PHYTOCHEMICALS AND VAM FOR MANAGEMENT OF NEMATODES IN BRINJAL

(Solanum melongena L.)

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1997

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THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Entomolgy
COLLEGE OF AGRICULTURE
Vellayani, Thiruvananthapuram

1997

DECLARATION

I hereby declare that this thesis entitled **Phytochemicals and VAM for management of nematodes in brinjal** (*Solanum melongena* L.) 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 to me of any degree, diploma, associateship, fellowship or other similar title of this or any other University or Society.

Vellayani,
23.05.1997.

ASHA JOHN

CERTIFICATE

Certified that this thesis entitled **Phytochemicals and VAM for management of nematodes in brinjal *(Solanum melongena* L.)** is a record of research work done independently by Mrs. Asha John under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENTS

It is obvious that a task of this nature cannot be carried out without active guidance and co-operation of :

Dr. Hebsy Bai, Associate Professor, Department of Entomology and Chairman of Advisory Committee who, inspite of her busy schedule managed to suggest suitable ideas and was always responsive to my difficulties for clearing the bottlenecks encountered during the thesis work. Indeed this thesis could not have been done without her, for which I am highly indebted to her.

Dr. A. Visalakshi, Professor and Head, Department of Entomology for her helpful suggestions, constant encouragement and critical scrutiny of the manuscript.

Dr. M.S. Sheela, Associate Professor, Department of Entomology, for the overwhelming support, guidance and valuable suggestions rendered during the course of study and the preparation of the thesis.

Dr. P. Sivaprasad, Associate Professor, Department of Plant Pathology for his keen interest, constructive criticism and inspiring encouragement in completing this errand.

Dr. C. Gokulapalan, Associate Professor, Department of Plant Pathology for the everwilling help in taking photographs.

The teaching and non-teaching staff of the Department of Entomology for their sincere co-operation and assistance rendered during the course of investigation.

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

Kerala Agricultural University for granting me the Junior fellowship.

All friends and colleagues for the most generous help, friendly co-operation and assistance given to me during the course of study.

City Computers for the prompt and timely help rendered in typing the thesis.

My husband and all other family members deserve a special mention in this context for their affectionate help, constant encouragement and moral support showered on me throughout the study which made me witness this heyday.

ASHA JOHN

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INTRODUCTION

INTRODUCTION

Solanum melongena L. commonly known as egg plant or brinjal is an important and popular vegetable of Kerala. Among the factors responsible for its low productivity, nematodes too play a key role. Though several species of this 'unseen enemy' are associated with the crop, the reniform nematode *Rotylenchulus reniformis* Linford and Oliveira, 1940 and the root-knot nematode *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 are the major ones causing considerable damage. Of these, *M. incognita* is the most commonly occurring and destructive pest. Due to continuous cultivation of the crop, the nematode is often prevalent in menacing proportions. Plants infested by the nema loose their vigour and become stunted with discoloured leaves. The roots of such plants are reduced and show severe galling which is a confirmatory symptom of the nematode attack. Plants which are able to survive the infestation yield less and often die early. The reduction in yield due to this pest has been estimated to be 27.3 per cent by Bhatti and Jain (1977), 33.68 per cent by Reddy and Singh (1981) and 44.87 per cent by Krishnappa *et al.* (1981). Despite this alarming situation, no specific recommendation is there for tackling the problem besides the nematicides with high residual toxicity. Spurred by the ecocidal effects of chemical based management tools, pest management strategists shifted their focus to eco-friendly practices which maintain the soil health. Contrary to earlier

concepts that soil is an input to be manipulated and exploited, it is now recognised as a living resource. The inherent capacity of soil to prevent or reduce the spread of a harmful agent through biotic factors is now being exploited to the fullest for managing soil-borne pathogens. Among the options available for nematologists, use of botanicals and antagonistic potentials like endomycorrhizae are gaining momentum.

Though botanicals are generally used as soil amendment for controlling nematodes, bare-root dip of seedlings of transplanted crops like brinjal, tomato and chilli at the time of tranplanting in the extracts or oils of pesticidal plants is an attractive proposition. Not only are these less costly and non environment polluting but also they impart sufficient protection to the plant at a crucial period of its growth. Different organic oils (Devakumar, 1985; Pradhan *et al.*, 1989) and leaf extracts (Husain *et al.*, 1984; Nandal and Bhatti, 1986; Vats and Nandal, 1994) have shown promise as bare-root dip of brinjal against *M. incognita*.

The VAM fungi, a bio-control agent also offer an eco-friendly and low-cost approach to control root-knot nematode. The 'fungus root' is a symbiotic association between roots of higher plants and soil fungi. Among the different types of mycorrhizae associated with crop plants, the VAM is the most common one. Its association enhances the soil nutrient uptake (Islam

et al., 1980; Champawat, 1989), improves crop growth and yield (Daft and Nicolson, 1972; Islam and Ayanaba, 1981; Chhabra *et al.*, 1990; Channabasappa *et al.*, 1995) improves stress tolerance and helps in suppressing plant parastic nematodes (Rich and Bird, 1974; Jain and Sethi, 1988a; Sharma *et al.*, 1995a). Hence development of this bio-agent as a potential technology for nematode management is worthwhile.

The present investigation was taken up with a view to :

a) Identify phytochemicals suitable for bare-root dip treatment of brinjal seedlings to counter nematode invasion.

b) Isolate effective mycorrhizae to provide initial protection to the transplanted seedlings.

c) Determine the efficacy of the selected bio-component and bio-agent under field conditions.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The efficacy of plant products and vesicular arbuscular mycorrhizae (VAM) in combating nematode menace and the performance of these management tools under field conditions were studied in the present investigation. The important literature relevant to these aspects have been reviewed briefly.

2.1. Plant products in the management of nematodes

2.1.1. Effect of bare-root dip

2.1.1.1. In oils

Pradhan *et al.* (1989) showed that seedling root-dip in oils of chalmogra, neem and karanj at half to one eighth dilution was highly effective in preventing larval penetration and gall production by root-knot nematode in the roots of tomato.

2.1.1.2. In plant extracts

Root-dip treatment of egg plant seedlings in margosa and marigold leaf extracts considerably reduced root-knot development compared to treatment with piperazine citrate, chenopodium oil and groundnut cake (Husain *et al.*, 1984). Bare-root dip of tomato seedlings in extracts of

undecomposed castor cake and leaves significantly reduced root-knot development in pre-infected seedlings and in those inoculated with second stage juveniles of *Meloidogyne incognita* after dip treatment. The oil cake extracts were more effective than leaf extracts (Akhtar and Alam, 1990; Akhtar, 1994).

Fresh leaf extracts of Eucalyptus and neem plants (40 per cent w/v) with a dip duration of six hours were found to be highly effective in improving the growth parameters and suppressing the population of *M.javanica* on tomato (Vats and Nandal, 1994). Pannu and Paruthi (1995) reported that seedling root-dip of tomato in neem formulations (Achook, Margoside, Neemguard and Neemark at 0.0, 1.0, 2.0, 4.0, 6.0, 8.0 and 10.0 per cent concentrations) for half, one and two hours against *M. javanica* resulted in more than 50 per cent mortality of the seedlings at and above 6.0 per cent concentrations of all the formulations at a dipping period of half an hour. At longer dipping periods, phytotoxicity to seedlings was high even at low concentrations. However plant growth was significantly improved when dipped in two to six per cent concentrations for half an hour. Reduction in gall index over untreated check was observed at and above four per cent concentration.

An increase in the concentration of plant latices of *Calotropis procera* (Willd.), *Euphorbia neriifolia* L. and *E. tirucalli* L. and the

dip duration reduced the population of *Rotylenchulus reniformis* on tomato and egg plant, consequently improving the plant growth (Siddiqui and Alam, 1995). The multiplication rate of the nematode was found to be considerably low when tomato and egg plants were dipped in s, s/2 and s/10 concentrations of latices of these three plants.

2.1.2. Effect of soil application

Addition of organic matter to soil generally reduce the incidence of nematodes by the release of volatile fatty acids (formic, acetic, propionic and butyric acids), ammonia, hydrogen sulphide and amino acids during the microbial decomposition of organic amendments by rapid reproduction of microbivorous nematodes, changes in the physical and chemical condition of the soil or by improving soil conditions for rapid root growth which enhances the utilization of soil nutrients and masks the effects of nematode damage.

2.1.2.1. Oil cakes

Coconut oil cake reduced the infestation of root-knot nematode on okra and increased the growth of plants (Kumar and Nair, 1976). Similarly, population of nematodes like *Hoplolaimus indicus* Sher, 1963, *Tylenchorhynchus brassicae* Siddiqi, 1961, *Helicotylenchus* sp. and *M. incognita*

were highly reduced in tomato, carrot and potato fields amended with oil-cakes of neem, groundnut, mustard or mahua (Siddiqui *et al.*, 1976).

Soil amended with cakes of *Shorea robusta* Gaertn.f. and *Calophyllum inophyllum* L. resulted in slow hatching of *M. incognita* from eggmasses. (Goswami and VijayaLakshmi, 1986 b). Alam (1989) reported that soil amendment with hornmeal, bonemeal and oil seed cakes of mahua, castor, mustard, neem and peanut were effective in inhibiting the root-knot development and population build up of *T. brassicae* on their respective hosts (egg plant, chilli, okra, cabbage and cauliflower), consequently improving the plant growth.

Cakes of mustard and karanj significantly reduced the penetration of juveniles of *M. incognita* in tomato roots and remarkably increased the growth of plants. Fifty per cent reduction in root penetration of the nematode juveniles were observed in amended soil compared to untreated soil (Goswami and Meshram, 1991).

2.1.2.2. Organic wastes

Galling of tomato roots by *M. incognita* was reduced by 77 to 99 per cent on plants grown in soil mulched with flax, luceme or orchard grass residue (Johnson, 1972). Water extracts of neem leaf effectively reduced

the population of *Pratylenchus brachyurus* (Godfrey, 1929) Filipjev & Schuurmans Steckhoven, 1941 and increased plant growth and yield of maize (Egunjobi and Afalami, 1976). Studies conducted on the use of green leaves and organic wastes like *Calotropis* sp., *Eupatorium* sp., mango and cashew and farmyard manure for the control of root-knot nematode on okra showed reduced nematode infestation and increased growth of plants by most treatments. (Kumar and Nair, 1976).

The extract of *Argemone mexicana* L. acted as a nematicide to *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 in okra raised in microplots (Nath *et al.*, 1982). Similalry, Haseeb *et al.* (1982) identified the nematicidal properties of *Mentha viridis* L., *Cassia fistula* L., *Cordia myxa* L., *Carrissa carandas* L., *Colocasia antiquorum* Schott and *Dalbergia sissoo* Roxb. against *R. reniformis*. Minimum galling and increase in growth of okra after the application of *Clerodendron inerme* (L.) Gaertn. @ 1.5 per cent w/w was observed by Patel *et al.*(1985). Extracts of *Andrographis paniculata* (Burm.f.), *Calendula officinalis* L., *Enhydra fluctuam* and *Solanum khasianum* C.B.Clarke. reduced root galling by *M. incognita* on tomato transplants (Goswami and Vijayalakshmi, 1986a). Soil amended with plant materials of *A. mexicana* and *Phyllanthus niruri Hook. F.* showed slow hatching of nematodes from egg masses (Goswami and Vijayalakshmi,1986b).

Latex extracts (10 to 0.1 per cent dilution) of *Euphorbia caducifolia* L. and *C.procera* were highly effective against *M. javanica* on tomato and brinjal showing improved crop growth (Maqbool *et al.*, 1987). Ground neem leaves and neem seed kernel effectively reduced population of *Pratylenchus penetrans* (Cobb, 1917) Filipjev & Schuurmans Steckhoven, 1941 and *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949 and improved growth and yield of tomato plants (Roosner and Zebitz, 1987). Soil amendment with chopped shoots of latex bearing plants *viz. Carica papaya* L., *Artocarpus heterophyllus* Lamk., *Ficus carica* L., *F. elastica* Roxb., *F. glomerata* Roxb., *Ipomoea fistulosa* Mart.ex.Choisy, *Nerium odorum* Soland. and *Tabernaemontana coronaria* Stapf. were effective in reducing the populations of *H. indicus, R.reniformis, T. brassicae* and *Tylenchus filiformis* Bastian, 1965 infecting tomato and egg plant *F.glomerata* and *F.elastica* improved the growth of plants significantly (Siddiqui *et al.*, 1992).

Extracts of leaves of citronella *(Cymbopogon winterianus)* reduced root galls and populations of *M. incognita* in soil and roots at concentrations of s/20, s/10 and s/5 on tomato (Mahapatra and Swain, 1993). Sundarababu *et al.* (1993a) reported that chopped leaves of bougainvillea, ocimum, onion, prosopis, calotropis and subabul enhanced the growth of tomato and greengram and suppressed the final population of root-knot

nematode in tomato and reniform nematode in greengram . Among them, prosopis was superior followed by subabul, calotropis and bougainvillea. Leaf extracts of *Polyalthia longifolia* (Sonner.) Thw. *C. procera, Jatropha gossypifolia*.L. and *Ocimum sanctum* L. were found to have nematicidal activity against *Heterodera avenae* Wollen weber, 1924 (Sharma and Trivedi., 1995).

2.2. Vesicular arbuscular mycorrhizae (VAM) in the management of nematodes

Vesicular arbuscular mycorrhizal association is reported to induce tolerance 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; Suresh *et al.*, 1985; Hussey and Roncadori, 1982). Development and reproduction of nematodes are often inhibited by mycorrhizal association (Cooper and Grandison 1986 and 1987; Grandison and Cooper, 1986; Jain and Sethi, 1988a).

Graham and Menge (1982) opined that the reduced intensity of disease in mycorrhizal plants may be due to the increased vigour of the plants to tolerate the disease. Accumulation of phenols, quinones, phytoalexins and a number of other compounds have been observed in tissues of plants during vesicular arbuscular mycorrhizal infection (Krishna and Bagyaraj, 1986; Vidhyasekharan, 1988 and 1989; Singh *et al.*, 1990). Remarkable increase in total

and ortho di-hydric phenol content of mycorrhizal tissue culture plantlets of jackfruit was reported by Sivaprasad *et al.* (1995).

2.2.1. Effect on root-knot nematode

The number of giant cells formed in mycorrhizal tomato when infected with the root-knot nematode was significantly low when compared with the non-mycorrhizal plants (Suresh *et al.*, 1985). Mc Guidwin *et al.* (1985) reported that colonisation of *Allium cepa* L. by *G. fasciculatum* appeared to alter the ability of *Meloidogyne hapla* Chitwood, 1949 to penetrate roots. Furthermore, there was no significant difference in nematode density in mycorrhizal and non-mycorrhizal plants 10 weeks after joint inoculation of *M.hapla* and *G.fasciculatum*. Similarly, the gall formation by *M. incognita* and its multiplication were hampered by the early establishment of *G. fasciculatum* on cowpea (Jain and Sethi, 1988a).

Sivaprasad *et al.* (1990) found that occurrence of vesicular arbuscular mycorrhiza along with *M. incognita* reduced the adverse effect of the latter while presence of *M. incognita* alone drastically reduced the growth of cowpea. Cowpea plants inoculated with *M. incognita* in association with *G.fasciculatum, G. mosseae* and *A. morroweae* recorded a root-knot index of 1,3.16 and 3.43 respectively as against 4.89 observed for control plants (Deepthi,

1993). Among 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.*, 1993b). Colonisation by the VAM fugus *G.fasciculatum* was found to reduce root-knot infestation in tomato (Sharma *et al.*, 1994). Mycorrhizal tomato seedlings had lesser number of galls, egg masses per plant, eggs and juveniles per egg mass. The symbiont *G.fasciculatum* caused a reduction of 30 per cent in galls and egg masses per plant (Sharma *et al.*, 1995a). Pea *(Pisum sativum)* CV PG3 roots colonised with the VAM, *G.intraradices* produced fewer galls than non-mycorrhizal roots (Chahal and Chahal, 1995).

Contrary to these findings, Cason *et al.* (1983) found that inoculation of the VAM fungi, *Gigaspora margarita* or *Glomus mosseae* two weeks prior to nematode inoculation did not alter infection by the root-knot nematode *M.incognita* compared to non-mycorrhizal plants on tomato. Sitaramaiah (1995) observed no difference in percentage of mycorrhizal root colonisation in the presence or absence of the nematode. No difference was observed in the duration of life cycle of *M.incognita* on both non-mycorrhizal and mycorrhizal tomato plants inoculated with *G. fasciculatum* (Sharma *et al.*, 1995a).

2.2.2. Effect on other nematodes

G. fasciculatum increased the resistance of tomato plants to *R. reniformis* infestation. Inoculation of tomato transplants or the seed bed with the fungus significantly reduced juvenile penetration and development on mycorrhizal plants compared with the control (Sitaramaiah and Sikora, 1982). Soybean plants inoculated with *G. fasciculatum* and *Heterodera glycines* Ichinohe, 1952 produced more biomass than non-mycorrhizal plants with the nematodes (Francl and Dropkin, 1985). A positive interaction between VAM and stunt nematode *Tylenchorhynchus vulgaris* Swarup and Sethi, 1972 in which the former offset nematode damage and increased the plant growth and phosphorus content of berseem in green house experiment was reported by Hasan and Jain (1987). However, an increase in inoculum level of the nematode *H. cajani* invariably resulted in reduced root infection and spore production by the mycorrhizal fungi *G.fasciculatum* or *G. epigaeus*. *G. epigaeus* showed a profound favourable effect on cyst production (Jain and Sethi, 1987).

Jain and Sethi (1988b) observed that prior establishment of *G.fasciculatum* could offset the adverse effect of *H. cajani* on cowpea. Cyst formation and multiplication of the nematode was also hampered by the VAM fungus. Soil and root population of the burrowing nematode of banana,

Radopholus similis Cobb, 1913 was lesser in mycorrhizal plants than in non-mycorrhizal plants inoculated with the nematode (Umesh *et al.*, 1990; Channabasappa *et al.*, 1995). Lingaraju and Goswami (1993a) observed that *G.fasciculatum* induced tolerance in cowpea to *R. reniformis* even in the presence of damaging levels of the nematode under phosphorous deficient condition. Colonisation of soybean roots by vesicular arbuscular mycorrhizal fungi was negatively correlated with *H. glycines* population densities due to nematode antagonism to the mycorrhizal fungi rather than suppression of nematode populations (Winkler *et al.*, 1994). Sitaramaiah (1995) reported a reduction in the population of *R. reniformis* in roots and soil in *G. fasciculatum* inoculated tomato and cotton plants.

2.3. Nematicides in the management of nematodes

2.3.1. Effect of bare-root dip

2.3.1.1. Tomato

Root-dip of tomato seedlings in aldicarb, parathion, dimethoate and diazinon provided effective control of the root-knot nematode *M.incognita*, (Nelmes and Keerweewan, 1970) while malathion, fenitrothion, formothion, disulfoton and carbofuran were ineffective (Bindra and Kaushal, 1971).

Alam *et al.* (1973) obtained a reduction in the development of root-knot nematode on tomato with bare-root dips in VC-13 and Basamid liquid, while nematode was eliminated from the roots of infested tomato seedlings when they were dipped for 15 minutes in 500 ppm aqueous solution of thionazin (Reddy and Seshadri, 1975). Similarly, complete control of root-knot nematode was obtained following root-dip of three weeks old seedlings in oxamyl (1200 ppm) for 30 minutes (Alam *et al.*, 1975).

Jain and Bhatti (1978) observed that root-dip in dimethoate at 500 ppm for six hours was effective in preventing root-knot infestation in tomato. Least root-knot index was observed in plants dipped in oxamyl at 1000 ppm for 15 minutes when organophosphate (dimethoate) and carbamate (aldicarb sulfone, carbofuran, methomyl and oxamyl) where tested as bare-root dips for the control of *M.incognita* on tomato (Reddy and Singh, 1979)

Haq *et al.* (1984) found significantly poor penetration of *M. incognita* into the roots of tomato dipped in phorate, fensulfothion, dimethoate, aldicarb or carbofuran when seedlings were inoculated immediately after dip treatment. Root-knot development was also reduced by all the nematicides.

2.3.1.2. Brinjal

A reduction in the development of root-knot nematode on egg plant was obtained with bare-root dips in VC-13 and Basamid liquid for 20 to 30 minutes (Alam *et al.*, 1973).

Ahuja (1978) observed that root-dip treatment with oxamyl at 5000 ppm for 60 minutes and dimethoate at 7500 ppm reduced galling by *M. incognita* on brinjal. Thirty minute root-dip in 500 to 1000 ppm of aldicarb or carbofuran or turbufos protected brinjal seedlings from reniform nematode infestation (Krishnaprasad and Krishnappa, 1981).

In a study conducted at the College of Agriculture, Vellayani, root - dip of brinjal seedlings in triazophos, monocrotophos, carbosulfan and zolone for one and a half hour resulted in significant decline in galling and 7.7 to 43.4 per cent increase in the yield of brinjal (K.A.U., 1993a).

Results of seedling bare-root dip of brinjal seedlings in carbosulfan, triazophos, monocrotophos and phosalone for managing root-knot nematode indicated that root-knot index was minimum in carbosulfan (0.1 per cent) treated plots and it was on par with phosalone (0.1 per cent) (Mohanty *et al.*, 1994).

2.3.1.3. Other plants

Zinophos, nemacur and D-1410 were equally effective as bare-root dips, soil drenches or soil mixes for controlling *M. incognita* on *Gardenia* sp. (Miller, 1971). Vydate (oxamyl), VC-13 and dazomet when used as bare-root dips were found to signficantly reduce the population of plant parasitic nematodes around the roots of chilli plants and the development of root-knot disease was considerably suppressed (Saxena *et al.*, 1974). Mani (1989) reported the effectiveness of root-dip in 1000 ppm of carbofuran, chlorpyriphos and monocrotophos in checking the multiplication of citrus nematode *T.semipenetrans* on acid lime seedlings, wherein 88.8, 86.4 and 85.0 per cent reduction in nematode population was recorded respectively.

2.3.2. Effect of soil application

Several nematicides like carbofuran (Singh and Prasad, 1974; Prasad *et al.*, 1977; Mahajan, 1978; Sitaramaiah and Vishwakarma 1978; Upadhyay *et al.*, 1979; Nandal and Bhatti, 1980; Rao *et al.*, 1987; Borah and Phukan, 1990; Patel *et al.*, 1992 and Mohanty *et al.*, 1995), oxamyl (Mc Leod, 1977; Prasad *et al.*, 1977; Ahuja, 1978), fensulfothion (Prasad *et al.*, 1977; Sitaramaiah and Vishwakarma, 1978; Upadhyay *et al.*, 1979; Nandal and Bhatti, 1980; Jaiswal *et al.*, 1987), ethoprop (Mc Leod, 1977; Singh *et al.*, 1978; Rao

et al; 1987; Patel *et al.,* 1992), aldicarb (Mc Leod, 1977; Sitaramaiah and Vishwakarma, 1978; Susannamma kurien, 1980; Jain *et al.,* 1988; Jain and Bhatti, 1991), phorate (Singh *et al.,* 1978; Borah and Phukan, 1990) and monocrotophos (K.A.U., 1993a) have been reported to be effective against several nematodes when applied in the soil.

2.4. Relative efficacy of plant products,VAM and nematicides in the management of nematodes

2.4.1. Relative efficacy of plant products and VAM

Lingaraju and Goswami (1993b) observed that mustard oilcake + *G. fasciculatum* amendment in cowpea resulted in high plant growth responses in the presence of the nematode *R. reniformis.* Compared to plants treated with *G. fasciculatum* alone, neem cake in combination with *G. fasciculatum* gave maximum shoot weight, shoot length and root weight in acid lime while karanj in combination with *G. mosseae* gave maximum root length. Higher reduction in the citrus nematode population both in roots and soil was obtained with karanj cake + *G. fasciculatum* and neem cake + *G. mosseae* treatments (Reddy *et al.,* 1993).

G. mosseae 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 complimentary interactive effect of both components on the manangment of root-knot nematode due to their synergystic 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 (Channa basappa *et al.,* 1995). Soil application of *G.fasciculatum* along with a neem product, Achook effectively managed the incidence of *M. incognita* to a safer level and increased the forage biomass of cowpea (Jain and Hasan, 1995).

2.4.2. Relative efficacy of plant products and nematicides

Carbofuran, fensulfothion , saw dust and NPK significantly reduced *M.javanica* infestation on Pusa Sawani, the saw dust treatment giving the highest yield (Sitaramaiah *et al.,* 1976). Verma (1986) observed that carbofuran and *Melia azadirachta* L. cake + urea have effective control of root-knot nematode and moderate increase in the yield of tomato under field conditions.

Jain and Hasan (1986) investigated the effect of neem cake, the nematicide phenamiphos (2.5 kg ai. per ha) on oat (variety - 801) and its residual effect on subsequent cowpea (variety HCF 42-1) and found that neem cake and nematicide treatments reduced the total nematode population considerably. A similar trend was observed in the successive cowpea crop. Neem cake also increased the fodder and seed yield. Application of aldicarb (1 kg a.i. per ha) + neem oil cake (0.5 ton per ha) followed by carbofuran (1 kg a.i. per ha) + neem oil cake (0.5 ton per ha) proved most effective in reducing the population of *R. reniformis* infecting okra and increasing growth of the plants (Rao *et al.*, 1987).

Paruthi *et al.* (1987) observed a significant improvement in plant growth characters of okra and reduction in number of galls and egg masses of *M. javanica* when subabul leaves (@ 40 g per kg soil) were supplemented with carbofuran (@ 1 kg a.i. per ha). Tomato plants were found to grow equally well in mustard and karanj amended soil as compared to carbofuran treatment (Goswami and Meshram, 1991). All the treatments suppressed root-knot index, number of galls per plant and the nematode population in soil and increased the shoot weight. Jain and Bhatti (1991) obtained a reduction of 48.9 and 26.7 per cent in the population of *M. javanica* infecting tomato in nursery treated with neem leaves (@50 qts. per ha) + spot application of aldicarb (@ 1 kg a.i. per ha) and nursery treated with neem + spot application of neem leaves respectively.

In brinjal, carbofuran, phenamiphos, phorate, Margoside EC and Nimbidin EC proved effective in reducing the populations of *M. incognita, P. delattrei* and *R.reniformis,* phenamiphos 5 g being the best followed by carbofuran 3 G and phorate 10 G. Oil cakes ranked next to the chemicals. Plant extracts were least effective. Oil cakes boosted the growth of the plants and root weight was increased by the chemicals (Poornima and Vadivelu, 1993). Neem cake, both as spot and general application and carbofuran alone and in combination with neem cake were very effective in reducing the larval population of *M. incognita* on tomato 30 and 60 days after transplanting (Kaul and Bhat, 1995).

Pits amended with chopped leaves of marigold, calotropis, castor, neem, subabul and bakain (500, 1000, 1500 g per m^2) and incorporated with carbofuran @ 5g per pit exhibited considerable reduction of *M. incognita* infestation in plant roots. Comparatively, carbofuran application decreased the nematode population and occurrence of disease significantly than amendment with the leaves (Verma and Anwar, 1995).

Application of neem oil seed cake @ 5,10, 20g per kg soil, aldicarb @ 0.002g a.i. per kg soil, carbofuran @0.0015 g a.i. per kg soil, Bavistin @ 0.001 g a.i. per kg soil, powdered leaves of *Adhatoda vasica* Nees. and

Murraya koenigii (L.) Spreng. @ 50 and 100 g per kg soil to autoclaved soil (filled in 12 inches of earthen pots) significantly reduced root-knot rematode population in soil and root. The root-knot indices were decreased signicantly (Reddy *et al.*, 1995).

Among the organic amendments, mahua cake, neem cake and saw dust and nematicide tested against *H. zea* on maize, carbofuran 2 kg a.i. per ha gave maximum reduction over check (28.25 cyst per plant). Among the organic amendments, neem cake @ 25 qt per ha was found best giving 65.5 per cent reduction in the population of the nematode (Singh, 1995).

2.4.3. Relative efficacy of VAM and nematicides

In a field trial, the nematicide carbofuran and oncol controlled the root-knot disease significantly more than VAM and VAM treated plants showed significantly reduced nematode population over control (Sharma *et al.*, 1995b).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Pot culture studies were conducted to determine the efficacy of phytochemicals and vesicular arbuscular mycorrhizae (VAM) in suppressing root-knot nematode infestation in brinjal. The effective phytochemical and VAM fungus obtained from the pot culture studies were further evaluated in comparison with two standard chemicals in a field trial to assess their performance.

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 of 2:1:1 and the mixture was spread on a level ground in the form of beds of 15 cm thickness. The beds were divided into blocks of one square feet. The potting mixture in each block was moistened and then drenched uniformly with 10 per cent formaldehyde solution and was covered with polythene sheet for denematisation. After two weeks, the polythene sheets were removed and the mixture was raked well and exposed. This sterilized potting mixture was used for pot culture studies.

3.1.2. Raising pure culture of root-knot nematode

Egg masses of *Meloidogyne incognita* collected from infested coleus roots were used for raising pure culture of the nematode on brinjal plants maintained in sterilized soil. Subculturing was done periodically to ensure availability of sufficient larval population for the experiments.

Viable egg masses were hand picked from infested roots and allowed to hatch in sterile distilled water in a petridish. Only those larvae which hatched within 48 hours were used for inoculation purpose. The number of larvae present in the inoculum was determined with the help of a stereo microscope and hand tally counter. The larval concentration was adjusted to the required number per ml of suspension by dilution with sterile water.

3.1.3. Evaluation of efficacy of phytochemicals

Neem (*Azadirachta indica* A. Juss.) leaf extract and oil and marotti (*Hydnocarpus laurifolia* (Dennst.) Sleumner) oil were evaluated for their efficacy as seedling bare-root dip in suppressing nematode infestation.

3.1.3.1. Raising of brinjal seedings

Brinjal seeds (var. Surya) were sown in pots containing denematised soil and maintained as per the package of practices of KAU (1993b).

3.1.3.2. Preparation of phytochemicals for bare-root dip

The oils were emulsified with teepol (one per cent) and four concentrations, *viz.*, 50, 25, 12.5 and 6.25 per cent were prepared. Neem leaf extract was prepared by macerating 25 g of leaves in 100 ml water. It was kept undisturbed for 24 hours and then filtered through thin muslin cloth and Whatman No. 1 filter paper to obtain the stock solution. This was further diluted to concentrations of 50, 25, 12.5 and 6.25 per cent.

3.1.3.3. Bare-root dip and transplanting

Four week old healthy brinjal seedlings were selected for the experiment. The seedlings were uprooted, washed well and dipped in the above oils for 15 minutes and in neem leaf extract for one hour. These seedlings were then planted in pots containing sterile pot mixture at the rate of two seedlings per pot. The experiment was laid out in completely randomised design with 13 treatments replicated thrice as follows.

T1 - Seedling root-dip in neem leaf extract 50%

T2 - Seedling root-dip in neem leaf extract 25%

T3 - Seedling root-dip in neem leaf extract 12.5%

T4 - Seedling root-dip in neem leaf extract 6.25%

T5 - Seedling root-dip in neem oil 50%

T6 - Seedling root-dip in neem oil 25%

T7 - Seedling root-dip in neem oil 12.5%

T8 - Seedling root-dip in neem oil 6.25%

T9 - Seedling root-dip in marotti oil 50%

T10 - Seedling root-dip in marotti oil 25%

T11 - Seedling root-dip in marotti oil 12.5%

T12 - Seedling root-dip in marotti oil 6.25%

T13 - Untreated check

3.1.3.4. Inoculation of nematodes

Newly hatched second stage larvae of *M. incognita* were inoculated to the root zone of the transplanted seedlings @ 1 larva per g soil. Inoculation was done as per the method suggested by Venkitesan and Setty (1977). The required quantity of nematode suspension was pipetted out equally

into the holes, which were closed immediately. The pots were irrigated daily to keep the soil moist. Sixty days after transplanting, the plants were uprooted. Observations on height of the plants and number of leaves per plant were taken at planting, 30, 45 and 60 days after planting. At uprooting, observations on gall index, number of egg masses per plant, number of larvae per egg mass and nematode population in 200 g soil and 5 g root were taken.

3.1.4. Evaluation of efficacy of VAM

3.1.4.1. Raising pure culture of VAM

Six cultures of VAM *viz. Glomus fasciculatum, Glomus etunicatum, Glomus constrictum, Glomus monosporum, Glomus mosseae* and *Acaulospora morroweae* obtained from the Department of Plant Pathology, College of Agriculture, Vellayani were maintained on guinea grass *(Panicum maximum)* for four months in pots containing sterile sand:soil mixture.

3.1.4.2. Raising of VAM seedlings

Root segments of *P. maximum* colonised with the respective 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. The respective VAM culture (200g inoculum) was mixed thoroughly

with the two inch upper layer of the potting mixture. Brinjal seeds (var.Surya) were sown over it and covered with a thin layer of soil. Brinjal seeds sown in pots containing denematised potting mixture alone served as check. The pots were watered daily to ensure proper germination and growth of seedlings.

3.1.4.3. Transplanting

One month old seedlings were transplanted into pots containing sterilized pot mixture. Inoculation of nematodes was done as described in 3.1.3.4. Plants were maintained well for two months and observations on the height of plants and number of leaves were taken at transplanting, 30, 45 and 60 days after planting. Plants were uprooted and observations on root-knot index, number of larvae per egg mass, nematode population in 200 g soil and five g root and mycorrhizal colonisation percentage and intensity were taken. There were seven treatments each replicated four times in a completely randomised design as detailed below.

T1 - Inoculation with *Glomus fasciculatum*

T2 - Inoculation with *G. mosseae*

T3 - Inoculation with *G. constrictum*

T4 - Inoculation with *G. etunicatum*

T5 - Inoculation with *Acaulospora morroweae*

T6 - Inoculation with *G. monosporum*

T7 - Check (No VAM)

3.2. Field studies

A field experiment was conducted to evaluate the efficacy of the mycorrhizal fungus and the phytochemical selected from the pot culture studies in comparison with two chemicals namely monocrotophos and carbosulfan. The experiment was conducted at the Instructional Farm, Vellayani in an area infested with plant parasitic nematodes.

3.2.1. Raising of brinjal seedlings

Brinjal seeds, var. Surya were raised in cement tanks of 1.0 x 1.0 x 0.5 m size filled with denematized potting mixture. The mycorrhizal fungus selected from the pot culture study, *G. fasciculatum* was inoculated to half the number of tanks at the time of sowing of seeds as explained in 3.1.4.2. The seedlings were raised as per the package of practices of KAU (1993b).

3.2.2. Preparation of experimental field

Prior to the actual layout of the experiment, a buffer crop of brinjal was raised in the experimental area for building-up the nematode

population. The crop was maintained in the field for 40 days. When the crop was one week old, roots of coleus plants heavily infested with root-knots were collected, chopped and mixed with the soil uniformly in various plots. Thirty days after inoculation, the aerial parts of the plants were cut at their base and the roots were ploughed into the plots.

3.2.3. Transplanting

Four week old seedlings were transplanted to the field. The experimental details were as follows.

Plot size - 3.5 x 2.5 m

Spacing - 60 x 75 cm

Design - R.B.D

Replication - 4

Treatments - 12

T1 - Seedling root-dip in monocrotophos 500 ppm

T2 - Seedling root-dip in monocrotophos 250 ppm

T3 - Seedling root-dip in carbosulfan 500 ppm

T4 - Seedling root-dip in carbosulfan 250 ppm

T5 - Seedling root-dip in effective phytochemical

T6 - Nursery treatment with effective VAM

T7 - T6 + T1

T8 - T6 + T2

T9 - T6 + T3

T10 - T6 + T4

T11 - T6 + T5

T12 - Untreated check

The insecticides monocrotophos and carbosulfan were diluted to concentrations of 500 ppm and 250 ppm for bare-root dip of the seedlings. Neem leaf extract of 25 per cent was prepared as described in 3.1.**3.2.** Brinjal seedlings (mycorrhizal and non-mycorrhizal) were uprooted, cleaned well and dipped in neem leaf extract and insecticides for one hour and then transplanted. The plants were maintained as per the package of practices of KAU (1993b). Biometric observations were taken at 30, 45, 60, 90 and 120 days after transplanting. Harvest was done once in 5 days as and when the fruits were ready for picking. Number of fruits and weight of fruits per plot were determined each time. The plants were uprooted 120 days after transplanting and observations on initial nematode population in 200 g soil, nematode population in soil 30,

60, 90 days after planting and at harvest, mycorrhizal colonisation percentage and intensity, root-knot index at 45 days after planting and at harvest and yield were taken.

3.3. Assessment of Results

3.3.1. Gall index

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

Gall number plant $^{-1}$	Root-knot index
0-25	1
26-50	2
51-100	3
101-150	4
151-200	5
>200	6

3.3.2. Number of larvae per egg mass

A fixed number of 10 egg masses were hand-picked

from the roots and kept in sterile water in a petridish. The total number of freshly hatched larvae was counted and from that the number of larvae per egg mass was determined.

3.3.3. Nematode population in soil

Nematodes were extracted from the representative soil sample of 200 g following the modified method of Christie and Perry (1951) and the nematodes thus extracted were counted.

3.3.4. Nematode population in roots

Nematode population in roots was estimated by modified Baermann funnel technique. Root samples collected were cleaned of adhering soil particles in a stream of water under a tap. Five grams of the root was weighed and cut into small bits. These were moistened and kept in a 200 gauge polythene cover and incubated for 24 hours.

3.3.5. Mycorrhizal colonisation percentage and intensity

The percentage of mycorrhizal infection in root was estimated following the procedure of Phillips and Hayman (1970). Cleaned root samples which were free of soil particles were cut into one cm sized bits, fixed in FAA (formalin : acetic acid : ethanol in 5:5:90) for four hours. Roots were

depigmented by autoclaving with 10 per cent KOH solution at 1 kg/cm^2 for 15 minutes. The alkalinity was neutralised with one per cent hydrochloric acid. Staining was done by keeping the root bits in 0.05 per cent Trypan blue solution (Trypan blue (Romali) - 50 mg, Lactophenol - 100 ml) in Lactophenol reagent (lactic acid 20 ml, phenol 20 ml, glycerol 40 ml, distilled water 40 ml). Stained root bits were arranged on a slide and observed under microscope for the mycorrhizal mycelium, vesicles and arbuscules. Percentage of infection was calculated as follows:

$$\text{Percentage of mycorrhizal infection} = \frac{\text{Number of root bits positive for infection} \times 100}{\text{Number of root bits subjected for observation.}}$$

The number of spores in soil was estimated by adopting sieving and decanting technique. A volume of 100 cc of soil was mixed in water (100 ml) and heavier particles were allowed to settle for a few seconds. The liquid was poured through a coarse soil sieve (500-800 mm) to remove large pieces of organic matter. The liquid was collected and the sieve was washed in a stream of water to ensure that all small particles have passed through. Particles in the liquid which passed through the coarse sieve were resuspended and the heavier particles were allowed to settle for a few seconds. The suspension was then passed through a sieve fine enough to retain the desired spores. The material retained on the sieve was washed to ensure that all colloidal materials passed through the sieve.

Small amounts of the remaining debris were transferred to a petridish and examined under a dissecting microscope and the number of spores were determined.

RESULTS

4. RESULTS

Two pot culture experiments and a field trial were conducted to study the effect of root-dip of brinjal seedlings in phytochemicals at transplanting and basal application of vesicular arbuscular mycorrhizal fungi in the nursery on root-knot nematode infestation in brinjal and the results are presented herewith.

4.1. Bare-root dip of brinjal seedlings in phytochemicals

4.1.1. Effect on plant height

Observations on the height of brinjal plants recorded at different intervals are presented in Table 1. No significant difference was observed in the height of plants dipped in different phytochemicals *viz.*, neem leaf extract, neem oil and marotti oil when observed thirty days after transplanting. Different concentrations of the phytochemicals also had no significant effect on the height of the plants.

Forty five days after transplanting, among the three phytochemicals, bare-root dip in neem leaf extract (34.3 cm) resulted in a significant increase in the height of the plants compared to neem oil (26.1 cm) and marotti oil (26.1 cm) treatments which were on par with untreated plants

Table 1. Effect of bare-root dip of brinjal seedlings in phytochemicals on plant height and number of leaves (per plant)

Treatments	Height (cm)			Number of leaves		
	30DAT	45DAT	60DAT	30DAT	45DAT	60DAT
Neem leaf extract 50%	20.3	34.0	41.3	4.7	7.3	10.7
Neem leaf extract 25%	19.7	34.0	45.0	6.3	9.3	12.3
Neem leaf extract 12.5%	20.3	32.7	42.7	5.3	7.3	10.3
Neem leaf extract 6.25%	20.7	36.3	48.0	5.3	10.3	15.7
Mean	20.3	34.3	44.3	5.4	8.5	12.3
Neem oil 50%	18.3	24.7	30.7	5.7	5.3	8.3
Neem oil 25%	17.7	27.3	35.3	6.0	7.3	10.3
Neem oil 12.5%	18.0	27.0	34.3	5.0	7.3	10.7
Neem oil 6.25%	17.3	25.3	33.3	5.3	7.7	10.0
Mean	17.8	26.1	33.3	5.5	6.9	9.8
Marotti oil 50%	14.0	21.7	39.0	4.0	5.3	8.7
Marotti oil 25%	18.0	28.3	39.7	4.3	6.0	10.0
Marotti oil 12.5%	17.3	25.3	33.7	4.7	6.3	9.7
Marotti oil 6.25%	18.3	29.0	39.3	5.3	7.3	10.7
Mean	16.9	26.1	37.9	4.6	6.3	9.8
Untreated control	16.7	28.3	40.3	6.3	8.7	10.3
CD for phytochemicals	-	2.49	3.66	-	0.82	0.94
CD for treatments	-	4.99	7.32	-	1.65	1.88

DAT - Days after transplanting

(28.3 cm). Plants dipped in different concentrations of neem leaf extract (50,25 and 6.25 per cent) showed a significant increase in height being 34.0, 34.0, and 36.3 cm respectively compared to untreated plants (28.3 cm). However, root-dip in 12.5 per cent neem leaf extract (32.7 cm) showed no significant improvement in the height of plants. Among the different concentrations of neem leaf extract (50,25, 12.5 and 6.25 per cent) there was no significant difference. Different concentrations of neem oil and marotti oil also had no significant effect on the height of plants.

Sixty days after transplanting, root-dip treatments in marotti oil (37.9 cm) and neem oil (33.3 cm) were on par while root-dip in neem leaf extract (44.3 cm) was superior. Different concentrations of the phytochemical also had significant influence on the height of plants compared to untreated control. Root-dip of brinjal plants in 6.25 per cent neem leaf extract resulted in a significant increase in the height of plants (48.0cm). Treatments with neem leaf extract of 25 per cent (45.0 cm), 12.5 per cent (42.7 cm) and 50 per cent (41.3 cm) though were on par with untreated control (40.3 cm), showed an increase of 11.58 per cent (Plate IA), 5.88 per cent (Plate IB) and 2.4 per cent in plant hight respectively. Among the different concentrations of neem leaf extract, there was no significant difference. While neem oil 25 per cent (35.3 cm) and 12.5 per cent (34.3 cm) were on par with untreated control plants (40.3 cm), root-dip in 50 and

Plate I

Effect of bare-root dip in neem leaf extract on the height of brinjal plants.

A. Neem leaf extract (25 per cent)

B. Neem leaf extract (12.5 per cent)

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A

B

6.25 per cent concentrations resulted in reduced height. However, among the different concentrations, there was no significant difference. Similarly, the different concentrations of marotti oil tested did not show any significant difference.

4.1.2. Effect on number of leaves

The number of leaves produced by plants dipped in different concentrations of the phytochemicals showed no significant difference when observed thirty days after transplanting (Table 1).

Forty five days after transplanting there was a significant difference in the number of leaves produced in plants dipped in different phytochemicals. There was a reduction in leaf numbers due to the application of marotti oil and neem oil compared to control. Neem leaf extract did not show such effect and was on par with control. Among the different concentrations of neem leaf extracts tested, 6.25 and 25 per cent concentrations were found to be superior with 10.3 and 9.3 leaves per plant respectively. Excepting the highest concentration of neem oil (50 per cent) which had the lowest number of leaves, all other levels of neem oil tested (25, 12.5 and 6.25 per cent) were on par. Similarly, marotti oil at 50 per cent concentration resulted in the lowest number of leaves per plant (5.3).

Two months after transplanting, neem leaf extract with 12.3 leaves per plant proved its effectiveness and was superior to other phytochemicals which were on par with untreated control. Among the different concentrations of neem leaf extract, 6.25 per cent with 15.7 leaves per plant was definitely superior to all other treatments followed by neem leaf extract 25 per cent (12.3 leaves per plant). Different concentrations of neem oil and marotti oil showed no significant difference in the number of leaves produced.

4.1.3. Effect on nematode infestation

The effect of the phytochemicals on root-knot nematode infestation assessed in terms of gall index, fecundity, hatching of eggs, population of the nematode in soil and root are presented in Table 2.

4.1.3.1. Gall index

Compared to the untreated plants, reduced gall formation was seen in plants dipped in different phytochemicals (Plate II and Plate III). A decrease of 50.2, 25.2 and 25.1 per cent in the gall indices were observed in plants dipped in neem leaf extract, neem oil and marotti oil respectively. But the difference was not significant (Table 2).

Table 2. Effect of bare-root dip of brinjal seedlings in phytochemicals on the population of root-knot nematode

Treatments	Gall index	No.of egg mass per plant	No.of larvae per egg mass	Percentage increase/ decrease	Nematode population	
					Soil (200 g)	Root (1 g)
Neem leaf extract 50%	1.0	3.9 (2.2)	180	-16.3	92.2 (9.7)	36.9 (6.2)
Neem leaf extract 25%	1.0	6.6 (2.8)	205	-4.7	43.6 (6.7)	35.5 (6.1)
Neem leaf extract 12.5%	1.3	10.3 (3.4)	160	-25.6	39.7 (6.4)	50.3 (7.2)
Neem leaf extract 6.25%	2.0	12.3 (3.6)	240	+11.6	31.7 (5.7)	53.4 (7.4)
Mean	1.3	7.9 (2.9)			62.8 (7.1)	46.3 (6.9)
Neem oil 50%	1.3	9.2 (3.2)	190	-11.6	228.6 (15.2)	51.8 (7.3)
Neem oil 25%	2.0	9.9 (3.3)	210	-2.3	211.1 (14.6)	46.1 (6.9)
Neem oil 12.5%	2.3	10.9 (3.5)	200	-6.9	193.9 (13.9)	53.3 (7.4)
Neem oil 6.25%	2.3	10.8 (3.4)	185	-13.9	163.2 (12.8)	39.6 (6.4)
Mean	1.9	10.2 (3.4)			198.4 (14.1)	47.6 (6.9)
Marotti oil 50%	1.7	5.6 (2.6)	210	-2.3	304.4 (17.5)	38.0 (6.2)
Marotti oil 25%	2.0	6.9 (2.8)	240	+11.6	283.9 (16.9)	43.8 (6.7)
Marotti oil 12.5%	2.0	5.6 (2.6)	160	-25.6	234.1 (15.3)	52.6 (7.3)
Marotti oil 6.25%	2.3	5.7 (2.6)	180	-16.3	211.1 (14.6)	55.2 (7.5)
Mean	2.0	5.9 (2.6)			256.9 (16.1)	47.2 (6.9)
Untreated control	2.7	11.5 (3.4)	215		338.0 (18.4)	92.7 (9.6)
CD for phytochemicals	-		NA		(1.25)	-
CD for treatments	-	(0.566)			(2.50)	(0.86)

NA - Not analysed
Figures in parantheses are $\sqrt{x+1}$ transformed values.

Plate II

Root-knot formation in brinjal plants dipped in neem leaf extract

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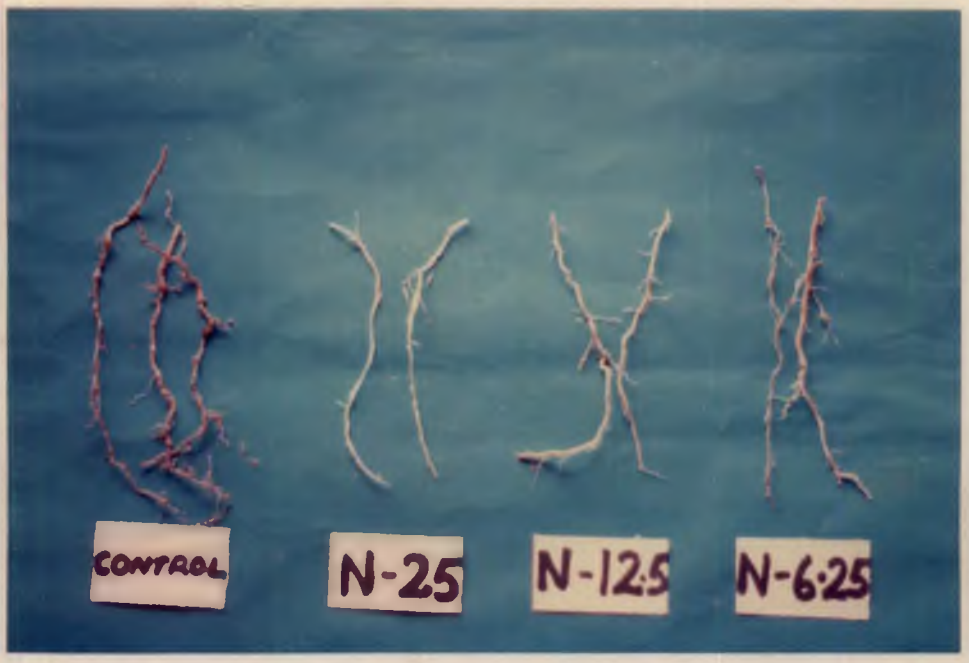
Plate III

Root-Knot formation in brinjal plants dipped in neem oil and marotti oil.

A. Neem oil (25,12.5 and 6.25 per cent)

B. Marotti oil (25, 12.5 and 6.25 per cent)



A

B

4.1.3.2. Fecundity

Among the three phytochemicals, marotti oil resulted in the lowest number of egg masses per plant (5.9) followed by neem leaf extract (7.9) and neem oil (10.2) compared to 11.5 egg masses per plant in untreated control. The data was not statistically signiicant. Different concentrations of neem leaf extracts differed significantly in suppressing fecundity of *M.incognita*. Aqueous extracts of neem leaf at 50 and 25 per cent concentrations resulted in significant reduction in egg mass production, being 3.9 and 6.6 per plant respectively. The 12.5 and 6.25 per cent concentrations had higher number of egg masses (10.3 and 12.3 per plant) and they were on par. The lower concentrations (12.5 and 6.25 per cent) were also on par with untreated plants (11.5). Different doses of neem oil and marotti oil did not differ significantly among themselves in reducing the egg mass production. But compared to control plants, the different concentrations of marotti oil (50, 12.5 and 6.25 per cent) were significantly effective in reducing the number of egg masses (Table 2).

4.1.3.3. Hatching of eggs

Root-dip treatment in phytochemicals did not appreciably inhibit the hatchability of *M. incognita* egg masses as evidenced by the number of second stage larvae emerging from the egg masses in the different treatments. However,

all the treatments except 6.25 per cent neem leaf extract and 25 per cent marotti oil resulted in reduced emergence of second stage juveniles from the egg masses. The percentage reduction ranged from 2.3 in 25 per cent neem oil and 50 per cent marotti oil root-dip treatments to 25.6 in 12.5 per cent neem leaf extract and marotti oil root-dip treatments (Table 2).

4.1.3.4. Population of the nematode in soil

The density of root-knot nematode in the root zone of plants dipped in different phytochemicals was significantly reduced. The lowest number of nematodes was recovered from the root zone of neem leaf extract treated plants (62.8 per 200 g soil), followed by neem oil (198.4 per 200 g soil) and marotti oil (256.9 per 200 g soil). All the treatments were significantly superior to untreated control (338.0 per 200 g soil). Among the different concentrations of neem leaf extract, excepting 50 per cent which had the highest soil population of the nematode (92.2 per 200 g soil), all other doses had lower nematode density and were on par. The difference in nematode population in the different doses of marotti oil and neem oil were insignificant. The nematode population ranged from 163.2 to 228.6 per 200 g soil in neem oil treatment and 211.1 to 304.4 per 200 g soil in marotti oil treatment respectively (Table 2).

4.1.3.5. Population of the nematode in root

The population of nematode in the roots of plants dipped in neem leaf extract, neem oil and marotti oil did not vary significantly. Among the different doses of neem leaf extract, 6.25 and 12.5 per cent concentrations supported higher population (53.4 and 50.3 per g root, respectively). Similarly, no significant difference in the population of nematodes in the root was observed in the plants dipped in different doses of neem oil and marotti oil (Table 2). However, compared to the untreated plants (92.7 per g root), all the treatments reduced population of root-knot nematode in the root significantly. While the nematode population in 1 g root varied from 35.5 to 53.4 in plants dipped in different doses of neem leaf extract, it varied from 39.6 to 53.3 in neem oil and 38.0 to 55.2 in marotti oil treatments.

4.2. Nursery treatment with VAM fungi

The relative efficacy of six cultures of VAM given as nursery treatment in offsetting root-knot nematode infestation was evaluated in pot culture trials and the results are presented below.

4.2.1. Effect on plant height

Results presented in Table 3 showed that there was no significant difference in the height of brinjal seedlings treated with various

Table 3. **Effect of inoculating VAM fungi in the nursery and *Meloidogyne incognita* at transplanting on the height of brinjal (per plant)**

Treatments	Small pot (15 cm)				Large pot (30 cm)			
	At transp-lanting	30DAT	45DAT	60DAT	At transp-lanting	30DAT	45DAT	60DAT
Glomus fasciculatum	8.8	14.8	19.4	21.0	10.3	23.5	41.8	52.8
Glomus mosseae	9.4	13.0	16.4	20.0	11.8	23.0	39.5	49.5
Glomus constrictum	7.8	11.7	15.5	19.2	13.8	25.5	40.0	49.3
Glomus etunicatum	8.4	13.7	19.4	27.8	15.3	31.8	56.5	82.8
Acaulospora morroweae	9.4	14.1	18.0	19.4	8.0	21.0	45.8	58.5
Glomus monosporum	7.1	12.2	15.1	15.8	12.3	25.8	39.0	47.5
Control	8.4	12.2	14.2	16.0	10.0	19.5	31.8	34.8
CD (P=0.05)	-	-	-	2.93	-	-	9.73	11.31

DAT -Days after transplanting

cultures of VAM fungi at the time of transplanting and one month after inoculation with *Meloidogyne incognita* when raised both in small and large pots. Still an increase of 6.6 to 21.3 per cent (Small pot) and 7.7 to 63.1 per cent (Large pot) could be observed in the height of the mycorrhizal plants inoculated with the nematode 30 days after transplanting.

Similarly, though a notable increase was seen in the height of plants in the different treatments (6.3 to 36.6 per cent) 45 days after transplanting when raised in small pots, the data was not statistically significant. But a significant increase in the height of plants due to treatment with mycorrhizal cultures was observed when large pots were used. With the exception of *Glomus constrictum* (40.0cm), *G. monosporum* (39.0cm) and *G. mosseae* (39.5cm) which were on par with control (31.8cm) all the other treatments were effective. The maximum height was recorded in plants inoculated with *G. etunicatum* (56.5cm) and the culture was superior to all other VAM cultures. This was followed by *Acaulospora morroweae* (45.8 cm) and *G. fasciculatum* (41.8cm) and they were on par.

With the exception of *G. monosporum* (15.8cm) which was on par with control (16.0cm) all the other VAM fungi treated seedlings in small pots showed a significant increase in height when observed 60 days after transplanting. Among the treatments, again *G. etunicatum* (27.8cm) was

superior and *G. mosseae* (20.0cm), *G. fasciculatum* (21.0cm), *G. constrictum* (19.2cm) and *A. morroweae* (19.4cm) were on par. The difference in height of plants raised in large pots also agreed with the above findings. All the VAM cultures were superior to control (34.8cm) and *G. etunicatum* (82.8cm) which recorded the maximum increase in height (Plate IV) *G. fasciculatum* (52.8cm), *G.mosseae* (49.5cm), *G. constrictum* (49.3cm), *G.monosporum* (47.5cm) and *A.morroweae* (58.5 cm) were on par.

4.2.2. Effect on number of leaves

The number of leaves in the plants inoculated with different VAM cultures did not vary significantly from that of control plants at the time of transplanting and a month after inoculation with *M. incognita* irrespective of the pot size (Table 4).

Forty five days after transplanting, no significant difference could be observed in the number of leaves produced in plants receiving different treatments in the small pots. But, significantly more number of leaves were recorded in plants treated with *G. etunicatum* (12.5 per plant) and *G.constrictum* (10.5 per plant) and raised in large pots. The other VAM cultures *G. monosporum* (7.5 per plant), *G. mosseae* (8.3 per plant), and *G. fasciculatum* (9.3 per plant) with lower number of leaves were on par with control (9.0 per plant).

Plate IV

Effect of inoculating VAM fungi in the nursery on the height of brinjal plants.

A. *Glomus etunicatum*

B. *Glomus fasciculatum*

A

B

Table 4. Effect of inoculating VAM fungi in the nursery and *Meloidogyne incognita* at transplanting on the number of leaves of brinjal (per plant)

Treatments	Small pot (15 cm)				Large pot (30 cm)			
	At transp-lanting	30DAT	45DAT	60DAT	At transp-lanting	30DAT	45DAT	60DAT
Glomus fasciculatum	4.4	6.6	6.4	6.4	2.8	6.5	9.3	11.3
Glomus mosseae	4.8	6.0	6.0	7.2	3.8	7.3	8.3	9.5
Glomus constrictum	3.4	4.6	5.4	5.2	5.3	8.8	10.5	9.5
Glomus etunicatum	4.0	6.2	6.6	6.6	6.0	10.5	12.5	13.8
Acaulospora morroweae	3.6	5.4	5.6	6.2	3.3	7.0	8.3	7.3
Glomus monosporum	3.8	5.2	5.4	6.4	4.5	6.8	7.5	8.8
Control	3.4	4.8	6.8	6.8	5.0	7.5	9.0	11.0
CD (P=0.05)	-	-	-	-	-	-	2.29	2.7

DAT -Days after transplanting

No significant increase could be seen in the number of leaves in the different treatments 60 days after transplanting when the plants were raised in small pots. However a significant influence of the VAM cultures was observed when the plants were raised in large pots. *G. etunicatum* with 13.8 leaves per plant and *G. fasciculatum* with 11.3 leaves per plant were on par and superior to control (11.0 per plant) and the other mycorrhizal cultures *A. morroweae* (7.3 leaves per plant), *G. monosporum* (8.8 leaves per plant), *G. mosseae* (9.5 leaves per plant) and *G. constrictum* (9.5 leaves per plant) had only reduced number of leaves.

4.2.3. Effect on mycorrhizal colonisation and nematode population

The results on mycorrhizal colonisation and nematode population are presented in Tables 5 and 6.

4.2.3.1. Mycorrhizal colonisation percentage and intensity

There was a marked increase in the colonisation of mycorrhizal fungi in plants raised in various cultures of VAM even in the presence of *M. incognita* when observed 60 days after planting. The highest colonisation of 92 per cent was recorded in plants inoculated with *G. fasciculatum* and raised in small pots (Table 5). Other mycorrhizal cultures *viz.*, *G. mosseae* (85 per cent), *G. constrictum* (89 per cent), *G. etunicatum* (82 per cent),

Table 5. **Effect of inoculating VAM fungi in the nursery and *Meloidogyne incognita* at transplanting on nematode infestation in brinjal.**

Treatments	Small pot (15 cm)						
	Mycorrhizal colonisation percentage and intensity	Gall index	Egg mass per plant	Number of larvae per egg mass	Nematode population		Mycorrhizal spore count in soil
					Root (1g)	Soil (200g)	
Glomus fasciculatum	92	1.4	24.8 (5.1)	125	39.1 (6.3)	83.1 (9.2)	82
Glomus mosseae	85	2.4	8.9 (5.5)	140	57.8 (7.7)	201.2 (14.2)	67
Glomus constrictum	89	2.2	55.4 (7.5)	110	47.1 (6.9)	28.5 (5.4)	63
Glomus etunicatum	82	1.4	8.4 (3.1)	265	223.5 (14.9)	696.5 (26.4)	74
Acaulospora morroweae	63	2.4	11.8 (3.6)	140	49.9 (7.1)	401.4 (20.1)	36
Glomus monosporum	75	1.6	14.3 (3.9)	105	67.0 (8.3)	1734.7 (41.7)	48
Control	44	3.0	60.4 (7.8)	305	717.3 (26.8)	431.5 (20.8)	18
CD (P = 0.05)	NA	0.73	(2.34)	NA	(5.63)	(7.74)	NA

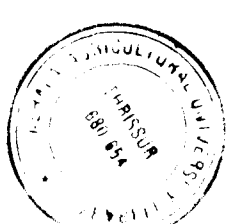
NA - Not analysed

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

Table 6. Effect of inoculating VAM fungi in the nursery and *Meloidogyne incognita* at transplanting on nematode infestation in brinjal

Treatments	Large pot (30 cm)						
	Mycorrhizal colonisation percentage and intensity	Gall index	Number of egg mass per plant	Number of larvae per egg mass	Nematode population		Mycorrhizal spore count in soil
					Root (1g)	Soil (200g)	
Glomus fasciculatum	88	2.0	15.3 (4.0)	120	48.5 (7.0)	118.7 (10.9)	79
Glomus mosseae	73	2.8	35.9 (6.1)	160	57.1 (7.6)	203.4 (14.3)	76
Glomus constrictum	69	3.0	26.1 (5.2)	200	46.7 (6.9)	128.9 (11.4)	54
Glomus etunicatum	93	2.0	12.9 (3.7)	180	78.0 (8.9)	637.8 (25.3)	86
Acaulospora morroweae	89	3.0	22.8 (4.9)	275	44.4 (6.7)	358.9 (18.9)	44
Glomus monosporum	76	2.0	15.4 (4.0)	155	83.6 (9.2)	657.9 (25.7)	57
Control	35	3.0	27.3 (5.3)	285	89.9 (9.5)	232.6 (15.3)	23
CD (P=0.05)	NA	0.39	(0.73)	NA	(0.92)	(2.52)	NA

NA - Not analysed
Figures in parantheses are $\sqrt{x+1}$ transformed values



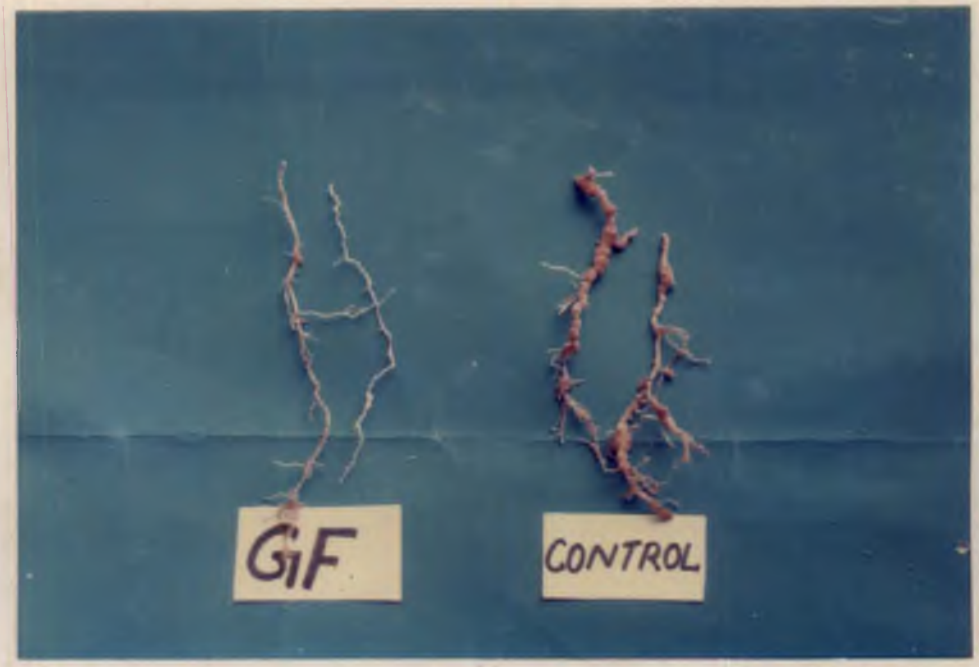
A.morroweae (63 per cent) and *G. monosporum* (75 per cent) also showed higher colonisation percentage than the uninoculated plants (44 per cent). When grown in large pots, the highest percentage of colonisation (93 per cent) was recorded in *G. etunicatum* treated plants (Table 6). Compared to uninoculated plants (35 per cent), all the other mycorrhizal cultures showed increased colonisation with 89 per cent in *A. morroweae*, 88 per cent in *G.fasciculatum*, 76 per cent in *G.monosporum*, 73 per cent in *G. mosseae* and 69 per cent in *G. constrictum* respectively.

4.2.3.2. Gall index

Though the root-knot indices were generally low in the mycorrhizal plants inoculated with *M. incognita*, only a few proved effective in reducing nematode infestation. The VAM fungi, *G. fasciulatum*, (Plate V) *G. etunicatum* and *G. monosporum* showed significant reduction in the root-knot indices, irrespective of the pot size. The root-knot indices recorded in these treatments were 1.4, 1.4 & 1.6 respectively when raised in small pots (Table 5) and 2.0, 2.0 and 2.0 respectively in large pots (Table 6). *G. mosseae* (2.4 and 2.8), *A.morroweae* (2.4 and 3.0) and *G. constrictum* (2.2 and 3.0) generally were not as effective as other VAM cultures in reducing the root-knot formation.

Plate V

Root-knot formation in brinjal plants inoculated with *Glomus fasciculatum*


GF
CONTROL


GF
CONTROL

4.2.3.3. Egg mass per plant

The number of egg masses were reduced significantly in all the VAM treated plants in small pots inoculated with *M. incognita* excepting *G.constrictum* (55.4 egg mass per plant). These treatments did not differ significantly from each other and the number of egg masses observed in them were significantly low being 24.8, 14.3, 11.8, 8.9 and 8.4 in *G. fasciculatum*, *G.monosporum*, *A. morroweae*, *G. mosseae* and *G. etunicatum* respectively, compared to control (Table 5).

The number of egg masses were significantly lower in plants inoculated with *G. monosporum* (15.4 per plant), *G. fasciculatum* (15.3 per plant) and *G. etunicatum* (12.9 per plant) and grown in large pots. They were also on par and superior than all the other treatments. *G. mosseae* (35.9 egg masses per plant), *G. constrictum* (26.1 egg masses per plant) and *A.morroweae* (22.8 egg masses per plant) showed no significant difference from control (27.3 egg masses per plant) (Table 6).

4.2.3.4. Number of larvae per egg mass

The number of larvae obtained per egg mass was low in the different treatments compared to control plants (305 per egg mass in small pots and 285 per egg mass in large pots). The least number of larvae (105 per egg

mass) was obtained from the egg masses collected from *G. monosporum* inoculated plants gown in small pots. This was followed by *G. constrictum* (110 per egg mass) and *G. fasciculatum* (125 per egg mass). The other mycorrhizal cultures *viz., G. mosseae* (140 per egg mass), *A.morroweae* (140 per mass) and *G. etunicatum* (265 per egg mass) also resulted in lower number of larvae per egg masses compared to control (Table 5). When the plants were grown in large pots, the least number of larvae was obtained from *G. fasciculatum* (120 per egg mass) followed by *G. monosporum* (155 per egg mass) and *G. mosseae* (160 per egg mass). The mycorrhizal cultures *G. etunicatum* (180 per egg mass), *G. constrictum* (200 per egg mass) and *A. morroweae* (275 per egg mass) also produced lesser number of larvae when compared to control (Table 6).

4.2.3.5. Nematode population in root

Significantly lesser number of nematodes were obtained from the roots in mycorrhizal plants inoculated with *M. incognita* (Table 5). The number of *M.incognita* larvae recovered from the root was significantly low in all the mycorrhizal plants in small pots compared to control plants (717.3 per g root).

Among the mycorrhizal treatments, excepting *G.etunicatum* (223.5 per g root), all others effectively reduced the nematode infestation in brinjal plants. The population of the nematode observed in these

treatments are 67.0, 57.8, 49.9, 47.1 and 39.1 per g root in *G. monosporum, G.mosseae, A. morroweae, G. constrictum,* and *G. fasciculatum* respectively. All these treatements were on par.

When plants were raised in large pots, all the treatments excepting *G.monosporum* (83.6 larvae per g root) and *G.etunicatum* (78.0 larvae per g root) reduced the nematode population in root though these treatments did not show any significant difference among them. The nematode population observed ranged from 46.7 to 57.1 per g root (Table 6).

4.2.3.6. Nematode population in soil

The population of root-knot nematode in the soil was significantly low when the plants were treated with *G. constrictum* (28.5 per 200 g soil) and *G. fasciculatum* (83.1 per 200 g soil) and grown in small pots (Table 5). Treatment with *G. mosseae* also resulted in lower population of the nematode (201.2 per 200 g soil) in the soil compared to the population of the nematode in untreated plants (431.5 per 200 g soil). The population of root-knot nematode was higher in the soils of plants treated with *A. morroweae* (401.4 per 200 g soil) and *G. etunicatum* (696.5 per 200 g soil) and they were on par with control plants (431.5 per 200 g soil). *G. monosporum* treatment had significantly higher population (1734.7 per 200 g soil) than the control plants.

But when raised in large pots, minimum number of nematodes were recovered from the rhizhosphere of plants treated with *G.fasciculatum* (118.7 per 200 g soil). Statistically it was on par with *G.constrictum* (128.9 per 200 g soil). The number of nematodes recovered from the root zone of *G. monosporum* (657.90 per 200g soil), *G. etunicatum* (637.75 per 200 g soil) and *A. morroweae* (358.9) were significantly higher than that obtained from control plants (232.6 per 200 g soil). It was on par with *G. mosseae* (203.35 per 200 g soil) (Table 6).

4.2.3.7. Mycorrhizal spore count in soil

Compared to control there was a marked increase in the spore count ofmycorrhizae in soil of plants inoculated with different isolates of mycorrhizae when observed 60 days after transplanting. In the trial conducted in small pots, highest spore count (82 per 100 g soil) was recorded from the root zone of *G. fasciculatum* treated plants followed by *G.etunicatum* (74 per 100 g soil), *G. mosseae* (67 per 100 g soil). *G. constrictum* (63 per 100 g soil), *G.monosporum* (48 per 100 g soil) and *A. morroweae* (36 per 100 g soil) when compared to control (18 per 100 g soil) (Table 5). Highest number of spores were recovered from *G. etunicatum* (86 per 100 g soil) followed by *G.fasciculatum* (79 per 100 g soil) when raised in large pots. Other mycorrhizal cultures *viz.* *G.mosseae* (76 per 100 g soil), *G. monosporum* (57 per 100 g soil), *G. constrictum*

(54 per 100 g soil) and *A.morroweae* (44 per 100 g soil) also resulted in higher number of spores than the uninoculated control plants (23 per 100 g soil) (Table6).

4.3. Field Evaluation

The results on the efficacy of nursery treatment with *G.fasciculatum* and bare-root dip in aqueous neem leaf extract (25 per cent) individually and in combination under field condition are presented herewith.

4.3.1.Effect of different treatments on plant height and number of leaves

Effect on plant height recorded periodically are presented in Table 7. No significant difference was observed in the height of brinjal seedlings obtained from untreated nursery and VAM inoculated nursery at the time of transplanting.

Thirty days after transplanting a significant difference was observed in the height of plants in the various treatments. Maximum plant height was observed in plants subjected to seedling root-dip in carbosulfan 500 ppm (14.8 cm), which was on par with seedling root-dip in monocrotophos 250 ppm (13.1 cm) and 500 ppm (12.6 cm). There was no significant difference in the height of plants in the other root-dip treatments, *viz.*, seedling root-dip in carbosulfan 250 ppm (10.9 cm) and neem leaf extract (10.6 cm). Plants transplanted from nursery treated with *G. fasciculatum* (10.1 cm), also showed no significant increase in

Table 7. Effect of nursery treatment with *Glomus fasciculatum* and bare-root dip in neem leaf extract (25 per cent) and nematicides at transplanting on height and number of leaves of brinjal (per plant)

Treatments	Height (cm)				Number of leaves			
	30DAT	60DAT	90DAT	120DAT	30DAT	60DAT	90DAT	120DAT
RD Monocrotophos 500 ppm	12.6	46.6	64.4	84.7	4.6	49.5	64.9	84.8
RD Monocrotophos 250 ppm	13.1	46.7	62.0	82.7	5.3	46.0	63.1	82.5
RD Carbosulfan 500 ppm	14.8	51.9	64.3	79.8	5.8	48.9	62.8	83.8
RD Carbosulfan 250 ppm	10.9	42.7	57.6	76.1	4.4	40.1	59.5	76.8
RD Neem leaf extract 25%	10.6	44.6	61.9	84.0	4.0	48.3	66.1	91.7
NT *Glomus fasciculatum* (GF)	10.1	42.0	53.1	64.6	4.5	41.0	56.7	70.5
NT GF+ RD Monocrotophos500ppm	10.5	42.4	57.3	80.2	4.5	44.2	60.3	87.5
NT GF+ RD Monocrotophos 250ppm	10.2	40.5	51.0	70.0	4.6	38.0	54.4	84.3
NT GF+ RD Carbosulfan 500ppm	10.0	39.8	58.4	74.3	4.4	46.9	60.3	73.1
NT GF+ RD Carbosulfan 250ppm	9.6	38.6	51.4	68.2	3.9	40.3	55.5	69.6
NT GF+ RD Neem leaf extract 25%	8.4	43.7	55.7	70.9	4.1	43.1	59.4	79.7
Control	11.4	51.3	73.3	93.6	4.9	52.5	76.6	95.8
CD (P = 0.05)	3.01	-	-	-	-	-	-	-

DAT - Days after transplanting RD - Bare-root dip
NT - Nursery treatment

height. Similarly root-dip of mycorrhizal seedlings in monocrotophos 500 ppm (10.5 cm), monocrotophos 250 ppm (10.2 cm), carbosulfan 500 ppm (10 cm), carbosulfan 250 ppm (9.6 cm) and neem leaf extract (8.4 cm) were on par with control (11.4 cm). Subsequent observations on plant height (60, 90 and 120 days after transplanting) showed no significant difference due to various treatments. Again no significant difference was observed in the number of leaves on the plants in different treatments at transplanting and subsequently (30, 60, 90 and 120 days after transplanting) (Table 7).

4.3.2. Effect of different treatments on shoot weight, root weight and yield of brinjal

4.3.2.1. Shoot weight

The results presented in Table 8 indicated a significant increase in the shoot weight of the treated plants. Among the root-dip treatments, only root-dip in neem leaf extract (25 per cent) resulted in increased shoot weight (3 kg per plant) compared to the control plants (1.9 kg per plant). Bare-root dip of seedlings at transplanting in monocrotophos and carbosulfan did not have any significant effect on shoot weight. Nursery treatment with *G. fasciculatum* significantly increased the shoot weight of brinjal plants (4.8 kg per plant). Combination of mycorrhizal treatment in the nursery and root-dip of seedlings

Table 8. **Effect of nursery treatment with *Glomus fasciculatum* and bare-root dip in neem leaf extract (25 per cent) and nematicides at transplanting on shoot and root weight and yield of brinjal**

Treatments	Shoot weight (kg)	Root weight (kg)	Number of fruits	Weight of fruits(kg)
RD Monocrotophos 500 ppm	2.1	0.46	121.0	5.8
RD Monocrotophos 25o ppm	2.3	0.46	141.0	5.2
RD Carbosulfan 500 ppm	2.2	0.42	134.3	5.7
RD Carbosulfan 250 ppm	2.2	0.63	93.3	4.1
RD Neem leaf extract 25%	3.0	0.67	101.3	4.3
NT *Glomus fasciculatum* (GF)	4.8	0.65	137.3	5.9
NT GF+ RD Monocrotophos 500ppm	2.8	0.45	166.0	7.1
NT GF+ RD Monocrotophos 25oppm	2.4	0.55	86.0	2.8
NT GF+ RD Carbosulfan 500ppm	2.4	0.51	182.7	7.9
NT GF+ RD Carbosulfan 250ppm	2.3	0.62	136.3	5.9
NT GF+ RD Neem leaf extract 25%	2.6	0.44	138.3	5.8
Control.	1.9	0.57	110.0	4.1
CD (P=0.05)	0.56	-	29.77	1.51

RD - Bare-root dip
NT - Nursery treatment

in monocrotophos (500 ppm) at the time of transplanting also increased shoot weight significantly (2.8 kg). All other root-dip treatments of mycorrhizal seedlings did not have any significant effect on the shoot weight of brinjal.

4.3.2.2. Root weight

The results presented in Table 8 showed an increase in the root weight (8 to 17 per cent) of mycorrhizal plants subjected to root-dip treatments in carbosulfan (250 ppm), normal seedlings given root-dip treatment in carbosulfan (250 ppm), *G. fasciculatum* inoculated seedlings and seedlings given root-dip treatment in neem leaf extract. But this increase in root weight was not sufficient to give statistical significance.

4.3.2.3. Yield

4.3.2.3.1. Number of fruits

Among the root-dip treatments, only root-dip treatment in monocrotophos (250 ppm) resulted in significantly higher number of fruits per plant (141), all other treatments being on par with control. Nursery treatment with *G. fasciculatum* alone (137.3) also did not show any significant increase in the number of fruits. However, bare-root dip of mycorrhizal seedlings in monocrotophos (500 ppm) and carbosulfan (500 ppm) resulted in significantly

higher number of fruits (being 166.0 and 182.7 per plant respectively) compared to untreated plots (110 fruits per plant). No significant increase was observed in the number of fruits in all other treatment combinations (Table 8).

4.3.2.3.2. Weight of fruits

Root-dip of mycorrhizal seedlings in higher dose (500 ppm) of monocrotophos and both the doses (500 and 250 ppm) of carbosulfan gave significantly better yield, the weight of fruits in the treatments being 7.1 and 7.9 and 5.9kg per plant respectively compared to 4.1 kg per plant in control (Table 8). Similarly, a significant increase in the weight of fruits was observed in normal plants given root-dip treatments at transplanting in higher concentration (500 ppm) of monocrotophos (5.8 kg per plant) and carbosulfan (5.7 kg per plant). Nursery treatment with *G.fasciculatum* also resulted in significantly higher yield (5.9 kg per plant). While root-dip of normal seedlings in neem leaf extract (25 per cent) gave only a slight increase in yield (4.3 kg per plant), root-dip of mycorrhizal seedlings in neem leaf extract resulted in significantly higher yield (5.8 kg per plant). No significant difference was observed in the yield of other treated plants.

4.3.3. Effect of different treatments on nematode infestation and VAM colonisation

4.3.3.1. Gall index/Number of galls per plant

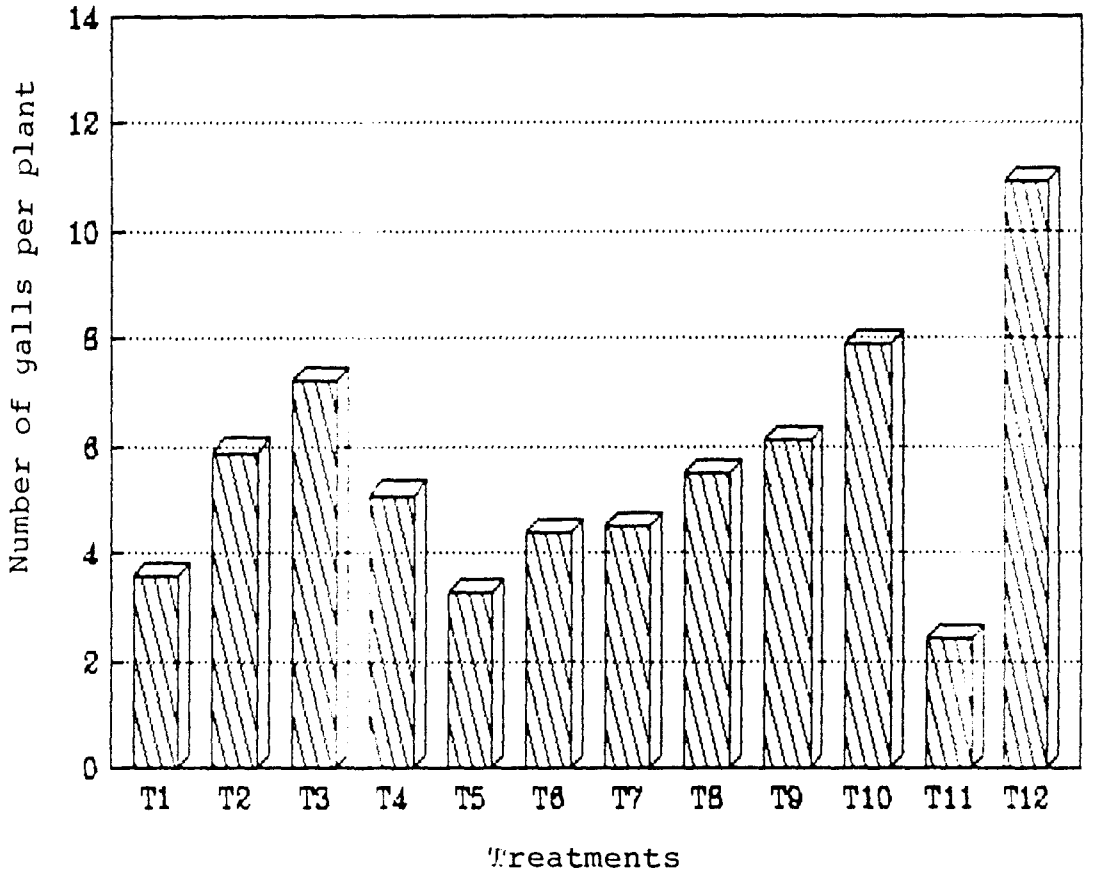
The gall index was found to be uniform (1) in all the treatments and untreated plants when observed forty five days after planting (Table9). However the number of galls per root system (Fig No.1) varied significantly in the different treatments, 45 days after transplanting. Root-dip treatment in monocrotophos (500 ppm) and carbosulfan (250 ppm) resulted in significantly lower number of galls being 3.6 and 5.2 per plant respectively. The least number of galls was recorded in neem leaf extract (25per cent) root-dip treatment. Nursery treatment with *G.fasciculatum* also resulted in significantly reduced galling (4.4). While root-dip of mycorrhizal seedlings in monocrotophos at both doses showed reduced galling, root-dip of the seedlings in carbosulfan had significantly higher number of galls. Root-dip of mycorrhizal seedlings in neem leaf extract significantly reduced the number of galls per plant (2.4 per plant). When observed at harvest (120 days after transplanting) the root-knot index in the different treatments varied from 2 to 3.3. The index was very high in untreated plants (6.0). The number of galls in root-dip treatments alone varied from 40.7 (monocrotophos 500 ppm) to 91.5 (carbosulfan 500 ppm) (Fig No.II). Root-dip in neem leaf extract resulted in 62.7 galls per plant. Plants treated with

Table 9. Effect of nursery treatment with *Glomus fasciculatum* and bare-root dip in neem leaf extract (25 per cent) and nematicides at transplanting on nematode infestation and VAM colonisation in brinjal

Treatments	45 days after transplanting			120 days after transplanting			
	Gall index	Number of egg mass per plant	Mycorrhizal colonisation percentage and intensity	Gall index	Number of egg mass per plant	Population of nematodes in root (5g)	Mycorrhizal colonisation percentage and intensity
RD Monocrotophos 500 ppm.	1	0.3 (1.1)	15	2	9.6 (3.3)	81.9 (9.1)	22
RD Monocrotophos 250 ppm.	1	0 (1)	13	3	17.9 (4.4)	82.3 (9.1)	27
RD Carbosulfan 500 ppm.	1	0.3 (1.1)	13	3.3	14.7 (3.9)	34.0 (5.9)	18
RD Carbosulfan 250 ppm.	1	0.2 (1.1)	35	2.3	8.9 (3.2)	90.2 (9.6)	32
RD Neem leaf extract 25%	1	0 (1)	33	3.0	14.9 (3.9)	51.8 (7.3)	39
NT *Glomus fasciculatum* (GF)	1	0 (1)	80	2.3	10.1 (3.3)	44.9 (6.8)	88
NT GF+RD Monocrotophos 500 ppm.	1	0 (1)	63	3.0	15.5 (4.1)	64.7 (8.1)	55
NT GF+RD Monocrotophos 250 ppm.	1	0.6 (1.3)	53	3.0	16.5 (4.2)	131.7 (11.5)	56
NT GF+RD Carbosulfan 500 ppm.	1	0 (1)	68	3.0	20.4 (4.6)	43.0 (6.6)	72
NT GF+RD Carbosulfan 250 ppm	1	0 (1)	55	2.7	15.8 (4.1)	40.2 (6.4)	64
NT GF+RD Neem leaf extract 25%	1	0 (1)	60	3.0	24.8 (5.1)	55.6 (7.5)	74
Control	1	1.1 (1.44)	38	6.0	90.1 (9.5)	171.5 (13.1)	40
CD(0.05)	NA	-	NA	-	(1.46)	(4.12)	NA

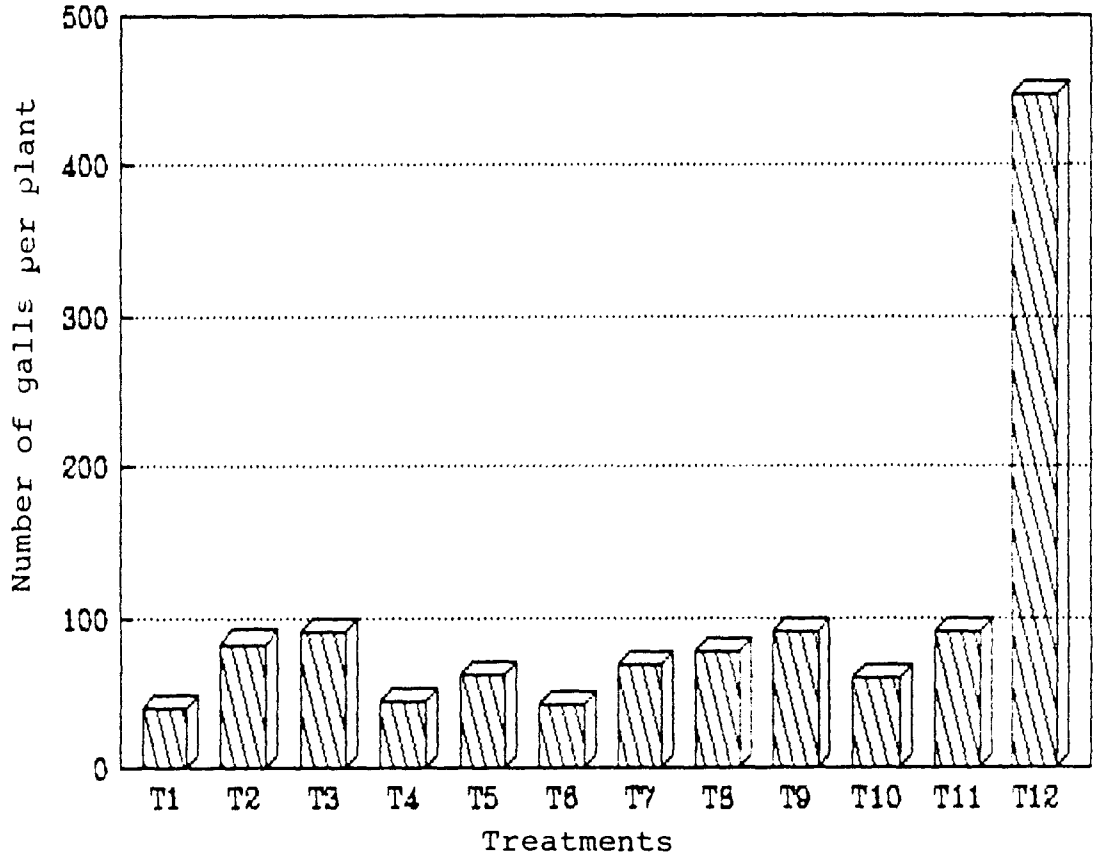
RD - Bare-root dip
NT - Nursery treatment
NA - Not analysed
Figures in parantheses are $\sqrt{x+1}$ transformed values

FIG.1.EFFECT OF VAM, NEEM LEAF EXTRACT AND NEMATICIDES ON NUMBER OF GALLS FORMED 45 DAYS AFTER TRANSPLANTING



T1-Bare-root dip in monocrotophos 500 ppm
T2-Bare-root dip in monocrotophos 250 ppm
T3-Bare-root dip in carbosulfan 500 ppm
T4-Bare-Root dip in carbosulfan 250 ppm
T5-Bare-root dip in neem leaf extract 25%
T6-Nursery treatment with Glomus fasciculatum
T7-T6+T1
T8-T6+T2
T9-T6+T3
T10-T6+T4
T11-T6+T5
T12-Control

FIG.II.EFFECT OF VAM, NEEM LEAF EXTRACT AND NEMATICIDES ON NUMBER OF GALLS FORMED 120 DAYS AFTER TRANSPLANTING



T1-Bare-root dip in monocrotophos 500 ppm
T2-Bare-root dip in monocrotophos 250 ppm
T3-Bare-root dip in carbosulfan 500 ppm
T4-Bare-root dip in carbosulfan 250 ppm
T5-Bare-root dip in neam leaf extract 25%
T6-Nursery treatment with Glomus fasciculatum
T7-T6+T1
T8-T6+T2
T9-T6+T3
T10-T6+T4
T11-T6+T5
T12-Control

G. fasciculatum in the nursery showed reduced gall infestation, the number of galls per plant being 42.1. The number of galls in all other combined treatments varied from 59.9 in *G. fasciculatum* + carbosulfan 250 ppm to 91.2 in *G.fasciculatum* + neem leaf extract (25 per cent).

4.3.3.2. Number of egg mass

Data presented in Table 9 revealed no significant difference in the number of egg mass per plant when observed 45 days after transplanting. However significantly reduced number of egg masses were seen in the treated plants when observed at harvest. The number of egg mass in plants dipped in the nematicides at different concentrations varied from 8.9 to 17.9 while root-dip in neem leaf extract resulted in 14.9 egg masses per plant. The number of egg masses per plant in *G. fasciculatum* treated nursery was only 10.1 per plant. The number of egg masses in mycorrhizal seedlings dipped in different nematicides varied from 15.5 to 20.4 per plant while root-dip of these seedlings in neem leaf extract resulted in 24.8 egg masses per plant compared to 90.1 in untreated plants.

4.3.3.3. Mycorrhizal colonisation percentage and intensity

The mycorrhizal colonisation percentage was found to be low in seedlings given bare-root dip in nematicidal solutions (Table 9) when

observed 45 days after transplanting, the percentage intensity being 15,13,13 and 35 per cent respectively in monocrotophos (at 500 ppm and 250 ppm) and carbosulfan (at 500 and 250 ppm) respectively. The colonisation intensity in the neem leaf extract treatment, (33 per cent) was comparable to control (38 per cent). Seedlings raised in mycorrhizae treated nursery recorded the highest percentage of colonisation (80 per cent). Similarly, mycorrhizal seedlings dipped in nematicidal solutions also showed higher intensity of colonisation, the percentage being 63 and 53,68 and 55 and 60 in monocrotophos (500 and 250 ppm), carbosulfan (500 and 250 ppm) and neem leaf extract respectively. A similar trend was observed in the colonisation percentage and intensity when observed 120 days after planting being 22 and 27 in monocrotophos (500 and 250 ppm), 18 and 32 in carbosulfan (500 and 250 ppm), 39 in neem leaf extract, 88 in *G. fasciculatum* 55 and 56 in *G. fasciculatum* + monocrotophos (500 and 250 ppm), 72 and 64 in carbosulfan (500 and 250 ppm) and 74 in *G. fasciculatum* + neem leaf extract (25 per cent) respectively as against 40 in untreated plants.

4.3.3.4. Nematode population in root

Though the nematode population in five gram root of plants given seedling bare-root dip at transplanting in monocrotophos (500 ppm and 250 ppm) and carbosulfan (250 ppm) were low, they did not differ significantly from control plants (Table 10). However, the population of the

Table 10. Effect of nursery treatment with *Glomus fasciculatum* and bare-root dip in neem leaf extract (25 per cent) and nematicides at transplanting on nematode population in soil (100g)

Treatments	30 DAT	60 DAT	90 DAT	120 DAT
RD Monocrptophos 500 ppm.	22.8	16.1	36.2	211.6
	(4.9)	(4.1)	(6.1)	(14.6)
RD Monocrotophos 250 ppm.	8.4	30.9	48.1	258.2
	(3.1)	(5.7)	(7.0)	(16.1)
RD Carbosulfan 500 ppm.	8.0	34.5	45.7	332.4
	(3.0)	(5.9)	(6.8)	(18.3)
RD Carbosulfan 250 ppm	24.6	36.6	52.3	252.7
	(5.1)	(6.1)	(7.3)	(15.9)
RD Neem leaf extrract 25%	17.2	28.2	62.7	282.9
	(4.3)	(5.4)	(7.9)	(16.8)
NT *Glomus fasciculatum* (GF)	30.1	52.3	73.6	302.9
	(5.6)	(7.3)	(8.6)	(17.4)
NT GF+RD Monocrotophos 500 ppm.	40.2	28.5	42.8	228.4
	(6.4)	(5.4)	(6.6)	(15.2)
NT GF+RD Monocrotophos 250 ppm.	45.1	14.7	40.8	297.9
	(6.7)	(3.9)	(6.5)	(17.3)
NT GF+RD Carbosulfan 500 ppm.	17.7	34.1	58.1	233.9
	(4.3)	(5.9)	(7.7)	(15.3)
NT GF+RD Carbosulfan 250 ppm.	15.5	18.4	36.6	242.9
	(4.1)	(4.4)	(6.1)	(15.6)
NT GF+RD Neem leaf extract 25%	20.7	25.5	36.9	301.4
	(4.7)	(5.2)	(6.2)	(17.4)
Control.	41.1	45.9	66.5	465.6
	(6.5)	(6.9)	(8.2)	(21.6)
CD (P=0.05)	(1.52)	(1.87)	(0.96)	

RD - Bare-root dip
NT - Nursery treatment
Figures in parantheses are $\sqrt{x+1}$ transformed values

nematode in roots of plants dipped in neem leaf extract was significantly low (51.8 per 5g root). Similarly, plants raised in nursery treated with *G. fasciculatum* had significantly lower nematode population, the number of nematodes in 5 g root being 44.9 compared to the heavy population of 171.5 per 5g root in untreated plants. With the exception of mycorrhizal seedlings dipped in lower dose of monocrotophos (250 ppm), (131.7 per 5 g root), all other treatments involving root-dip of mycorrhizal seedlings in nematicidal solutions and neem leaf extract resulted in significantly lower number of nematodes in the roots. While the nematode population was 55.6 per 5 g root in *G. fasciculatum* + neem leaf extract root-dip treatment, it was 64.7, 43.0 and 40.2 per 5 g root in monocrotophos (500 ppm) and carbosulfan (500 ppm and 250 ppm) respectively as against 171.5 per 5 g root in control plants. Mycorrhizal seedlings dipped in monocrotophos (250 ppm) at transplanting had 131.7 nematodes per 5 g root at harvest (Table 9).

4.3.4. Nematode population in soil

The population of the root-knot nematode recovered from 100 gram soil are presented in Table 10. Pre-planting population of the nematode was uniform in the field.

4.3.4.1. Thirty days after transplanting

With the exception of the treatments root-dip in carobsulfan (250 ppm) (24.6 per 100g soil), nursery treatment with *G.fasciculatum* (30.1 per 100 g soil) and nursery treatment with *G. fasciculatum* + root-dip in monocrotophos 500 ppm (40.1 per 100g soil) and 250 ppm (45.1 per 100g soil) which were on par with control (41.1 per 100 g soil), the population of root-knot nematode in all other treatments were significantly low.

While the nematode population in 100g soil in root-dip in nematicide treatments ranged from 8.01 (carbosulfan 500 ppm) to 22.8 (monocrotophos 500 ppm) it was 17.2 in neem leaf extract (25 per cent) treatment. Root-dip of plants treated with *G. fasciculatum* in the nursery in carbosulfan had 17.7 nematodes per 100g soil (500 ppm) and 15.5 per 100 g soil (250 ppm) while root-dip of the mycorrhizal seedlings in neem leaf extract resulted in 20.7 nematodes per 100g soil (Table 10).

4.3.4.2. Sixty days after transplanting

Data presented in Table 10 revealed that with the exception of root-dip of mycorrhizal seedlings in monocrotophos 250 ppm (14.7 per 100g soil) and carbosulfan 250 ppm (18.4 per 100g soil), there was no significant difference in the soil nematode population in all the other treatments.

The nematode population in the different treatments ranged from 25.5 to 52.3 as against 45.9 in control in 100g soil.

4.3.4.3. Ninety days after transplanting

Ninety days after transplanting, with the exception of root-dip in carbosulfan 250 ppm (52.3 per 100 g soil), all other root-dip treatments in nematicidal solutions *viz.*, monocrotophos (500 and 250 ppm) and carbosulfan (500 ppm) resulted in significantly lower nematode population in the soil being 36.2, 48.1 and 45.7 respectively in 100g soil (Table 10). However compared to control plots, there was no significant reduction in the nematode population in the rhizosphere of plants dipped in neem leaf extract (62.7 per 100g soil) at transplanting and in plants raised in *G.fasciculatum* treated nursery (73.6 per 100g soil). When nursery treatment with mycorrhizae was combined with root-dip in nematicidal solution and neem leaf extract, with the exception of root-dip treatment in carbosulfan (500 ppm) all the treatments showed significantly reduced nematode population in the soil. While the nematode population in 100g soil in *G. fasciculatum* nursery treatment + root-dip in carbosulfan 500 ppm was 58.1 it was only 42.8 and 40.8, 36.6 and 36.9 in mycorrhizal seedlings dipped in monocrotophos 500 and 250 ppm, carbosulfan 250 ppm and neem leaf extract (25 per cent) respectively.

4.3.4.4. One hundred and twenty days after transplanting

There was no significant difference in the population of the nematode in the soil in the different treatments when observed 120 days after transplanting (Table 10).

4.3.5. Mycorrhizal spore count in soil

No remarkable difference was observed in the spore count of *G.fasciculatum* in the different treatments compared to untreated control (Table 11). Most of the treatments showed an increase in the spore count till ninety days after transplanting and a decrease was observed 120 days after transplanting.

Table 11. Mycorrhizal spore count in soil

Treatments	30 DAT	60 DAT	90 DAT	120 DAT
RD Monocrotophos 500 ppm.	8	16	19	17
RD Monocrotophos 250 ppm.	10	17	21	13
RD Carbosulfan 500 ppm.	14	21	23	09
RD Carbosulfan 250 ppm	17	16	24	16
RD Neem leaf extrract 25%	15	15	19	23
NT Glomus fasciculatum (GF)	15	21	28	32
NT GF+RD Monocrotophos 500 pm.	14	25	32	19
NT GF+RD Monocrotophos 250 ppm.	9	21	23	15
NT GF+RD Carbosulfan 500 ppm.	16	27	25	14
NT GF+RD Carbosulfan 250 ppm.	11	25	28	05
NT GF+RD Neem leaf extract 25%	20	30	32	18
Control.	20	26	29	19

RD - Bare-root dip
NT - Nursery treatment
The data was not analysed

DISCUSSION

5. DISCUSSION

The root-knot nematode causes considerable loss in plants either directly by damaging the root system, thus interfering with nutrient and water uptake, or indirectly by its association with many fungal and bacterial plant pathogens. When plants are infected early at the seedling stage, as is usual in the case of transplanted vegetable crops, the losses are very high. The infected plants may even fail to establish. Hence, the noxious pest should be effectively checked in the early stage. Till now, application of nematicides remain the prime strategy in nematode management. To replace this costly and hazardous control measure, alternate modes of management are being explored. Recently, bare-root dip of seedlings at transplanting in phytochemicals (Husain *et al.*, 1984; Pradhan *et al.*, 1989; Akhtar and Alam, 1990; Siddiqui and Alam, 1995) and mycorrhizal treatment (Cason *et al.*, 1983; Suresh *et al.*, 1985; Jain and Sethi, 1988a; Deepthi, 1993; Sharma *et al.*, 1995b) two relatively low cost eco-friendly management practices have shown promise for the control of *Meloidogyne incognita*.

Various mechanisms have been ascribed to explain the nematostatic properties of these practices. The phytochemicals adversely affect the hatching, host invasion and development of root-knot nematode in plants thus keeping the population in check (Khair and Mc Leod, 1973; Nandal and

Bhatti, 1986) VA mycorrhizae in addition to providing a physical barrier, induce tolerance against nematode infestation through the physiological and biochemical changes brought about by its association (Krishna and Bagyaraj, 1986; Vidhyasekharan, 1988 and Singh *et al.*, 1990). Further, nutritional advantages provided by VAM association makes the host plant more vigourous and resistant to pathogenic infection. (Cason *et al*., 1983; Sivaprasad *et al.*, 1990; Srivastava *et al.*, 1990; Tylka *et al.*, 1991).

The present investigation was conducted to identify an effective phytochemical for root-dip of brinjal seedlings and an efficient VA mycorrhizal fungus as a biocontrol agent against root-knot nematode infestation in brinjal.

5.1. Efficacy of bare-root dip of brinjal seedlings in phytochemicals for the management of root-knot nematode

The phytochemicals tested in the study *viz.*, aqueous neem leaf extract, neem oil and marotti oil varied in their efficacy in combating nematode infestation. Considering the growth parameters of the plant at forty fifth and sixtieth day after transplanting, a significant increase in height was observed in plants dipped in different concentrations of neem leaf extract. Though there was no significant differences among the different concentrations of neem leaf extract, the lowest

dose (6.25 per cent) resulted in maximum increase in height closely followed by 25 per cent concentration (paragraph 4.1.1.). Evidently these lower doses were more effective than the highest dose (50 per cent). Though statistically not significant, root-dip in oils (neem and marotti) generally resulted in reduced height. This may be due to the mild phytotoxic effect of the phytochemicals. Similar suppression of plant stature due to phytotoxicity of plant products was reported by Mahapatra and Swain (1993) in tomato dipped in higher concentrations of citronella leaf extracts.

It is evident from the results presented in paragraph 4.1.2.that root-dip of brinjal seedlings in neem leaf extract result in significantly more number of leaves than root-dip treatments in neem oil and marotti oil. The ineffectiveness of root-dip treatments in neem oil and marotti oil may probably be due to slight phytotoxic effect. Of the different doses of neem leaf extract tested, the lowest dose (6.25 per cent) was best closely followed by 25 per cent extract. Earlier workers have also recorded significant improvement in plant growth due to bare-root dip treatments in different phytochemicals like water extract of leaves of Eucalyptus and neem in tomato (Vats and Nandal, 1994) and neem and its different formulations in tomato (Vats and Nandal, 1994; Pannu and Paruthi, 1995).

The pronounced effect of neem leaf extract manifested on plant growth was due to the suppressive effect of the extract on the nematode as indicated by the observations recorded on the nematode infestation on paragraph 4.1.3. Effectiveness of root-dip of brinjal plants in phytochemicals in reducing root-knot development has been observed by Husain *et al.,* (1984). Though Pradhan *et al.,* (1989) reported that seedling root-dip of tomato seedlings in oils of neem and karanj was highly effective in preventing gall formation, the results of the present trial mentioned in paragraph 4.1.3.1. showed that neem leaf extract was better than neem oil in reducing root-knot development in brinjal.

The fecundity of the nematode was significantly impaired by root-dip treatment in neem leaf extract and to some extent by neem and marotti oils as evidenced by the number of egg masses in the treated plants (paragraph 4.1.3.2). The higher concentrations of water extract of neem leaves (50 and 25 per cent) significantly reduced the number of egg masses produced. Though the lowest concentration (6.25 per cent) resulted in significantly better plant growth, the gall index and number of egg masses per plant were higher in this treatment indicating the possibility of build-up of the nematode population to economic injury levels subsequently. Considering the effect of the phytochemicals on the hatchability of the egg masses, no significant adverse effect was observed,

though a slight decrease was seen in the different treatments, Contrary to the present findings on hatchability, inhibitory effect of several phytochemicals on the hatching of root-knot nematode has been reported by several workers (Alam *et al.*, 1975; Alam *et al.*, 1978; Patel *et al.*, 1985).

The population of root-knot nematode in the rhizophere of the treated plants was significantly reduced in all the three phytochemical treated plants. Higher doses of the botanicals had higher population density in the soil, the lowest being in neem leaf extract treatment which was below economic threshold level. Such observations have been recorded by earlier workers (Mahapatra and Swain, 1993; Vats and Nandal, 1994).

The nematode population in the roots of the treated plants was also significantly low compared to the untreated plants. However, among themselves, there was no significant difference. The results confirmed the findings of Pradhan *et al.* (1989) and Mahapatra and Swain (1993). Of the different phytochemicals tested, neem leaf extract (25 per cent) was more effective in suppressing the nematode infestation and improving plant growth characteristics. Hence, this treatment was selected for further field testing.

5.2. Testing of native VAM cultures against *M. incognita* infestation

In nature, a beneficial association is seen to exist between the 'soil-fungus' and the roots of higher plants. Several of these VAM fungi adversely affect soil-borne pathogens, though a few VAM have been reported to be effective against *M.incognita* in brinjal. The present study conducted with six VAM cultures *viz., Glomus fasciculatum, G. mosseae, G.constrictum, G. etunicatum, G. monosporum* and *Acaulospora morroweae* established the effectiveness of some of these isolates in suppressing root-knot nematode infestation in brinjal.

In the nursery, there was no significant difference in the height of seedlings (paragraph 4.2.1.). Probably, the colonization of VAM on the root system during this short period was not sufficient to establsih an effective symbiotic system. Later (45 and 60 days after transplanting) a significant increase in the height was observed in the different treatments. Though the different isolates of VAM showed no significant difference, in the height of plants raised in small pots, the isolates *G. etunicatum, A. morroweae* and *G. fasciculatum* showed significant increase in height of plants raised in large pots. Sixty days after transplanting all the above three isolates recorded a significant increase in height irrespective of the pot size, *G.etunicatum* being the most effective.

A similar trend was observed in the number of leaves produced per plant. While initially there was no significant difference in leaf production in the mycorrhizal and control plants, later (45 and 60 days after transplanting) leaf production was improved in the mycorrhizal plants especially in those raised in the large pots, *G. etunicatum, G. constrictum* and *G. fasciculatum* being significantly superior. The results agree with the findings of Sundarababu *et al.* (1993b) who reported improved plant growth in tomato raised in *G. fasciculatum* treated nursery beds, Hasan and Jain (1987) in berseem and Francl and Dropkin (1985) in soybean.

Thus among the six VA mycorrhizal fungi tested, *G. etunicatum* and *G. fasciculatum* were more effective in improving growth of the plants in the presence of *M.incognita*. This denotes the effectiveness of the two VAM fungi is protecting the plant against *M. incognita* infestation. This kind of variation in stimulating plant growth as well as suppressing nematode infestation among VA mycorrhizal- fungi have been recorded by earlier workers (Jain and Sethi, 1987; Reddy *et al.*, 1993). Large pots favoured the growth of VAM inoculated plants, probably due to higher volume of soil available for exploration by mycorrhizal root system. Further, better nutrition and effective mycorrhizal colonisation might have rendered the plant more tolerant to nematode invasion and multiplication.

The plants artificially inoculated with VA mycorrhizal fungus always recorded a remarkably higher percentage of VA mycorrhizal colonization even in the presence of *M. incognita.* Among the cultures tested, better colonization was recorded in plants raised in *G. fasciculatum* and *G.etunicatum.* The other cultures too showed high colonization percentage compared to the uninoculated plants. This indicates the capability of the mycorrhizal fungi in establishing its superiority in the competition with nematodes for infection site as observed by earlier workers (Sitaramaiah and Sikora, 1982; Jain and Sethi, 1987; Jain and Sethi, 1988a; Sharma *et al.*, 1994)

As observed from the results presented in paragraph 4.2.3.2. root- knot indices were significantly reduced by mycorrhizal colonization. The plants inoculated with *G. etunicatum, G. fasciculatum* and *G.monosporum* recorded very low root-knot index as against uninoculated plants. This indicates the capability of these fungal roots in curbing the nematode entry and multiplication in the root. The other cultures *viz. G. mosseae, G. constrictum* and *A. morroweae* registered higher root-knot indices than the above cultures proving to be not as effective as the above three cultures. The effectiveness of *G.fasciculatum* in reducing root infection by *M. incognita* has been reported earlier (Jain and Sethi, 1988a; Deepthi, 1993; Sharma *et al.*, 1994; Sharma *et al.*, 1995a). The ineffectiveness of *G. mosseae* against *M. incognita* has also been observed by Cason *et al.* (1983).

The fecundity of the nematode was also significantly reduced in mycorrhizae treated plants. A reduction of 8.3 per cent to 86.1 per cent in the number of egg masses per plant was observed when the plants were raised in small pots while 4.5 per cent to 52.5 per cent reduction was observed when raised in large pots.

An overall assessment of the trial revealed that *G.fasciculatum*, *G. etunicatum* and *G. monosporum* were more effective in reducing the fecundity of the nematode. The number of larvae emerging per egg mass was low in the different treated plants. While *G. fasciculatum* and *G.monosporum* recorded 59 (small pot) and 57.9 (large pot) per cent and 65.6 (small pot) and 45.6 (large pot) percent decrease in the number of larvae hatching per egg mass, *G. etunicatum* resulted only in 13.1 (small pot) and 36.8 (large pot) per cent decrease.

Mycorrhizal plants inoculated with *M. incognita* recorded significantly lesser number of nematodes per gram root. *G.fasciculatum* inoculated plants recorded the lowest root population of *M. incognita* irrespective of the pot size. The difference between the effects of the different isolates may be due to the improved resistance offered by the *G.fasciculatum* colonized roots against the entry of the nematodes. Similar results have been

observed in tomato, white clover (Cooper and Grandison, 1986), cotton (Hussey and Roncadori, 1982) and cowpea (Sivaprasad, *et al.*, 1995).

Compared to control plants inoculated with *M.incognita,* plants inoculated with *G. fasciculatum* and *G. constrictum* supported significantly lower nematode population in the rhizosphere. However *G. etunicatum* and *G. monosporum* treatments had higher nematode population than the control plants while *A. morroweae* and *G. mosseae* were on par.

On the whole, the performance of the six VA mycorrhizal fungi used in the present study showed that *G. fasciculatum* was most effective for checking *M. incognita* infestation in brinjal plants. *G. etunicatum* though found equally good as *G. fasciculatum* in stimulating plant growth, had a higher population of the nematode in the rhizosphere which detracts its merit as a potential biocontrol agent. All the other cultures were found to lack in one or the other desirable attribute. Hence *G. fasciculatum* was included in further studies.

5.3. Effect of root-dip with neem leaf extract and mycorrhizal inoculation on *M. incognita* infestation in the field

Any control agent, be it a phytochemical or a VAM, to be effective under field condition has to withstand the vagaries of nature. Hence the promising phytochemical *viz.,* aqueous neem leaf extract (25 per cent) and mycorrhizal fungi *G. fasciculatum* obtained in pot culture studies were evaluated along with proven nematicides to determine their efficacy in controlling root-knot nematode under field condition. None of the treatments showed any significant effect on the height of plants, number of leaves (paragraph 4.3.1.) and root weight of plants. Though no significant difference was observed in the root weight (paragraph 4.3.2.2.) of plants, there was an increase of 13.4 and 16.9 per cent in plants given root-dip treatment in neem leaf extract (25 per cent) and mycorrhizal plants. However shoot weight of brinjal plants showed a significant increase over control when given root-dip treatment in neem leaf extract (25 per cent) at transplanting (paragraph 4.3.2.1.) Similarly, the shoot weight of plants raised in nursery treated with *G. fasciculatum* also increased significantly. Among the root-dip treatment of mycorrhizal seedlings, only root -dip in the nematicide monocrotophos (500 ppm) showed significant increase in shoot weight. Significant increase in the plant growth parameters of tomato under field conditions were observed by Rao *et al.* (1993) as a consequent effect of rational

integration of neem cake and *G. fasciculatum*. Channabasappa *et al.* (1995) also reported improved growth of banana when inoculated with *G. fasciculatum*.

Considering the yield obtained in the different treatments (paragraph 4.3.2.3.) root-dip treatments in higher doses of nematicides (monocrotophos and carbosulfan) were definitely superior to root-dip in neem leaf extract in increasing the yield. Mycorrhizal treatment in the nursery also registered significantly higher yield. However root-dip of mycorrhizal seedlings in higher doses of nematicides (monocrotophos and carbosulfan) were far more superior than the individual treatments in improving the yield of plants. Obviously the nematicides had no adverse effect on the mycorrhizae. Similarly root-dip of mycorrhizal seedlings in neem leaf extract gave better yield than root-dip of untreated seedlings showing that neem leaf extract also had no adverse effect on the mycorrhizae. Thus the combined treatments (mycorrhizal nursery treatment + bare-root dip of seedlings) proved more effective than the individual treatments. Inoculation of mycorrhizae in the nursery might have boosted its population appreciably thus protecting the plant from nematode infestation. Even in the later stages of plant growth this initial inoculum provided sufficient protection against the multiplying nematode population. Besides, the root-dip treatment at transplanting served to provide immediate protection to the plant from the initial nematode population present in the main field at a vulnerable

stage of the plant. This together with the added protection obtained from the mycorrhizal root in the later stage probably accounted for the comparatively higher yield in the combined treatments than the individual treatments. Several reports on the effects of the different individual treatments like root-dip in phytochemical or nematicides and inoculation of mycorrhizae are available (Krishnaprasad and Krishnappa, 1981; Jain and Sethi, 1988a; Pradhan *et al.*, 1989; Mohanty *et al.*, 1994; Sharma *et al.*, 1995b; Siddiqui and Alam, 1995).

The nematode infestation on the plant was also significantly suppressed by the different treatments. While 45 DAT, no significant difference was observed in the various parameters studied like gall index, number of egg mass per plant and mycorrhizal colonisation percentage and intensity, a significant difference was seen in these parameters at a later stage. All the treatments significantly reduced gall index, number of egg mass per plant and nematode population in the root. Excepting root-dip treatments in monocrotophos (500 ppm), carbosulfan (250 ppm) and nursery treatment with *G. fasciculatum*, there was no significant difference in the number of egg masses between the treatments. A comparatively higher mycorrhizal colonisation percentage and intensity was observed in the *G. fasciculatum* inoculated plants than the uninoculated plants when observed 45 and 120 days after planting. Root-dip in nematicides or neem leaf extract did not show any deleterious effect on mycorrhizal colonisation.

Thus though pot culture studies showed the potential of bare-root dip treatment of brinjal seedlings in neem leaf extract (25 per cent) for one hour and treatment of nursery beds with the mycorrhizal fungi, *G. fasciculatum* in checking root-knot nematode infestation, results of the field trial indicated that combination of the treatments extended better protection to the plants. These results obtained from a single trial gives only an indication of the relative performance of these management practices under field conditions. Conclusive inferences can be drawn only after conducting repeated field trials.

SUMMARY

SUMMARY

Management strategies for pests today mainly focus on low-cost and eco-friendly strategies. In this context rational integration of biological agents and bio components are being tried for nematode control. With this view, the present investigation was taken up to identify an effective phytochemical for bare-root dip of brinjal seedlings and a suitable VAM for controlling root-knot nematode and to evaluate their efficacy under field conditions.

Two separate pot culture trials were conducted to screen out the effective phytochemical and an efficient mycorrhiza for checking nematode infestation. The promising ones were further evaluated in a field along with proven nematicides to establish their efficacy.

Among the phytochemicals tested, *viz.* aqueous neem leaf extract, neem oil and marotti oil, neem leaf extract resulted in better height of brinjal plants. The lower doses proved more effective than the higher doses. Though statistically not significant, root-dip in oils (neem and marotti) generally resulted in reduced height.

The number of leaves produced per plant also showed a similar trend. Neem leaf extract resulted in significantly more number of leaves than root-dip treatment in neem oil and marotti oil, 6.25 and 25 per cent extracts of neem leaves proving more effective.

A reduction of 25.1 to 62.5 per cent in the gall index was observed in neem leaf extract treated plants, 12.7 to 50.2 per cent in neem oil and 12.7 to 37.5 per cent in marotti oil treated plants thus showing the superiority of aqueous neem leaf extract in suppressing host invasion. The fecundity of the nematode was also significantly impaired by neem leaf extract root-dip treatment, and to some extent by neem and marotti oils. The higher concentrations of water extract of neem leaves (50 and 25 per cent) significantly reduced the number of egg masses produced. However none of the phytochemicals (neem leaf extract, neem oil and marotti oil) had any adverse effect on the hatching of the egg masses. All the three phytochemicals significantly reduced the population of root-knot nematode in the rhizosphere of the treated plants. On the whole aqueous neem leaf extract at 25 per cent concentration proved effective in imparting sufficient protection to brinjal plants from nematode infestation, while the different doses of marotti and neem oil showed slight phytotoxicity.

The different isolates of VAM tested like *Glomus monosporum*, *G. fasciculatum*, *G. constrictum*, *G. mosseae*, *G. etunicatum* and *Acaulospora morroweae* differed significantly in their capacity to check root-knot infestation.

No significant difference was observed in the height and number of leaves of brinjal seedlings raised in these isolates at transplanting and one month after transplanting irrespective of the pot size. Later (45 and 60 days after transplanting) significant increase in height and number of leaves was observed in plants raised in larger pots in the different treatments. While *G.etunicatum, A. morroweae* and *G. fasciculatum* significantly increased the height of plants, *G. etunicatum, G. constrictum* and *G. fasciculatum* increased the number of leaves.

The plants artificially inoculated with VA mycorrhizal fungus recorded higher percentage of VA mycorrhizal colonisation. Root-knot indices were significantly reduced, the plants inoculated with *G.etunicatum, G. fasciculatum* and *G. monosporum* recording significantly low root-knot indices. The fecundity of the nematode was also significantly reduced in mycorrhizae treated plants. A 8.3 to 86.1 per cent reduction in the number of egg masses per plant was observed when the plants were raised in small pots while 4.5 to 52.5 per cent reduction was observed when raised in larger pots. *G. fasciculatum* and *G. monosporum* recorded 59 (small pot) and 57.9 (large pot) per cent and 65.6 (small pot) and 45.6 (large pot) per cent decrease in the number of larvae hatching per egg mass, while *G. etunicatum* resulted only in 13.1 (Trial I) and 36.8 (Trial II) per cent decrease.

Mycorrhizal plants inoculated with *M. incognita* recorded significantly lesser number of nematodes per gram of root with *G.fasciculatum* giving the lowest population irrespective of the size of the pots. Again *G. fasciculatum* and *G. constrictum* significantly lowered the nematode population in the rhizosphere soil. Thus *G. fasciculatum* proved to be the most effective mycorrhizae among the isolates tested for protecting brinjal plants from root-knot infestation.

When evaluated in the field, none of the individual treatments nor their combination showed any significant effect on the height, number of leaves and root weight of plants. However a significant increase was seen in the shoot weight of plants in some treatments. Both, root-dip in neem leaf extract (25 per cent) at transplanting and nursery treatment with the mycorrhizae *G. fasciculatum* resulted in a significant increase in shoot weight. Among the root-dip treatment of mycorrhizal seedlings, only root-dip in the nematicide, monocrotophos (500 ppm) showed significant increase in shoot weight.

While root-dip treatments in higher doses of nematicides (monocrotophos and carbosulfan) was definitely superior to root-dip in neem leaf extract and nursery treatment with mycorrhizae, these treatments also registered significantly higher yield. Interestingly, root-dip of

mycorrhizal seedlings in the nematicides monocrotophos and carbosulfanwere far more superior than the individual treatments in improving the yield of plants.

No significant difference was seen in the gall index, number of egg mass per plant and mycorrhizal colonisation percentage and intensity in the different treatments 45 days after transplanting. But towards the later stage, a significant difference was seen in these parameters.

Root-dip in neither nematicides nor neem leaf extract showed any deleterious effect on the mycorrhizal colonisation.

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* Orginals not seen

ABSTRACT

PHYTOCHEMICALS AND VAM FOR MANAGEMENT OF NEMATODES IN BRINJAL (*Solanum melongena* L.)

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

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Vellayani, Thiruvananthapuram

1997

Abstract

Aqueous neem leaf extract, neem oil and marotti oil at different concentrations were tested as bare root-dip treatments for their efficacy in containing root-knot nematode infestation in brinjal. Root-dip in neem leaf extract for one hour resulted in significantly better height and number of leaves in the treated plants than neem oil and marotti oil. Among the different concentrations of neem leaf extract tested, 6.25 and 25 per cent extracts proved more effective.

Significant reduction in gall index was also seen in neem leaf extract treated plants. Higher concentrations of the extract (50 and 25 per cent) significantly reduced the number of egg masses produced. But none of the phytochemicals had any adverse effect on the hatching of the egg masses. All the three phytochemicals irrespective of the doses reduced population of the nematode in the soil. An overall assessment of the result established the superiority of neem leaf extract (25 per cent) among the different phytochemicals tested in checking nematode infestation.

Different isolates of VAM fungi like, *G. fasciculatum*, *G. etunicatum*, *G. mosseae*, *G. constrictum* *G. monosporum* and *A. morroweae* did not show any significant difference in the growth parameters of brinjal plants (height and number of leaves) at transplanting and one month after transplanting irrespective

of the pot size. Later (45 and 60 days after transplanting) significant increase in height and number of leaves were observed in plants raised in soil inoculated with *G.etunicatum* and *G. fasciculatum.*

Higher percentage of VA mycorrhizal colonisation was observed in plants artificially inoculated with VAM. Plants raised in *G.etunicatum* *G. fasciculatum* and *G. monosporum* recorded significantly lower root-knot indices. The fecundity of the nematode and the number of larvae hatching per eggmass was also significantly reduced in mycorrhizae treated plants. Irrespective of the pot size, *G.fasciculatum* registered the lowest population per gram root while *G. fasciculatum* and *G. constrictum* significantly lowered the nematode population in the soil. Overall assessment of the results revealed *G. fasciculatum* as the most effective mycorrhizae among the isolates tested for protecting brinjal plants from root-knot infestation.

Field trial with bare-root dip in 25 per cent neem leaf extract and insecticides monocrotophos (500 and 250 ppm) and carbosulfan (500 and 250 ppm) nursery treatment with *G. fasciculatum* and root-dip of the mycorrhizal seedlings in neem leaf extract and nematicides did not show any significant effect on growth parameters of the plant like height, number of leaves and root weight. But the bare-root dip treatment in neem leaf extract and mycorrhizal nursery treatment and bare-root dip treatment in monocrotophos 500 ppm resulted in significant increase in shoot weight.

Root-dip in nematicides was definitely superior to root-dip in neem leaf extract and nursery treatment with *G. fasciculatum* in increasing yield significantly. Bare-root dip in neem leaf extract, nursery treatment with *G.fasciculatum* also registered significantly higher yield. Root-dip of mycorrhizal seedlings in monocrotophos and carbosulfan were far more superior than the individual treatments in increasing the yield of brinjal.

During the early stage (45 DAT) no significant difference was seen in the gall index, number of egg mass per plant and mycorrhizal colonization percentage. Later, as the plant matured a significant difference was seen in these parameters. Root -dip in neither nematicide nor neem leaf extract showed any deleterious effect on mycorrhizal colonisation.