solution and chemicals for analysis were provided by Department of Agricultural Entomology, Post Graduate Institute, M.P.K.V., Rahuri. Bioagents (*Pseudomonas fluorescens, Trichoderma viride, Purpureocillium lilacinum*), nematicide, FYM, neem cake and fertilizers were obtained from Department of Agricultural Entomology, Post Graduate Institute, M.P.K.V., Rahuri. Glasshouse, microscopes, electronic weighing balance, laboratory test sieves (20, 60, 200 and 350 mesh), glassware (Petri dishes, pipettes, test tubes and beakers) and labours were required and provided by the Department of Agricultural Entomology, Post Graduate Institute, M.P.K.V., Rahuri.

3.2 Assessment of Avoidable Yield Losses Caused due to *M. incognita* Infesting Bawchi, *Psoralea corylifolia* L.

A field experiment was carried out in a root-knot nematode, *M. incognita* infested sick plot of Bawchi, *Psoralea corylifolia* L. at AICRP on MAP & Betelvine, M.P.K.V., Rahuri with paired plot design with Ten replications from July 2021 to February 2022.

3.2.1 Details of experiment

Table No. 3.2 Details of experiment for assessment of yield losses

1	Location	AICRP on MAP & Betelvine project, M.P.K.V., Rahuri
2	Crop	Bawchi (*Psoralea corylifolia* L.)
3	Plot size	3 × 4 m^2
4	Spacing	45×30 cm
5	Replications	10
6	Treatments	02
	T_1	Treated with Neem cake 2 ton/ha and *Trichoderma* plus 20 kg/ha
	T_2	Untreated control
7	Design	Paired Plot Design
8	Date of Transplanting	28/07/2021
9	Date of application of treatment	28/07/2021
10	Date of Termination	06/02/2022

3.2.2 Method of recording observations

In order to count the nematode population at initial and terminal stage of the experiment, the soil have been sampled with a soil auger at a depth of 30 to 60 cm of the field. 200 g of soil and root composite samples were taken after 60 days of transplanting from each treatment for recording intermediate and termination observation at time of harvesting. For counting nematodes from the samples, Cobb's decanting and sieving technique was used in the laboratory. In a plastic beaker, the residues from the 200 mesh and 350 mesh sieves were obtained and by adding tap water, the volume of beaker was increased to 200 ml. 10 counts of 1 ml solution were recorded for the nematode count, which was multiplied by 200 ml of solution. On the basis of these findings the per cent decrease in nematode population was calculated. At each observation, 5 g of root samples were collected and the root galling and egg masses were recorded. Based on these observations, a per cent decrease in root galls and egg masses was calculated. The yield from the each plot of every treatment in the field was calculated and indicated in quintals per hectare from harvesting to termination. The increase in the yield over control was calculated based on these observations.

3.2.3 Analysis of the experimental data

The collected data was statistically analysed using the 't' test to determine the significance of the difference between two treatments.

3.3 Management of Root Knot Nematode, *M. incognita* infesting Bawchi, *Psoralea corylifolia* L.

An experiment was conducted during July, 2021 to February, 2022 in naturally *M. incognita* infested sick field of AICRP on MAP & Betelvine project, M.P.K.V., Rahuri. The bionematicides, bioagents and antagonist crops were utilised to control nematode. The field was regularly irrigated and fertilizers given as per recommended dose. The details of the experiment are provided below.

3.3.1 Details of experiment

Table No. 3.3. Details of experiment for Management of Root Knot Nematode

1.	Location	AICRP on MAP & Betelvine project, M.P.K.V., Rahuri
2.	Crop	Bawchi (*Psoralea corylifolia* L.)
3.	Plot size	3×4 m^2
4.	Spacing	45×30 cm
5.	Replications	03
6.	Treatments	09
7.	Design	RBD (Randomized Block Design)
8.	Date of Transplanting	28/07/2021
9.	Date of application of Treatment	28/07/2021
10.	Date of Termination	06/02/2022
11.	Fertilizer dose	60: 60: 30 NPK/ha

3.3.2 Treatment details:

Table No. 3.4. Treatment details

Treatments	Name of Biopesticides
T_1	Neem cake @ 2 ton / ha.
T_2	Ground nut cake @ 2 ton / ha.
T_3	Karanj cake @ 2 ton / ha.
T_4	*Trichoderma plus* @ 20 kg/ha.
T_5	*Purpureocillium lilacinum* @ 20 kg/ha.
T_6	*Trichoderma viride* @ 20 kg/ha.
T_7	*Pseudomonas fluorescens* @ 20 kg/ha.
T_8	Intercropping of *Tagetes* spp. @ 3:1 proportion
T_9	Untreated control

3.3.3 Method of recording observations

The soil sampled at initial, intermediate and termination stage also roots from each plot were sampled at the intermediate and termination stage of the experiment for calculating *M. incognita* population, root gall and egg mass. 200 g of soil and root composite samples were taken from each plot after treatment application while recording observation. Cobb's sieving and decanting method was used to process sampled soil in the laboratory, followed by a modified Baermann's funnel method. In a plastic beaker, the residues from the 200 mesh and 350 mesh sieves were obtained and by adding tap water, the volume of the plastic beaker was increased to 200 ml. For the nematode count, 10 counts of 1 ml solution were recorded which was multiplied by 200 ml of solution. A per cent decrease in nematode population was calculated based on this observation.

After observing infection of root-knot nematode, randomly five plants from each field plot were selected and uprooted at the time of termination of the experiment and washed under clean tap water to remove the adhering soil particles of the roots. The plants then cut at the base and observations like number of root galls and egg masses on roots was counted. The number of egg masses recorded by observing each plant and counted visually for the numbers of galls. To remove soil particles that had attached to the roots, the 5 g roots obtained at each observation was rinsed under clean tap water. The root knots and egg mass on the roots was counted. Based on these observations, the per cent decrease in root knots and egg mass compared to control was computed. Galled roots were dyed for simple counting of egg mass by immersing them for 5 minutes in a 1.0 % solution of trypan blue. The roots were thoroughly cleansed with water after dipping to remove any excess stain. The bawchi seed yield obtained from each treatment's individual plant from field at each picking, expressed in quintals per hectare were recorded. The yield increase over an untreated control was calculated based on these observations. Number of root galls and egg masses on roots per plant will be recorded with gall indices 1 to 5 scale by considering the number of root galls and egg masses per plant. On the basis of gall index infestation categorized in different reaction as below.

3.3.4 Analysis of the experimental data

The data collected were statistically analysed and an analysis of variance was performed to calculate the significance of differences among treatments. The data obtained are subjected to statistical analysis and the percentages of decreased nematode population, number of root galls or egg masses then transformed into angular transformations to reduce the variation in the percentage in different treatments for final analysis.

To reduce variation in the percentages in various treatments for final analysis, the percentages of decreased nematode population, root knots and egg mass were transformed into angular transformations (Fisher and Yates, 1963). The significance level of treatments was determined at a 5 % level.

Table No. 3.5 Gall Index

Gall index	No. of root galls/ egg masses /plant	Reaction
1	0	Highly resistant (HR)
2	1 to 10	Resistant (R)
3	11 to 30	Moderately resistant (MR)
4	31 to 100	Susceptible (S)
5	>101	Highly susceptible (HS)

(Sasser & Taylor, 1978)

4. RESULTS AND DISCUSSION

This chapter consist of the findings of studies on the *Meloidogyne incognita* infesting bawchi in terms of assessment of avoidable yield loss and integrated nematode management.

4.1 Assessment of Avoidable Yield Losses Caused due to *M. incognita* Infesting *Psoralea corylifolia* L.

The data on monetary losses caused by nematodes is decisive for implementing control strategies. With a paired plot design and treatment of neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha, this field experiment was ventured for assessing the avoidable yield losses owing to *M. incognita* in *Psoralea corylifolia* L.

The observations on soil nematode population at initial and termination stage per plot and number of root galls, egg masses per 5 g roots and yield per plot at termination stage of the experiment were recorded and presented in Table 4.1 to 4.5.

4.1.1 Root-knot nematode population

Table 4.1 present that there were highly significant differences in recording population of nematode from plot that have been treated with neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha and plot that have not been treated at initial and termination stage. The initial population of *M. incognita* (520-620 J_2/200 cm^3 of soil) in plot were found to be non-significant.

At the termination stage the reduction in population of *M. incognita* varied from 31.03 to 50.00 per cent in plot treated with neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha. This treatment resulted in an average population reduction of 40.98 per cent of *M. incognita* nematode.

4.1.2 Number of root galls and egg masses

Table 4.2 present that there were highly significant differences in root galls of *M. incognita* in plot that have been treated and plot that have not been treated at termination stage. At termination stage, the reduction in the root galls number varied from 21.21 to 43.90 per cent in the plot that have been treated with neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha over untreated plot. This treatment however, resulted in an average reduction of 34.02 per cent in the root galls of *M. incognita*.

Table 4.3 shows that there were highly significant differences in egg masses of *M. incognita* in treated and untreated plot at termination stage. At termination stage, the reduction in the number of egg masses varied from 30.30 to 54.84 per cent in the plot that have been treated with neem cake @ 2 ton/ha and *Trichoderma* plus @ 20 kg/ha. This treatment resulted in an average reduction of 41.25 per cent in egg masses of *M. incognita*.

4.1.3 Yield losses caused due to *M. incognita*

Table 4.4 shows that the average yield in treated and untreated Bawchi plots were 13.84 and 6.72 q/ha, respectively. Bawchi seed yield loss ranged from 46.16 to 59.38 per cent in untreated plot. However, when neem cake @ 2 ton/ha and *Trichoderma* plus @ 20 kg/ha was applied to the plot, an average loss of 6.72 per cent in Bawchi seed production was reported in untreated plot.

The literature on yield loss assessment due to *M. incognita* in Bawchi is very scanty. Hence, the current findings are also compared with the other crops. The result obtained by study are in agreement with Pant and Pandey (2002), who study *M. incognita* on Chickpea. The observation on organic amendment and *Trichoderma* spp. showed an increase in the growth of chickpea. The better growth observed in neem cake and *Trichoderma* spp. due to additional supply of nutrients available from organic substance. Reduction in root-knot nematode was maximum with neem cake and *Trichoderma* spp. thus the results were observed to be in line with the findings.

The present results are in agreement with result of Sumita and Das (2014), who found in study on efficacy of different bio-agents (T*richoderma viride, T. harzianum* and neem cake) against root-knot nematode, *Meloidogyne incognita* in green gram (*Vigna radiata*) revealed that soil application of neem cake @ 2 ton/ha significantly increased the shoot length, fresh and dry weight of shoot of green gram, followed by soil application of *T. viride* @ 2.5 kg/ha as compared to untreated control. The present study revealed that all bio-agents significantly reduced the number of galls per root system, number of egg masses per root system and final nematode population as compared to untreated control.

Nematodes are established constraints in the cultivation of many medicinal, aromatic and spice plant species (Haseeb, 1994). However, there is very limited information available regarding the nature and extent of nematode disease problems in *P. Corylifolia* L. Research conducted at National Bureau of Plant Genetic Resources studied infestation of root-knot nematode on Bawchi (Zakaullah *et al*. 2014).

Table 4.1. Effect of the treatment of Neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha on population of *M. incognita* in assessment of avoidable yield losses in *Psoralea corylifolia* L.

Replication	**Root knot nematode population (J_2) / 200 cm^3 of soil**				
	Treated (Neem cake @2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)	**Untreated control**	**Treated (Neem cake @ 2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)**	**Untreated control**	**Per cent decline in nematode population in treated plot (%)**
	Initial		**Termination**		**Termination**
1	580.00	680.00	420.00	740.00	43.24
2	600.00	580.00	420.00	680.00	38.24
3	560.00	480.00	400.00	580.00	31.03
4	520.00	580.00	360.00	640.00	43.75
5	540.00	620.00	380.00	680.00	44.12
6	520.00	580.00	320.00	640.00	50.00
7	580.00	600.00	360.00	640.00	43.75
8	540.00	620.00	380.00	640.00	40.63
9	620.00	540.00	420.00	640.00	34.38
10	600.00	550.00	380.00	640.00	40.63
Mean	566.00	583.00	384.00	652.00	40.98
‘t’ cal.	**0.84**		**16.14**		

‘t’ Table (0.05) = = 2.262 and (0.01) = 3.250

a = ‘t' tests for paired comparison revealed very significant differences from the untreated control

Table 4.2. Effect of the treatment of Neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha on root galls of *M. incognita* in assessment of avoidable yield losses in *Psoralea corylifolia* L.

Replication	**Number of root galls / 5 g roots**		
	Treated (Neem cake 2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)	**Untreated control**	**Per cent decline in nematode population in treated plot (%)**
	Termination		**Termination**
1	28	36	22.22
2	25	35	28.57
3	22	37	40.54
4	25	35	28.57
5	26	33	21.21
6	24	36	33.33
7	23	41	43.90
8	25	40	37.50
9	25	42	40.48
10	23	41	43.90
Mean	24.60	37.60	34.02
‘t’ cal.	**11.51**		

‘t’ Table (0.05) = 2.262 and (0.01) = 3.250
a = ‘t' tests for paired comparison revealed very significant differences from the untreated control.

Table 4.3. Effect of the treatment of Neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha on Egg masses of *M. incognita* in assessment of avoidable yield losses in *Psoralea corylifolia* L.

Replication	**Number of egg masses / 5 g roots**		
	Treated (Neem cake @ 2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)	**Untreated control**	**Per cent decline in number of egg masses in treated plot (%)**
	Termination		**Termination**
1	19	28	32.14
2	19	33	42.42
3	20	32	37.50
4	23	33	30.30
5	20	35	42.86
6	15	30	50.00
7	17	31	45.16
8	14	31	54.84
9	19	28	32.14
10	17	31	45.16
Mean	18.30	31.20	41.25
‘t’ cal.	**11.9**		

‘t’ Table (0.05) = 2.262 and (0.01) = 3.250

a = ‘t' tests for paired comparison revealed very significant differences from the untreated control

Table 4.4. Assessing yield losses due to *M. incognita* in Bawchi, *Psoralea corylifolia* L.

Replication	Yield (q/ha)		Loss in yield (%)
	Treated plot (Neem cake @ 2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)	**Untreated control**	
1	12.63	6.80	46.16
2	14.00	6.50	53.57
3	13.20	7.00	46.97
4	14.00	6.35	54.64
5	12.73	7.02	44.85
6	14.00	7.02	49.86
7	12.68	6.48	48.90
8	14.00	7.25	48.21
9	15.20	6.32	58.42
10	16.00	6.50	59.38
Mean	**13.84**	**6.72**	**51.10**
't' cal.	**19.45**		

't' Table (0.05) = 2.262 and (0.01) = 3.250

a = 't' tests for paired comparison revealed very significant differences from the untreated control

Table 4.5. Assessment of avoidable yield losses caused due to *M. incognita* infesting *Psoralea corylifolia* L. under field circumstances

Sr. No	Treatment	Root-knot nematode population (J_2) /200 cm^3 of soil*		Number of root galls / 5 g roots*	Number of egg masses / 5 g roots*	Yield (q/ha)**
		Initial	Termination	Termination	Termination	
1.	**Treated (Neem cake @ 2 ton/ha+ *Trichoderma* plus @ 20 kg/ha)**	566	384a	24.60a (19.33)	18.30a (41.25)	13.84a (51.10)
2.	**Untreated control**	583	646 (-)	37.60 (-)	31.20 (-)	6.72
	't' value	0.84	18.80	11.51	11.90	19.45

't' Table (0.05) = 2.262 and (0.01) = 3.250
a = 't' tests for paired comparison revealed very significant differences from the untreated control.
* Figures presented in parentheses are per cent (%) reduction over an untreated control
** Figures presented in parentheses are per cent (%) loss in yield over an untreated control

4.2 Management of Root-knot Nematode, *M. incognita* Infesting Bawchi, *Psoralea corylifolia* L.

An experiment was carried out for assessing the effect of different treatments *viz*., nematicides, bioagents and antagonist crop for the management of *M. incognita* infesting Bawchi plot cultivated at AICRP on MAP & Betelvine project, MPKV, Rahuri.

The initial, intermediate and termination observations on population of *M. incognita* per 200 cm^3 soil, root galls and egg masses/5 g roots were obtained from the field. Root galls and egg masses were calculated based on the per cent reduction in *M. incognita* population. At the conclusion of the experiment, yield data per ha were also recorded. Tables 4.6 to 4.10 show observed information.

It could be observed from Table 4.6 to 4.8 that the treatment of Neem cake @ 2 ton/ ha was found significantly superior in reducing *M. incognita* population, root galls and egg masses up to intermediate and termination which is at par with *Trichoderma* plus @ 20 kg per ha. However, bioagents *viz*., *Trichoderma viride* ($2×10^6$ cfu/g) @ 20 kg/ha, *Purpureocillium lilacinum* @ 20 kg/ha, *Pseudomonas fluorescens* @ 20 kg/ha, was observed effective after *Trichoderma* plus @ 20 kg/ ha application which reduced the *M. incognita* population, root galls and egg masses and increasing the yield.

4.2.1 Effect of various treatments on population of *M. incognita* infesting bawchi, *Psoralea corylifolia* L.

The pre-treatment population of *M. incognita* in field before transplanting was in the range of 540.67 to 601.33 J_2/200 cm^3 of soil. It could be observed from the Table 4.6 that the all treatments were comparatively superior over control in reducing *M. incognita* population at intermediate and termination stage. The treatment of Neem cake application was observed significantly superior treatment in reducing *M. incognita* population (57.14 %) and found at par with *Trichoderma* plus ($2×10^6$ cfu/g) @ 20 kg/ ha in reducing the *M. incognita* population (54.55 %) at intermediate stage.

The next promising treatment was of *Trichoderma viride* ($2×10^6$ cfu/g) @ 20 kg/ha, *Purpureocillium lilacinum* (($2×10^8$ cfu/g) @ 20 kg/ha and *Pseudomonas fluorescens* (1×10^9 cfu/ml) @ 20 kg/ha in reducing 47.00, 31.57 and 43.42 per cent root-knot nematode population at intermediate stage, respectively.

At termination stage, treatment of Neem cake @ 2 ton/ha was significantly superior which were found at par with the treatment *Trichoderma* plus ($2×10^6$ cfu/g) @ 20 kg/ha which reducing *M. incognita* population 55.36 and 49.76 per cent, respectively. However, next best treatment was *Trichoderma viride* ($2×10^6$ cfu/g) @ 20 kg/ha (41.18 per cent) found at par with the treatment *Purpureocillium lilacinum* (1 x 10^9 cfu/ml) @ 20 kg/ha and *Pseudomonas fluorescens* (1 x 10^9 cfu/ml) @ 20 kg per ha in reducing *M. incognita* population ranging from 38.59 and 35.88 per cent, respectively. However, efficacy of Karanj cake application @ 2 ton/ha with 34.15 per cent reduction in nematode population was recorded. However, next effective treatment was intercropping of Bawchi with *Tagetes* spp. @ 3:1 proportion which was at par with Groundnut cake application @ 2 ton/ha observed 24.17 and 16.20 per cent reduction in *M. incognita* population.

The present experiment results are in agreement with Kerakalamatti *et al*. (2020) research findings. Among the oil cakes, neem cake was found significantly superior over all other nematicides as it recorded least number of juveniles emerged in fields of pomegranate were infested by root knot nematode caused by *Meloidogyne incognita*.

4.2.2 Effect of various treatments on root galls of *M. Incognita* infesting bawchi, *Psoralea corylifolia* L.

The root galls before application of treatment in trial field was in the range of 31.33 to 34.00 /5 g roots which was comparatively superior over control in reducing the root-galls produced by the root-knot nematode at intermediate and termination stage.

At intermediate stage, the treatment of Neem cake @ 2 ton/ha and *Trichoderma* plus (2×10^6 cfu/g) @ 20 kg/ha were found significantly superior and at par with each other in reducing the root-galls/5 g of roots by 39.01 and 35.12 per cent, respectively. The next superior treatments was *Trichoderma viride* (2×10^6 cfu/g) @ 20 kg/ha which is at par with *Purpureocillium lilacinum* (2×10^8 cfu /g) @ 20 kg/ha in reducing root galls 31.57 and 28.41 per cent, respectively.

However, the treatment with Groundnut cake @ 2 ton/ha was observed least effective in reducing root galls amongst all treatments and recorded 15.15 per cent decline in root galls of *M. incognita* at intermediate stage.

At termination stage, treatment of Neem cake @ 2 ton/ha significantly superior over all other treatment tested which was observed at par with *Trichoderma* plus (2×10^6 cfu/g) @ 20 kg/ha by reducing the root knots/5 g roots from 30.00 and 22.34 per cent, respectively. However, treatment with Groundnut cake @ 2 ton/ha was observed to be the least effective in reducing root galls (5.05 %).

4.2.3. Effect of various treatments on egg masses of *M. incognita* infesting bawchi, *Psoralea corylifolia* L.

It could be observed from the Table 4.8 and Fig. 4.4 showed reduction in the egg masses at intermediate and termination stage. Among all treatment, application with Neem cake @ 2 ton/ha which was recorded highest decrease in egg masses (53.33 %) was at par with

Trichoderma plus (2×10^6 cfu/g) @ 20 kg/ha reducing the egg mass by 50.00 per cent at intermediate stage. However, the next superior treatments was *Trichoderma viride* (2×10^6 cfu/g) @ 20 kg/ha which is at par with *Purpureocillium lilacinum* (2×10^8 cfu/g) @ 20 kg/ha and *Pseudomonas fluorescens* (1×10^9 cfu/ml) @ 20 kg/ha recorded decline in egg masses of 43.42, 42.86, 42.31 per cent, respectively. The groundnut cake application @ 2 ton/ha was found to be least efficient in reducing egg masses/5 g of root sample.

The efficacy of Neem cake @ 2 ton/ha at the termination stage has been decreased but still was superior among all other treatments and egg mass /5g of root sample recorded 44.00 per cent reduction and found at par with treatment of *Trichoderma* plus (2×10^6 cfu/g) @ 20 kg/ha by 41.89 per cent egg mass reduction. Next in order was *Trichoderma viride* (2×10^6 cfu/g) @ 20 kg/ha which is at par with *Purpureocillium lilacinum* (2×10^8 cfu/g) @ 20 kg/ha and *Pseudomonas fluorescens* (1×10^9 cfu/ml) @ 20 kg/ha in reducing egg masses were 36.84, 36.37, 35.90 per cent, respectively.

4.2.4 Effect of various treatments on gall index of *M. incognita* infesting bawchi, *Psoralea corylifolia* L.

It could be observed from the data form Table 4.9 that Neem cake application @ 2 ton /ha was found to be most effective in reducing gall index per plant to 20.00 per cent which was equally effective with *Trichoderma* plus (2×10^6 cfu/g) @ 20 kg/ha. The next effective treatment *Pseudmonas fluorescens* (1×10^9 cfu/ml) @ 20 kg/ha was equally effective with *Trichoderma viride* (2×10^6 cfu/g) @ 20 kg/ha and *Purpureocillium lilacinum* (2×10^8 cfu/g) @ 20 kg/ha recording 13.33 per cent reduction in gall index per plant.

Rehman *et al*. (2014) findings are in consonance with present findings. Among various treatments the Neem cake @ 100 g/pot was found most effective in limiting root gall index and enhancing plant growth parameters in blackgram. Root knot nematode, *Meloidogyne incognita* reduces all plant growth characters of untreated inoculated control plants as compared to all other treated or uninoculated control plants.

4.2.5 Effect of various treatments on yield of bawchi seeds

It is revealed from data shown in Table 4.10 and Fig. 4.3 that all the treatments added significant effect on increase in yield of Bawchi plant. Among all treatments, Neem cake application @ 2 ton/ha was found to be significantly superior in recording highest yield of 18.19 q/ha with 61.41 per cent yield over untreated control which was at par with treatment of *Trichoderma* plus @ 20 kg/ha recorded 13.83 q/ha with 49.24 per cent increase in yield over untreated control.

Rao (2008) are in present experiment on effectiveness of neem cake treatment was at par with the bio-agents in decreasing the root and soil population densities of the nematode until 6 months after the third application, but it did not decrease significantly the nematode populations thereafter when compared with the bio-agents for the management of the root-knot nematode *Meloidogyne* spp. on acid lime are in agreement with present findings.

However, Next superior treatment were *Trichoderma viride* (2×10^6 cfu/g) @ 20 kg/ha followed by *Purpureocillium lilacinum* @ 20 kg/ha and *Pseudomonas fluorescens* @ 20 kg/ha which recorded 11.95, 11.60, 11.53 q/ha yield, respectively with 41.26, 39.48, 39.12 percent yield over untreated control. However, the lowest yield obtained from intercropping with *Tagetes* spp. which was 7.53 q/ha over untreated plot which recorded 7.02 q/ha.

Table 4.10 shows the increased yield above the untreated control as well as the net profits (Rs./ha) of the various treatments. Table 4.10 states that the treatment of Neem cake @ 2 ton/ha recorded highest additional returns of Rs.1,11,700 per hectare with an ICBR of 1:4.20. The next treatment from which economical returns were obtained are of *Trichoderma* plus @ 20 kg/ha which gave net profit of Rs.62,150 with an ICBR of 1:10.45.

These results are in consonance with Jagdev and Mhase (2019) who reported that at termination stage, the treatment of Phule *Trichoderma* plus at 20 kg/ha was found to be effective in reducing the root-knot nematode population (40.36 %), number of root galls (37.08 %) and egg masses (41.02 %) and increasing the fruit yield of fig (13.54 %) with 1:11.20 ICBR. This was followed by the treatments with rest of the bioagents. The reduction in root-knot nematode population, number of root galls and egg masses and increase in fruit yield at termination recorded in *Trichoderma viride* treatments ranged from 32.03, 29.71, 32.26 per cent and 10.05 q/ha respectively with 1:7.66 ICBR.

The result obtained by study are in agreement with Saravaran *et al*. (2020), who found while studying in banana that individual application of neem cake and *P fluorescens* is effective in the control of root knot nematode population *M. incognita* both soil and roots, also recorded highest plant growth parameters thus the results were observed to be in line with the findings.

Table.4.6 Effect of various treatments on population of *M. incognita* infesting *Psoralea corylifolia* L.

Sr. No.	Treatments	Root-knot nematode population / 200 cm^3 of soil			Decline in nematode population at termination (%) *	
		Initial	Intermediate	Termination	Intermediate	Termination
1	Neem cake @ 2 ton / ha.	560.00	240.00	250.00	57.14 (49.11)	55.36 (48.08)
2	Groundnut cake @ 2 ton/ ha	543.33	430.00	455.33	20.86 (27.18)	16.20 (23.73)
3	Karanj cake @ 2 ton / ha.	570.00	350.00	375.33	38.60 (38.41)	34.15 (35.76)
4	*Trichoderma* plus @ 20 kg/ha.	550.00	250.00	276.33	54.55 (47.61)	49.76 (44.86)
5	*Purpureocillium lilacinum* @ 20 kg/ha.	553.67	323.33	340.00	41.60 (40.17)	38.59 (38.41)
6	*Trichoderma viride* @ 20 kg/ha.	566.67	300.33	333.33	47.00 (43.28)	41.18 (39.92)
7	*Pseudomonas fluorescens* @ 20 kg/ha.	540.67	330.33	346.67	38.90 (38.59)	35.88 (36.80)
8	Intercropping of *Tagetes* spp.@ 3:1 proportion	562.67	400.00	426.67	28.91 (32.53)	24.17 (29.45)
9	Untreated control	601.33	610.00	650.00	0.00 (0.00)	0.00 (0.00)
	SE	13.56	12.50	11.74	1.33	1.93
	C. D. at 5 %	NS	37.47	35.18	3.98	5.80

*Figures presented in parentheses are arc sin transformed values.

Table.4.7 Effect of various treatments on root galls of *M. incognita* infesting *Psoralea corylifolia* L.

Sr. No.	Treatments	Root galls/ 5 g of roots			Per cent decline in root galls (%) *	
		Initial	Intermediate	Termination	Intermediate	Termination
1	Neem cake @ 2 ton/ ha.	33.33	20.33	23.33	39.01 (38.65)	30.00 (33.21)
2	Groundnut cake @ 2 ton/ ha	33.00	28.00	31.33	15.15 (22.91)	5.05 (12.99)
3	Karanj cake @ 2 ton/ ha.	31.67	24.67	29.33	22.09 (28.04)	7.37 (15.75)
4	*Trichoderma* plus @ 20 kg/ha.	31.33	20.33	24.33	35.12 (36.34)	22.34 (28.21)
5	*Purpureocillium lilacinum* @ 20 kg/ha	31.67	22.67	26.67	28.41 (32.21)	15.79 (23.41)
6	*Trichoderma viride* @ 20 kg/ha.	31.67	21.67	26.33	31.57 (34.18)	16.84 (24.23)
7	*Pseudomonas fluorescens* @ 20 kg/ha.	32.00	24.33	27.00	23.97 (29.31)	15.63 (23.28)
8	Intercropping of *Tagetes* spp. @ 3:1 proportion	32.67	26.67	31.00	18.36 (25.37)	5.10 (13.05)
9	Untreated control	34.00	35.00	36.00	0.00 (0.00)	0.00 (0.00)
	S. E. (±)	0.84	0.37	0.43	1.48	2.43
	C. D. at 5 %	NS	1.10	1.28	4.44	7.29

*Figures presented in parentheses are arc sin transformed values.

Table.4.8. Effect of various Treatments on Egg Masses of *M. incognita* Infesting *Psoralea corylifolia* L.

Sr. No.	Treatments	Egg masses/ 5 g roots			Per cent decline in egg masses (%) *	
		Initial	Intermediate	Termination	Intermediate	Termination
1	Neem cake @ 2 ton / ha.	25.00	11.67	14.00	53.33 (46.91)	44.00 (41.55)
2	Ground nut cake @ 2 ton / ha.	25.33	18.33	20.00	27.63 (31.71)	21.05 (27.31)
3	Karanj cake @ 2 ton / ha.	26.00	16.33	18.00	37.18 (37.57)	30.77 (33.69)
4	*Trichoderma* plus @ 20 kg per ha.	24.67	12.33	14.33	50.00 (45.00)	41.89 (40.33)
5	*Purpureocillium lilacinum* @ 20 kg /ha.	25.67	14.67	16.33	42.86 (40.90)	36.37 (37.09)
6	*Trichoderma viride* @ 20 kg/ha.	25.33	14.33	16.00	43.42 (41.22)	36.84 (37.37)
7	*Pseudomonas fluorescens* @ 20 kg/ha.	26.00	15.00	16.67	42.31 (40.58)	35.90 (36.81)
8	Intercropping of *Tagetes* spp. @ 3:1 proportion	25.33	18.00	19.67	28.95 (32.55)	22.37 (28.23)
9	Untreated control	26.00	27.00	29.00	0.00 (0.00)	0.00 (0.00)
	S. E. (±)	0.27	0.34	0.36	1.17	1.34
	C. D. at 5 %	NS	1.03	1.08	3.52	4.02

*Figures presented in parentheses are arc sin transformed values

Table.4.9 Effect of different treatments on gall index of root-knot nematode infesting *Psoralea corylifolia* L.

Sr. No.	Treatment	Average gall index/plant	Decline in gall index at termination (%) *
1.	Neem cake @ 2 ton/ ha.	4.00	20.00 (26.57)
2.	Ground nut cake @ 2 ton/ ha.	4.67	6.67 (14.96)
3.	Karanj cake @ 2 ton/ ha.	4.33	13.33 (21.42)
4.	*Trichoderma* plus @ 20 kg/ha.	4.00	20.00 (26.57)
5.	*Purpureocillium lilacinum* @ 20 kg/ha.	4.33	13.33 (21.42)
6.	*Trichoderma viride* @ 20 kg/ha.	4.33	13.33 (21.42)
7.	*Pseudomonas fluorescens* @ 20 kg/ha.	4.33	13.33 (21.42)
8.	Intercropping of *Tagetes* spp. @ 3:1 proportion	4.67	6.67 (14.96)
9.	Untreated control	5.00	0.00 (0.00)
	S.E. ±	0.11	2.43
	CD at 5 %	0.33	7.29

*Figures presented in parentheses are arc sin transformed values

Table.4.10 Effect of different treatments on ICBR of *Psoralea corylifolia* L.

Sr. No.	Treatments	Yield (q/ha)	Per cent increase in yield over untreated control	Additional yield over untreated control (q/ha)	Gross profit (Rs/ha)	Additional Profit (Rs/ha)	Cost of treatment and Labour (Rs/ha)	Net profit (Rs/ha)	ICBR
1	Neem cake @ 2 ton/ha.	18.19	61.41	11.17	181900	111700	21500	90200	1: 4.20
2	Ground nut cake @ 2 ton/ ha.	7.91	11.25	0.89	79100	8900	65500	56600	1: 0.87
3	Karanj cake @ 2 ton/ ha.	10.63	33.96	3.61	106300	36100	55500	19400	1: 0.35
4	*Trichoderma* plus @ 20 kg/ha.	13.83	49.24	6.81	138300	68100	5950	62150	1: 10.45
5	*Purpureocillium lilacinum* @ 20 kg/ha.	11.60	39.48	4.58	116000	45800	5950	39850	1: 6.70
6	*Trichoderma viride* @ 20 kg/ha.	11.95	41.26	4.93	119500	49300	5950	43350	1: 7.29
7	*Pseudomonas fluorescens* @ 20 kg/ha.	11.53	39.12	4.51	115300	45100	5950	39150	1: 6.58
8	Intercropping of *Tagetes* spp. @ 3:1 proportion	7.53	6.77	0.51	75300	5100	1700	3400	1: 2.0
9	Untreated control	7.02	0	0	0	0	0	0	0

Market rates: 1. neem cake @Rs 10000/Ton 2. *Pseudomonas fluorescens* @ Rs. 200/kg 3. *Trichoderma viride* @ Rs. 200/kg 4. *Purpureocillium lilacinum* @ Rs. 200/kg 5. Groundnut cake @Rs.32/Kg 6. Karanj cake @ Rs. 27/Kg 7. *Trichoderma* plus @ Rs. 200/Kg 8. Labour (5 units/ha)- Rs.300/unit/Day 9. Marigold seeds -Rs.200 10.FYM /Kg- Rs. 450.

5. SUMMARY AND CONCLUSION

Phytonematodes are one of the vital factor which causes losses in crop yields. As medicinal importance of bawchi is all get acquainted by introduction, thus being medicinal herb bawchi seeds are important part of utilization for medicinal purpose. Among medicinal and aromatic plant, several plant parasitic nematodes, root-knot nematode (*Meloidogyne incognita*) is the predominant species threatening the bawchi plant. Therefore, the study was carried out on root-knot nematode infesting Bawchi in respect of studying assessment of avoidable yield losses caused due to *M. incognita* and management of root-knot nematode infesting Bawchi. The findings of these investigations are summarized and concluded in this chapter.

5.1 Summary

5.1.1 To Study Assessment of Avoidable Yield Loss Caused Due to *M. Incognita*

A field trial was carried out for assessing avoidable yield loss caused due to *M. incognita* in Bawchi, *Psoralea corylifolia* L. with a paired plot design by soil application of Neem cake @ 2 ton /ha and *Trichoderma* plus @ 20 kg/ha. The results specified that the average yield of seeds in treated and untreated plot of bawchi were 13.84 and 6.72 q/ha, respectively. The average yield loss in Untreated plot over treated plot with neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha was 51.10 per cent.

Avoidable loss in yield of Bawchi seeds over an untreated plot ranged from 44.85 to 59.38 per cent. However, an average loss of 51.10 per cent in bawchi seed production was reported in untreated plot over treated plot with Neem cake @ 2 ton/ha + *Trichoderma* plus @ 20 kg/ha.

5.1.2 Management of Root Knot Nematode, *M. incognita* Infesting Bawchi

A field trial was conducted for assessing the effect of various treatments *viz*., nematicides, bioagents and antagonist crops for eco-friendly management of *M. incognita* infesting Bawchi, *Psoralea corylifolia* L. infested with *M. incognita*. In randomised block design with nine treatments, including an untreated control, were replicated three times.

Neem cake @ 2 ton/ha, Groundnut cake @ 2 ton/ ha, Karanj cake @ 2 ton/ha and bioagents like *Trichoderma* plus @ 20 kg/ha, *Purpureocillium lilacinum* @ 20 kg/ha, *Trichoderma viride* @ 20 kg/ha, *Pseudomonas fluorescens* @ 20 kg/ha are applied by mixing with FYM @ 100 kg/ha then application done at time of transplanting of Bawchi seedling.

At intermediate stage, all of the treatments outperformed an untreated control significantly in reducing the *M. incognita* population, root knots and egg masses and increased yield of Bawchi seeds. However, Neem cake @ 2 ton/ha was observed significantly superior in reducing *M. incognita* population (57.14 %), root galls (39.01 %) and egg masses (53.33 %) and increasing yield of Bawchi seeds (61.41 %) with an ICBR of 1: 4.20 and net profit of Rs.

90,200/ha. Next superior treatment was of *Trichoderma* plus @ 20 kg per ha. The reduction in *M. incognita* population, root knots and egg masses and yield increase recorded in this treatment were 54.55, 35.12, 50.00 and 49.24 per cent, respectively, with 1: 10.45 ICBR and net profit of Rs. 62,150/ha.

While at termination, treatment of Neem cake @ 2 ton/ha was observed significantly superior in reducing *M. incognita* population (55.36 %), root galls (30.00 %) and egg masses (44.00 %) followed by the treatment *Trichoderma* plus @ 20 kg per ha which was recorded reduction in nematode population, root galls, egg masses in Bawchi were 49.76, 22.34 and 41.89 per cent, respectively.

It could be observed from the result that the treatment Neem cake @ 2 ton/ha were found significantly superior over all other treatment tested, in reducing *M. incognita* population, root knots and egg masses, and recorded highest yield (18.19 q/ha) with ICBR 1: 4.20 and Net profit of Rs. 90,200/ha followed by the treatment *Trichoderma* plus @ 20 kg per ha with yield (13.83 q/ha) and Net profit of Rs. 62,150/ha with ICBR 1: 10.45.

5.2 Conclusions

On the basis of results obtained during the course of current investigation, it could be concluded that the

1. The avoidable yield loss caused due to *Meloidogyne incognita* infesting Bawchi was recorded 51.10 per cent seed yield loss in the untreated plot of Bawchi, *Psoralea corylifolia* L.
2. The field trial was carried out for the management of *Meloidogyne incognita* infesting Bawchi, *Psoralea corylifolia* L. observed that the treatment application of Neem cake @ 2 ton/ha was observed significantly superior in reducing *Meloidogyne incognita* population (55.36 %), root galls (30.00 %) and egg masses (44.00 %) at termination stage and yield (18.19 q/ha) with ICBR 1: 4.20 and net profit of Rs. 90,200 /ha followed by the treatment *Trichoderma* plus @ 20 kg/ha which was recorded reduction in nematode population, root galls and egg masses in Bawchi were 49.76 %, 22.34 % and 41.89 %, respectively and yield (13.83 q/ha) with ICBR 1: 10.45 and net profit of Rs.62,150 /ha.

6. LITERATURE CITED

Baheti, B. L., Bhati, S. S., and Singh, H. 2019. Efficacy of different oil-cakes as soil amendment for the management of root-knot nematode, *Meloidogyne incognita* infecting okra (*Abelmoschus esculentus* L.). *International Journal of Current Microbiology and Applied Sciences*. 8(12): 799-808.

Blok, V.C., and Powers, T.O. 2009. Biochemical and molecular identification. *International Turfgrass Society Research Journal*. 98-112.

Chormule, A. J., Mhase, N. L., and Gurve, S. S. 2017. Management of root-knot nematode, *Meloidogyne incognita* infesting grape under field conditions. *Annals of Plant Protection Sciences*. 25: 81-185.

Choudhary, B. S. 1981. In Proceedings of the third Research Planning Conference on Root- knot nematodes, *Meloidogyne* spp. Region VI: 20-24 Jakarta, Indonesia. *International Meloidogyne Project*. 142–145.

Cobb, N. A. 1918. Estimating the nematode population of soil. United States, Department of Agriculture, Agricultural Technical Circular. 1: 1-47.

Danish, M., Seikh, H., and Robab, M. 2018. Study on Morphological and Biochemical Characteristics of Babchi (*Psoralea corylifolia* L.) infected with the Root-Knot Nematode, *Meloidogyne incognita*. *Journal of Agricultural Science and Technology*. 20: 633-645.

Darekar, K. S., Mhase, N. L., and Shelke, S. S. 1990. Effects of placement of non-edible oilseed cakes on the control of root-knot nematodes on tomato. *International Nematology Network Newsletter*. 7(1): 5-7.

Fisher, R. A., and Yates, F. 1963. Statistical tables (sixth edition) for biological, agricultural and medicinal research, Oliver and Boyd, Edinburgh and London. 76-78.

Gommers, F. J., Bakker, J., and Smith, L. 1980. Effect of singlet oxygen generated by the nematicidal compound α– terthienyl from *Tagetes* on the nematode *Aphelenchus avenae*. *Nematologica*. 6: 369–375.

Goswami, B., and Swarup, G. 1971. Effect of oilcake amended soil on growth of tomato and root knot nematode population. *Indian Phytopathology*. 24: 291-294.

Haseeb, A. 1994. Plant parasitic nematodes of medicinal and aromatic plants. Vistas in seed Biology, Allahabad, India: Printwell Publisher. 98-119.

Hisamuddin, A., Azam. T., and Robab, M. 2010. Effect of Initial Inoculation of *Meloidogyne javanica* on Growth and Yield of *Lagenaria siceraria*. *Journal of American Science*. 6(10): 617-622.

Jagdev, G. H., and Mhase, N. L. 2019. Management of Root knot nematode, *Meloidogyne incognita* infesting fig under field conditions. *Journal of Entomology and Zoology Studies*. 7(6): 193-197.

Jatala, P., and Alam, M. 1990. Biological control of plant parasitic nematodes. *Annual Review of Phytopathology*. 24: 453–489.

Javed, N., Gowen, S. R., Inam-ul-Haq, M., and Anwar, S. A. 2007. Protective and curative effect of neem (*Azadirachta indica*) formulations on the development of root-knot nematode *Meloidogyne javanica* in roots of tomato plants. *Journal of Crop Protection*. 26(4): 530-534.

Karssen, G., and Moens, M. 2006. Root-Knot Nematodes. *Plant Nematology* CABI Publishing, Wallingford, UK. 59– 90.

Kerakalamatti, M., Mesta, R. K.,Kiran Kumar, K.C., and Rudresh, D.L. 2020. Evaluation of Nematicides and oil cakes against Root knot nematode caused by *Meloidogyne incognita* in Pomegranate. *International Journal of Current Microbiology and Applied Sciences*. 9(7): 1763-1775.

Khair H, Nagdi and Ameen H, 2008. Antagonistic effects of rhizobacteria isolates against *Meloidogyne incognita* infecting tomato plants under greenhouse conditions. *International Journal of Pharmtech Research*. 9: (97–107).

Khan, M. L., and Rathi, R. 2001. Effect of organic amendments and carbofuran on *Meloidogyne incognita* population and yield in tomato. *Indian Journal of Nematology*. 31(1): 41-45.

Khan, M., Hasan, Q., and Mahmood., K. 2015. Babchi (*Psoralia corylifolia* L.) and its therapeutic uses in Unani system of medicine. *International Journal of Pharmaceutical and Phytopharmacological Research*. 5(1): 41-45.

Khan, Z., Kumar, A., Mahamood, M., Gawade, B., and Gautam, N. K. 2014. The root-knot nematode, *Meloidogyne incognita*, on *Psoralea corylifolia* L. in India. *Nematropica*. 44: 81-84.

Khushboo, P. S., Jadhav, V., Kandam, M., and Sathe, N. S. 2010. *Psoralea corylifolia* L. “Kushtanashini”. *Pharmacognosy Journal*. 4: 69–76.

Kumar, V., Khan, M.R., and Walia, R. K. 2020. Crop loss estimations due to plant-parasitic nematodes in major crops in India. *National Academy Science Letters*. 43: 409–412.

Mali, R., Lavhe, N. V., Deotale, R. O., and Panchbhai, P. R. 2019. Evaluation of different marigold cultivars against Root knot nematode (*Meloidogyne incognita)* under pot culture condition. *International Journal of Current Microbiology and Applied Sciences*. 8(5): 2130-2135.

Muthulakshmi, M., Devrajan, K., and Jonathan, E. I. 2010. Biocontrol of Root knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 in mulberry (*Morus alba* L.). *Journal of Biopesticides.* 3(2): 479–482.

Nagesh, M., Reddy P. P., and Rama, N. 2001. Influence of oil cakes in combination with inorganic fertilizer on growth and sporulation of *P. lilacinus* and its antagonism on *M. incognita* infesting tomato. *Nematologia Mediterranea*. 29: 23-27.

Niranjana, A., and Dhan, P. 2018. Management of root knot nematode (*Meloidogyne incognita)* in Turmeric. *Journal of Entomology and Zoology Studies.* 6(1): 1112-1116.

Oka, Y., Koltai, H., Meira, B., Mor, M., Sharon, E., Chet, I., and Spiegel, Y. 2000. New Strategies forthe Control of Plant-Parasitic Nematodes. *Pest Management Science*. 56(11): 983–988.

Pandey, R. 2007. Biological control of plant parasitic nematodes. *Annual Review of Phytopathology*. 15(1): 98-108.

Pant, H., and Pandey, G. 2002. Use of *Trichoderma harzianum* and neem cake alone and in combination on *Meloidogyne incognita* galls in chickpea. *Annals of Plant Protection Sciences*. 10(1): 134-178.

Pawar, S. A., Mhase, N.L., Kadam, D.B., and Chandele, A.G. 2013. Management of root-knot nematode, *Meloidogyne incognita*, race- II infesting pomegranate by using bioinoculants. *Indian Journal of Nematology.* 43(1): 92-94.

Ploeg, A. T. 1999. Greenhouse studies on the effect of marigolds (*Tagetes* spp.) on four *Meloidogyne* spp. *Journal of Nematology.* 31: 62-69.

Ploeg, A. T. 2002. Effect of selected marigold varieties on root-knot nematode and tomato and melon yields. *Journal of Plant Diseases and Protection*. 86(5): 505-508.

Prasad, N. R., Anand, C., Balasubramanian, S., and Pugalendi, K. V. 2004. Antidermatophytic activity ofextracts from *Psoralea corylifolia* L. (Fabaceae) correlated with the presence of a flavonoid compound. *Journal of Ethnopharmacology*. 91: 21-24.

Rao, M. S., Parvatha, S., Reddy, P., and Nagesh, M. 1997. Management of root-knot nematode *Meloidogyne incognita* on tomato by integration of *Trichoderma harzianum* with neem cake. *Journal of Plant Diseases and Protection*. 104(4): 423-425.

Rao, M. S. 2008. Management of *Meloidogyne javanica* on acid lime using *Paecilomyces lilacinus* and *Pseudomonas fluorescens*. *Nematologia Mediterranea.* 36: 45-50.

Rehman, B., Mohamad, A. G., Kavita, P., Asif, M., and Mansoor, S. 2014. Biopotency of oilcakes against *Meloidogyne incognita* affecting *Vigna mungo*. *European Journal of Applied Sciences.* 6(3): 57-63.

Saravaran, P., Ilavarasan., N., Karthikeyan, A., and Padmanaban, B. 2020. Management of root-knot nematode *Meloidogyne incognita* in Banana (Cv. Robusta) through biocontrol agents and Neem cake. *Indian Journal of Agricultural Research.* 55(2): 231-234.

Sasser, J. N., and Taylor, A. L. 1978. Biology, Identification and Control of Root Knot Nematodes. (*Meloidogyne* spp). *International Nematology Project*, North Carolina State University, Graphics, Raleigh, NC. 9-11.

Sasser, J. N., and Taylor, A. L. 1980. Biology, Identification and Control of Root Knot Nematodes. (*Meloidogyne* spp). *Journal of Plant Pathology*. 77-94.

Shadab, S., and Shamsi, S. 2019. *Psoralea corylifolia* Babchi: A popular herb of Unani, Ayurvedic and Chinese system of medicine for *Vitiligo*. *International Journal of Herbal Medicine.* 7(4): 51-55.

Sharma, P., and Pandey, R. 2009. Biological control of root-knot nematode; *Meloidogyne incognita* in the medicinal plant, *Withania somnifera* and the effect of biocontrol agents on plant growth. *African Journal of Agricultural Research*. 4(6): 564-567.

Siddiqui, I. A., and Shaukat, S. S. 2004. *Trichoderma harzianum* enhances the production of nematicidal compounds in vitro and improves bio-control of *M. javanica* by *Psuedomonas fluorescens* in tomato. *Journal of Applied Microbiology*. 38(2): 169-175.

Sultan, M. S., Sharma, S. K., and Dhillon, N. K. 2010. Identification of nematode problems in medicinal, aromatic, and spice plants in Punjab, India. *International Journal of Biosciences*. 3:56-57.

Sumita, K., and Das, D. 2014. Management of root-knot nematode, *Meloidogyne incognita* on green gram through bioagents. *International Journal of Plant, Animal and Environmental Sciences.* 4(4): 287-289.

Walunj, A.R. 2013. Seasonal incidence and biological management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 infesting pomegranate (*Punica granatum* L.). *Agricultural Research Communication Centre Journal*. 40: 309-313.

Walunj, A. R., and Mhase, N. L. 2015. Bioagents for biological management of root-knot nematode, *Meloidogyne incognita* infesting pomegranate. *Bioinfolet*. 12(1A): 30-34.

Windham, G., Windham, M., and Williams, W. 1989. Effects of *Trichoderma* spp. on maize growth and *Meloidogyne arenaria* reproduction. *Journal of Plant Diseases and Protection.*73: 493– 494.

Zakaullah, K., Kumar, A., Mahamood, M., Gawade, B., and Gautam, N. 2014. The Root-knot nematode, *Meloidogyne incognita* on *psoralea corylifolia* L. *Nematropica*. 44(1): 81-84.

7. VITAE

Miss. KSHIRSAGAR PRIYANKA PRAKASH

A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRICULTURAL ENTOMOLOGY

2023

Title of thesis		:	"Crop loss assessment and management of Root-knot nematode *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 on Bawchi, *Psoralea corylifolia* L."
Major field		:	Agricultural Entomology
Biographical information		:	
Personal	**Date of Birth**	:	8th March,1999
	Place of Birth	:	Baramati
	Father's Name	:	Mr. Kshirsagar Prakash Uttam
	Mother's Name	:	Mrs. Kshirsagar Padmini Prakash
Educational	**Bachelor Degree Obtained**	:	Received Bachelor of Science (Agriculture) from College of Agriculture Karad, Tal. Karad, Dist. Satara, Pin- 415 110
	Class	:	First class with distinction
	Name of the University	:	Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722
Address		:	Desai Estate jalochi plot no 35,Baramati, Tal. Baramati, Dist. Pune, Pin- 413 102
	Email- id	:	kshirsagarp2015@gmail.com
	Contact No.	:	8459022272