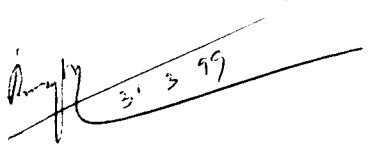
BIOECOLOGY AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White) Chitwood in Kacholam, *Kaempferia galanga* Linn.



By

RAJANI. T. S.

THESIS
Submitted in partial fulfilment of the requirement for the degree
MASTER OF SCIENCE IN AGRICULTURE
(ENTOMOLOGY)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1998

DECLARATION

I hereby declare that this thesis entitled "**Bioecology and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood in kacholam, *Kaempferia galanga* Linn.**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

13-10-1998

13.10.98

RAJANI. T. S.

CERTIFICATE

Certified that this thesis entitled "**Bioecology and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood in kacholam, *Kaempferia galanga* Linn.**" is a record of research work done independently by Ms. Rajani.T.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
-10- 1998

Dr. M. S. SHEELA
Chairman, Advisory Committee
Associate Professor
Department of Entomology
College of Agriculture, Vellayani

APPROVED BY:

CHAIRMAN

Dr. M. S. SHEELA
Associate Professor
Department of Entomology
College of Agriculture, Vellayani

29.12.98

MEMBERS

1. Dr. A. Visalakshi
   Professor and Head
   Department of Entomology
   College of Agriculture, Vellayani

29/12/98

2. Dr. B. R. Reghunath
   Associate Professor
   Department of Horticulture
   College of Agriculture, Vellayani

3. Dr. P. Sivaprasad
   Associate Professor
   Department of Plant Pathology
   College of Agriculture, Vellayani

EXTERNAL EXAMINER

29.12.98

(Dr. RAJESWARY SUNDARABABU)

ACKNOWLEDGEMENT

I wish to place on record my deep sense of gratitude and indebtedness to:

Dr. M. S. Sheela, Associate Professor of Entomology and Chairman of Advisory Committee for the valuable and inspiring guidance, constructive criticism and constant encouragement throughout the period of investigation and in the preparation of this manuscript. Words fail to express my deep and sincere obligation for the sincerity, everwilling help and affection shown by her during the entire course of study.

Dr. A. Visalakshi, Professor and Head and Dr. George Koshy, Professor, Department of Entomology for providing me every facilities and for their helpful suggestions and inspiring encouragement in completing this errand.

Dr. B. R. Reghunath, Associate Professor, Dept. of Horticulture for the sincere help, guidance and pertinent suggestions rendered during the course of investigation.

Dr. P. Sivaprasad, Associate Professor, Dept. of Plant Pathology for his keen interest, overwhelming support and guidance during the course of study and the preparation of thesis.

Dr. B. Balakrishnan, Dr. C. Gokulapalan, Associate Professors, Dept. of Plant Pathology and Sri. Robert for the everwilling help in taking photographs.

Sri. C. E. Ajith Kumar, Junior Programmer, Agrl. Statistics for analysing the experimental data.

The teaching and non teaching staff of Dept. of Entomology for their sincere co-operation and assistance during the course of study.

All friends and colleagues for the co-operation and assistance rendered during the course of investigation.

ARDRA computers for the prompt and timely help in typing the thesis.

Kerala Agricultural University for the award of Junior Research Fellowship.

My husband and all other family members for their affectionate help, moral support and everlasting encouragement for making this endeavour a success.

Above all, I bow my heads before God, the Almighty for the bountiful blessings showered upon me to complete the work successfully.

RAJANI. T. S.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LISLT OF FIGURES

INTRODUCTION

1. INTRODUCTION

India has one of the oldest, richest and most diverse cultural traditions associated with the use of medicinal plants. The remarkable fact is that it is still a living tradition. In the recent years, there has been an increasing interest in the cultivation of medicinal and aromatic plants to meet the requirement of essential oils for use in cosmetics, perfumes, pharmaceuticals and for earning foreign exchange. Improvement in agronomic practices and use of high yielding superior varieties have necessitated the application of plant protection measures which ensure better yields through the management of pests and diseases especially plant parasitic nematodes which are serious threat to the cultivation of medicinal and aromatic plants.

Kacholam, *Kaempferia galanga* Linn. is an economically important attractive medicinal plant of class monocots series Epigyneae, Family Scitaminae and Subfamily Zingiberaceae. It is grown in the tropics and sub tropics of Asia and Africa. Kacholam is known for its medically important compounds such as n-penta decana, ethyl p-methoxy einnamate, I-A3-cerene, camphene, borneol and p-methoxy styrene. The rhizomes are considered as stimulant, expectorant, carminative and diuretic. The leaves are used in cosmetic industry.

K. galanga was now found infected by the root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 (Kerala Agricultural University, 1993) *M. incognita* infestation produce characteristic galls on the distal end of the roots of kacholam which affect the translocation of water and nutrients. There is only

little information on the biology, pathogenicity, host parasite relationship and influence of edaphic factors on the growth, development and survival of root-knot nematode on this plant. Informations regarding the association of other plant parasitic nematodes with this crop is also very scarce. Sulochana *et al*, (1991) reported the occurrence of endotropic mycorrhizal association with the roots of this plant play an important role in suppressing the plant parasitic nematodes. With these basic informations, the present investigation was taken up to study.

1. The biology of root-knot nematode infesting kacholam
2. The histopathology of nematode infested kacholam roots.
3. The effect of various soil factors like soil moisture, soil pH and soil type on the multiplication and survival of *M. incognita*
4. The crop loss incurred by *M. incognita* on kacholam under field conditions and
5. To develop suitable strategies for the management of root-knot nematode infesting kacholam.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The biology and histopathology of root-knot nematode of kacholam, the effect of various soil factors on survival and multiplication of the nematode, the crop loss incurred by them under field conditions and their management aspects were studied in the present investigation. The important literature relevant to these aspects are reviewed.

2.1 **Biology**

Penetration of second stage juveniles of *M. incognita* into the young roots took place one day after inoculation in egg plant, within 24 hours in guava, 72 hours in Japanese mint cultivar shivalik and cotton var. Bikaneri Nerma. (Dhawan and Sethi, 1976 ; Fernandez *et al.*, 1986 ; Singh and Kumar, 1995b and Nadwana and Yadav, 1995).

Juvenile penetration of *M. incognita* continued upto seven days in egg plant (Dhawan and Sethi, 1976) and 16 days in Japanese mint where the maximum penetration (49 per cent of initial inoculum) occurred on fifth day after inoculation (Singh and Kumar, 1995b).

Sedentary phase of the *M. incognita* juveniles with typical tail spike was observed six days after inoculation in egg plant and seven days after inoculation in Japanese mint cultivar Shivalik (Dhawan and Sethi, 1976; Singh and Kumar, 1995b).

Second, third and fourth moult occurred 8, 10 and 13 days after inoculation (dai) respectively in egg plant (Dhawan and Sethi, 1976) 9, 14 and

16 dai in Japanese mint (Singh and Kumar, 1995b) and 7, 13 and 16 dai in cotton (Nadwana and Yadav, 1995).

The deposition of gelatinous matrix took place 21 dai in egg plant (Dhawan and Sethi, 1976) and 22 dai in Japanese mint cultivar Shivalik (Singh and Kumar, 1995b).

Dhawan and Sethi (1976) reported that in egg plant, *M. incognita* deposit eggs on 22 dai. Fernandez *et al.* (1986) found that under lab conditions, oviposition of *M. incognita* females began after 19 and 23 days at a mean temperature of 29 and 24^{0}C respectively. In Japanese mint, cultivar Shivalik eggs were noticed at 23 dai (Singh and Kumar, 1995b). Nadwana and Yadav (1995) observed that in cotton, var. Bikaneri Nerma, ovpisition of *M. incognita* started on 21 days after inoculation.

Dasgupta and Gaur (1986) found that the total number and size of eggs of *M. incognita* were influenced by the host status and the level of environmental stress.

The total duration of life cycle vary in different crops. In egg plant *M. incognita* took 36 days for the completion of one life cycle (Dhawan and Sethi, 1976). Fernandez *et al.* (1986) found that in guava the duration of life cycle was 26 and 30 days at a mean temperature of 29 and 24^{0}C respectively. Time required for the completion of one life cycle of *M. incognita* on tomato and cotton was 30 and 32 days respectively (Rai and Jain, 1988). In Japanese mint cultivar Shivalik *M. incognita* complete its life cycle in 29 days at temperatures ranging from 13 - 37^{0}C (Singh and Kumar, 1995b). Nadwana

and Yadav (1995) reported that *M. incognita* took 21 days to complete its life cycle in cotton var. Bikaneri Nerma.

2.2 **Histopathology**

Entry of nematode into the host tissue brings about several histomorphological changes. Second stage juveniles of root-knot larvae penetrate the root epidermis and make their way through the root cortex to the infection site (Shetty and Rudramuniyappa, 1992).

Feeding site of nematode was found as the vascular region. It has been established by many workers (Siddiqui *et al.*, 1974; Jacob, 1977; Shah and Raju, 1977; Sudha and Prabhoo, 1983; Molina and Nelson, 1983; Pasha *et al.*, 1987; Fawole, 1988; Sosamma, 1988; Shetty and Rudramuniyappa, 1992; Mohanty and Das, 1994 ; Das and Barman, 1995).

Histopathological changes due to *M. incognita* infection is characterised by hypertrophy and hyperplasia (Hasan and Jain, 1985). Characteristic giant cell formation in susceptible hosts have been reported by many workers (Baldwin and Barker, 1970 ; Siddiqui *et al.*, 1974 ; Jacob, 1977 ; Shah and Raju, 1977 ; Sudha and Prabhoo, 1983 ; Molina and Nelson, 1983 ; Pasha *et al.*, 1987 ; Fawole, 1988 ; Sosamma, 1988 ; Shetty and Rudra Muniyappa, 1992 ; Das and Barman, 1995).

There is controversy regarding the tissue from which giant cells originate. Siddiqui *et al.* (1974) reported that the giant cells are produced from the phloem or the interfasicular region while some others reported giant cell formation from the xylem (Jacob, 1977 ; Shah and Raju, 1977 ; Charles, 1978 ; Fawole, 1988). Molina and Nelson (1983) found giant cell formation

from xylem and phloem. According to Shetty and Rudramuniyappa (1992), giant cells originate from the phloem and ray parenchyma.

The number of giant cells produced as a result of *M. incognita* infection vary in different crops. The number of giant cells formed is four to six in pepper (Jacob, 1977), two to six in brinjal (Pasha *et al.*, 1987), four in *Coleus parviflorus* (Sosamma, 1988) and seven in greengram var : AAU - 34 (Das and Barman, 1995). The giant cells are multinucleate (Molina and Nelson, 1983 ; Sudha and Prabhoo, 1983 ; Pasha *et al.*, 1987 ; Fawole, 1988 ; Das and Barman, 1995) poligonal or roughly quadrangular in shape (Kozhakaru, 1985 ; Sosamma, 1988) and thick walled with dense cytoplasm (Pasha *et al.*, 1987 ; Das and Barman, 1995). Fawole (1988) observed thin walled giant cells in white yam, *Diascorea rotundata* tubers.

Abnormal xylem elements of variable size and shape have been reported by Siddiqui *et al.*, 1974 ; Pasha *et al.*, 1987 and Shetty and Rudramuniyappa, 1992. Siddiqui and Ghouse (1975) found that roots of *Lagenaria leucantha* when infested with *M. incognita*, at the early stage of infestation phloem first partially and later completely got distroyed due to pressure of accumulating piles of undifferentiated tissues in the induced cambial zone. Advanced stage of infection revealed that after the destruction of normal phloem, new phloem develop out of the outer derivatives of the newly formed mass of cells. Charles (1978) observed that in ginger the affected portion of the root get decayed and pre-disposed the roots for attack by other micro organisms. Necrosis of the roots due to *M. incognita* has been reported by Baldwin and Barker, 1970 ; Pasha *et al.*, 1987 and Sosamma, 1988.

2.3 **Effect of soil factors**

The growth, survival and multiplication of root knot nematode is governed by a number of ecological factors like soil type, soil moisture, pH, temperature, etc.

2.3.1 **Soil moisture**

Nematodes are essentially aquatic animals even though they occupies many different ecological niches. Soil moisture level is one of the most important factor determining the osmotic pressure, suction, aeration, thermal changes and nutrient availability etc. It affects the nematode directly by regulating hatching, movement and root invasion and indirectly by determining the host growth.

Brown (1933) found that high moisture condition in the soil do not favour nematodes and suggested flooding as a method for the control of root-knot nematode. Peacock (1957) opined that there is an optimum soil moisture for the survival of root-knot nematode. Root-knot counts were significantly higher in tomato roots grown at field capacity and absent or few on roots at permanent wilting point where as the eggs of *M. hapla* hatch equally well at field capacity and permanent wilting point but nematode mobility is reduced under low moisture conditions (Couch and Bloom, 1960). The study conducted by Daulton and Nusbaum (1962) revealed that the egg viability of *M. javanica* (Trueb, 1885) Chitwood, 1949 was much reduced in wet soil than in dry soil.

Szczygiel and Soroka (1983) found that the population of *M. hapla* decreased with an increase in moisture level. High moisture did not prevent the

hatching of *M. incognita* larvae, but only lowered nematode mobility (Khan *et al.*, 1986).

Sosamma and Koshy (1986) reported that the burrowing nematode *R. similis* population survived in air dried soil (moisture range 0.1 to 1.0 per cent) for a period of three months. More over, the nematode population came out from the severed coconut roots survived under field conditions for six months in moist soil and only one month in dry soil.

The maximum survival of second stage juveniles of *M. incognita* took place at 0.8 bar moisture tension (Gaur and Sehgal, 1988). They also reported that nematodes could persist over the entire test range of 0.01 to 30 bars over a period of 450 days in sandy loam soil without host. At the end of 450 days, 9 to 20 per cent of *M. incognita* were found surviving.

The mortality, loss of infectivity and development of the root-knot nematode *M. incognita* were positively correlated to the rate of moisture loss from soil (Gaur and Sehgal, 1990). Khan and Sharma (1990) found that the fluctuation in the population densities of *Helicotylenchus dihystera* and *M.incognita* was correlated more with the temperature than with soil moisture.

2.3.2 **Soil pH**

Peters (1926) made the first attempt to correlate soil pH levels and nematode populations in soil. Godfrey and Hagen (1923) found no differences in the infestation of *Meloidogyne* sp. when pineapple was raised in soils having pH ranging from 4 to 8.5 in Hawai. In another study it was revealed that pH played only a second role in the development of root-knot nematode, although

it was observed that the larvae of *M. javanica* were repelled at a higher and lower range of pH (Bird, 1959).

The hatching and survival of *M. incognita* was maximum at pH 6.5 in Heller's nutrient solution (Loewenberg *et al.*, 1960). Watson and Lownsberry (1970) reported that the hatching of eggs of *M. naasi* was significantly greater at pH 5.9 in distilled water than at pH 3.8, 6.8 or 10.5 obtained with buffered solution. The pH range favourable for the hatching of eggs of *Meloidogyne* which attack guava was from six to seven (Fernandez *et al.*, 1986).

The nematodes could survive neither high acidic nor alkaline media (Naseem and Jairajpuri, 1982). Sheila *et al.* (1985) revealed that the development of root-knot nematode was more at pH 7 than at pH 3 or 9, when tomato seedlings were inoculated with single egg mass population of *M.incognita* maintained at different soil pH levels.

In another investigation, increased biotic activity of nematode was observed in acidic soil and rapid decline in alkaline soil (Das *et al.*, 1990)

Chaudhary and Phukan (1995) reported the population density of *M. incognita* was maximum at pH level ranging from 5.0 to 5.9. Charles *et al.* (1996b) reported that temperature of 20^0C, flooded condition and pH 6.7 gave maximum percentage of juvenile emergence of *Heterodera oryzicola* (Rao and Jayaprakash, 1978) infesting banana in shortest period of 55-56 days.

2.3.3 **Soil type**

There is always a soil phase in the life cycle of all the nematodes which greatly influence the distribution and multiplication of the nematode species.

Upadhyay *et al.*, 1972 studied the effect of different soil types on the density of nematode population and found that textural composition as well as other unidentified soil factors have a determinant influence on the fate of inoculated nematodes. They found *Aphelenchoides ritzemabosi*, *Pratylenchus aeratus* and *Meloidogyne hapla* reported better in sandy soils.

Vadivelu (1973) stated that comparatively higher fertility status of the red soil with lower pH, higher percentage of coarse fractions, less dense property and organic matter content, lesser percentage of pore space and adequate moisture holding capacity supported very high population of root-knot nematode *M. incognita* and its multiplication was influenced to a greater extent under these conditons. Sumangalakuttyamma (1975) found that forest soil having comparatively high fertility status with moderate pore space, water holding capacity, acidity and high organic matter was most favourable for the development of root-knot nematode, *M. incognita* on bhindi and the predominance of clay, silt and fine sand fractions of soil was found to retard the development of *M. incognita*.

M. incognita was most damaging in low clay content mixtures (Shane and Berker, 1986). *Meloidogyne* spp. are generally more abundant in sandy and sandy loam soils with 50 per cent or more sand (Dasgupta and Gaur, 1986). Nakasono *et al.* (1989) revealed the gall indices of tomato roots were not different among soil types. Ahamad *et al.* (1991) noticed that increase in clay content of soil decreased the ability of larvae to move freely and penetrate the roots of cowpea plants.

Hossain *et al.* (1992) reported that the severity of root-knot (gall) formation and population of *M. incognita* were highest in coarse sand followed by sandy loam soil. Further, the nematode activity was low in silty loam and clay loam soils. Lopez *et al.* (1992) found that the severity of root-knot disease vary with soil texture and was highest in loamy sand followed by sandy loam, loam, sandy clay loam and clay loam soils. Another study conducted in medicinal herb, *Paeconia lactiflora* revealed that the *M. hapla* juvenile population was highest in sandy and sandy loam soil (Park *et al.*, 1994).

Haseeb (1995) studied the effect of different soil types on plant growth, oil yield, physiological and biochemical changes and root-knot development in inoculated plants of *Mentha arvensis* cv. CIMAP / HY 77. He found that highest per cent reduction in fresh or dry plant weight and oil yield in sandy-clay loam followed by loamy sand, silt, clay and sandy loam. The per cent reduction in chlorophyll content of leaves, photosynthetic rate, total sugar, total phenol and rate of multiplication of nematode also high in sandy clay loam followed by loamy sand and sandy loam. Multiplication factor of *M. javanica* in grape vine was found to be highest in sandy soil followed by sandy loam and lowest in clay soil. Further, the nematode population in soil and root, number of galls and eggs were high in sandy and lowest in clay soil (Didwaniya and Baghel, 1995). Studies carried out by Charles *et al.* (1996a) with six soil types viz., forest, red, alluvial, laterite coastal sandy and sandy loam on the parasitic abilities and multiplication of *H. oryzicola* on banana upto a period of 90 days revealed that coastal sandy and sandy loam soil types significantly affected the plant growth parameters and nematode population per

gram root as compared to the uninoculated plants grown in the same soil types. Kumar and Vadivelu (1996) reported that the rate of reproduction of *M.incognita* and *Rotylenchulus reniformis* (Linford and Oliveiria, 1940) infecting egg plant was significantly higher in red soil than in black soil which could be due to the higher silt and coarse sand content in red soil.

2.4 **Pathogenicity**

The pathogenicity studies of root-knot nematode in various host plants were conducted earlier. Charles (1978) studied the pathogenicity of *M. incognita* in ginger var. Rio-de-Janeiro and found that the extent of damage done by the nematode progressively increased with graded inoculum levels of 10, 100, 500, 1000 and 5000 larvae per plant. The growth characteristics such as number of tillers, plant height, leaf length; leaf width, shoot weight and root weight of ginger also showed reduction as the number of larvae inoculated increased from 10 to 5000.

Routaray *et al.* (1987) reported that in ginger significant pathogenic effects due to *M. incognita* were noticeable at 1 - 10 nematode onwards and the fibrous roots were very much reduced at highest inoculum level. Pathogenicity of *M.incognita* on garlic revealed that increasing population has a positive correlation with reduction in plant growth (Midha and Trivedi, 1988).

Mohanty and Das (1994) conducted studies on the effect of *M. incognita* on tube rose plants var. Single, using different inoculum level of 0, 10, 100, 1,000, 5,000, 10,000, and 20,000 nematodes per plant. They found

significant reductions in plant height, root length, shoot dry weight, root dry weight and number of leaves over control plants. In betel plants infested with 1000 larvae of *M. incognita* per plant significantly reduced the chewable leaves (Nalinakumari *et al.*, 1995).

Singh and Nath (1996) found that in papaya, an initial population of 1000 *M. incognita* per 500 g sandy loam soil was found pathogenic. An initial inoculum level of 100 juveniles of *M. incognita* per plant caused significant reduction in fresh and dry fibrous root weight and tuber yield of *Diascorea rotundata* (Mohandas and Ramakrishnan, 1997).

Kumar and Singh (1997) studied the influence of different initial densities (0, 10, 100, 1000 and 10000 J_2 per pot) on the growth of *Mentha arvensis* cv. Shivalik under pot culture condition and found that there was progressive decrease in length and weight of shoot and root with the increase in the initial nematode inoculum. Pathogenicity studies of root-knot nematode *M. incognita* associated with three medicinal plants viz. *Ammi visnaga, Costus speciosus* and *Solanum indicum* revealed that growth parameters of the plants were inversely correlated with initial population densities of *M. incognita* (Pandey and Haseeb, 1997).

2.5 **Crop loss assessment**

Loss is a function of the damage potential, density and distribution of the parasitic nematode in an area. Bhatti and Jain (1977) reported that the losses in yield of lady's finger, tomato and brinjal were 90.9, 46.2 and 27.3 per cent respectively in a field infested with *M. incognita* @ 2800-3460 larvae/kg

soil. *Meloidogyne* spp. had incurred 32.66 per cent yield loss in tobacco in Pinar del Rio Province, Cuba (Garcia and Espinosa, 1982). Under field condition *M. incognita* causes 47 and 86.7 per cent reduction respectively in top weight and shade dried leaf yield of Patchouli, *Pongostemon cablin* (Prasad and Reddy, 1984).

An yield loss of 45.4 per cent in terms of bunch weight of banana cv giant cavendish occurred at an inoculum level of 10000 *M. incognita* larvae/plant (Davide and Marasigan, 1985). Reddy (1986) reported that yield loss due to *M. incognita* varied from 28-43 per cent between crops, *Solanum melongena*, *Abelmoschus esculenta*,*Phaseolus vulgaris* and *Vigna unguiculata*. According to Fademi (1987) yield loss and galling due to *Melodogyne* on rice were directly related to inoculum level. In soybean field heavily infested with *M. incognita* yield was reduced by 55.6 per cent and 100 seed weight by 33.6 per cent (Antonio, 1988). *M. incognita* caused 33 per cent yield loss in wheat (Patel and Patel, 1988), 12.7 and 12.3 per cent in greengram and cowpea crops (Patel *et al.*, 1993). 46.1 per cent yield loss was observed in small cardamom at 4 nematodes/100 cm^3 soil (Eapen, 1994). Root-knot nematode *M. javanica* had incurred losses to the tune of 23 per cent in grain yield of urd bean (Ali, 1995).

In brinjal an initial population of 248 *M.incognita* larvae/250 g soil sample resulted in an avoidable loss of 20 and 22 per cent in weight of fruits and number of fruits (K.A.U., 1993). The avoidable yield loss due to *M.incognita* in ginger was 43 per cent at an initial population level of 166 larvae/250 g soil sample (Sheela *et al.*, 1995). Nalinakumari *et al.* (1995)

reported 56.9 and 67.7 per cent reduction of chewable leaves of betel vine at an initial inoculum level of 4000 and 5000 *M.incognita* larvae/plant. Makhnotra and Khan (1997) reported that in Himachal Pradesh 20 per cent loss in ginger yield was caused due to *M. incognita* with an initial population of 200 larvae per 200 cc of the soil.

Patel *et al.* (1981) revealed heavy galling of roots and reduced size of rhizomes in turmeric infected with *M. incognita*. French bean plants infected with *M. incognita* show reduction in chlorophyll content, plant dry weight, number of buds, flowers, pods and seeds (Malakeberhan *et al.*, 1986).

2.6 **Management**

The root-knot nematode which cause severe damage in kacholam warrented the need for management practices. Being a medicinal plant, management using nematicides is prohibited. Hence, the efficiency of neem cake and vesicular arbuscular mycorrhiza are compared with carbofuran for managing the root-knot nematode population and for producing better yield of kacholam.

2.6.1 **Chemicals**

The effect of chemicals for managing root-knot nematode in various crops are reviewed here. Sivakumar *et al.* (1973) reported that seed treatment of okra with carbofuran does not give absolute protection against root knot nematode, but it reduces the severity of infection. Mahajan (1978) observed reduced root-knot index after four weeks by the application of furadan

flowable paste at different concentrations in okra seeds. Spot application of chemical was superior than row or broadcast in reducing root knot incidence (Sitramaiah and Viswakarma, 1978).

Carbofuran at 2.0 kg a.i. ha^{-1} effectively controlled *Meloidogyne incognita* on ginger and improved plant growth in pot culture experiments (Parihar and Yadav, 1986). Jain *et al.* (1988) reported that aldicarb and aldicarb based chemicals are most effective in increasing tomato yield in *M.javanica* infested plots. Application of carbofuran 3 G @ 4 kg a.i. ha^{-1} to four month old turmeric reduced the population of *M. incognita* by 81.6 % four months after treatment compared with control (Mani *et al.*, 1989). Carbofuran reduced the galls and egg mass in roots of pea and increased the yield (Bhagavati and Phukan, 1990). Borah and Phukan (1990) tried carbofuran 3G, phorate 10G, Mocap 10G and diazinon 10G each at one, two and three per cent a.i. as seed treatment for the control of *M. incognita* on green gram and revealed that increase in concentration of chemicals resulted in the decrease in number of galls and egg masses and increase in plant growth characters and yield. In another study carbofuran was found effective in suppressing the *M. incognita* activity and improved plant growth of French bean, *Phaseolus vulgaris* (Mohan and Mishra, 1993). Upadhyaya *et al.* (1993) reported that in French bean, application of carbofuran @ 3 kg a.i. / ha resulted in 53.11 per cent increse in yield and 41.18 per cent decrease in root-knot index. Carbofuran 2.5 kg a.i. ha^{-1} is effective in reducing the total nematode population (81.4 to 88.8 %) in fields cultivated with fodder crops. (Hasan and Jain, 1993).

Soil application of Carbofuran @ 2 kg a.i. ha^{-1} and seed dressing @ 2 g a.i. / kg were highly effective in controlling *M. incognita* larvae and reduced root knot galls in pea compared to control plants. This treatments also improved the plant growth parameters and yield of crop (Devi, 1993). Patel *et al.* (1993) reported that application of carbofuran @ 2 kg / ha. a day prior to crop seeding under the crop row increased yield by 14.6 and 14 per cent in greengram and cowpea crops respectively. Mohanty *et al.* (1995) found Carbofuran 0.6 kg a.i. m^{-2} effectively reduced the number of galls per 25 seedling in brinjal nursery. Carbofuran 2 kg a.i. ha^{-1} is effective in reducing the population *M. incognita* and increasing the growth parameters like root length, shoot dry weight, root fresh weight, number of leaves etc. of Japanese mint (Singh and Kumar, 1995a).

Field studies conducted revealed that application of carbofuran at planting or 45 days after planting will not have the terminal residues in ginger rhizomes harvested at 300 and 255 days later (Sheela *et al.*, 1995).

2.6.2 **Oil cakes**

Alam and Khan (1974) reported that in the field, greatest reduction in the population of stylet bearing nematodes took place with neem cake. They observed that neem cake, mahua cake and mustard cake controlled phytonematodes in the filed almost as effective as DD and nemagon (1975). Application of neem cake greatly reduced the total nematode population in oats and the succeeding *Vigna* sp. crop (Jain and Hasan, 1980). Out of the five

oil cakes tried, cakes of *Azadirachta indica* was most favourable for the control of nematodes in berseem followed by bajra (Hasan and Jain, 1984).

Neem oil cake @ 1 t ha^{-1} applied in drenches near the root zone of betel vine at the time of planting of vines was most effective in controlling the root-knot nematode and increased yield of betel vine (Acharya and Padhi, 1988). Among the neem products tried for the management of *M. incognita* in chick pea (*Cicer arietinum*) neem cake and neem seed kernel were found to be most effective (Mojumder and Mishra, 1993). Sundararaju and Sudha (1993) reported that application of neem oil cake @ 1 kg/palm/year was found reducing the nematode population and increasing the yield significantly in arecanut, banana and black pepper under arecanut based farming system.

Soil amendment with neem cake at 0.1, 0.5 and 1 % w/w reduced infection of *M. incognita* on mung bean *Vigna radiata* and significantly improved the plant height, but reduced root nodulation (Abid *et al.* 1995). Acid extracts of neem cake at different dilutions also enhanced the growth of *Vigna ungiculata* and reduced the population build up of nematode (Alagumalai *et al.* 1995). Neem cake application reduced the population of *M. incognita* and improved the plant growth characters of Japanese mint (Pandey, 1995; Singh and Kumar, 1995a). Neem cake @ 2 t/ha reduced the number of galls in betel vine (Rao *et al.*, 1995). Spot application of neem cake @ 30 g per plant resulted in 30.6 per cent increase in shoot length and 40.6 per cent increase in root length of tomato plants (Kaul and Bhatt, 1995).

Singh *et al.* (1980) recommended combined application of oil cakes and nematicides for effective control of nematode population, since it was found

superior to oil cakes alone and also only a low concentration of nematicide is required when mixed with oil cakes.

In a field study Kaul and Bhatt (1995) revealed that neem cake both spot application 30 g/plant and general application 1 t/ha and also carbofuran alone and in combination with neem cake were most effective in reducing the larval population of *M. incognita* in 30 and 60 days of transplantation.

A study conducted by Sheela *et al.* (1995) in ginger revealed that neem cake @ 2.5 t/ha at the time of planting and carbofuran 1 kg a.i./ha forty five days after planting was effective in reduce the *M. incognita* population in soil and root samples. It also reduced the root-knot index and increased the yield of ginger.

Ajith *et al.* (1993) reported that application of chopped neem leaves @ 7.5 t/ha 15 days prior to sowing of cowpea seeds significantly reduced the pathogenic nematodes like *M. incognita*, *R. reniformis* and *Helicotylenchus* sp.

Pillai and Desai (1975) observed that second stage juveniles of *M.javanica* was effectively controlled by marotti cake (*Hydnocarpus laurifolia*). They also reported that undecomposed *Calaphyllus inophyllum* oil cake gave best control of *M. javanica* in tobacco plants (1976). Coconut oil cake reduced the infestation of root-knot nematode on okra and increased the growth of plants (Kumar and Nair, 1976). Groundnut cake was also found effective against root-knot nematode (Trivedi *et al.*, 1978). Soil amended with cakes of *Shorea robusta* and *C. inophyllum* resulted in slow hatching of *M.incognita* from egg masses (Goswami and Vijalakshmi, 1986). Alam

(1989) reported that soil amendment with horn meal, bone meal and oil cakes of mahua, caster, mustard, neem and pea nut were effective in inhibiting the root knot development and population build up of *T. brassica* on egg plant, chilli, okra, cabbage and cauliflower consequently improving the plant growth.

2.6.3 **Vesicular Arbuscular Mycorrhizal fungi**

VAM fungi have potential in reducing plant diseases caused by plant parasitic nematodes. VAM association is reported to induce, tolerence to root pathogens (Sharma and Trivedi, 1995). The interaction between VAM and plant parasitic nematodes have been studied by several workers (Shenck and Kellam, 1978 ; Bagyaraj *et al.*, 1979 ; Hussey and Roncadori, 1982 ; Suresh *et al.*, 1985). Development and reproduction of nematodes are often inhibited by mycorrhizal association (Cooper and Grandison, 1986 and 1987, Grandson and Cooper, 1986 ; Jain and Sethi, 1988).

Bagyaraj *et al.*(1979) reported that tomato roots colonised by *Glomus fasciculatum* and infested by *M.incognita* or *M.hapla* exhibited fewer and smaller galls than nematodes infected non-mycorrhizal plants. Soybeans inoculated with *Glomus macrocarpyus* and *M.incognita* exhibited fewer galls per gram root in comparison to nematode alone (Kellam and Schenk, 1980). Mc Guidwin *et al.* (1985) reported that the colonisation of *Allium cepa* by *G. fasciculatum* appeared to alter the ability of *M.hapla* to penetrate the roots while the survival and reproduction of *M.hapla* were not affected *by G. fasciculatum*.

Suresh *et al.* (1985) found that mycorrhizal roots did not prevent the penetration by *M.incognita* larvae, but the giant cells found in mycorrhizal plant was significantly low. The gall cell formation by *M.incognita* and their multiplication were hampered by the early establishment of *Glomus fasciculatum* on cowpea (Jain and Sethi, 1988).

Sivaprasad *et al.* (1990) reported the deleterious effect of *M. incognita* on cowpea was insignificant wherever mycorrhiza and *M. incognita* occurred together. Further the galling, root-knot index and nematode population was reduced to a great extend by VAM association.

In pepper there was reduction in root and soil nematode population, root-knot index and increased growth of vines when plants were pre inoculated with *G. fasciculatum* and *G. etunicatum* (Sivaprasad *et al.*, 1990). Cowpea plants inoculated with *M. incognita* in association with *G. fasciculatum*, *G. mosseae* and *G. morroweae* recorded a root-knot index of 1, 3.16 and 3.43 respectively as against 4.89 observed in plants inoculated with nematode alone (Deepthi, 1993).

Rao *et al.* (1993) found that *G. mosseae* is effective in reducing the infestation of *M. incognita* in egg plant. Among the five species of mycorrhizae tested against *M. incognita* on tomato, *G. fasciculatum* was superior in enhancing plant growth, suppressing nematode population and increasing yield (Sundarababu *et al.*, 1993).

Sharma *et al.* (1994) found VAM colonisation reduce the root-knot infestation in tomato. They opinioned that application of VA mycorrhiza first

followed by nematodes resulted in growth reduction in nematode infestation than simultaneous inoculation or nematode first followed by mycorrhiza.

Malathi (1994) observed increased growth in kacholam plants when incoulated with VAM alone or VAM first followed by the inoculation of nematode.

Sharma *et al.* (1995a) studied the effect of VA mycorrhizal fungus *G. fasciculatum* in the survival, penetration and development of root-knot nematode, *M. incognita* in tomato under glass house condition and found that mycorrhizal seedlings produced less number of galls, egg mass per plant, eggs and juveniles per egg mass. They reported that the symbiont caused a reduction of 30 per cent in galls and egg mass per plant. In field trials also VAM treated plants show significantly reduced population over control (Sharma *et al.*, 1995b).

In pea, mycorrhizal roots showed fewer galls than non-mycorrhizal roots but the nematode suppressed spore production (Chahal and Chahal, 1995). Asha (1997) found that *G. fasciculatum* lowered the population of *M. incognita* in rhizosphere soil and *G. fasciculatum* was the most effective VA mycorrhizal fungi in reducing the root-knot infestation in brinjal.

G. mossae in combination with neem leaf or neem leaf extract proved significantly effective in increasing the plant growth parameters of egg plant seedlings in the nursery beds and reducing nematode infestation, indicating combined and complimentry interacting effect of both components on the management of root-knot nematode due to their synergistic actions (Rao *et al.*, 1993). Integration of neem cake, carbofuran and the biological

agents *G. fasciculatum* and *Pasteuria penetrans* was found to be most effective in reducing the population of the nematode *R. similis* significantly both in root and soil by more than 50 per cent. Besides, it also improved the growth of banana plants by increasing the girth of pseudostem, plant height, number of leaves and leaf area (Channabasappa *et al.*,1995). Jain and Hasan (1995) reported that soil application of *G. fasciculatum* along with neem product, Achook effectively managed the incidence of *M. incognita* to a safer level and increased the forage biomass of cowpea. In a field trial, the nematicides, carbofuran and oncol controlled the root-knot disease more than VAM and VAM treated plants showed significantly reduced nematode population over control (Sharma *et al.*, 1995a).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Pot culture studies were conducted to work out the biology and histopathology of root-knot nematode infesting kacholam, *Kaempferia galanga* Linn. Effect of soil factors like, soil moisture, soil pH on the hatching of eggs and survival of root-knot nematodes were assessed *in vitro* using the egg mass and larvae collected from the kacholam roots. The effect of soil type and pathogenicity were studied in pot culture condition. The crop loss assessment and management strategy were tried in microplot condition.

3.1. Pot culture studies

3.1.1. Preparation of denematized potting mixture

Sieved field soil, sand and well decomposed farmyard manure were mixed in the ratio 2 : 1 : 1 and the mixture was spread on the ground in the form of beds of 15 cm thickness. The beds were divided into blocks of one square feet which were moistened and drenched uniformly with 10 per cent formaldehyde solution. The beds were then covered with polythene sheet for two weeks. The sheets were removed and mixture raked well and exposed after two weeks. This denematized potting mixture was used for pot culture studies.

3.1.2 Raising pure culture of *M. incognita*

Egg masses of *M. incognita* collected from infested kacholam roots were used for raising pure culture of nematode on kacholam maintained in

sterilized soil. Subculturing was done periodically to ensure availability of sufficient larval population for inoculation purposes for the experiment.

For obtaining one day old larvae of the nematode for experiments, viable egg masses were hand picked from the infested roots of culture plants and kept in cavity blocks containing sterile water. Every 24 hours the larvae hatched were collected. The number of larvae per ml. of suspension was determined with the help of a stereoscopic microscope using hand tally counter. The larval concentration was adjusted to required number of larvae per ml. of suspension by adding required quantity of sterile water.

3.1.3 **Inoculation of nematode**

Newly hatched second stage larvae of *M. incognita* were inoculated to the root zone of the plants. Inoculation was done by making five holes in the soil around the root zone about four centimeter deep with a glass rod, 1.5 cm away from the base of the plant and required quantity of inoculum was pipetted out and equally poured in the bore holes. The holes were closed immediately with sterile moist sand. Then the pots were irrigated gently to keep the soil just moist.

3. 1. 4 **Estimation of the biology of root-knot nematode in kacholam**

Denematized potting mixture was filled in small pastic pots and rhizomes of kacholam with one or two buds were planted. One month after planting, when the plant has sufficient roots, 1000 *M. incognita* second stage juveniles (J_2) were inoculated to the root zone. Periodical sampling of infested roots were done at five days interval continued for 45 days of inoculation of

M. incognita juveniles. The roots thus obtained were subjected to staining. Then sections were taken and examined under the microscope to study the different life stages of nematode. The period of different life stages and the period to complete one life eyele were noted.

3. 1. 5 **Histopathology of root-knot nematode**

Rhizomes of kacholam were planted in small pots containing denematized soil. One month after planting, the plants were inoculated with 1000 second stage juveniles of *M. incognita*. Periodical sampling of the roots were done and fixed in FAA fixative (formalin acetic acid alcohol fixative). The fixed roots were then processed for microtomy using safranin as described by Johanson (1940). The sections were examined for studying the histopathological changes in the root due to root-knot nematode infestation.

3.1.6 **Evaluation of the effect of soil moisture**

Sieved, well dried and denematized sandy soil taken in 100 ml capacity ice-cream cups was used for the study. Three moisture levels viz., field capacity, permanent wilting point and flooding were maintained throughout the experimental period by adding the required volume of water lost due to evaporation. This was standardised by recording the weight of moisture loss for every 72 hours period and the required volume of water to compensate the loss of moisture were worked out before the actual setting up of the experiment.

3.1.6.1 **On the hatching of eggs of *M. incognita***

For studying the hatching of eggs at different moisture levels, viable eggs collected from infested kacholom were used and the number of eggs hatched at two days interval was noted at different soil moisture levels maintained.

3.1.6.2 **On the survival of larvae of *M. incognita***

100 freshly emerged second stage juveniles of *M. incognita* were inoculated and larval survival at five days interval was estimated from different levels of moisture maintained as mentioned in 3.1.6 by Cobb's sieving and decanting method.

3.1.7 **Evaluation of the effect of soil pH**

The effect of pH on hatching and survival of larvae was studied in sandy soils taken in 100 ml capacity ice cream cups. The pH levels maintained for the study are 5.0, 5.5, 6.0, 6.5, 7.0 and 7.5. Quantity of lime required for each treatment was worked out by following the methodology suggested by Jackson (1956).

3.1.7.1 **On the hatching of eggs of *M. incognita***

The effect of pH on hatching of eggs was studied by taking viable egg mass from the infested kacholam and placed in ice cream cups maintained at different pH levels as mentioned in 3.1.7. The number of eggs hatched out at two days interval was noted.

3.1.7.2 **On the survival of larvae of *M. incognita***

After maintaining the different soil pH as mentioned in 3.1.7, 100 freshly emerged second stage juveniles of *M. incognita* larvae were inoculated and placed in BOD inocubator maintained at a temperature of 30^0C. Larval survival at five days interval was estimated from the soil by Cobb's sieving and decanting method.

3.1.8 **Evaluation of the effect of different soil types on the pathogenicity of root-knot nematode**

The pathogenic reaction of root-knot nematode in four major soil types namely forest (Alfisol) red (Oxisol) laterite (Ultisol) and sandy soils (Entisol) collected from different locations were studied under pot culture conditions with five levels of inoculum viz., 0, 10, 100, 1000 and 10,000 *M. incognita* per plant. The experiment was laid out in completely randomised design with four replications in all the four types of soil.

Main items of observations taken are

1. Nematode population in soil at 45 days interval
2. Biometric character of the plant viz., number of leaves and weight of root
3. Weight of rhizomes (yield)
4. Root-knot count per 5 g of root
5. Number of eggs per egg mass
6. Number of females per 5 g root.

3.2 Microplot studies

3.2.1 Crop loss assessment

A micro plot study was conducted to assess the crop loss incurred by *M. incognita* on kacholam. The experiment was conducted at College of Agriculture, Vellayani by raising kacholam plants in micro plots as mentioned in 3.2.1.1.

3.2.1.1 Raising of kacholam plants

The micro plots were filled with garden soil which was made into good tilth and rhizomes were planted at a spacing of 20 x 15 cm at a depth of 4-5 cm. Plants were maintained as per the Package of Practices of Kerala Agricultural University (1996).

The experimental details are given as follows.

Plot size - 1 x 1 m

Design - RBD

Replication - 4

Treatments - 4

T_1 - *M. incognita* 200 second stage juveniles (J_2) per plant at 30 days after planting (DAP).

T_2 - *M. incognita* 500 J_2 per plant 30 DAP

T_3 - *M. incognita* 1000 J_2 per plant 30 DAP

T_4 - Control (without nematode)

The main items of observations recorded are,

1. Population of *M. incognita* in 250 g soil sample at 8 months after planting.
2. Biometrics characters of plant (number of leaves, weight of roots and length of rhizomes) at the time of harvest.
3. Yield
4. Root-knot count per g of root
5. Population of nematode in 5 g root sample

3.2.2 **Management studies**

An experiment was conducted in sick microplots to evaluate the efficiency of carbofuran, neem cake and Vesicular Arbuscular mycorrhiza (*Glomus fasciculatum*) for the management of root-knot nematode in kacholam. The micro pltos were filled with root-knot infested garden soil and plants were maintained as mentioned in 3.2.1.1.

3.2.2.1 **Preparation of VAM inoculum**

Pure culture of VAM fungi were maintained on guinea grass *Panicum maximum* in pots containing sterile sand : soil mixture at Department of Plant Pathology, College of Agriculture, Vellayani. Root segments of *P. maximum* colonised with the mycorrhizal fungi and the chlamydospores in the soil : sand mixture on which the grass was grown were mixed thoroughly and it served as the mycorrhizal inoculum. 25 g of inoculum was applied per pit (300 g/m^2), mixed with the top soil and rhizomes were planted over it.

The experimental details of management trial are as follows.

Design - RBD

Replication - 4

Treatments - 4

T_1 - Neem cake 200 g per m2 at 45 DAP

T_2 - Carbofuran 3.33 g per m^2 (1 kg ai per ha) at 45 days after planting

T_3 - VAM fungi 300 g inoculum per m^2 (25 g per plant) at planting

T_4 - Untreated control

Nematode population in 250 g of soil sample was estimated at 2, 4, 6 and 8 months after treatment. Biometric characters of the plant viz., number of leaves, weight of roots and length of rhizomes as well as the yield, root-knot count per g of root, number of larvae emerged per egg mass and nematode population in 5 g root sample were recorded at the time of harvest i.e., 8 months after planting.

3.3 Assessment of results

3.3.1 Gall index

The number of galls per gram of root were counted and the gall index determined. The following scale was followed for calculating the root-knot index.

Gall number	Root-knot index
1-5	1
6-10	2
11-15	3
16-20	4
Above 20	5

3.3.2 **Number of eggs per egg mass**

A fixed number of egg masses were hand picked and kept in sterile water in a petridish. The total number of freshly hatched larvae was counted and from that the number of viable eggs per egg mass was determined. Then the egg mass is kept between two microscopic slides (glass slides), crushed thoroughly, stained and examined under a microscope to count the remaining eggs. The number of viable eggs plus the eggs remaining in the egg sac gave the total number of eggs present per egg mass.

3.3.3 **Number of larvae per egg mass**

A fixed number of egg masses were hand picked and kept in sterile water in a petridish. The number of freshly emerged larvae was counted and from that the number of larvae per egg mass was determined.

3.3.3 **Number of female per 5 g root**

5 g root sample from the root system of plant was teased with a needle and examined under a microscope to count the number of females present.

3.3.4 **Estimation of nematode population in soil**

Nematodes were extracted from the representative soil samples following the modified method of Cobb's sieving and decanting technique. The nematodes thus extracted were counted.

3.3.5 **Estimation of nematode population in roots**

Nematode population in root sample was estimated by modified Baermann funnel technique as follows. Root samples collected were washed thoroughly in a steam of water under a tap. five g of the root was weighed and cut into small bits of 2-3 cm length and placed above the tissue paper supported by the wire guaze placed on a petri plate. After 24 hours the nematode suspension were collected, pooled and counted under a stereoscopic microscope. These were moistened and kept in 200 gauge polythene cover and incubated for 24 hours.

RESULTS

4. RESULTS

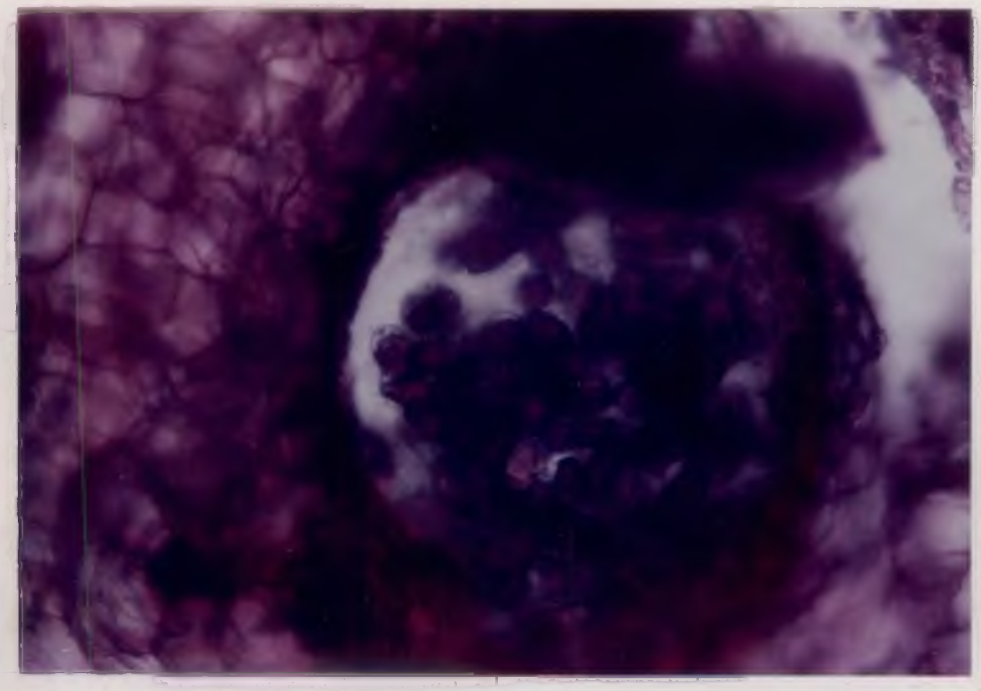
Pot culture experiments were conducted to study the biology, histopathology, the effect of soil factors like soil moisture, soil pH and soil type on the hatching and survival of *M. incognita* and the pathogenicity of the nematode in kacholam. Studies on the crop loss incurred by the nematode and its management strategies were tried in microplot condition. The result relating to the above aspects are presented herewith.

4.1. Biology of root-knot nematode in kacholam

Eggs are laid in egg masses embedded in gelatinous matrix adhering to the root tissues (Plate 1). The mean number of eggs per egg mass is 130. The eggs are ovate to oblong and arranged irregularly. Second stage larvae hatch from the eggs and invade new root lets near the tip, just above the root cap. They penetrate the cortex and establish themselves with the anterior end in contact with the vascular cylinder. Then they induce the formation of giant cells upon which they feed. Then the larvae grow slightly in length and assume a flask shape. The male, which appears as long filiform is seen folded inside the cuticle of fourth larval stage. The adult female at first retain the same shape of last larval stage then enlarges and become pyriform. Females after maturity move towards the periphery of root and lay eggs in egg masses outside the body (Plate 2). The mean period to complete one life cycle (from eggs to egg stage) is 37 days at a mean temperature of 27 ± 3^0C.

PlateI. Eggs in eggmasses embedded on the gelatinous matrix

Plate II. Section of kacholam root showing female nematode



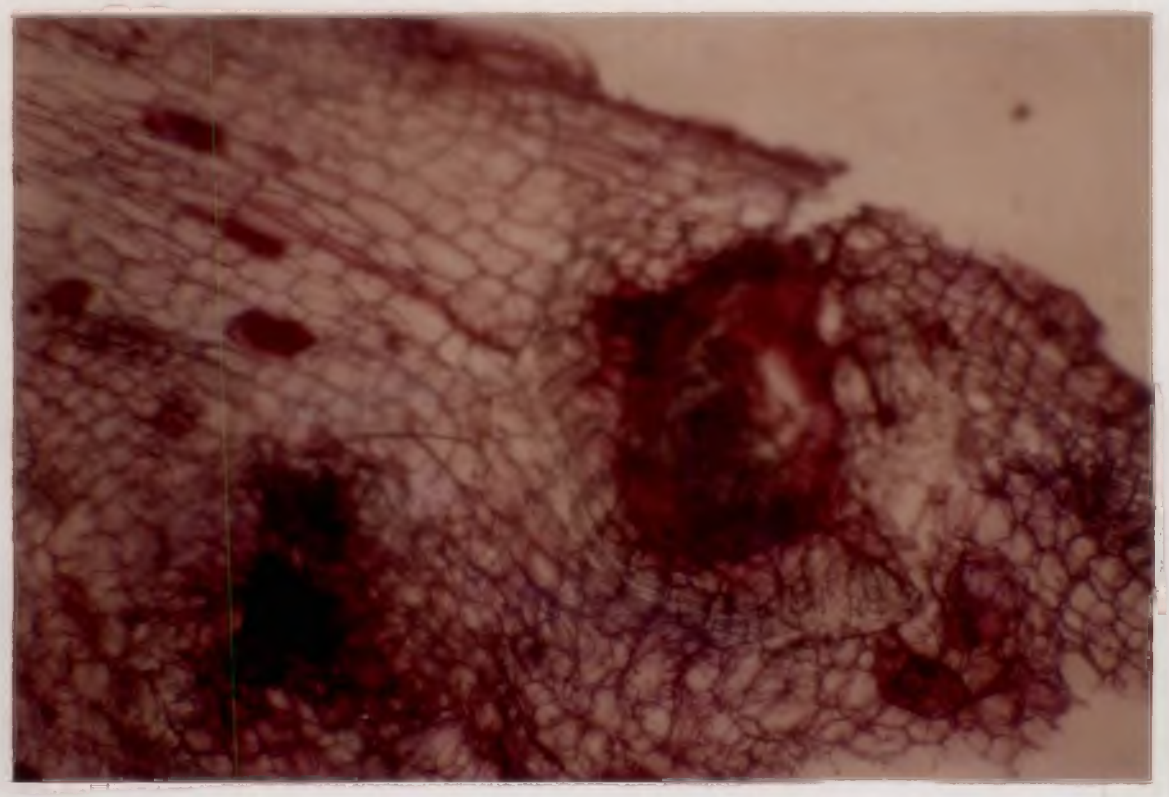
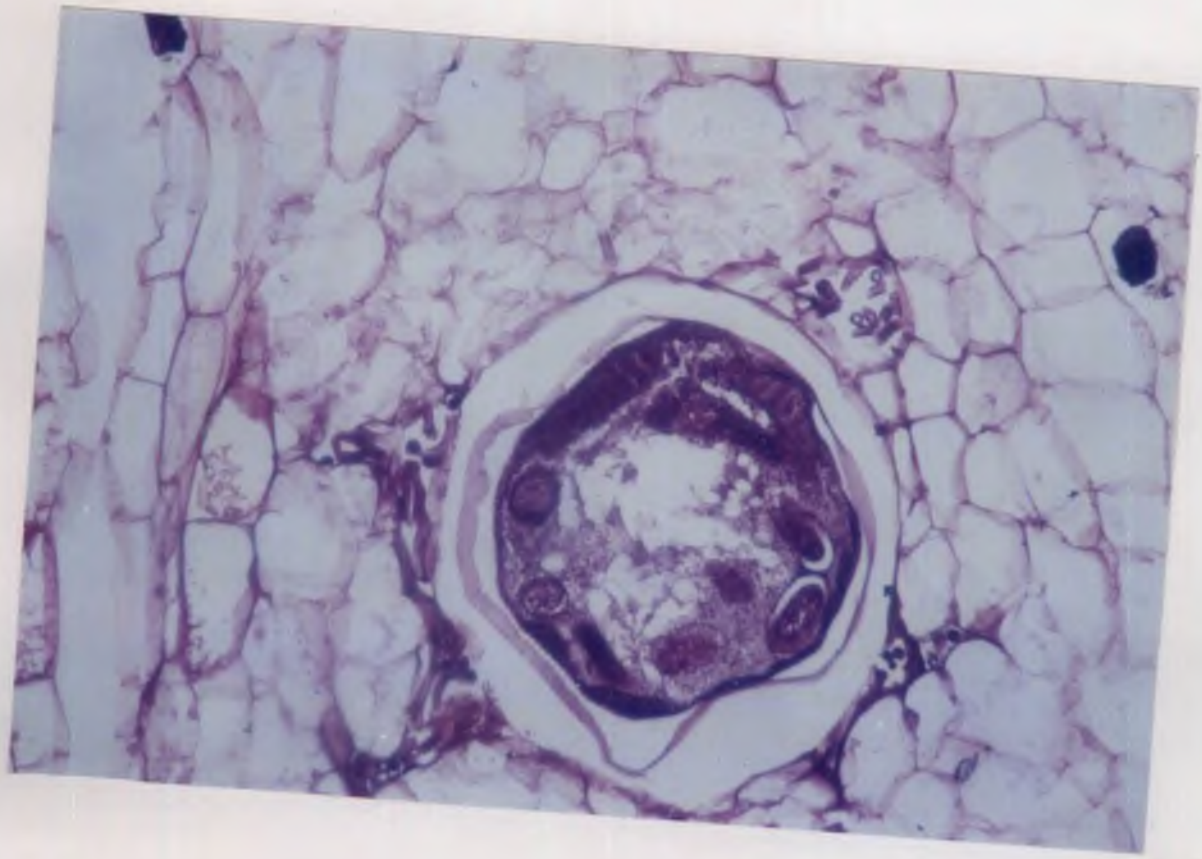
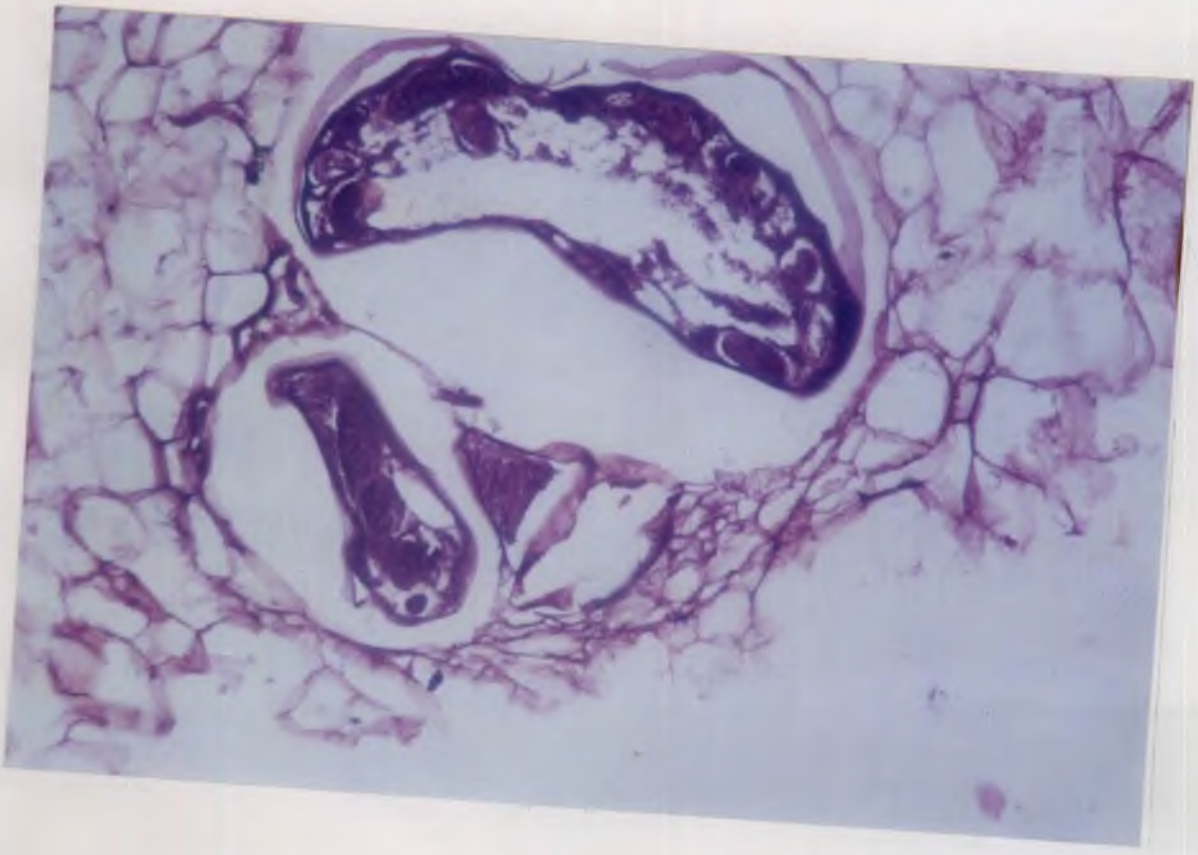


Plate III. Enlarged or hypertrophied cortical cell

Plate IV. Hypertrophied cortical cell in the process of cell wall disintegration





4.2. Histopathology of root-knot infested kacholam

Sections of healthy and infected roots of kacholam were prepared and examined under the microscope. Second stage juveniles of *M. incognita* penetrate the root tissues and established its feeding site on the vascular parenchyma. The head of the nematode was seen directed towards the stellar region. The nematode larvae mainly infest the xylem vessels, which affect the transport of food materials to various parts of the plant. The phloem vessels are not affected by the nematode. There is no difference between the phloem vessels in healthy and infested roots. Females of *M. incognita* induce hypertrophy of cortical cells to form the giant cell. The cytoplasm of the hypertrophied cells get shrivelled and located at the center of the cell. The parenchymatous cells of the nematode infested roots are slightly larger than the cells in uninfested roots (Plate III and IV). The giant cells observed are quartrangular in shape and three in number.

In longitudinal sections of infested roots taken at the time of harvest, many adult females were observed within the tissues. Numerous cavities are also seen which are formed by disintegration of giant cells, egg masses and adult females.

4.3. Evaluation of soil factors on the pathogenicity of root-knot nematode

4.3.1 Effect of soil moisture

4.3.1.1 On the hatching of eggs of *M. incognita*

Results presented in Table 1 showed that field capacity was the most suitable moisture level for the hatching of eggs of *M. incognita*. The

Table. 1 Effect of soil moisture on hatching of eggs of *M. incognita* at different periods
(mean of five replications)

Moisture levels	Percentage hatching at different intervals						
	2 dai	4 dai	6 dai	8 dai	10 dai	12 dai	14 dai
Flooding (F)	21.40 (4.73)	19.52 (4.53)	11.54 (3.54)	2.81 (1.95)	1.63 (1.62)	0.51 (1.23)	0.17 (1.08)
Field capacity (FC)	51.05 (7.21)	56.94 (7.61)	48.98 (7.07)	25.26 (5.12)	15.10 (4.01)	5.99 (2.64)	1.84 (1.69)
Permanent wilting point (PWP)	15.00 (4.00)	12.22 (3.64)	8.99 (3.16)	3.58 (2.14)	0.95 (1.40)	0.17 (1.08)	0.00 (1.00)
CD (0.05)	(1.48)	(1.35)	(1.29)	(0.77)	(0.65)	(0.65)	(0.39)

dai - days after inoculation
Figures in parenthesis are $\sqrt{x+1}$ transformed values

percentage hatching at field capacity ranged from 57 to 2 from second to fourteenth day after inoculation of *M. incognita* eggs with maximum hatch on fourth day. At flooding and permanent wilting point the highest percentage of hatching (21.4 and 15 respectively) was noticed at two days after inoculation and then a decreasing trend was noticed till fourteenth day. The moisture levels flooding and PWP were found to be on par at various intervals and is inferior to field capacity in the percentage hatching of eggs.

Table 2. Effect of soil moisture on the survival of *M. incognita* larvae in soil at different periods
(mean of 5 replications)

Moisture levels	Percentage survival at different interval			
	5 DAI	10 DAI	15 DAI	20 DAI
Flooding (F)	19.37 (4.51)	8.37 (3.06)	1.28 (1.51)	0.36 (1.17)
Field capacity (FC)	36.1 (6.09)	20.73 (4.66)	12.18 (3.63)	6.01 (2.65)
Permanent wilting point (PWP)	8.82 (3.13)	3.46 (2.11)	0.72 (1.31)	0.00 (1.00)
CD (0.05)	(1.02)	(0.43)	(0.57)	(0.43)

Figures in parenthesis are $\sqrt{x+1}$ transformed values

DAI - Days after inoculation

4.3.1.2 On the survival of *M. incognita* larvae

There was statistically significant variation in the effect of different soil moisture levels on the survival of *M. incognita* juveniles.

Table 3. Effect of soil pH on hatching of eggs of *M. incognita* at different periods
(mean of three replications)

Treatments (pH levels)	Number of larvae emerged at different periods													
	2 dai		4 dai		6 dai		8 dai		10 dai		12 dai		14 dai	
5.0	78.67	(8.93)	77.67	(8.87)	59.33	(7.74)	21.67	(4.76)	13.67	(3.83)	4.00	(2.27)	3.00	(2.00)
5.5	76.00	(8.77)	64.00	(8.06)	68.00	(8.30)	20.00	(4.58)	16.00	(4.12)	6.00	(2.65)	4.33	(2.31)
6.0	77.33	(8.85)	71.33	(8.50)	47.00	(6.93)	20.67	(4.66)	8.00	(2.95)	3.00	(2.00)	1.67	(1.63)
6.5	75.33	(8.74)	66.67	(8.22)	47.33	(6.94)	23.33	(4.93)	6.67	(2.68)	4.67	(2.38)	1.33	(1.53)
7.0	80.33	(9.02)	74.33	(8.68)	47.67	(6.81)	19.33	(4.51)	4.00	(2.52)	5.00	(2.45)	2.00	(1.73)
7.5	76.33	(8.79)	64.00	(8.06)	26.67	(5.19)	15.00	(4.00)	6.00	(2.20)	4.33	(2.37)	2.33	(1.82)
CD (0.05)		ns		ns		(1.153)		ns		ns		ns		ns

dai : days after inoculation

Figures in parenthesis are $\sqrt{x+1}$ transformed values.

The maximum juvenile survival was noticed at field capacity on different periods of observation. At field capacity, the percentage survival vary from 36.1 at 5 days after inoculation (dai) to 6.01 at 20 dai. Maximum survival of juveniles was noticed on 5 dai in all moisture levels. At 5 and 10 dai, the larval survival was found to be more in flooded condition than in PWP whereas at 15 and 20 dai they were on par (Table 2).

4.3.2 Effect of Soil pH

4.3.2.1 On the hatching of eggs of *M.incognita*

Results relating to the effect of soil pH on the hatching of *M. incognita* eggs at different intervals were presented in Table 3. The hatching of eggs observed from 2 to 14 days after inoculation of eggs (dai) revealed that there was no statistically significant variation in different levels of soil pH except on the sixth day after inoculation. On 2 dai the hatching percentage was 75 and 80 at a pH of 6.5 and 7.0 respectively. On 4 dai maximum hatching (78 per cent) was observed at a pH of 5.0 and minimum in pH 5.5 and 7.5. On six day, egg hatching varied significantly at different pH levels. Maximum hatching (68 per cent) was observed at a pH of .5.5 which was on par with pH of 5.0 (59 per cent). Minimum hatching was found at a pH of 7.5 (27 per cent). Eight days after exposure also the lowest egg hatching percentage was noticed at a pH of 7.5 revealing that alkaline pH is not fovourable for egg hatching. On 10 and 12 dai, maximum egg hatching was observed at a pH of 5.5 revealing that acidic condition is not detrimental to egg hatching.

Table 4 Effect of soil pH on the survival of *M. incognita* larvae at different periods
(mean of three replications)

Soil pH levels	Percentage survival at varying intervals							
	5 dai		10 dai		15 dai		20 dai	
5.0	48.33	(7.01)	38.00	(6.22)	14.67	(3.91)	4.00	(2.09)
5.5	41.33	(6.51)	20.30	(4.61)	8.00	(2.99)	2.67	(1.79)
6.0	30.67	(5.62)	21.00	(4.69)	9.33	(3.21)	2.67	(1.88)
6.5	26.67	(5.25)	16.00	(4.19)	3.67	(2.03)	0.67	(1.24)
7.0	24.33	(5.02)	19.33	(4.49)	2.67	(1.88)	0.67	(1.24)
7.5	19.00	(4.43)	8.67	(3.09)	1.67	(1.55)	0.33	(1.14)
CD (0.05)		(0.57)		(1.06)		(0.97)		(ns)

dai : days after inoculation

Figures in parenthesis are $\sqrt{x + 1}$ transformed values.

4.3.2.2 On the survival of *M.incognita* larvae

There was statistically significant variation in the percentage survival of *M.incognita* larvae at varying levels of soil pH on 5, 10 and 15 days after inoculation of the juveniles in *in vitro* condition. On 5 dai maximum juvenile survival (48 per cent) was in pH 5.00 which was on par with the pH 5.5 level. Minimum (19 per cent) survival was found at a pH of 7.5. At 10 dai, the survival of the larvae was maximum at a pH level of 5.0 and it is statistically superior to all other levels. The larval survival at pH levels 5.5, 6.0, 6.5 and 7.0 were statistically on par giving 16 to 20 per cent. Minimum survival of the larvae (8.67 per cent) was recorded at a pH level of 7.5. At 15 dai, the effect of survival of the larvae at pH levels 5 and 6 were on par. There was no statistically significant variation in the survival percentage of *M.incognita* larvae on varying levels of soil pH at 20 dai (Table 4).

4.3.3. Effect of soil type

4.3.3.1. Number of leaves

Results presented in Table 5 showed that there was significant variation in the number of leaves of kacholam at different population levels of *M. incognita* in various types of soil. In sandy soil (entisol), the maximum reduction in leaf number was observed in plants inoculated with 10, 000 larvae per plant (37 percent). The number of leaves produced in plants inoculated with 10, 100 and 1000 larvae of *M. incognita* are statistically on par.

In laterite soil (ultisol) the leaf number in plants inoculated with 10, 000 second stage juvenile (J_2) of *M. incognita* were on par with plants

Table. 5 Effect of different inoculum levels of *Meloidogyne incognita* on the number of leaves of kacholam on various soil types (mean of four replications)

Number of larvae inoculated per plant	Number of leaves in different soil types			
	Sandy (Entisol)	Percentage reduction	Laterite (Ultisol)	Percentage reduction
0	21.75	-	25.00	-
10	21.00	3.44	23.75	5.00
100	19.25	11.49	21.50	14.00
1000	18.75	13.79	19.25	23.00
10000	13.75	36.78	16.50	34.00
CD (0.05)	4.45		3.64	
	Red (Oxisol)	Percentage reduction	Forest (Alfisol)	Percentage reduction
0	27.75	-	28.75	-
10	26.25	5.41	26.75	5.30
100	23.75	14.40	24.00	15.00
1000	20.00	27.90	21.75	23.00
10000	17.75	36.00	18.50	34.50
CD (0.05)	4.03		3.61	

inoculated with 1000 J_2 giving 19 and 17 leaves per plant respectively. The effect of 1000 J_2 was on par with 100 J_2 per plant. The average number of leaves in uninoculated plant was 25, which was on par with plants inoculated with 10 J_2 and 100 J_2 with 24 and 25 leaves per plant respectively.

In red soil (oxisol), leaf production in plants inoculated with 100, 1000 and 10,000 larvae were statistically on par ranging from 18 to 24 per plant. The percentage reduction in leaf number was maximum in plants inoculated with 10, 000 J_2 (36).

In forest soil (alfisol), leaf number in uninoculated control plant (28) was on par with plants inoculated with 10 J_2 and 100 J_2 . The effect of reduction in leaf number was uniform in 100 and 1000 J_2. The 1000 and 10,000 J_2 levels were statistically on par causing 23 and 35 percent reduction in number of leaves of kacholam plants.

At the highest level of larval inoculum, the percentage reduction in leaf number vary from 34 to 37 in laterite and sandy soil respectively.

4.3.3.2. Weight of roots

The weight of roots recorded from kacholam plants grown in different soil type revealed statistically significant variation in root production at different inoculum levels of *M.incognita* on various soil types (Table. 6).

In sandy soil, plants inoculated with 10,000 J_2 recorded the lowest root weight (36.25 g). It was followed by the 1000 and 100 J_2 levels which were statistically on par giving 77.86 percent reduction over uninoculated control plants. Plants inoculated with 10 J_2 were statistically different from the above

Table. 6 Effect of different inoculum levels of *M. incognita* on the root weight of kacholam on various soil types (mean of four replications).

Number of larvae inoculated per plant	Root weight (g) in different soil types			
	Sandy (Entisol)	Percentage reduction	Laterite (Ultisol)	Percentage reduction
0	163.75	-	166.25	-
10	116.25	29.01	141.25	15.04
100	82.50	49.62	126.25	24.10
1000	61.25	62.60	79.25	52.33
10000	36.25	77.86	61.75	62.85
CD (0.05)	22.68		13.57	
	Red (Oxisol)	Percentage reduction	Forest (Alfisol)	Percentage reduction
0	202.50	-	211.25	-
10	188.75	6.79	188.75	10.65
100	158.75	21.60	148.75	29.59
1000	137.50	32.10	120.00	43.20
10000	101.25	50.00	107.50	49.11
CD (0.05)	16.62		14.46	

levels with 29 percent reduction over uninoculated (control) plants. Percentage reduction in root weight at different levels of larval inoculum ranged from 29 to 78.

In laterite soil, the mean root weight was minimum (61.25 g) in plants with 10,000 J_2 level followed by 1000, 100 and 10 J_2 levels having 79.25, 126.25 and 141.25 g roots respectively. The percentage reduction in root weight ranged from 15.04 to 62.85 in plants inoculated with 10 larvae to 10,000 larvae.

Mean root weight of uninoculated plant was statistically on par with 10 J_2 level in red soil. The reduction in root weight was 50 per cent in plants inoculated with 10,000 J_2 while it was 32 and 23 percent respectively in 1000 and 100 J_2 levels.

In forest soil, root weight of plants at different inoculum levels varied from 107.5 to 211.25 g. Mean root weight of plants with 10,000 J_2 level was 107.5 g which was statistically on par with 1000 J_2 level having 120 g root weight. Percentage reduction in root weight over control plants was maximum for 10,000 J_2 level (49-11) followed by 1000, 100 and 10 J_2 levels having 43.2, 29.59 and 10.65 percent reduction respectively. The reduction in root weight was maximum in sandy soil in all the inoculum levels ranging from 29 to 78 per cent.

4.3.3.3. Yield

Yield (rhizome weight) of kacholam varied significantly at different inoculum levels of *M. incognita* on various soil types (Table. 7).

Table. 7 Effect of different inoculum levels of *M. incognita* on the yield (rhizome weight) of Kacholam on various soil types (mean of four replications)

Number of larvae inoculated per plant	Rhizome weight (g) in different soil types							
	Sandy (Entisol)	Percentage reduction	Laterite (Ultisol)	Percentage reduction	Red (Oxisol)	Percentage reduction	Forest (Alfisol)	Percentage reduction
0	213.75	-	210.50	-	220.00	-	240.00	-
10	195.00	8.77	191.25	9.14	206.25	6.25	207.50	13.54
100	147.50	30.99	161.25	23.40	177.50	19.32	188.75	21.35
1000	128.00	40.12	143.75	31.71	165.00	25.00	157.50	34.38
10000	87.50	59.06	108.75	48.34	135.00	38.64	140.00	41.67
CD (0.05)	18.77		20.54		22.16		12.72	

In sandy soil, lowest yield was obtained in plants inoculated with 10,000 J_2 level (87.5 g) followed by plants with 1000 J_2 (128 g) and 100 J_2 (147.5 g). Yield of plants with 10 J_2 level was statistically on par with uninoculated control plants. Percentage reduction in yield at different inoculum levels ranged from 9 to 59.

Rhizome weight of kacholam grown in laterite soil was influenced by different levels of *M. incognita* larval inoculation. Plants inoculated with 10 J_2 produced 191.25 g rhizome which was statistically on par with uninoculated plants (210.5 g). Weight of rhizome in plants with 100 J_2 and 1000 J_2 levels were also on par. Lowest yield was recorded by plants inoculated with 10,000 J_2 of *M. incognita* larvae (108.75 g). Percentage reduction in yield varied from 9 to 48 in 10 J_2 level to 10,000 J_2 level.

In red soil, lowest yield was obtained in plants inoculated with 10,000 J_2 (135 g), with an yield reduction of 38.64 percent over untreated (control) plants. The 100 J_2 and 1000 J_2 levels were statistically on par producing 177.5 and 165.5 g rhizomes respectively. Inoculum level of 10 larvae per plant was on par with uninoculated plants. Reduction in rhizome weight in different inoculum levels over control ranged from 6 to 39 per cent.

The effect of various levels of larval inoculum resulted statistically significant difference in the yield of kacholam grown on forest soil. Uninoculated plants recorded the highest yield (240 g) and then decreased with increasing level of larval inoculum (10 to 10,000 J_2). The rhizome weight at different levels of J_2 varied from 140 to 207 g. Highest reduction in yield was recorded in 10,000 J_2 (42 percent over untreated) (Table 7).

Table. 8 Effect of different soil types on number of eggs, females, root - knot count and gall index 8 months after inoculation (mean of four replications)

Soil types	Root - knot count per 5 g root sample	Root - knot index	Number of eggs per egg mass	Number of females per 5 g root sample
Sandy	13	3	154	16
Laterite	9	2	135	13
Red	10	2	148	12
Forest	10	2	139	15
CD (0.05)	-		ns	ns

4.3.3.4. Root- knot count

Root-knot count in 5 g root sample and gall indices were presented in Table-8. The result indicated that root - knot count was maximum in sandy soil and minimum in laterite soil followed by red and forest soil. The root - knot indices were also uniform for the laterite, red and forest soil (root-knot index -2 each).

4.3.3.5. Number of eggs per egg mass

There was no statistically significant variation in the number of eggs per egg mass collected from roots of kacholam plant grown in different types of soil. The average number of eggs per egg mass varied from 135 to 154 in laterite and sandy soil respectively (Table - 8).

4.3.3.6. Number of females

Statistical analysis of data revealed that there was no statistically significant variation in the number of females per 5 g root sample collected

Table. 9 Effect of different inoculum levels of *M. incognita* on the final population of nematode in various soil types (mean of four replications)

Inoculum levels (*M. incognita* larvae per plant)	*M. incognita* population in soil sample (100 g)			
	Sandy	Laterite	Red	Forest
0	0 (1)	0 (1)	0 (1)	0 (1)
10	56.75 (7.57)	39.00 (6.31)	37.00 (6.17)	41.00 (6.50)
100	67.75 (8.29)	49.00 (7.07)	49.75 (7.12)	54.50 (7.40)
1000	78.25 (8.90)	56.30 (7.56)	60.75 (7.84)	66.75 (8.20)
10,000	88.00 (9.43)	60.80 (7.86)	68.00 (8.29)	81.25 (9.04)
CD (0.05)	(0.659)	(0.464)	(0.74)	(0.48)

Figures in parenthesis are $\sqrt{x+1}$ transformed values

from kacholam grown in various soil types. Average number of females in 5 g root sample ranged from 12 to 16 (Table -8).

4.3.3.7. Nematode population in soil

The results relating to population of nematode in kacholam rhizosphere was presented in Table -9. Analysis of data on nematode population in soil at the time of harvest (eight months after planting) revealed that there was statistically significant variation in the number of nematodes present at varying levels of *M. incognita* in different soil types.

In sandy soil, maximum nematode population (88 larvae per 100 g soil) was recovered from 10,000 J_2 level which was on par with 1000 J_2 level (78 larvae per 100 g soil). The recovery of nematodes in 1000 J_2 level was on par with 100 J_2 level (68 larvae per 100 g soil).

The mean number of *M. incognita* recovered from laterite soil the soil was 56 per 100 g sample in treatment having 1000 larvae and 61 per 100 g in 10,000 J_2. The effect of two inoculum levels were statistically on par and higher than other levels of *M. incognita* (100 J_2 and 10 J_2).

In red soil, maximum recovery of nematode population was present in 10,000 J_2 level (68 per 100 g soil sample). *M. incognita* recovered from 100 J_2 (50 per 100 g soil sample) and 1000 J_2 (60 per 100 g soil sample) were statistically on par. The mean number of larvae recovered from forest soil also showed statistical significance. The maximum number of *M. incognita* were recovered from an inoculum level of 10,000 J_2 per plant (81 per 100 g sample).

4.4. Pathogenicity

The results relating to the pathogenicity of *M. incognita* tested in kacholam under pot culture conditions in different soil types are presented in Tables 5, 6, 7 and 9.

4.4.1. Number of leaves

Reduction in leaf number was noticed from 100 J_2 per plant onwards in all soil types studied. The higher levels of inoculum such as 1000 and 10,000 J_2 was statistically on par in laterite, red and forest soils (Table 5).

4.4.2. Weight of roots

The root weight of kacholam recorded from plants with different levels of inoculum indicated that its reduction was statistically significant from 10 J_2 level onwards in all soils except red soil. In red soil significant reduction in root weight was observed only at 100 J_2 level. The percentage reduction in root weight was maximum at 10,000 J_2 level in sandy soil (78) followed by literate (63) and minimum in forest soil (Table 6).

4.4.3. Yield

The yield in terms of rhizome weight was reduced significantly in all the soil types studied. In laterite and red soil 100 and 1000 J_2 levels were statistically on par. Highest reduction in yield at 10000 J_2 level was obtained in sandy soil (59 per cent) followed by laterite (48 per cent) and minimum in red soil (39 per cent) (Table 7).

4.4.4. Nematode population in soil

Results presented in Table 9 revealed that the recovery of nematode from soil at the time of harvest of the crop was maximum at 10,000 J_2 level in all the soil types. In sandy soil the effect of inoculation of 100, 1000 and 10,000 J_2 were statistically on par. The number of larvae recovered from 100 g soil samples was 57 at 10 J_2 level and 88 at 10,000 J_2 level in sandy soil. In laterite soil the 1000 and 10,000 J_2 levels were statistically on par giving 56 and 61 larvae respectively, while in red soil the 100 and 1000 larvel levels of *M. incognita* were on par. In forest soil the number of larvae recovered from 100 g soil sample at 10,000 J_2 level was 81 which is almost double than at 10 J_2 level.

4.5 Crop loss assessment

The data on the effect of different levels of *M. incognita* population on various biometric characters and yield of kacholam were furnished in Table 10.

4.5.1 Number of leaves

There was statistically significant variation among different treatments on the production of leaves. The average number of leaves of the plants inoculated with *M. incognita* larvae at varying levels ranged from 29 to 42 while the average number of leaves in the control plant was 51. The effect of inoculation of 500 larvae were on par with that of 200 larvae per plant. Minimum number of leaves was produced by the plants inoculated with 1000 larvae per plant (Plate V). The percentage reduction in number of leaves over

Table. 10 Effect of different population levels of *M. incognita* on the biometric characters and yield of *K. galanga*

Number of larvae inoculated per plant	Number of leaves	% decrease over control	Length of rhizome (cm)	% decrease over control	Weight of roots (g)	% Decrease over control	Per plant yield (g)	% decrease over control	Yield per plot (kg)	% decrease over control
0	51.35		14.68		192.13		87.43		2.14	
200	41.93	18.34	13.75	6.34	162.38	15.49	71.55	18.16	1.84	14.02
500	37.93	26.13	14.00	4.63	130.50	32.08	46.13	47.24	1.56	27.10
1000	29.10	43.33	11.20	23.71	103.25	46.26	31.75	63.69	1.21	43.46
CD (0.05)	7.94		1.79		18.94		11.94		0.114	

control ranged from 18.34 to 43.33 in various population levels ranging from 200 to 10000 larvae.

4.5.2 Length of rhizome

A significant reduction was seen in the rhizome length of plants inoculated with different levels of *M. incognita* larvae. It was minimum in plants inoculated with 1000 larvae (11.2). Length of rhizome of plants inoculated with 200 and 500 larvae were on par with plants under control. The percentage reduction in rhizome length vary from 6.34 to 23.71.

4.5.3 Weight of roots

Statistical analysis of the data revealed that there is significant variation in the root weight of different treatments. The lowest root weight (31.75 g) was recorded in plants inoculated with 1000 larvae. The percentage reduction in weight of roots over control ranged from 15.49 to 46.26 per cent in 200 to 1000 larval level.

4.5.4 Yield per plant

There was statistically significant variation in the yield, in terms of weight of rhizome produced per plant in different treatments. The average yield on inoculated plants ranged from 31.75 to 87.43 g while in the uninoculated control the rhizome weight was maximum (87.4 g). In plants inoculated with 1000 larvae the yield was minimum (31.75 g).

Plate V. Effect of different levels of larval inoculum of *M. incognita* on kacholam plants


CONTROL
200 J2
1000 J2

4.5.5 Yield per plot

The various levels of nematode population showed significant reduction in the yield per plot compared to control. The average yield of control plot was 2.14 kg while that of the inoculated plots ranged from 1.21 to 1.84 kg per plot. The lowest yield was recorded in plots inoculated with 1000 larvae. The yield reduction per plot yield vary from 14.02 to 43.46 per cent (Table 10).

4.5.6 Nematode population

4.5.6.1 In soil

Statistical analysis of the data indicated significant difference in the population of *M. incognita* in soil collected at different intervals. Two months after planting (MAP), maximum number of nematodes (14 per 100 g soil) were observed in soil sample collected from plots inoculated with 1000 larvae per plant. Population of *M. incognita* on 4 MAP showed that the treatment 1000 larvae per plant was on par with 500 larvae per plant and the latter was on par with 200 larvae per plant. On 6 and 8 MAP, highest population of *M. incognita* was present in soil samples collected from plots inoculated with 1000 larvae per plant (Table 11).

4.5.6.2 In roots

The larval population estimated from the roots varied significantly in different treatments. Population of *M. incognita* in roots at the time of harvest was maximum in 1000 J_2 level (96 per 5 g root) and the populations were 78 and 53 in 500 and 200 J_2 levels respectively.

Table11. Effect of different inoculam levels of *M. incognita* on the population of nematodes in Kacholam rhizosphere at various intervals (mean of four replications)

Number of larvae inoculated per plant	*M. incognita* in 100 g soil sample at two months interval								*M. incognita* in 5 g root sample		Root-knot count per g sample	Gall index
	2 MAP		4 MAP		6 MAP		8 MAP		8 MAP			
0	0	(1.00)	0	(1.00)	0	(1.00)	0	(1.00)	0	(1.00)	0	0
200	6.00	(2.65)	11.5	(3.54)	16.5	(4.18)	29.0	(5.48)	52.75	(7.30)	4	1
500	9.50	(3.24)	16.5	(4.18)	31.75	(5.72)	46.5	(6.89)	77.50	(8.86)	9	2
1000	13.75	(3.84)	22.5	(4.85)	54.75	(7.46)	62.0	(7.9)	95.75	(9.84)	12	3
CD (0.05)		(0.36)		(0.95)		(0.888)		(0.85)		(1.54)	-	-

MAP : Months after planting

Figures in parenthesis are $\sqrt{x+1}$ transformed values

4.5.6.3. Root-knot count

The root-knot count per gram root sample was maximum in 1000 J_2 level followed by 500 and 200 J_2 levels. The index also increased from one to three from 200 to 1000 J_2 levels (Table 11.

4.6 Management of root-knot nematodes in kacholam

The results of management trial are presented in Table 12.

4.6.1 Number of leaves

The number of leaves per plant at the time of harvest showed statistically significant variation. The neem cake treated plants produced maximum number of leaves (46) followed by VAM (45) and these two were statistically on par and superior to untreated plants (Plate VI). The average number of leaves in untreated plant (29) was on par with the carbofuran treatment (37) (Table 12).

4.6.2 Length of rhizome

The results presented in Table 12 showed that the mean length of rhizome varied significantly in different treatments and length ranged from 11.2 cm in control plants to 14.43 cm in neem cake treated plants. Neem cake treatment was significantly superior to all other treatments. VAM and carbofuran treatments were on par and superior to control.

4.6.3 Weight of roots

Statistical analysis of the data pertaining to the root weight of kacholam plants under various treatments revealed significant difference between control

Table. 12 Effect of different management practices on the biometric characters and yield of *K. galanga* (mean of four replication)

Treatments	Number of leaves	Length of rhizome (cm)	Weight of roots (g)	Yield per plant (g)	Yield per plot (kg)
T_1 (Neem cake 200 g / m^2)	46.03	14.43	84.13	189.75	2.27
T_2 (Carbofuran 3.33 g / m^2)	37.18	13.13	52.38	168.35	2.00
T_3 (VAM 300 g inoculum / m^2)	44.85	12.93	70.13	163.50	2.05
T_4 (Untreated)	29.10	11.20	31.75	103.13	1.21
CD (0.05)	10.02	0.977	13.63	22.35	0.265

and other treatments. Neem cake treated plants produced a mean root weight of 84.13 g which was superior to all other treatments. Next best treatment was VAM, with a mean root weight of 70.13 g which is statistically superior to carbofuran treatment (Table 12).

4.6.4 Yield per plant

The result presented in Table 12 showed statistically significant variation in per plant yield in terms of weight of rhizome. Neem cake treated plants have the highest rhizome weight (189.75 g) followed by carbofuran (168.35 g) and they were on par. The VAM treatment was on par with the carbofuran treatment and they were superior to untreated control.

4.6.5 Yield per plot

The average yield per plot vary from 2 kg to 2.27 kg in various treatments. The neem cake treated plots produced 2.27 kg rhizomes which was statistically on par with carbofuran treatment with a mean yield of 2.0 kg rhizomes per plot and VAM treatment with 2.05 kg rhizomes per plant. All the treatments were statistically superior to untreated control (Table 12).

4.6.6 Number of egg mass per root-knot

There was no statistically significant variation in the number of egg masses present per root-knot. The average number of egg mass per root-knot varied from two in the treated plants to three in the untreated control plants (Table 13).

Plate VI. Effect of different management practices on kacholam

a) **Neem cake (200 g / m^2) treated plot**

b) **Carbofuran (3.33 g / m^2) treated plot**


Neem


Carb

Plate VI. Effect of different management practices on kacholam

c) VAM (300 g inoculum / m^2) treated plot

d) Untreated control


VAM


C

4.6. 7 Number of larvae emerged per egg mass

The mean number of larvae emerged from single egg mass ranged from 76 in VAM treated plants to 115 in control plants. The average number of larvae emerged from the egg masses of neem cake treated plants and carbofuran treated plants were 78 and 80 respectively (Table 13).

Table 13. Effect of different management practices on the population characteristics of *M. incognita*.

Treatments	Larvae in 5 g root	Root-knot count per g root	Gall index	Number of egg mass per root knot	Number of larvae per egg mass
T_1 (Neem cake 200 g / m^2)	21.50	4	1	1.75	78.00
T_2 (Carbofuran 3.33 g / m^2)	40.50	5	1	1.50	80.00
T_3 (VAM 300g inoculum / m^2)	28.50	5	1	2.00	76.25
T_4 (Untreated)	83.25	12	3	2.75	115.00
CD (0.05)	37.65	-	-	ns	ns

4.6.8. Root-knot count

The root-knot count is lowest in neem cake treated plants (4) while it is uniform in carbofuran and VAM treatments (5). The root-knot count in the untreated control plant is very high (12). The gall index was one in all the treatments as against the index of three in control plants.

4.6.9. Nematode population

4.6.9.1. In root

Application of neem cake, carbofuran and VAM significantly reduced the number of root-knot nematodes present in root samples. The mean

Table. 14 Effect of different management practices on the population of *M. incognita* in 100 g soil sample taken at various intervals (mean of four replications)

Treatments	2 MAP	4 MAP	6 MAP	8 MAP	% reduction
T_1 (Neem cake)	8.10	10.50	20.25	19.50	68.050
T_2 (Carbofuran)	8.50	11.75	21.00	25.25	59.27
T_3 (VAM)	11.00	10.50	33.50	35.00	43.55
T_4 (Untreated)	13.75	22.50	54.75	62.00	-
CD (0.05)	3.10	9.46	10.40	13.80	-

population of larvae in root samples ranged from 22 to 41 per five g root in the various treatments as against 83 in untreated control. Lowest number of nematodes were present in the roots of neem cake treated plants (22) followed by VAM (29) and carbofuran (41) treatments respectively. The effect of these three treatments was statistically on par and superior to untreated control. (Table 13).

4.6.9.2. In soil

The variation in soil population of root-knot nematode examined at 2, 4, 6 and 8 months after planting were presented in Table 14. All the management practices significantly reduced the nematode population. Neem cake treatment was found superior in reducing the population of nematodes in soil throughout the crop period. Two months after planting the treatments, neem cake, carbofuran and VAM were statistically on par. The control plots supported the maximum nematode population which was on par with VAM treatment. Estimation of nematode population in soil four months after planting of kacholam revealed that both neem cake and VAM treatments have the same population of root-knot nematode (10.5/ 100 g soil sample). The population of root-knot nematode estimated six and eight months after planting indicated that neem cake application was found to be the best in reducing the population of nematode in soil, followed by carbofuran and VAM treatments respectively. At the termination of the experiment neem cake reduced the population of nematodes in the soil to a tune of 68 per cent over uninoculated control.

DISCUSSION

5. DISCUSSION

In the present study the basic aspects such as the biology of root-knot nematode *M. incognita* on kacholam, its histopathology and the effect of various soil factors like soil type, moisture and pH on the hatching, multiplication and survival of *M. incognita* were tested. The avoidable loss in yield incurred by *M. incognita* on kacholam under field condition was assessed. Field trials were also conducted in *M. incognita* infested microplots to develop suitable strategies for the management of root-knot nematode. The results on the above aspects were assessed in terms of the number of leaves, weight of roots, rhizome weight etc.

Though lot of information on the biology of *M. incognita* is available on several hosts, there is hardly any information on the biology of *M. incognita* on kacholam. The biology of *M. incognita* was worked out in kacholam and is presented in para 4.1. The result revealed that the eggs are laid in egg masses embedded on gelatinous matrix adhering to root tissues as in other host plants. The mean number of eggs per egg mass collected from kacholam root is 130. Dhawan and Sethi (1976) observed 305 eggs per egg mass collected from egg plant roots. The reduced rate of egg production in kacholam roots may be due to difference in the nutrient status or host acceptability of the nematode. This view was already expressed by Dasgupta and Gaur in 1986. They observed that total number and size of eggs of *M. incognita* were influenced by the host status and the level of environmental stress. The second stage larvae invade the tender roots and penetrate the cortex. The mean period to complete one

life cycle (from egg to egg stage) in kacholam plant is 37 days at room temperature of (27 ± 3^{0}C). A more or less same duration was observed in egg plant by Dhawan and Sethi (1976). They reported 36 days for the completion of one life cycle of *M. incognita* on egg plant. In gauva, the life span of *M. incognita* varied from 26 to 30 days at a mean temperature of 29 and 24 ^{0}C respectively (Fernandez *et al.*, 1986). But in Japanese mint var. Shivalik the life cycle of *M. incognita* was completed in 29 days.

The histopathology of kacholam roots infested by *M. incognita* was studied for the first time and the results are presented in para 4.2. The stellar portion of the kacholam roots was attacked by *M. incognita* larvae and the head of the nematode was directed towards the stellar portion. Similar observation was made on coleus by Sosamma (1988). In kacholam roots, within the stele, the nematode larvae mainly infest the xylem vessels and the phloem vessels are more or less intact. This finding is in agreement with the observations made in pepper by Jacob (1977) and ginger by Charles (1978). But there are controversial reports also in this regard. Siddiqui *et al.* (1974) recorded that the phloem and intra fascicular region of the root was affected by *M. incognita* larvae. Shetty and Rudramuniyappa (1992) also reported the target of infection of *M. incognita* larvae is the phloem and ray parenchyma cells in mulberry roots.

Females of *M. incognita* induce hypertrophy of cortical cells to form the giant cell. The cytoplasm of the hypertrophied cells get shrivelled and located at the centre of the cell. The parenchymatous cells of the nematode infested roots are slightly larger than the cells in uninfested roots. It might be due to

the dissolution of cell walls and merging of adjacent cells. Similar findings were made on coleus by Sosamma (1988). The giant cells caused by *M. incognita* on kacholam roots are quadrangular and three in number while in other roots the minimum number of giant cells observed is two. In different host plants the number ranged from two to six. The giant cells ranged from four to six in pepper (Jacob, 1977) two to six in egg plant (Pasha *et al.*, 1977) and four in coleus (Sosamma, 1988).

In longitudinal sections of the roots taken at the time of harvest, many adult females and numerous cavities were noticed within the root. Sosamma in 1988, reported that these cavities were caused by the deterioration of giant cells and death of adult females within the tissues. Thus the favourable host plants should behave in an advantageous manner for the proper development of the nematode.

There is always a soil phase in the life cycle of all the nematodes which influence greatly the distribution and multiplication of the nematode species. The effect of soil moisture on the hatching of egg and survival of *M. incognita* was studied *in vitro* and the results are presented in para 4.3.1. Moisture at field capacity was the most suitable moisture level for the hatching of eggs of *M. incognita*. At flooding and permanent wilting point, the highest percentage hatching (21 and 15 per cent respectively) was noticed 2 days after exposure of eggs and then a decreasing trend was noticed till fourteenth day.This indicates that sufficient soil moisture is essential for the proper hatching of *M. incognita* eggs. At high moisture level (flooding), hatching of *M. incognita* was higher than at permanent wilting point (PWP). The investigations done by Khan *et al.*

(1986) revealed that high moisture did not prevent hatching of *M. incognita* but lowered nematode mobility. But according to Couch and Bloom (1960), the eggs of *M. hapla* hatched equally well at field capacity and PWP and the nematode mobility is reduced under low moisture conditions. Daulton and Nusbaum (1962) also made similar observations in *M. incognita*. This reduced nematode mobility may contribute to the low extraction of *M. incognita* under flooding and PWP.

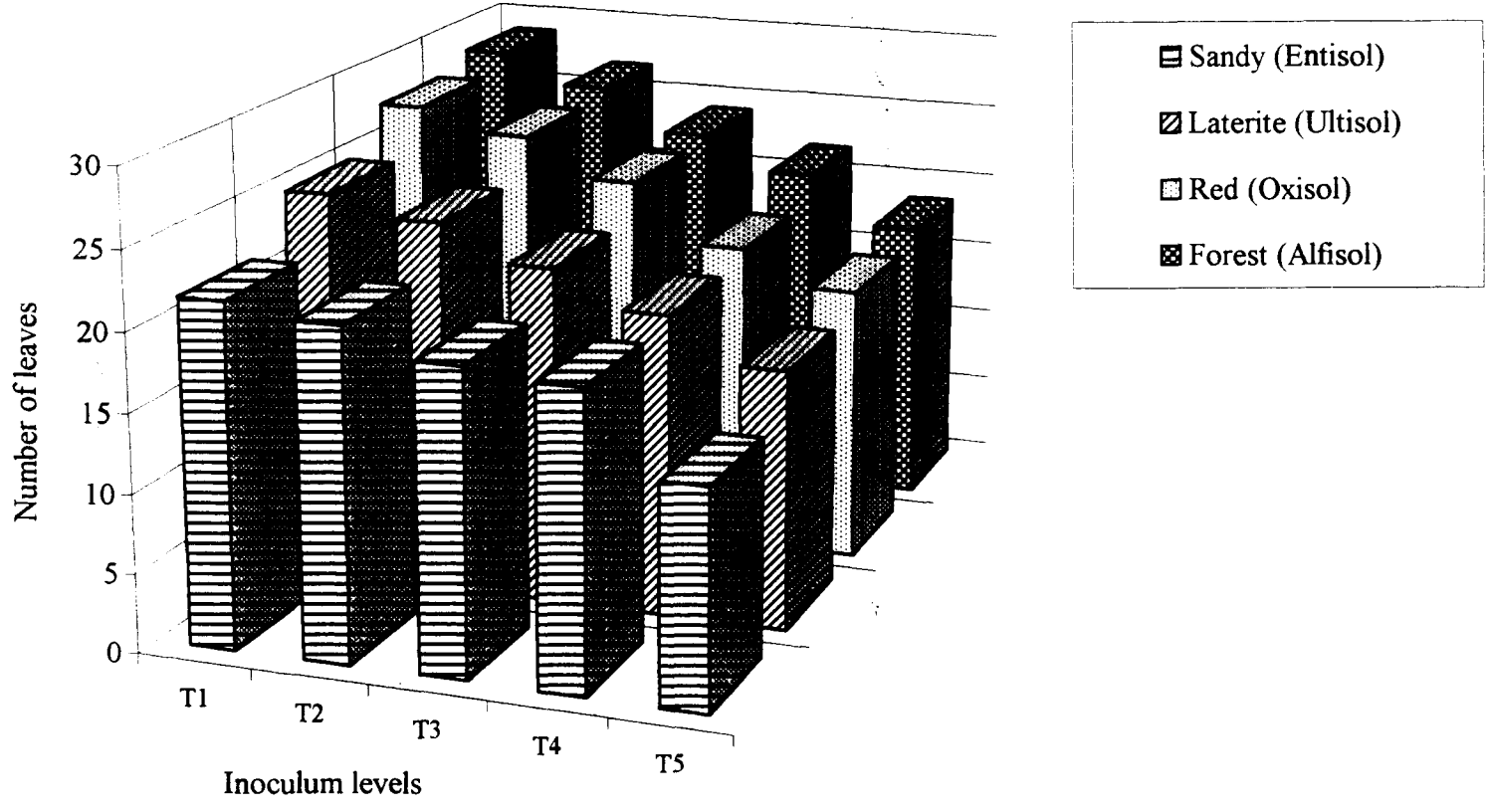
The maximum survival of *M. incognita* larvae was noticed at field capacity at different stages of observation. At field capacity, the percentage survival vary from 36 to 6 at 5 and 20 days after inoculation respectively. This was in line with the findings of several workers. Couch and Bloom (1960) reported that the root-knot counts were significantly higher on tomato plants grown at field capacity and absent or few on roots at PWP. According to Gaur and Sehgal (1988) the maximum survival of second stage larvae of *M. incognita* (J_2) took place at 0.8 bars moisture tension and the nematode persist for a period of 450 days in sandy loam soil without a host plant at a soil moisture of 0.01 to 30 bars. At all moisture levels, the maximum survival of *M. incognita* larvae taken from kacholam roots was recorded as five days.

The pH of the soil was found to affect the nematode development. The effect of soil pH in the hatching of eggs of *M. incognita* was studied *in vitro* and the results are presented in para 4.3.2.1. The results revealed that the maximum egg hatching was noticed at a pH of 5.5 and minimum at a pH of 7.5. This revealed that acidic condition is favourable for the hatching of eggs of *M. incognita*. The effect of soil pH on the survival of *M. incognita* larvae was

presented in para 4.3.2.2. Maximum larval survival was observed at a pH of 5 and minimum at pH 7.5 on 5, 10 and 15 days of exposure of the larvae under *in vitro* condition. This result also stressed that acidic condition is favourable for the survival of *M. incognita* larvae. Supporting observation in this regard was made by many workers. Sumangalakuttyamma (1975) found that the development of root-galls of bhindi was minimum in black soil having a pH of 7.5. According to Naseem and Jairajpuri (1982), nematodes generally prefer soil pH between 5.0 and 6.0 and cannot survive in highly acidic or alkaline conditions. But Sheila *et al.* (1985) found that the development of root-knot nematode was more in plants grown at a neutral pH (7.0) than at highly acidic (pH 3.0) and highly alkaline condition. (pH 9.0).

The effect of different soil types on the pathogenicity of root-knot nematode on kacholam was studied under pot culture condition. The results in terms of plant growth characters and root-knot development as influenced by soil types and different levels of larval inoculation were presented in para 4.3.3 and 4.4. In all the soil types, percentage reduction in plant growth parameters increased as the inoculum level increases. Reduction in leaf number (three to 37 per cent occurred from 100 J_2 per plant onwards and higher levels such as 1000 and 10,000 J_2 was statistically on par in all these soils except sandy (para 4.3.3.1). Maximum percentage reduction on various growth characters was observed at 10,000 J_2 level in all soil types (Fig. 1). This observation is in conformity with that of Nakasono *et al.* (1989). They reported that the average fresh weight of above ground parts of tomato seedlings grown in different soil types decreased with increased inoculum levels. At 10,000 J_2

Fig. 1. Effect of different inoculum levels of *M. incognita* on the number of leaves of kacholam on various soil types

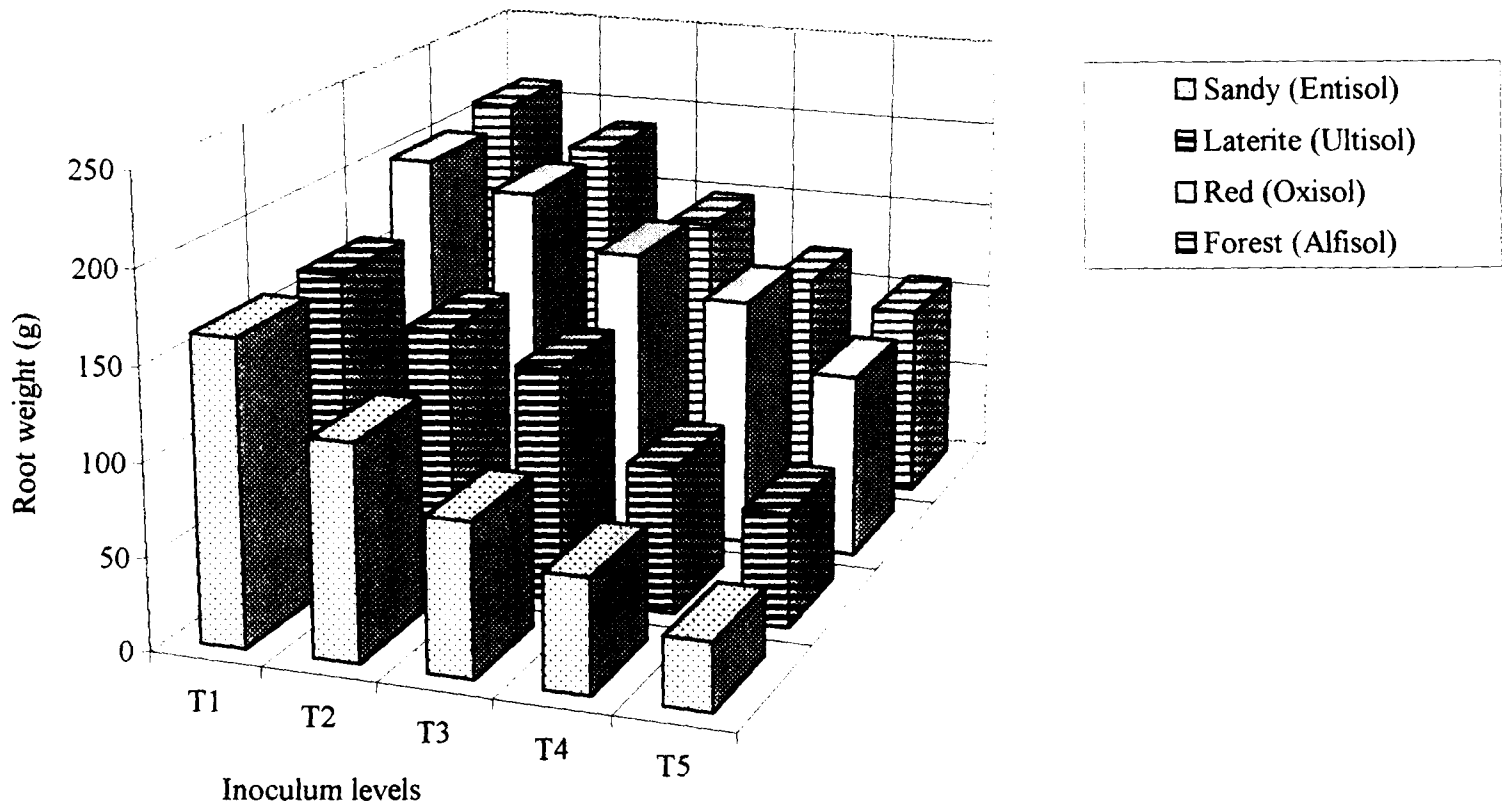


T1 - Un inoculated control plants T2 - Plants inoculated with 10 second stage juveniles of *M. incognita* T3 Plants inoculated with 100 second stage juveniles of *M. incognita* T4 Plants inoculated with 1000 second stage juveniles of *M. incognita* T5 Plants inoculated with 10000 second stage juveniles of *M. incognita*

level, the highest percentage reduction in leaf number was in sandy soil and lowest in laterite and forest soils. Haseeb (1995) found highest reduction in fresh or dry weight of *M. incognita* inoculated plants of *Mentha arvensis* cv. CIMAP / HY-77 grown in sandy-clay-loam soil.

Mean weight of roots in different treatments indicated that infestation of *M. incognita* resulted in the reduction of fresh weight of kacholam roots and there was a gradual decrease in weight of roots as the inoculum density increased. The same observation was noted in bhindi by Sumangalakuttyamma (1975) and in *Mentha arvensis* c.v. Shivalik by Kumar and Singh (1997). Reduction of root weight of kacholam in different soil types occurred from 10 J_2 level onwards except in red soil were it was from 100 J_2 level. Though the root development was comparatively low in sandy soils with low organic matter and clay content, the percentage reduction in root weight due to *M. incognita* inoculation was very high with 77.86 per cent at 10,000 J_2 level. The percentage reduction in root weight was lowest (49 per cent) in forest soil at the highest inoculation level (Fig. 2). This may be due to the high organic matter and clay content in the forest soil. The percentage reduction in yield was also maximum (59.06 per cent) in sandy soil and lowest in red soil (38.64 per cent) followed by forest soil (41.67 per cent) at 10,000 j_2 level (Fig. 3). These findings confirmed the fact that the clay fraction in soil have an enemical effect on the development of *M. incognita*. Many workers have contributed in this aspect. According to Shane and Barker (1986) the damaging effect of *M. incognita* was highest in soils with low clay content. The increase in clay content of soil decreased the ability of nematode larvae to move freely and

Fig. 2. Effect of different inoculum levels of *M. incognita* on the root weight of kacholam on various soil types



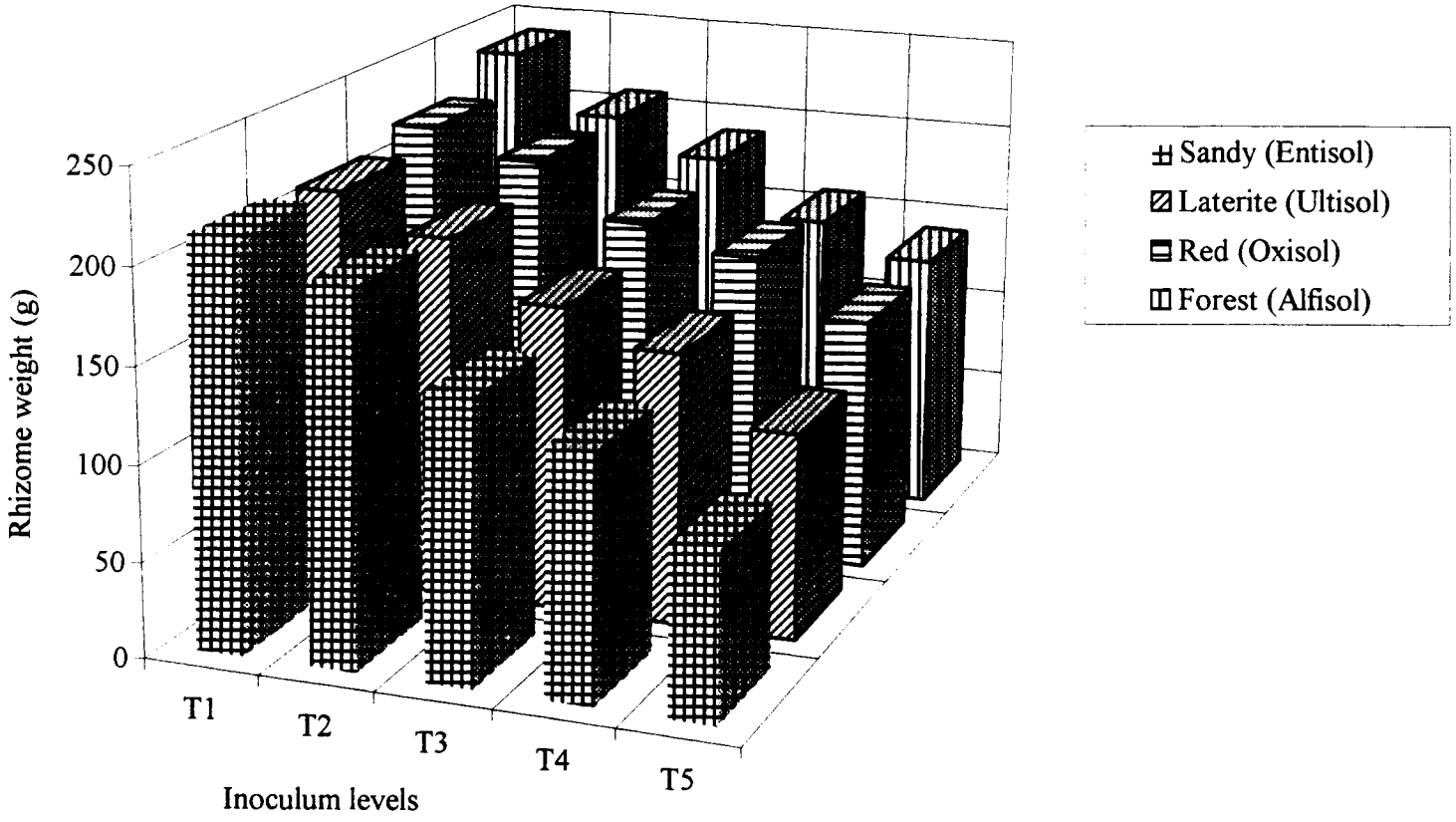
T1 - Un inoculated control plants, T2 - Plants inoculated with 10 second stage juveniles of *M. incognita*, T3 Plants inoculated with 100 second stage juveniles of *M. incognita*, T4 Plants inoculated with 1000 second stage juveniles of *M. incognita*, T5 Plants inoculated with 10000 second stage juveniles of *M. incognita*

penetrate the roots in cowpea plants (Ahmad *et al.*, 1991). Significant reduction in yield was noticed from 100 J_2 level onwards in all the soil types studied. In laterite and red soils 100 and 1000 J_2 levels were statistically on par.

The results presented in para 4.3.3.5 showed that the root-knot count recorded was low in laterite soil and high in sandy soil. This may be due to the increased supply of oxygen in soil pore spaces which result in the fast distribution of larvae and enhancement of root infection and root-knot count. On contrary, Nakasono *et al.* (1989) observed no difference in gall indices of *M. incognita* inoculated tomato roots grown in different soil types. There is no significant difference among different soil types regarding the number of eggs per egg mass and the number of female nematodes present. But Didwaniya and Baghel (1995) noticed that in grape vine infested with *M. incognita*, the number of egg mass produced were highest in sandy and lowest in clay soils.

The multiplication of *M. incognita* on kacholam rhizosphere in different soil types are presented in para 4.3.3.7. and 4.4.4. The maximum recovery of larvae from soil samples collected at eight months after planting of the crop was at 10,000 J_2 levels in all soil types. In sandy soil the effect of inoculation of 100, 1000 and 10,000 J_2 were statistically on par. Among the different soil types maximum number of nematodes were recovered from sandy soil (88 larvae per 100 g soil) and minimum in laterate soil (61 larvae per 100 g soil). It was obvious that among the different soil types, sandy soil is found to be ideal for the development of root-knot nematode *M. incognita* infesting kacholam.

Fig. 3 Effect of different inoculum levels of *M. incognita* on the yield (rhizome weight) of kacholam on various soil types



T1 - Un inoculated control plants, T2 - Plants inoculated with 10 second stage juveniles of *M. incognita* , T3 Plants inoculated with 100 second stage juveniles of *M. incognita*, T4 Plants inoculated with 1000 second stage juveniles of *M. incognita* , T5 Plants inoculated with 10000 second stage juveniles of *M. incognita*

This is in agreement with the findings of the following workers. Haseeb (1995) recorded highest rate of multiplication of *M. incognita* in sandy clay loam mixtures and Hossain *et al.* (1992) stated that the survival of the larvae, root-knot formation and population of *M. incognita* were highest in coarse sand.

Different levels of *M. incognita* population contributed losses on account of biometric characters and yield of kacholam. The results were assessed and presented in para 4.5. Reduction in number of leaves over untreated control was 18 and 43 per cent in plants inoculated with 200 and 500 larvae respectively under microplot condition. This reduction in number of leaves was directly correlated to the pathogenic effect of *M. incognita* larvae on the root system of kacholam. A progressive decrease in plant growth in relation to the increased level of nematode population was observed.

The biometric characters together with the yield attributing characters like length of rhizome, weight of roots and weight of rhizome were also reduced significantly by the various levels of inoculation of *M. incognita* larvae. The percentage reduction in rhizome length vary from 6 to 24 while the weight of roots reduced from 15 to 46 per cent at different inoculum levels. This reduction in weight of roots and length of rhizome directly affected the yield of plants. The percentage reduction in yield per plant vary from 18 to 64 and per plot yield 14 to 43 per cent. The yield reduction due to *M. incognita* on various crops was already reported. Yield loss is 45.4 per

cent at 10,000 J_2 level per plant in banana (David and Marasigon, 1985), 55.6 per cent in Soyabean (Antonio, 1988), 33 per cent in wheat (Patel and Patel, 1988), 46.1 per cent in cardamom cv. malabar at 4 nematodes per 100 cm^3 soil (Eapen, 1994) and 43 per cent in ginger at an initial nematode population of 166 larvae per 250 g soil sample (Sheela *et al.*, 1995). Bhatti and Jain (1977) reported the yield loss of lady's finger, tomato and brinjal as 90.9, 46.2 and 27.3 per cent respectively under field conditions. Yield loss of kacholam was increased as the inoculum level increases. Similar observations was made by Fademi (1987) on rice.

The recovery of nematode population from soil and root also showed statistically significant variation when observed at different intervals. Maximum recovery of nematodes from soil was obtained from plots inoculated with 1000 larvae per plant. The *M. incognita* population in roots varied significantly at different levels of inoculation of the larvae. The population of *M. incognita* in roots at the time of harvest also increased with increased rate of inoculum. The root-knot index and gall index were also maximum at 1000 J_2 level. This increased multiplication of *M. incognita* in roots was directly proportional to the yield loss assessed in terms of length and weight of rhizome.

Management studies of root-knot nematode on kacholam was conducted in microplot having uniform infestation of *M. incognita* and the results are presented in para 4.6. The improvement in the number of leaves, length of rhizome and weight of roots due to various treatments were estimated and presented in para 4.6.1. to 4.6.3. Neem cake (200 g per m^2) treated plants

have maximum number of leaves (46), rhizome length (14.4 cm) and weight of root (84.13 g) followed by VAM (*Glomus fasciculatum*) 300 g inoculum per m^2 and carbofuran 3.33 g per m^2. The increase in above biometric characters directly attributed to the increase in yield of kacholam, both in terms of weight of rhizome per plant and per plot. The yield per plant was maximum in neem cake treatment which is followed by carbofuran treatment. The effect of carbofuran and VAM treatments on the yield was statistically on par. Hence neem cake, carbofuran and VAM were equally effective in managing the *M. incognita* population in kacholam. The beneficial effects of neem cake, carbofuran and VAM treatments on different crops for nematode management were already reported. According to Alagumali *et al.* (1990), amending the soil with neem cake at 0.01, 0.5 and 1 per cent w/w reduced infestation of *M. incognita* on mung bean, *Vigna radiata*. Singh and Kumar (1995) found neem cake @ 2 per cent w/w was very effective and better than uninoculated control and carbofuran treatment. The spot application of neem cake resulted in increase in yield to a tune of 30.6 and 40.6 per cent over control. The shoot length also increased in tomato (Kaul and Bhat, 1995). Sheela *et al.* (1995) also reported neem cake treatment was effective in reducing *M. incognita* in ginger rhizosphere and increasing the yield.

The efficiency of carbofuran for the management of *M. incognita* and increase in crop yield of kacholam was in agreement with the contributions of Mahajan (1978), Bhagavathi and Phukan (1990), Mohan and Mishra (1993), Chahal and Chahal (1993) in okra, french bean and cowpea.

VAM fungus especially *G. fasciculatum* can be used as a potential biocontrol agent against root-knot nematode. This view was confirmed by the findings of Rao *et al.* (1992). They found that VAM treatment is very effective in enhancing the growth of egg plant seedlings and reducing the infestation of *M. incognita*. Sharma *et al.* (1995) also reported a higher percentage reduction of root-knot nematode population in VAM treated tomato plants than neem cake treated plants. Deepthi (1993) found out that *G. fasciculatum* as the best VAM fungus in reducing the root-knot infestation in cowpea.

There is no statistically significant variation in the number of egg masses per root-knot in various treatments. The number of larvae emerged from eggmass is lowest in VAM treatment indicating that VAM is having slight ovicidal effect. Sharma *et al.* (1995 b) reported that mycorrhizal tomato seedlings produced less number of galls, egg mass per plant, eggs and juveniles per egg mass. Sivaprasad *et al.* (1990) reported reduced galling, root-knot index and nematode population in cowpea plants treated with VAM. The gall indices were found to be uniform (one) in all the treated plant roots as against the index of three in control plants. The root-knot count and the population of *M. incognita* in soil and roots of kacholam were lowest in neem cake treated plants. At the termination of the experiment, neem cake reduced the soil population of nematode to the tune of 68 per cent over uninoculated control plants while the percentage reduction in nematode population by carbofuran treatment is only 59 per cent revealing that neem cake application is more better than the chemicals in managing *M.incognita*.

Neem cake, a treatment of promise with slight nematicidal and nematostatic properties needs more emphasis because it is environmentally safe and also improves the soil condition and subsequently the vigour of plants. VAM especially *G. fasciculatum* is very effective in managing the root-knot nematode in the egg stage itself and it can be used as a successful bio control agent in the integrated nematode management strategy. Thus, in the context of ecofreindly / farmer friendly management strategy, more emphasis is to be given for neem cake and VAM.

SUMMARY

SUMMARY

Studies were conducted to work out the biology of root- knot nematode infesting kacholam, its histopathological changes in roots and the effect of various soil factors like soil type, soil p^H and soil moisture on the hatching, multiplication and survival of *M. incoginita*. The crop loss due to this nematode was assessed in terms of number of leaves, length of rhizomes ,weight of roots and weight of rhizome (yield) per plant and per plot under field conditions. Microplot trials were also conducted using neem cake (200 g/m^2), VAM (300 g/m^2) and carbofuran (3.33 g/m^2) to develop a suitable management strategy for the root- knot nematode, *M. incognita* infesting kacholam.

The studies on the biology of root-knot nematode on kacholam conducted in micropots revealed that *M. incognita* took 37 days for the completion of one life cycle in kacholam roots. The eggs are laid in egg masses embedded in gelatinous matrix and the mean number of eggs present per egg mass was estimated as low as 130.

Histopathological studies revealed that the nematode mainly infest stellar region especially the xylem vessels and the phloem were found intact. The giant cells are formed by enlargement or hypertrophy of cortical cells. These cells were quadrangular in shape and three in number. Numerous cavities, formed by the disintegration of giant cells and females nematodes were found in the sections of roots, taken at later stages.

The hatching of eggs and survival of larvae of *M. incognita* at different moisture levels namely field capacity, permanent wilting point and flooding was studied *in vitro* in micro pot conditions. Soil mositure level at field capacity was found to be the most suitable for the hatching of eggs of *M. incognita*. The moisture level at permanent wilting point and flooding were found to reduce larval hatching. Maximum larval survival was noticed at field capacity on five days after inoculation of the larvae.

In vitro studies to find out the effect of soil pHon the hatching of eggs and survival of the larvae of *M.incognita* at different intervals revealed that there was no significant variation in the hatching of eggs and survival of larvae at different pH levels ranging from 5 to 7.5. But there was numerical variation in the hatching and survival of larvae and were more at acidic condition (pH 5 and 5.5) than at alkaline (pH 7.5).

The pot culture studies conducted to evaluate the effect of soil type on the pathogencity of root-knot nematode revealed that in all soil types namely forest (Alfisol), red (Oxizol), laterite (Ultisol) and sandy soil (Entisol), the percentage reduction in plant growth parameters increased with increase in the inoculum levels. Maximum percentage reduction in various biometric characters and yield were observed at 10,000 J_2 level. The number of nematodes recovered from 100 g soil samples at the time of the harvest of crop is also maximum at this level. Among the soil types, sandy soil (Entisol) was found to be the best soil type for the effective multiplication of root-knot nematode infesting kacholam. The reduction in leaf number, root weight and yield were highest in sandy soil.

The crop loss assessment studies conducted in micro plots of size 1m X 1m revealed that different levels of *M.incognita* population had statistically significant effect on the biometric characters and yield of kacholam. At 1000 J2 level, the percentage reduction in number of leaves, length of rhizome, weight of root, weight of rhizome (yield) per plant and per plot recorded over control plants (without nematode) were 43.33, 23.71, 46.26, 63.69 and 43.46 respectively.

Management trials were conducted in nematode infested micro plot of size 1 x 1 m using carbofuran @ 3.33 g/m^2, neem cake @ 200 g/m^2 and VAM fungi (*G. fasciculatum*) 300 g/m^2. All these treatments were found effective in reducing the nematode population and increasing the biometric characters and yield of kacholam. Among the three treatments, neem cake treatment ranked first as it produced the maximum number of leaves (46), rhizome length (14.43 cm) root weight (84.13 g) and yield in terms of rhizome weight (189.75 g per plant and 2.27 kg. rhizome per plot). The nematode population in soil taken at 2, 4, 6 and 8 months after planting and population in roots taken at the time of harvest also revealed that neem cake treatment @ 200 g/m^2 was very effective in controlling the nematode. There was no statistically significant variation in the number of egg masses per root-knot in various treatment. The number of larvae emerged per egg mass was lowest in VAM treatment. The root-knot count is lowest in neem cake treated plants. The gall index is uniform (one) in all the treatments..

REFERENCES

REFERENCES

Abid, M., Ehteshamul - Haque, S., Sultana,V., Ara, J., Ghaffar, A. and Maqbool, M.A. 1995. Comparative efficiency of neem cake and other organic amendments in the control of root - knot nematode. *Pakistan J. Nematol.* 13 : 103 - 107

Acharya, A. and Padhi, N.N. 1988. Effect of neem oil and saw dust against root-knot nematode *M. incognita* in betel vine *(Piper betle) Indian J. Nematol.* 18 : 105

Ahmad, S.S., Kandil, M.M. and Al-Ansi, N.A. 1991. Reaction of cowpea cultivars to root-knot nematode, *M. incognita* in relation to soil type. *Annals Agrl. Sci.* **29** : 1214

Ajith, K., Hebsybai and. Sheela, M.S. 1993. Green leaves - their effect on soil micro-organisms and efficacy in nematode management. Paper presented in the National Symposium on Recent Approaches in Integrated Nematode management of Agricultural crops. HAU, Hissar Abstr., pp. 18

Alagumalai, K., Thiruvalluvam, M., Nagendran, N., Ramray, P. and Ramraj, P. 1995. Effect of acid extract of neem cake on the population build up of *M. incognita. Environment and Ecology* **13** : 275-277

Alam, M.M. 1989. Control of root-knot and stunt nematodes with horn meal, bone meal and oil seed crops. *Indian J. Nematol.* 19 : 166 - 170

Alam, M.M., Khan, A.M. 1974. Control of phytonematodes with oil cake amendments in spinach field. *Indian J. Nematol.* 4 : 239 - 240

Alam, M. M. and Khan, A. M. 1975. Control of phytonematodes with oil cake amendments in spinach field. *Indian J. Nematol.* **4** : 239-240

Ali, S. S. 1995. Estimation of yield losses in urdbean crop due to *Meloidogyne javanica*. Paper presented in the National Symposium on Recent Approaches in Integrated Nematode management of Agricultural crops. HAU, Hissar Abstr., pp. 120

Antonio, H. 1988. Evaluation of losses caused by *M. incognita* race-4 on soybean cultivar BR - 4. *Nematolgia Brasileira* 12 : 29 - 34

Asha, J. 1997. Phytochemicals and VAM for management of nematodes in Brinjal (*Solanum melongena* L.) M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur

Badwin, J.G. and Barker, K.R. 1970. Histopathology of corn hybrids infected with root-knot nematode *M. incognita*. *Phytopathol.* **60** : 1195 - 1198

Bagyaraj, D. J., Manjunath, A. and Patil, R. B. 1979. Occurrence of vesicular-arbuscular mycorrhiza in some tropical aquatic plants. *Trans. Brit. Mycol. Soci.* **72** : 164-167

Bhagavati, B. and Phukan, P.N, 1990. Chemical control of *M. incognita* on pea. *Indian J. Nematol* **20** : 79 - 88

Bhatti, D.S. and R.K. Jain. 1977. Estimation of loss in okra, tomato and brinjal yield due to *M. incognita*. *Indian J. Nematol.* 7 : 37 - 41

Bird, A. F. 1959. The attractiveness of roots to the plant parasitic nematodes *M. javanica* and *M. hapla*. *Nematologica* **4** : 322-335

Brown, F.N. 1933. Flooding to control root-knot nematodes. *J. Agric. Res.* **47** : 883 - 888

Borah, A. and Phukan, P. N. 1990. Efficacy of certain chemicals as seed treatment for the control of *M. incognita* on greengram. *Indian J. Nematol.* **20** : 219-220

Chahal, P.P.K. and Chahal, V.P.S. 1995. Interactions of VAM and root-knot nematode on pea. Paper Presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr., pp. 67

Channabasappa, B. S., Krishnappa, K. and Reddy, B. M. R. 1995. Utilization of eco-friendly biological agents and biocomponents in the integrated management of *Radopholus similis* on banana. Paper presented in the National Symposium on Nematode Problems of India - An Apprisal of the Nematode Management with Eco-friendly Approaches and Biocomponents, New Delhi, Abstr. pp 42

Charles, J. S. K. 1978. Studies on the nematode diseases of ginger (*Zingiber officinale* Rose). M.Sc. Thesis, Kerala Agricultural University

Charles, J. S.K., Venkitesan, T.S. and Sreeja, P. 1996a. Influence of different soil types on population of cyst nematode *Heterodera oryzicola* (*Nemata : Tylenchina*). Paper presented in the symposium on Technological Advancement in Banana / Plantain production and processing - *India - International.* Abstr. pp. 34

Charles, J.S.k., T.S. Venkitesan and Sreeja, P. 1996. (b) Effect of temperature moisture and pH on the emergence of *Hetrodera oryzicola* larvae from cyst nematode. Paper presented in the symposium on Technological Advancement in Banana / plantain production and processing - *India - International.* Abstr., pp. 35

Choudhary, B. N. and Phukan, P. N. 1995. Study on the variations of certain plant parasitic nematodes at different levels of soil pH. *Indian J. Nematol.* **25** : 202-203

Cooper, K. M. and Grandison, G. S. 1986. Interaction of vesicular - arbuscular fungi with root-knot nematode on the cultivars of tomato and white clover susceptible to *M. hapla*. *Ann. Appt. Biol.* **108** : 1-11

Cooper, K. M. and Grandison, G. S. 1987. Effect of vesicular-arbuscular mycorrhizal fungi on infection of tamarillo (*Cyphomandra betacea*) by *M. incognita* in fumigated soil. *Pl. Dis.* **71** : 1101-1106

Couch, H.B. and Bloom, J.R. 1960. Influence of soil moisture stress on the development of the root-knot nematodes. *Phytopathol.* 50 : 319

Das, P. and Barmean, B. 1995. Histopathological changes due to root-knot nematode, *M. incognita* on green gram and screening of few germplasm against it. *Indian J. Nematol.* **25** : 224-225

Das, B.K., Sarkar, J. Sarkar, S., Das, N.K., Ray, I. and Sen, S.K. 1990. Correlation between some edaphic factors and *M. incognita* infection and mulberry in Malda, West Bangal. *Indian J. Nematol.* **20** : 91 - 94

Dasgupta, D.R. and Gaur, H.S. 1986. The root-knot nematode *Meloidogyne* spp. In : *plant parasite nematodes of India - Problems and progress.* (Ed. Swarup, Gaur and Dasgupta) p. 158 - 160. Pub. ICAR, New Delhi

Daulton, R.A. and Nusbaum, C.J. 1962. The effect of soil temperature on the survival of root-knot nematode *M. javnica* and *M. hapla*. *Nematologica* 6 : 280 - 292

Davide, R.G. and Marasigan, L. Q. 1995. Yield loss assessment and evaluation of resistance of banana cultivars to the nematode *R.similis* Thorne and *M. incognita* chitwood. *Philippine Agriculturist* 68 : 335 - 349

Deepthi, N.V. 1993. Control of collar rot and root-knot of cowpea with VA Mycorrhizae. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur

Devi, S. 1993. Evaluation of carbofuran 3G as a seed and soil treatment against *Meloidogyne incognita* on gram. Paper presented in the National Symposium on Recent Advances in Integrated Nematode Management of Agricultural crops, HAU, Hissar. Abstr. pp. 33

Dhawan, S.C. and Sethi, C.L. 1976. A comparative study on the life history of *M. incognita* in apparently healthy and little leaf affected egg plant roots, *Indian J. Nematol.* **6** : 109 - 111

Didwaniya, S. and Baghal, P.P.S. 1995. Multiplication of *M. javanica* on grapevine (*Vitis vinifera*) in different soil types. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the nematode management with Eco-friendly Approaches and Bio-components, *IARI, New Delhi, Abstr.*, pp. 32

Eapen, S.J. 1994. Pathogenicity of *M. incognita* on small cardamom, *Elettaria cardamom Maton. Indian J. Nematol.* **24** : 31 - 37

Fademi, O. A. 1987. Nature and importance of nematodes on rice in Nigeria. *Pakistan J. Nematol.* **5** : 5-13

Fawole, B. 1988. Histopathology of root-knot nematode (*M. incognita*) infection on white yam (*Diascorea rotundata*) tubers. *J. Nematol.* **20** : 23 - 28

Fernandez, E., Valdes. S. and Carrasco. J. 1986. Study of the biology of *Meloidogyne* sp. which attack gauva *Ciencia-y-Tecnica- en - la - Agricultura, Proteccion - de - plantas* **9** : 27 - 41

Garcia, O. and Espinosa, J. 1982. Assessment of economic losses caused by *Meloidogyne* spp. on light tobacco variety Hicks. 187. *Ciencia y - Tecnica - en - la - Agricultura, Proteccion - de - plantas* **5** : 79 - 95

Gaur, H.S. and Sehgal, M. 1988. A comparative study of the effect of moisture stress and period of storage on the storage of *M. incognita, R. reniformis* and *Tylenchulus semipenetrans* in soil. International Nematological Network News letter **5** : 5 - 8

Gaur, H. S. and Schgal, M. 1990. Effect of rate of drying of soil on the survival, infectivity and development of root-knot nematode, *Meloidogyne incognita. Indian J. Nematol.*. **20** : 89-90

Godfrey, G.H. and Hagen,H.R. 1993. Influence of soil hydrogen ion concentration on infection by *Heterodera radicicola* (Greeff) Muller. *Soil sci.* **35** : 175 - 184

Goswami, B.K. and K. Vijayalakshmi 1986. Efficacy of some indigenous plant materials and non-edible oil seed cakes against *Meloidoggne incognita* on tomato. *Indian J. Nematol.* 16 : 280 - 281

Grandison, G. S. and Cooper, K. M. 1986. Interaction of vesicular-arbuscular mycorrhizae and cultivars of alfalfa susceptible and resistant to *M. hapla. J. Nematol.* **18** : 141-149

Hasan, N and Jain, R. K. 1985. Varietal screening and histopahtological changes in *Brassica compestris* roots infected with root-knot nematode *M. incognita*. *Indian J. Nematol.* **15** : 105-106

Hasan, N. and Jain, R.K. 1993. Relative efficacy and residual effect of some organic amendments and a nematicide on nematode population, fodder yield and nutritional status of plant and soil. Paper presented in the National Symposium on Recent Approaches in Integrated Nematode management of Agricultural crops. HAU, Hissar, Abstr. pp. 35

Haseeb,A. 1995. Effect of different soil types on plant growth, oil yield physiological and biochemical charges in *Meloidogyne incognita* inoculated plants of *Mentha arevensis* C.v. CIMAP/ HY - 77 on root-knot development. Paper presented in the National Symposium on Nematode problems of India - An appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr, pp. 77

Hossain, M.S., Zahid, M.I., Goswami, B.K. and Khan,A.L. 1992. Influence of soil texture on the incidence and development of three soil borne diseases. *Annals of Bangladesh - Agriculture* 2 : 93 - 96

Hussey, R. S. and Roncadori, R. W. 1982. Vesicular-arbuscular mycrrhizae may limit nematode activity and improve plant growth. *Pl. Dis.* **66** : 9-14

Jacob, A.J. 1977. Studies on the root-knot nematode of pepper (*Piper nigrum* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur

Jackson, M. L. 1958. *Soil Chemical Analysis*. Prentice Hall Inc., U.S.A

Jain, R. K. and Hasan, N. 1980. Efficiency of neem cake on fodder production, photosynthetic pigments and nematodes associated with oats and its residual effect on cowpea. *Indian J. Nematol.* **16** : 98-100

Jain, R. K. and Hasan, N. 1995. Effective utilization of endomycorrhiza along with a neem product for integrated management of root-knot nematode on cowpea. Paper presented in the National Symposium on Nematode Problems of India - An Apprisal of the Nematode Management with Eco-friendly Approaches and Biocomponents, IARI, New Delhi. Abst. pp 61

Jain, R.K. and Sethi, C.L. 1988. Interaction between VAM and *M. incognita H. cajani* on cowpea as influenced by time of inoculation. *Indian J. Nematol.* 18 : 263 - 268

Jain, R. K., Paruthi, I.J. and Gupta, D. C. 1988. Control of root-knot nematode *M. javanica* in tomato through nursery bed alone and in combination with application of carbofuran at transplanting. *Indian J. Nematol.* **18** : 340-341

Johanson, 1940. *Plant microtechniques*. Mc Graw-Hill, New York, pp 523

K.A.U. 1993. Biennial report of AICRP on plant parasitic nematode with integrated approach for their control. Vellayani Centre. pp 32

K.A.U. 1996. *Package of Practice Recommendations-Crops* - 1996. Directorate of Extension, Kerala Agricultural University, Thrissur p 213-215

Kaul,V and Bhatt,O.K. 1995. Management of root-knot nematode. *Meloidogyne incognita* infesting tomato. Paper presented in the National symposium on Nematode Problems of India - An apprisal of the Nematode Management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 26

Khan, M. L. and Sharma, G. C. 1990. Effect of temperature and moisture on population fluctutation of nematode in an apple orchard. *Indian J. Nematol.* **20** : 10-13

Khan,A; Khanzada,A.K; Rajput,T., Fatima,M.B. and Aslam,M. 1986. Vertical distribution of plant parasitic nematodes in relation to soil moisture in okra field. *J. Agri. Res. Pakistan,* **24** : 215 - 221

Kellem, M.K. and Schenk, N.C. 1980. Interaction between a vesicular arbuscular mycorrhizal fungus and root-knot nematode on soybean. *Phytopathol.* **71** : 894

Kaozhokaru, G. I. 1985. Electron microscope study of galls caused by *Meloidogyne* on vegetables. In : *Ekologivai prakticheskoe znachenie zoo-i-fitopara zitiches kikh organisomi,* USSR, p 25-28

Kumar,T.P. and Nair, M.R.G.K. 1976. Effect of some green leaves and organic wastes on root-knot nematode infestation on bhindi. *Agric. Res. J. Kerala.* **14** : 64 - 67

Kumar, V. and Singh, R. V. 1997. Influence of different initial denisties of *M. incognita* on the growth of *Mentha arvensis* cv. Shivalik. *Indian J. Nematol.* **27** : 113-115

Lopez, R., Charpentier.E; Morales,H. and Gonzalez, M. 1992. Frequency, severity and etiology of the root-knot disease of tobacco in Perez-Zeldom. *Agronomia costarricense* 16 : 77 - 81

Lowenberg, J.R; Sullivan,T. and Schuster, M.L. 1960. The effect of pH and minerals on the hatching and survival of *M.incognita* larvae. *Phytopathol.* 50 : 215 - 217

Mahajan, R. 1978. Efficiency of carbofuran for the control of *M. incognita* on okra. *Indian J. Nematol.* **8** : 91-92

Makhnotra, A. K. and Khan, L. 1997. Assessment of yield losses in ginger due to *M. incognita. Indian J. Nematol.* **27** : 259-260

Malakeberhan,H., Brooke, R.C. and Webster, J.M. 1986. Relationship between physiological response of French beans of different age to *M.incognita* and subsequent yield loss. Plant pathol. **35** : 203 - 213

Malathy, M.R. 1994. Studies on the root-knot nematode *M.incognita* and vesicular-arbuscular mycorrhizae in *Kaempferia galanga* Linn. Mphil. Dissertation, University of Kerala

Mani, A., Naidu, P.H and Madhavachari, S. 1987. Occurrence and control of *Meloidogyne incognita* on turmeric in Andra Pradesh, India. *International Nematology News letter* 4 : 13 - 18

Mc. Guidwin,A.E., Brid,G.W. and Safir,G.R. 1985. Influence of *Glomus fasciculatum* on *Metoidogyne hapla* infecting *Allium cepa*. *J. Nematol.* **17** : 389 - 395

Midha, R. L. and Trivedi, P. C. 1988. Pathogenicity of *M. incognita* on garlic, *Allium cepa* L. **18** ; 373-374

Mohan,S. and Mishra,S. 1993. Management of *Meliodogyne incognita* infecting french bean through seed coating with chemicals. *Indian J. Nematol* **23** (1) : 92 - 94

Mohandas, C. and Ramakrishnan, S. 1997. Pathogenic effects of root-knot nematode, *M. incognita* on African white yam, *Dioscorea rotunda*. *Indian J. Nematol.* **27** : 233-236

Mohanty, L. and Das, S. N. 1994. Effect of different inoculum levels of *M. incognita* on Tuberose (*Polianthes tuberosa* L.). *Indian J. Nematol.* **24** : 249

Mohanty,K.C., Mahapatra,S.N., Patnaik,P.R. and Ray, S. 1995. Management of root-knot nematode, *Meloidogyne incognita* through chemical nursery treatments in brinjal. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr., pp. 21

Mojumder,V. and Mishra,S.D. 1993. Management of *Meloidogyne incognita* infecting chickpea through neem seed amendment in soil. Paper presented in the National symposium on Recent Approaches in Integrated Nematode Management of Agricultural crops, HAU, Hissar. Abstr. pp. 9

Molina,G.C. and Nelson, P.E. 1983. Histopathology of the nodulated root of soybean infected with root-knot nematode *Philippine-Agriculturist* **66** : 345 - 348

Nadwana,R.P and Yadav, B.S. 1995. Study on life cycle of *Meloidogyne incognita* in roots of cotton. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode Management with Eco-friendly Approaches and Bio-components, IARI. New Delhi, Abstr., pp. 98

Nakasono, K., Sano, Z., Araki,M and Itoh, Y. 1989. Effect of *M.incognita* on the growth of tomato plants under different soil type condition. *Japanese J. Nematol.* **18** : 45 - 53

Nalinakumari,T., Sheela, M.S., Hebsybai and Kuriyan,K.J. 1995. Comparative effect of root-knot and reniform nematode on growth and yield of betalvine. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode Management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 41

Naseem,A. and Jairajpuri,M.S. 1982. Effect of pH, mineral salts and fatty acids on the predatory nematode, *Parahadronchus shakili* (Jairajapuri, 1969), *Indian J. Nematol.* **12** : 22 - 30

Pandey,R. 1995. Performance of oil seed cake, pesticides and dry leaf matter on the reproduction potential of *Meloidogyne incognita* and yield of Japanese mint HY-77. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode Management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 37

Pandey, R. and Haseeb, A. 1997. Plant parasitic nematodes associated with three medicinal plants and the pathogenicity of root-knot nematode. *Indian J. Nematol.* **27** : 53-57

Parihar,A. and Yadav, B.S. 1986. *Meleidogyne incognita* on ginger (*Zingiber officinale, Rosce*) and its control. *Indian J. Mycol. and Pl. path.* **16** : 84 - 86

Park,S.D., Park,S.D., Choi, B.S. and Choi, Y.E. 1994. Annual phenology of root-knot nematode in the medicinal herb (*Paeconia lactiflora*) field. *Korean J. Appl. entomol.* **33** : 159 - 162

Pasha,M.J., Khan, Z.A., Khan, M.W. and Qureshi, S.I. 1987. Histopathology of egg plant roots infected with root-knot nematode, *M. incognita*. *Pakistan J. Nematol.* **5** : 27 - 34

Patel,Y.C. and Patel,D.J. 1988. Assessment of losses due to root-knot nematode in wheat. *Pakistan J. Nematol.* **6** : 45 - 47

Patel, D. J., Makadia, B.M. and Shah, H. M. 1981. Occurance of root-knot nematode on turmeric (*Curcuma longa*) and its chemical control. *Indian J. Nematol.* **11** : 125

Patel, D.J., Patel, H. B. and Patel, S. K. 1993. Estimation of avoidable yield losses in green gram and cowpea due to root-knot nematodes in field. Paper presented in National Symposium on Recent approaches in Integrated Nematode Management of Agricultural Crops. HAU, Hissar, Abst. pp 39

Peacock, F.C. 1957. Studies on the root-knot nematode of the genus *Meloidogyne* in the Gold coast Part - I. *Nematologica* 2 : 76 - 84

Peters,B.G. 1926. *Heterodera schachtii* (Schmidt) and soil acidity. *J. Helminthol.* **4** : 87 - 114

Pillai, S. N. and Desai, M. V. 1975. Antihelminthic property of marotti cake (*Hydrocarpus laurifolia*). *Pesticides* **9** : 37-39

Pillai, S. N. and Desai, M. V. 1976. Punnakai cake on the control of root-knot nematode. *Indian J. Mycol. and Pl. Path.* **6** 14-17

Prasad,P.R.K. and Reddy, D.D.R. 1984. Pathogenicity and analysis of crop loss in patchouli due to *Meloidogyne incognita*. *J. Nematol.* **14** : 36 - 38

Rai, B. S. and Jain, R. K. 1988. Comparative biology of root-knot nematode, *M. incognita* on cotton (*Gossypium hirsutum*) and tomato (*Lycopercicum esculentum*). *Indian J. Nematol.* **18** : 349

Rao,M.S., Mohandas,S. and P.P.Reddy. 1993. Integrated management of root-knot nematode on egg plant in nursery beds with the combination of *Glomus mosseae* and neem leaf. *Indian J.Nematol.* 23 : 14

Rao,M.S., Reddy,P.P. and Mohandas,S. 1995. Studies on development of a bio-rational management strategy against root-knot nematode attacking tomato. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Ecofreindly approaches and Bio-components IARI, New Delhi, Abstr. pp. 14

Reddy. P. P. 1986. Analysis of crop loss in certain vegetables due to *M. incognita*. *Int. Nem. Network News letter* **3** : 3-5

Routaray, B. N., Mahapatra, M. P. and Das, S. N. 1987. Effects of *M. incognita* on ginger, *Zingiber officinale* Rose. *Indian J. Nematol.* **17** 327-329

Shah, J.J. and Raju,E.C. 1977. Histopathology of ginger (*Zingiber officinale*) infected by soil nematode *Meloidogyne* sp. *Phyton.* **16** : 79 - 84

Shane,W.W. and Barker,K.R. 1986. Effect of temperature, plant age, soil texture and *M. incognita* on early growth of soybean. *J. Nematol* **18** : 320 - 327

Sharma,M.P., Bhargava,S., Varma,M.K. and Adholeya, A. 1994. Interaction between the endomycorrhizal fungus *Glomus fasciculatum* and the root-knot nematode *Meloidogyne incognita* on tomato. *J. Nematol.* **24** : 133 - 139

Sharma,M.P.,Bhargava,S..Varma, M.K. and Adholeya, A. 1995a. Comparative potentiality of VAM fungus *Glomus fasciculatum* against root-knot nematode *Meloidogyne incognita* on tomato. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 27

Sharma,M.P., Bhargava,S. Varma, M.K. and Adholeya, A. 1995b. Effect of VA mycorrhizal fungus *Glomus fasciculatum* on survival, penetration and development of root-knot nematode *M. incognita* in tomato. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 13

Sharma, I. R. and Trivedi, P. C. 1995. Efficiency of some chemicals against *Heterodera avenae* on barley. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi, Abstr. pp. 4

Sheela,M.S., Hebsybai, Jiji,T. and Kuriyan, K.J. 1995. Nematodes associated with ginger rhizosphere and their management in Kerala. *Pest Mgt. Hort. Ecosystm.* **1** : 43 - 48

Sheila, H., Pant, V. and Saxena,S.K. 1985. Effect of different pH levels on root-knot development and morphometrics of *M.incognita*. *Indian J. Nematol.* **15** : 60 - 61

Shenck, N. C. and Kellam, M. K. 1978. The influence of vesicular-arbuscular mycorrhizae on disease development. *Flo. Agric. Exp. Tech. Bull.* **798** : 16

Shetty,P.S. and Rudramuniyappa, C.K. 1992. Histochemical study on root-knots of mulberry. *Indian Phytopathol.* **45** : 361 - 363

Siddiqui, Z.A. and Ghouse, A.K.M. 1975. Formation of phloem in the roots of *Lagenaria leucantha* infected with *M. incognita*. *Indian J. Nematol.* **5** : 102-104

Siddiqui,Z.A., Rashid, A., Yunus, M. and Ghouse, A.K.M. 1974. Studies on the reaction-xylem developed due to *M. incognita* in the roots of *Lagenaria leucantha*. *Indian J. Nematol.* **4** : 46 - 52

Singh, U. S. and Nath, R. P. 1996. Pathogenicity of root-knot nematode, *M. incognita* on papaya. *Indian J. Nematol.* **26** : 115-116

Singh, S. P., Khan, A. M. and Saxena, S. K. 1980. Effect of nematicides and oil cakes seperately and in mixture on plant parasitic nematodes. *Geobios.* **7** : 111-113

Singh,R.V. and Kumar,V. 1995a. Effect of carbofuran and neem cake on *Meloidogyne incognita* infecting Japanese mint paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode Management with Eco-friendly Approaches and Bio-components, IARI, New Delhi. Abstr. pp. 37

Singh,R.V. and Kumar,V. 1995b. Studies on life cycle of root-knot nematode *Meloidogyne incognita* on Japanese mint cultivar. Paper presented in the National Symposium on Nematode Problems of India - An Appraisal of the Nematode management with Eco-friendly Approaches and Bio-components, IARI, New Delhi. Abstr., pp. 91

Sitaramaiah,K. and Vishwakarma, S.N. 1978. Relative efficiency of selected non-volatile nematodes in field for control of root-knot nematodes on okra and tomato. *Indian J. Nematol.* 8 : 32 - 42

Sivakumar,C.V., Kuppuswamy,S. and Merzainuddin,M. 1973. Evaluation of carbofuran seed treatment for the control of root-knot in okra. *Indian J. Nematol.* 3 : 71 - 72

Sivaprasad,P., Jacob,A. and George,B. 1990. Root-knot nematode infestation and nodulation as influenced by VA mycorrhizal association in cowpea *Indian J. Nematol.* **20** : 49 - 52

Sivaprasad,P., Jacob,A., Nair, S.K.and George,B, 1990. Influence of VA mycorohizal colonization on root-knot nematode infestation in *Piper nigrum.* L. In : Current trends in mycorrhizal research. *Proc.of National Conference on Mycorrhiza.* Hissar. p. 100 - 101

Sosamma,P. 1988. Crop loss caused by root-knot nematode (*M. incognita Kofoid*) infesting *coleus parviflorus* and its control M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur

Sosamma, V. K. and Koshy, P. K. 1986. Survival of *Radopholus similis* in host free soil. *Indian J. Nematol.* **16** 74-76

Sudha,S. and Prabhoo, N.R. 1983 *Meloidogyne* (Nematoda : *Meloidogynidae*) induced root galls of the banana plant *Musa paradisiaca* - a study of histopathology. *Proc. of Indian Academy of Sciences, Animal Sciences* **92** : 467 - 473

Sulochana,K.K, Sivaprasad,P. and Sreekandan Nair,G. 1991. Occurrence of vesicular-arbuscular mycorrhizae in medicinal plants. *Ancient science of Life* 11 : 38 - 39

Sumangalakuttyamma,S. 1975. Studies on the effect of different soil types and inoculum levels of larvae on the development of *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 on bhindi M.Sc. (Ag.) thesis Kerala Agricultural University, Thrissur

Sundarababu, R. Sankaranarayanan,C. and Vadivelu, S. 1993. Interaction of mycorrhiza sp. with *M. incognita* on tomato. *Indian J. Nematol.* **23** : 121-123

Sundararaju,P. and Sudha,S. 1993. Nematode management in arecanut and arecanut based farming system. Paper presented in the National Symposium on Recent Approaches on Integrated Nematode management of Agricultural crops, HAU, Hissar. Abstr. pp. 78

Suresh,C.K., Bagyaraj, D.J. and Reddy, D.D.R. 1985. Effect of vesicular arbuscular mycorrhiza on the survival, penetration and development of root-knot nematode in tomato. *Plant* and *Soil* **87** : 305 - 308

Szczygiel, A. and Soroka,A. 1983. Effect of soil moisture level on population and pathogenicity of three plant parasitic nematodes to straw berry plants. *Zeszyty problemowe postepowe Nacck Rolniczych.* **278** : 105 - 111

Trivedi, P. C., Bhatnagar, A. and Tiagi, B. 1978. Control of root-knot nematode on *Capsicum annum* by application of oil cake. *Indian Phytopathol.* **31** : 75-76

Upadhyay, R.S., M. Oostenbrink and Abrar.M.Khan 1972. The effect of different soil types on the density of nematode population. *Indian J. Nematol* 2 : 42 - 53

Upadhyaya, K. D., Palvs and Dwivedi, R. P. 1993. Studies on the assessment of yield loss and screening of french bean varieties against *M. incognita.* Paper presented in the National Symposium on Recent Approaches in Integrated Nematode Management of Agricultual Crops. HAU, Hissar Abstr. pp 37

Vadivelu, S. 1973. Interaction effect of *M. incognita* (Kofoid and White, 1919) Chitwood, 1949 and *P. delattrei* Lue. 1958 on tomato (*Lycosanthus esculentum* Linn.) with reference to two soil types. M.Sc. (Ag) thesis, Tamil Nadu Agricultural University

Watson,T.R. and B.F.Lownsberry 1970. Factors influencing the hatching of *Meloidogyne naasi,* a comparison with *Meloidogyne hapla. Phytopathol.* **60** : 457 - 460

BIOECOLOGY AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White) Chitwood in Kacholam, *Kaempferia galanga* Linn.

By

RAJANI. T. S.

Abstract of Thesis
Submitted in partial fulfilment of the requirement for the degree
MASTER OF SCIENCE IN AGRICULTURE
(ENTOMOLOGY)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1998

ABSTRACT

The biology of root-knot nematode of kachlolam, its histopathological effects on roots and the effect of soil type on the pathogenicity of *M.incognita* infesting kacholam were studied under pot culture conditions. The effect of soil moisture and pH on the hatching of eggs and survival of larvae were studied *in vitro* in micro pots. Field trials were carried out to assess the crop loss and to find out a suitable management strategy for the root-knot nematode infesting kacholam.

The root-knot nematode, *M.incognita* took 37 days for the completion of one life cycle in kacholam plants at room temperature of 27 + or - 3 ° C and the mean number of eggs observed per egg mass was 130.

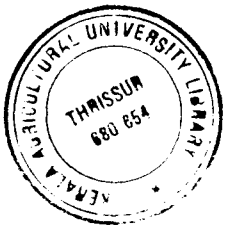
In kacholam roots, the nematode mainly infests the xylem vessels. The giant cells were quadrangular in shape and three in number and were observed adjacent to the head of the nematode.

Field capacity was the most favourable soil moisture level for the hatching of eggs and survival of larvae of *M.incognita*. There weas no statistically significant variation in the hatching of eggs and survival of larvae under different soil pH levels ranging from 5 to 7.5.

Sandy soil (Entisol) was found to be the best soil type for the multiplication of *M.incognita* infesting kacholam roots. The biometric characters and yield were reduced with the increase in inoculum levels and a maximum reduction was noticed at 10,000 J2 level in all soil types under pot culture conditions.

At field conditions, inoculation of 1000 J2 per plant resulted in the reduction of number of leaves, rhizome length, root weight and yield per plant and per plot yield to the tune of 43.33, 23.71, 46.26, 63.69 and 43.46 per cent respectively over control plants.

Neem cake 200 g/m^2, VAM (*Glomus fasciculatum*) 300 g/m^2 inoculum per plant and cabofuran 3.33 g/m^2 were found effective for the management of root-knot nematode, *M.incognita* infesting kacholam. But neem cake treatment was found to be the best in reducing the soil and root population of nematodes and increasing the plant growth characters (number of leaves, length of rhizome and weight of roots) and yield (rhizome weight per plant and per plot) of kacholam.



Department of Entomology,
College of Agriculture,
Vellayani, dt: 20.3.'99

No.E/55/95

From

Dr.M.S.Sheela,
Associate Professor

To

Shri.Sidhardhan.P.B.,
Registrar,
Kerala Agricultural University,
Vellanikkara.

Sir,

Sub:- M.Sc.(Ag.) final examination of Rajani.T.S.(95-11-15)- communication of result - reg.

Ref:- Order No.Acd.C3/38804/98 dt:3.11.'98.

.....

As per the order cited above, the M.Sc.(Ag.)final examination of Rajani.T.S.(95-11-15) was conducted on 29-12-98 in the Department of Agrl.Entomology, College of Agriculture, Vellayani with Dr.Rajeswari Sundarababu, Professor of Nematology, Tamil Nadu Agricultural University, Coimbatore as External Examiner. All the members of the advisory committee were present. The student has come out successfully in the final viva-voce examination.

I am enclosing herewith the result of the final examination (one copy) along with the evaluation report of the examiner, Dr.Rajeswari Sundarababu on the thesis entitled "Bioecology and management of root-knot nematode, Meloidogyne incognita (Kofoid and white) Chitwood in Kacholam, Kaempferia galanga. Linn." submitted by the student for M.Sc.(Ag) degree and a certificate to the effect that a copy of the thesis is submitted to the Library, College of Agriculture, Vellayani (Receipt enclosed).

It is certified that all the modifications and corrections suggested by the external examiner have been made wherever necessary in the thesis.

I request that the M.Sc.(Ag.) final examination of Mrs.Rajani.T.S.(95-11-1) may kindly be accepted and M.Sc.(Ag.) degree may be awarded to the student. A copy of the thesis entitled "Bioecology and management of root-knot nematode, Meloidogyne incognita (Kofoid and white) Chitwood in Kacholam, Kaempferia galanga is forwarded separately through the office of the Dean, College of Agriculture, Vellayani.

Yours faithfully,

(M.S.SHEELA)
Chairman, Advisory Committee.

Encl:
1. Result of M.Sc.(Ag.) final examination.
2. Thesis evaluation report by the external examiner.
3. Acknowledgement for the receipt of a copy of thesis by the Librarian.
4. Report of chairman along with certificate of corrections.

Copy

To Dean, College of Agriculture, Vellayani.