Effect of vermicompost and neem cake on rootknot nematode, *Meloidogyne incognita* infecting tomato

A Thesis submitted to the
Orissa University of Agriculture and Technology
in Partial fulfilment of the Requirement
for the degree of
Master of Sciences
in Agriculture (Nematology)

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BHUBANESWAR, ODISHA

2015

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CERTIFICATE- I

This to certify that the thesis entitled **"Effect of vermicompost and neem cake on rootknot nematode, *Meloidogyne incognita* infecting tomato"** submitted in partial fulfilment of the requirements for the award of degree of **Master of Sciences in Agriculture (Nematology)** to the Orissa University of Agriculture and Technology is a faithful record of bonafide and original research work carried out by **Chitta Ranjan Mahapatra** under my guidance and supervision.
No part of this thesis has been submitted for any other degree or diploma

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

(B.K. DASH)
CHAIRMAN
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CERTIFICATE-II

This is to certify that the thesis entitled "**Effect of vermicompost and neem cake on rootknot nematode, *Meloidogyne incognita* infecting tomato**" submitted by **Mr Chitta Ranjan Mahapatra** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment for the degree of Master of Sciences (Agriculture) in the subject of **Nematology** has been approved by the students' advisory committee and the external examiner.

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ACKNOWLEDMENT

I deem it a unique opportunity to express my profound sense infinitum gratitude, indebtness and reverence to the chairman of my Advisory Committee Dr. B.K.Dash, Nematologist and Officer-in-Charge, AICRP on Nematodes in cropping system, Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar for his sustained interest, persistent guidance, ceaseless encouragement and pensive remarks throughout the study to take this endeavour a reality.

I profess my heartfelt gratefulness and sincere esteem to Dr. S. N. Mahapatra, Professor and Head, Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar for his valuable insinuation, constructive suggestion and noble guidance during the entire course programme. Satchi Sir was more of a friend to us than being a teacher or member of the advisory commitee. He helped me grow in many ways by never declining my ideas however raw they were. This helped me to understand what can be the ground level mistakes and problems which helped me in defining and redefining my experiments in a better way every time and also shaping up my personal life. He has also forgiven me for my mistakes which had some economic costs on the lab also and taught me to be more responsible. He is a person with whom I also shared my deepest feelings which I had not been able to share with anyone else. Nematology was never a choice for me. Though we met each other professionally but he also maintained a personal relation with us to care for us. One thing I still want to quote here which Satchi said us at the beginning of our Master's programme "Students, don't get disheartened of being a part of Department of Nematology, you are here not because you wanted to be here rather God wanted you people to be here. So, don't worry God is with you. This is not just a formal department for you rather a small nematology family, of which you are the youngest members". I still seek inspiration from what Satchi Sir said on the first day. I don't know why but I am getting emotional while writing all these things. Well two years of time and works, can't be written here though I wish to pen them down sometime. For this only a word of gratitude would not be sufficient but being customary I would thank Dr. S.N. Mahapatra for holding my hands through my Master's programme.

During the course of my Master's proramme tenure Dr. N.K. Sahoo Professor of our department also played a vital role in my life. He used to inspire me a lot, and once said me " Chitta, if you read and prepare in the same way you are doing right now, definitely you will get ARS" also which I still remember about him being an extremely active person in spite of being in his late fifties. It will be a matter of great regret, if I fail to acknowledge the love,accelerating inspiration and help I got from Dr. N. K. Sahoo. I convey my sincere gratitude to him for being there to help me anytime I have required it.

I also express my deep sense of gratitude and reverence to Dr. S. Sahoo, Associate Professor, Dr. D.K. Nayak , Associate Professor of Department of Nematology, College of Agriculture, O.U.A.T., Bhubaneswar during my post graduation thesis work.

I sprightly acknowledge all the supporting staff members of department of Nematology for the help rendered by them all through the thesis work.

I also express my deep sense of appreciation to my seniors Simili nani, Swati nani, Jayant bhai, of course all of them now Assistant Professors Department of Nematology O.U.A.T. Last but not the least Pradip bhai who is also very close to me.

Finally, a big hug to my mother who gave up her happiness for me and my life and my most constant source of encouragement to start and complete this post graduation work. Words won't be sufficient for her support! My maternal uncle (Kanhu Senapati) deserves a special thank at whose place I stay (with my mother and brother) who tried his best to shape me as a good human being at every step of this journey. We (me, my mother and brother) will always be indebted to him for his stand during our dark time.

I reserve my final words of gratitude for that divine power, the Almighty God, who sailed me through the turbulent situations and blessed me to get through tough times, for making me believe about his presence, and enlightening me with rays of optimism.

Bhubaneswar Chitta Ranjan Mahapatra

Date:

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ABSTRACT

Pot culture experiment was conducted in the net house of the Department of Nematology, College of Agriculture, OUAT, Bhubaneswar to study the **"Effect of vermicompost and neem cake on rootknot nematode, (*Meloidogyne incognita*) infecting tomato"**. The first experiment comprised of 10 treatments in order of T_1= Vermicompost @ 500g/m², T_2= Vermicompost @ 250g/m², T_3= Neem cake @ 100g/m², T_4= Neem cake @ 50g/m², T_5= T_1 + T_3, T_6= T_1 + T_4, T_7= T_2 + T_3, T_8= T_2 + T_4, T_9= Carbofuran as standard check @ 0.3g a.i./m² and T_{10}= Untreated Check. Each treatment was replicated thrice following complete randomised design. Results indicated that all treatments increased the plant growth parameters and reduced root knot nematode population and other infection parameters over check. But combined application of vermicompost @ 500g/m^2 along with neem cake @ 100g/m^2 (T_5) performed the best by increasing the shoot and root length (86.17 and 82.36%), fresh root and shoot weight (79.44 and 50.24%) and fruit weight (70.48%) significantly with corresponding decrease in root galls (78.99%) and final root knot nematode population in soil (79.57%) over untreated check. In the second experiment, effect of vermiwash on penetration of juveniles of root knot nematode (*Meloidogyne incognita*) into tomato seedlings at different interval of time (treatments) was assessed. It comprised of six treatments viz. T_1, T_2, T_3, T_4, T_5 and T_6 at 4, 8, 12, 24, 48 and 72 hours respectively. For each treatment an untreated check was maintained where no vermiwash was added and only nematodes were inoculated. No penetration was recorded up to 8 hours, neither in vermiwash treated tomato roots nor in the corresponding untreated check (T_1 and T_2). At 12 hours interval (T_3), nematode penetration was reduced by 100% in vermiwash treated roots over the corresponding untreated check. At 24 hours interval (T_4) penetration was decreased by about 54.54% in vermiwash treated tomato roots over the untreated check. This was followed by 53.33% decline in penetration in vermiwash treated tomato roots over check at 48 hours interval (T_5). Reduction in nematode penetration at 72 hours interval (T_6) was same as that of 48 hours interval.

1. INTRODUCTION

Tomato (*Solanum esculentum* L.) is the world's largest grown vegetable crop and known as protective food both because of its special nutritive value and wide spread production. As a value added crop, it ranks first among the vegetables being widely employed in cannery and made into soups, ketchup, sauce, chutney, paste, juice, puree etc. Tomato is not only a rich source of vitamin A and C but contains minerals like Iron, Phosphorus, Magnesium, Sodium, Potassium, Calcium and Sulphur for which it is known as "Poor man's apple"

The estimated area under tomato cultivation in India is about 8,80,000ha. The average productivity of tomato in our country is merely 207 q/ha as per the survey report, 2014 conducted by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, while its productivity is 588 q/ha in USA, 498 q/ha in Greece, 466 q/ha in Italy and 465 q/ha in Spain. In Odisha, tomato is cultivated in an area of 97018 ha with the production of 1385957 tons/annum as per the survey report, 2013-14 conducted by Department of Horticulture, Odisha, Bhubaneswar. The productivity level in Odisha is low being 142.25 q/ha. Low yield of tomato is attributed to several factors like climate, soil type, fertilizers, planting time, non availability of good quality varieties, irrigation, weed infestation and the ravages due to pests and diseases including plant parasitic nematodes.

Root knot nematode, *Meloidogyne* in general and *Meliodogyne incognita* in particular is the most predominant and wide spread species causing serious menace in many crops. Its attack causes extensive formation of galls or knots in tomato roots (Fig. 1)The yield losses due to *Meloidogyne incognita* in tomato could range from 20.6% (Sasser, 1989) to 85% (Baker *et al.*, 1976) in certain cases. During the course of nematode faunistic survey, Ray and Das (1989) reported wide spread occurrence of *Meloidogyne incognita* in various localities of Odisha, associated with tomato crop. This nematode is very difficult to manage because of its endoparasitic mode of life, production of egg masses in gelatinous matrix, wide host range, development of physiological races and concomitant association with other secondary fungi and bacteria producing disease complex.

The majority of research works carried out for management of root knot nematode involve use of nematicidal treatment, organic amendment, resistant varieties etc. Management of this nematode by treatment of nematicide has several limitations because of involvement of high cost of nematicides not within the reach of the farmers to afford, non availability of many nematicides in the market, pollution problem particularly ground water pollution, high residual toxicity, poisonous hazards to user, development of resistant strains, resurgence of new pests due to killing of natural parasites and predators etc. Physical means of control has not been readily acceptable by the farmers. Development of a resistant variety is a time consuming process with the risk of resistance breaking. So an alternate, ecofriendly and economically viable proposition is the cultural method which involves use of organic amendments of management which is cheap, practical and can be easily adopted by the common farmers. Although the effects of organic amendments on nematodes, microbial communities, plants and soil environments are very complex yet, possible mechanisms involved in nematode suppression are: (1) release of pre-existing nematicidal compounds in soil amendments, (2) generation of nematicidal compounds, such as ammonia and fatty acids, during degradation, (3) enhancement and/or introduction of antagonistic microorganisms, (4) increase in plant tolerance and resistance, and (5) changes in soil physiology that are unsuitable for nematode behavior. Combinations of these mechanisms, rather than a single one, appear to produce nematode suppression in amended soils Among the various organic amendments, application of vermicompost, vermiwash and neemcake to the crops has been of late a popular practice of our farmers.

Composting has been recognized as a low cost and environmentally sound process for treatment of many organic wastes (Hoitink, 1993). A process related to composting which can improve the beneficial utilization of organic wastes is vermicomposting. Vermicompost, as a mesophilic biodegradation product resulting from interactions between earthworms and microorganisms in the breakdown of organic wastes (Edwards *et al.*, 2010), are humus-like materials which could act as suitable substitutes of chemical fertilizer. Vermicomposts are rich in bacteria, actinomycetes, fungi (Edwards, 1983; Tomati *et al.*, 1987; Werner and Cuevas, 1996) and cellulose-degrading bacteria (Werner and Cuevas, 1996). Replacing part of the ground soil by different amounts of vermicomposts with different origins leads to increased germination, growth and flowering in greenhouse condition on tomato (Atiyeh *et al.*, 2000) Vermicompost is a sustainable source of macro- and micro-nutrients and has a considerable potential for improving plant growth significantly when used as components of horticultural soils or container media (Sahni *et al.*, 2008) Vermicompost contains nutrients in plant-available forms such as nitrates, phosphates and exchangeable calcium and soluble potassium (Orozco *et al.*, 1996).

There are some reports of vermicompost, neem cake and vermiwash playing a significant role in reducing the intensity of root knot nematode attack (Arancon *et al.*, 2002; Oka 2010; Rehman *et al.*, 2011.) but the reports are none in Odisha. Therefore, it was planned to study the "Effect of vermicompost and neem cake on rootknot nematode, *Meloidogyne incognita* infecting tomato" with the following objectives:

1. Effect of vermicompost and neem cake alone and in combination on plant growth and multiplication of rootknot nematode, *Meloidogyne incognita* infecting tomato.

2. Effect of vermiwash on penetration of juveniles of rootknot nematode *Meloidogyne incognita* in young tomato roots.

2. REVIEW OF LITERATURES

Review of literatures is the over view of past works on a topic which enlightens a beginner to get an idea about the work done and enthuses to march ahead for refinement of the work. It forms a hidden treasure to generate a database prior to initiating any type of innovative work or proposing a hypothesis based on historical evidences laid by previous workersRoot knot nematode (*M. incognita*) is the serious pest of tomato and is considered as one of the major limiting factor in the cultivation of tomato. Since use of chemicals is not encouraging and it affects the agro ecosystem adversely, attention has been diverted to use eco-friendly management options. The present investigation is carried out to document the following available literatures pertaining to effect of organic amendments against root knot nematode (*Meloidogyne incognita*).

2.1. Effect of vermicompost :

Arancon *et al.,* (2002) conducted an experiment on commercial vermicomposts, produced from cattle manure, food and recycled paper wastes, were applied at rates of 5 t/ha, 10 t/ha and 20 t/ha, to field plots planted with tomatoes (*Lycopersicon esculentum*) bell peppers *(Capsicum anuum grossum*), strawberries (*Fragaria ananasa*) or grapes (*Vitis vinifera*).Control plots were treated with inorganic fertilizers only, and all vermicompost treated plots were supplemented with inorganic fertilizers, to equalize levels of available N in all plots. Nematodes populations were estimated by after extraction in Baermann funnels and nematodes were identified and classified to trophic level. Populations of plant-parasitic nematodes were depressed significantly by the three vermicomposts in all four field experiments compared with those in plots treated with inorganic fertilizer. Conversely, populations of fungivorous and bacterivorous nematodes tended to increase consistently compared with those in the inorganic fertilizer-treated plots.

Arancon *et al.,* (2003) studied the effects of vermicomposts on plant parasitic, fungivorous and baterivorous nematode populations in grape (Vitis vinifera) and strawberry (Fragaria ananasa) field crops. Commercially-produced vermicomposts derived from recycled paper, and supermarket food waste were applied to replicated plots at the rates of 2.5 t ha^{-1} or 5.0 t ha^{-1} for the grape crop and 5.0 t ha^{-1} or10 t ha^{-1} for the strawberry crops. All vermicompost treatments were supplemented with inorganic fertilizer to balance the initial availability of macronutrients especially N, to the crop in all plots. After extraction from soil samples in Baermann funnels, nematodes were identified to trophic levels under a stereomicroscope. Soils from all of the vermicompost-treated plots contained smaller populations of plant parasitic nematodes than soil from inorganic fertilizer-treated plots. Conversely, populations of fungivorous nematodes and to lesser extent bacterivorous nematodes increased in the vermicompost-treated plots in comparison with those in plots treated with inorganic fertilizers.

Dominguez *et al.,* (2003) studied the effect of the earthworm, *Eisenia andrei*, on the nematode community and on the microbial activity during the vermicomposting of two organic wastes, cow manure and sewage sludge. Fresh cow manure and sewage sludge was placed in five replicated boxes with and without earthworms for a period of 16 weeks. Samples were collected periodically and nematodes were extracted in Baermann funnels, counted and separated into different trophic groups. Samples were also analyzed for microbial respiration and microbial biomass nitrogen. Nematode communities were dominated by bacterivores, and their abundance was dramatically affected by earthworm activity. In both substrates, numbers of nematodes decreased in the presence of earthworms. Fungivore nematodes were observed after 6 weeks in the cow manure and in contrast to bacterial feeders, their number continuously increased in the treatment without earthworms but remained low in the presence of the earthworms. Results indicate that earthworms have a strong influence on nematode densities and nematode trophic structure, and that further investigations were necessary to determine the mechanisms of this influence.

Sabarad *et al.,* (2004) reported that, VAM inoculation to banana plants were more beneficial in reducing nematode population at 75 percent RDF along with vermicompost.

Saikia *et al.,* (2007) observed the efficacy of organic amendments *viz.,* neem cake, vermicompost, neem seed kernel, sawdust and carbofuran 3G against root-knot nematode, *Meloidogyne incognita* in brinjal under field condition by applying individually and in combinations. All the treatments showed significant effects on plant growth parameters and yield of brinjal with corresponding decrease in the nematode populations both in soil and roots. Among all the treatments, the treatment with neemcake + carbofuran 3G showed superior over control in respect of plant growth parameters and yield of brinjal and decrease in nematode multiplication.

Arancon *et al.,* (2007) demonstrated the considerable potential of vermicomposts – produced from a wide range of organic wastes, particularly cattle, pig, paper and food wastes – in suppressing plant diseases, such as Pythium, Rhizoctonia, Plectosporium and Verticillium; plant parasitic nematodes, such as soybean cyst nematodes *Heterodera* and root knot nematodes *Meloidogyne hapla* and further experimented the suppressing effects of vermicompost teas on plant parasitic nematodes.

Ami and Sipes, (2008) determined the efficacy of Vermicompost, Drangonfire-CPP, Actigard, and DiTera against the root-knot nematode *Meloidogyne javanica* in a greenhouse test. These compounds with low environmental impact were applied as pre- and postplant treatments to cowpea plants growing in a mixture of Hawaii soil and sand in pots. Nematode populations/plant and root galling, after 8 weeks, were suppressed in all treatments, although none was as effective as fenamiphos. Plant growth was also enhanced as compared to the untreated control. Pre-plant applications of Vermicompost, Dragonfire, and DiTera were more effective than their post-plant applications. Under the controlled conditions of the experiment, these compounds showed promise as safer alternatives to traditional nematicides like fenamiphos.

Khan *et al.,* (2009) conducted a field experiment with eight treatments comprising of farm yard manure (@ 20t/ha), vermicompost (@ 2t/ha), *Trichoderma viride* (@ 10g/pit), *Paecilomyces lilacinus* (@ 10g/pit), neem cake (@ 500 kg/ha), vine dipping in monocrotophos (at 1000ppm for 6hours), carbofuran 3G (@ 1 kg a.i./ha) and untreated control in different combinations at Simanta Seed farm, Kalyani of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. Experimental results revealed that VD + *Trichoderma viride* at 10 g/pit (in two split doses) was superior to all the treatments and this was followed by VD + vermicompost at 2t/ha, vine dipping (VD) with monocrotophos 36SL at 1000 ppm for 6h + decomposed organic matter @ 20t/ha. Adoption of vine dipping in monocrotophos 36SL at 1000 ppm followed by soil inoculation of *T. viride* at 10g / pit once at planting and second dose at 40 days after planting reduced root galling caused by *M. incognita* and gave fruit yield almost double of the untreated plots. No effect of nematode attack on fruit size and weight was observed.

Pandey and Kalra, (2010) evaluated the efficacy of various vermicomposts produced from agro- and distillation-waste of medicinal and aromatic crops on hatching of eggs of *Meloidogyne incognita* (Kofoid and White) Chitwood and root-knot disease development in tomato. Results revealed that considerable inhibition in hatching of eggs occurs in the aqueous extracts of vermicompost produced from wastes of menthol mint (*Mentha arvensis*), chamomile (*Matricaria recutita*), geranium (*Pelargonium graveolens*), qinghao (*Artemisia annua*) followed by pyrethrum (*Chrysanthemum cinerariaefolium*), isabgol *(Plantago ovata*), African marigold (*Tagetes minuta*), Boerhavia (*Boerhavia diffusa*), mustard (*Brassica compestris*), lemongrass (*Cymbopogon flexuosus*) and garden mint (*Mentha viridis*). In a pot experiment, vermicomposts of menthol mint, African marigold, qinghao, isabgol and pyrethrum effectively reduced the root-knot infection in tomato.

Investigations were undertaken in pots (30×20×18 cm) filled with 5 kg of sterilized potting mixture consisting of red soil:sand:FYM (2:1:1 v/v) to assess the effect of organic amendments viz., neem cake, vermicompost, pungam cake and castor cake; bio-agents viz., PGPR *Pseudomonas fluorescens*, the antagonistic fungus *Trichoderma viride*, the egg parasitic fungi *Paecilomyces lilacinus* and nematicides viz., carbofuran and phorate, against root-knot nematode, *Meloidogyne incognita* in jasmine (*Jasminum sambac* L). The results indicated that *P. fluorescens* @ 10g/ plant (6x108 colony forming units/g), gave maximum reduction of juveniles per 100g soil (69.7 %), number of adult females (70.1%) and eggs per g root (87.2%), gall index (2.6) and increased flower yield (36.6%). Carbofuran, phorate, *Paecilomyces lilacinus* and neem cake were next in line in efficacy. Further, organic amendments and bio-agents had a positive influence on growth parameters viz., plant height, shoot weight and root weight. The endophytic colonization potential of the bio-agents introduced into the soil was confirmed by re-isolating them from jasmine roots. Seenivasan and Poornima, (2010).

Seenivasan, (2010) experimented the efficacy of locally available organic amendments such as neem cake, castor cake, pungarn cake and vermicompost @ 500 kg/ha and 400 kg/ha against *Meloidogyne incognita* in medicinal coleus, *Coleus* *forskohlii* under glasshouse and field conditions. Results revealed that all the organic amendments were found to reduce *M. incognita* population and increase root tuber yield. Further, among all organic amendments, neem cake was found significantly superior in reducing the nematode population and increasing growth and yield of medicinal coleus than pungam cake, verrnicompost and castor cake. Neem cake application reduced *M. incognita* populations 28.6 -31.2 % in soil and neem cake amended coleus plants recorded the gall index 3.3 - 4.0. It increased the root tuber yield 39.8 - 42.4 % under glasshouse condition and 9.0 % under field conditions.

Serfoji *et al.,* (2010) **c**onducted a glass house experiment for the effectiveness of vermicompositing and rhizotrophic micro- organisms (arbuscular mycorrhizal fungus (AMF) *Glomus aggregatum* and mycorrhiza helper bacterium (MHB) *Bacillus coagulans*) for the management of *Meloidogyne incognita* on tomato cv Pusa Ruby. Among the different treatments evaluated, vermicompost and *G. aggregatum* alone and in combination with *B. coagulans* recorded the maximum growth, biomass and nutrients of tomato cv Pusa Ruby with decreased root- knot nematode population and root- knot index. But amending the soil with application of vermicomposting + *B. coagulans* + *G. aggregatum* in tomato was significantly increased the plant growth, biomass and nutrients of tomato cv Pusa Ruby. Similarly reduction in root- knot nematode population, root- knot index (RKI), nematode reproduction rate (NRR) number of galls and egg masses per plant were recorded in the above treatment. Highest mycorrhizal colonization of 92.5% and minimum nematode population of 145.0/ 250cc soil was observed in the same treatment. It can be concluded that application of vermicompost + *G. aggregatum*+ *B. coagulans* increased plant growth characters and reduced RKI, NRR, number of galls and egg masses on tomato cv Pusa Ruby.

Sitton, (2010) reported vermicompost application rates of 0, 20, and 40 percent has significant and repeatable suppression effect on plant parasitic nematodes, which damage a wide range of food crops.

Sinha *et al.,* (2010) studied the considerable suppression of root knot nematode (*Meloidogyne incognita*) a serious pest in tomato plants after application vermicompost and vermicompost teas (vermiwash liquid).

Pandey *et al.,* (2011) tested the usefulness of *Trichoderma harzianum* along with farmyard manure, cow urine, neem oil seed cake, and vermicompost separately and in combination to manage *Meloidogyne incognita* in *Withania somnifera*. A treatment combination of nematode inhibitory vermicompost and T. harzianum was found to be most effective against *M. incognita*.

Ramesh Kumar *et al.,* (2011) conducted a green house experiment to explore the influence of different concentrations of Vermicompost in root–knot nematode management against *Meloidogyne incognita* infecting Cluster bean *Cyamposis tetragonaloba.* Vermicompost fortification treatment resulted in reduced nematode infection and increased growth characteristics such as shoot – root length and shoot – root weight. With the increase of concentration of Vermicompost corresponding increase noticed in growth characteristics of treated plants. Vermicompost fortified plants showed increment in sugar, protein and lipid over untreated control. Increment of these metabolites reflects treated plants were metabolically cope up the infection and promoting excessive plant growth.In vitro studies of hatching trials revealed significant reduction in larval emergence. The percent reduction of larval emergence showed a significant positive correlation with increased concentration of Vermicompost. Vermicompost treatment significantly affects the soil population of nematode which again reflects a dosage dependent phenomenon. Present investigation confirms Vermicompost as an excellent growth promoters and potential prophylactic agent.

FCV tobacco is an important commercial crop grown in Karnataka under rain fed situations. Root-knot nematode is a limiting factor causing yield reduction in both nursery and main field crop to the tune of 59.4% and 52.9%, respectively. As an alternative to nematicides of chemical origin, beneficial fungi such as *Paecilomyces lilacinus* and *Glomus fasciculatum* were evaluated along with organic amendments *viz.,* neem cake and vermicompost as individual application and also in rational combinations against *Meloidogyne incognita* in FCV tobacco nurseries. Results revealed that application of *P. lilacinus* strain NBAII PLFT5 @ 100g/ m^2 recorded 31.3% increase in healthy transplants compared to check. Combined application of *P. lilacinus* with neem cake @ 1kg/ m^2 recorded 34.4% increase in healthy transplants count and was on par with *P. lilacinus* with vermicompost @ 1kg/m^2. Application of *P. lilacinus* + neem cake @ 1kg/ m^2 and *P. lilacinus* + vermicompost @ 1kg/ m^2 significantly reduced root-knot index to 1.89 compared to 2.05 in carbofuran @ 50g/ m^2 treated beds (standard chemical check) and 3.86 in untreated check. Similarly, these two treatments were on par with each other in significantly reducing the number of egg masses/g root and final soil nematode population. Ramakrishnan and Nagesh, (2011).

Ramakrishnan and Mahadevaswamy, (2011) reported, that application of vermicompost @ 4t/ha + NPK recorded maximum cured leaf yield and top grade equivalent yield followed by vermicompost @ 6t/ha + NPK. The increase in cured leaf yield and top grade equivalent was 7.6 and 9.7% respectively by application of vermicompost @ 4t/ha + NPK and NPK application alone. Whereas, all the treatments were significantly superior in reducing the RKI compared to check (recommended NPK only). Vermicompost @ 6t /ha + NPK caused maximum reduction in RKI to the tune of 58.2 per cent followed by vermicompost @ 4t/ha + NPK (51.5%) compared to check and further revealed that there is good scope for vermicompost as an alternative source to other organic manure to improve productivity and in effective management of root-knot nematodes in FCV tobacco crop.

Productivity of brinjal crop is strongly destroyed by the nematode (Meloidogyne incognita) in the eastern Uttar Pradesh. This species is injurious to the crop and attack to the plant in rainy season i.e. August and September. Phytoparasitic nematodes are harmful to the living plants and decreased the growth and Productivity. Vermicompost containing biopesticide is a useful tool to enhance the productivity of crop and to check the infestation of nematode. Single and binary combination of vermicompost with biopesticides were used in agricultural field to control the infestation of nematode (*Meloidogyne incognita*) and their effect on growth and yield of brinjal (Solanum melogena). Significant decrease in nematode population was observed in the soil, when binary combination of vermicompost with neem oil (92%) and custard apple leaves (80%) were applied in the field. The combination of garlic extract with vermicompost caused 98% control of nematode population. Vermicompost obtained from animal dung + gram bran with neem oil was also very effective against the *Meloidogyne*. The results clearly demonstrated that the use of vermicompost with biopesticide is more beneficial to organic farming. It is helpful to compensate the deficiency of nutrients in the soil as well as control of the harmful nematode pest. It is evident from the results that the vermicompost of the buffalo dung + gram bran with aqueous extract of garlic bulb / neem oil were very effective against infestation of nematode (*Meloidogyne incognita*) in agricultural field which ultimately enhance the productivity of brinjal crop Nath *et al.,* (2011).

Nath and Singh, (2011) used vermicomposts singly and in combination with different biopesticide in agricultural field to check the infestation of nematode (*Pratylenchus sp*.) and measured the growth and yield of tomato (*Lycopersicon esculentum*) crop. Significant reduction of nematode population was observed in the soil after mixing of combination of vermicompost with neem oil (95%) and custard apple leaves (83%). The combination of garlic extract with different vermicompost caused 100% control of nematode population. Vermicompost obtained from animal dung + gram bran with neem oil was also very effective against the nematode (*Pratylenchus sp.)*. Applications of vermicompost with biopesticide increased the productivity of tomato crop up to four times with respect to control. The results clearly demonstrate that the use of vermicompost with plant product is more beneficial in organic farming. It is helpful to compensate the deficiency of nutrients in the soil as well as control of the harmful nematode.

Dunn, (2011) reported that recent Ohio State University studies concluded that crops fed with vermicompost are also more resistant to parasitic nematode attacks than those on synthetic fertilizers.

Jagadeeswaran and Singh, 2(011) experimented soil application of organic amendments *viz.,* vermicompost @ 25 and 50 g/kg, neem cake @ 5 and 10 g/kg, castor cake @ 5 and 10 g/kg, groundnut cake @ 5 and 10 g/kg, sunflower cake @ 5 and 10 g/kg and FYM @ 50 and 100 9 / kg of soil significantly reduced nematode population and increased the plant growth compared to inoculated control. Neem cake @ 10 g / kg of soil was found effective in reducing nematode population and increasing overall plant growth.

Nath and Singh, (2011) studied the efficacy of vermicompost singly and in binary combination with different biopesticide in agricultural field to control the infestation of nematode (*Meloidogyne incognita*) and high yield of cauliflower (*Brassica oleracea*) crop. Mixing of binary combination of vermicompost with neem oil (94%) in the soil caused significant reduction in *M. incognita*. The combination of garlic extract with different vermicompost caused 97% control of the nematode population. Vermicompost obtained from animal dung + gram bran with neem oil was very effective against the nematode *M. incognita*. Application of vermicompost with biopesticide increased the productivity of cauliflower crop more than eight times. The results clearly demonstrate that the use of vermicompost with plant product is more beneficial in organic farming. It is helpful to compensate the deficiency of nutrients in the soil as well as control of the harmful nematodes.

Chaya and Rao, (2012) conducted field experiments to evaluate the efficacy of the formulation of the bio-control fungus, *Pochonia chlamydosporia* Zare *et al.,* (*Verticillum chlamydosporium* Goddard) for the management of *Meloidogyne incognita* (Kofoid *et* White) Chitw on Okra (*cv*. Solar 10) at Indian Institute of Horticultural Research, Bangalore, India. These experiments clearly indicated the potential of a bio-agent along with vermicompost. The results indicated that the application of *P. chlamydosporia* enriched vermicompost at the rate of 50g/ m2 was significantly effective in reducing the population of *Meloidogyne incognita* and increase the yield by 23.08 per cent. Through these investigations we could standardize a strategy for the sustainable management of nematode in okra.

Pathma and Sakthivel, (2012) studied that vermicompost amendments appreciably suppress plant parasitic nematodes under field conditions and also minimizes severity of attack by *Meloidogyne incognita* on tobacco, pepper, strawberry and tomato. Aditionally vermicompost decreased the numbers of galls and egg masses of *Meloidogyne javanica*. They concluded that vermicompost with excellent physio-chemical properties and buffering ability, fortified with all nutrients in plant available forms, antagonistic and plant growth-promoting bacteria are fantabulous organic amendments that act as a panacea for control of plant parasitic nematodes for sustainable agriculture.

Babidha and Ramaswamy, (2012) observed the suppressive effects of vermicompost on the root-knot nematode, *Meloidogyne incognita* (Kofoid and White) with reference to above ground and below ground growth parameters were studied in a selected vegetable plant, lady’s finger, *Hibiscus esculentus* L (var COBh H1) under pot culture experiment in different soil conditions such as in control soil, vermicompost amended soil, nematode inoculated soil and nematode inoculated soil with vermicompost. The suppressive effect of vermicompost on the parasitic effect of the root-knot nematode was well pronounced by significant elevation in the number of flowers and fruits, shoot length, leaf length and leaf area of *Hibiscus esculentus* grown in nematode inoculated soil with vermicompost compared to those in plants grown in nematode inoculated soil. The primary root length also showed significant increase in plants grown in vermicompost amended nematode inoculated soil which might help the plant to grow deeply thereby avoiding the parasitic effect so as to enhance the uptake of nutrients from deeper soil.

Root knot nematodes, *Meloidogyne* spp cause serious problems in both nursery and main field crop of flue cured Virginia tobacco crop. As an alternative to chemical nematicides, vermicompost was evaluated against root knot nematodes in both nursery and main field crop. Experimental results revealed that, application of vermicompost @ 2 kg/sq.m in nursery resulted in increase of healthy transplants count by 28.7% and decreased root knot index (RKI) by 45.3% compared to check. Similarly in main field crop, vermicompost @ 4t/ha improved cured leaf yield productivity by 7.6% compared to check. Vermicompost @ 6t/ha resulted in 58.2 % reduction in RKI compared to check. Results clearly indicate the usefulness and effectiveness of vermicompost as an alternative organic source to reduce root knot nematode incidence and to improve FCV tobacco crop productivity Ramakrishnan and Mahadevaswamy, (2012).

Baghel *et al.,* (2013) carried out investigations on the influence of integrated nitrogen application and varieties under aerobic rice (*Oryza sativa* L.) during wet season of 2010 at New Delhi. Treatment included four rice varieties *viz.,* 'Jaldi Dhan 13'; 'Pusa Sugandh 5'; 'Anjali' and 'Pusa 834' and four nitrogen (N) application options including N control (N0), recommended dose of N (120 kg N/ha) through urea and two combinations (60:60 and 90:30) of urea and vermicompost (VC). Results showed that 'Pusa Sugandh 5' superseded other varieties in growth and yield parameters. Maximum grain yield (3.98 t/ha) was recorded with 90 kg N through urea + 30 kg N/ha through VC. 'Anjali' showed maximum tolerance to root knot nematodes, while 'Pusa sugandh 5' was most susceptible. N application through chemical fertilizer significantly reduced the nematode population over control. Highest net returns (61,885/ha) obtained from 'Pusa Sugandh 5' and 90 kg N (urea) + 30 kg N (VC)/ha (61,273/ha).

Ramrao and Pathak, (2013) conducted an experiment in green house in thick plastic plates (10 x 10 x4 cm) at field capacity. Maximum seed germination and seedling emergence of tomato var. Kasha-Vishes was observed in vermicompost applied treatments receiving 1 kg VC/m^2 at 15, 30, 45, 65 and 75 days after V.C application. Maximum decrease (50.97%) in PPN was observed in treatment 1 kg V.C/m^2 at all days of observation. Lower levels of V.C at all recorded days after its application resulted in per cent increase in both seed germination and seedling emergence over untreated control, where as lower levels of V.C application recorded increasing percent decrease in plant parasitic nematode population with increase in days after V.C application. At all the recorded day after vermicompost application there was increase in free living nematode population. Higher doses of V.C application recorded more increase in free-living nematode population than at lower doses.

Singh and Mahanta, (2013) revealed the results to be significantly different from control in respect of increasing growth parameters including significant reduction of final nematode population in soil. Maximum growth parameters *viz.;* plant height, fresh and dry weight of shoot and root were recorded in the treatment with combination of all the control agents (*T. harzianum* @ 2.5 kg/ha + *G. fasciculatum* @ 300 spores/m2 +carbosulfan ST @ 1.5% w/w + vermicompost 1.5 tonne/ha) followed by the treatment with integration of *T. harzianum* and *G. fasciculatum*. Maximum reduction in nematode population and maximum yield were obtained in the treatment, with integration of all the control options.

Najar and Khan, (2013) concluded that two of the contributions of vermicompost to the field soils were the increased microbial populations with production of plant-growth-influencing materials and build-up of plant resistance or tolerance to crop disease and nematode attack.Additionally, they also further reported considerable suppression of root knot nematode (*Meloidogyne incognita*) in *Lycopersicon esculentum* plants after application of vermicompost.

Ramarao and Pathak, (2013) reported the influence of vermicompost at different dosage and moisture levels on nematode populations using plastic trays (10x10x4 cm) which accommodated 150 g nematode infested soil. With the increasing dose of vermicompost there was reduction in plant parasitic nematode population at all the observed days (15, 30, 40, 60 and 75). One kg vermicompost/m^2 was found to be the most effective. At submerge condition, there was maximum mortality of PPN followed by field capacity (F.C.) and 50% field capacity. Nematode mortality was maximum at 75 days after vermicompost application followed by 60, 45, 30 and 15 days in submerged condition. The population of free-living nematodes was significantlly increased in 0.250 kg vermicompost/m^2 and treated control at 15 and 30 days after vermicompost apllication. Field capacity recorded maximum free living nematode population at all days of observation after vermicompost application.

Sheela and Khimiya, (2013) investigated that presence of earthworms in the soil stimulates plant growth and good plant health as soil having earthworms, has less harmful nematodes.

Singh and Prasad, (2014) studied the suppressive effect of most of the biological control agents and organic materials including vermicompost against root-knot nematode infecting Ashwagandha (*Withania somnifera*) and concluded that highest root-knot suppression along with enhanced growth and yield of *Withania somnifera* was noticed in *Trichoderma harzianum* and vermicompost combination.

Sivananthi and Paul, (2014) studied the statistical significant suppression of plant-parasitic nematodes in field trials with pepper, tomatoes, strawberries and grapes. They further explained the reason behind this concept as, that high levels of agronomically beneficial microbial population in vermicompost protects plants by out-competing plant parasitic nematodes.

Renco and Kovacik, (2015) explained the addition of organic material to the soil can be an effective alternative to the environmentally unsafe chemical treatments that are used to control plant parasitic nematodes. They evaluated the effects of vermicompost alone, and aqueous solutions of vermicompost (vermicompost tea) either alone or mixed with urea, on the development and survival of two potato-cyst nematodes: *Globodera* *rostochiensis* (pathotype Ro1) and *G. pallida* (pathotype Pa2) and on the growth parameters of the host potato plants. Soil amendments with these materials significantly decreased the number of cysts · 400 g–1 of both species in the soil, the number of eggs and juveniles · cyst–1 of both species, and the number of eggs and juveniles · g–1 of both species in the soil, relative to the untreated controls. The suppressive effect was significantly higher at the highest dose than the lowest treatment dose, for all tested materials. *Globodera rostochiensis* was more sensitive to all the tested materials than *G. pallida*. The aqueous solutions of vermicompost alone or in combination with urea were more effective than the solid vermicompost used alone, for controlling both species. Vermicompost and the vermicompost teas had positive effects on plant fresh stem weight and stem height. The application of vermicompost tea instead of the solid vermicompost, substantially decreased the amount of material needed. These amendments are thus promising for the control of potato-cyst nematodes in sustainable agricultural systems.

Mistry and Mukherjee, (2015) investigated the effects of vermicompost tea on plant pest control. Vermicompost teas were prepared using various extraction methods (non - aerated, aerated, with additives) with various ratios of compost and water for several days to week. In aerated vermicompost teas, water and nutrient additives greatly increase microbial populations. The aerated, vermicompost 'teas' suppressed the plant diseases. Vermicompost 'teas' also suppressed population of plant roots nematode parasite, spider, mite and aphids significantly. Additionally, they had dramatic effects on the suppression of attacks by plant parasitic nematodes such as *Meloidogyne* on tomatoes both in terms of reducing the numbers of root cysts significantly and increasing root and shoot growth.

2.2. Effect of neem cake :

Bhattacharya and Goswami, (1987) conducted investigations on tomato plants to evaluate the efficacy neem and groundnut cakes in comparison with aldicarb on plant growth parameters, penetration, development and population build up of *Meloidogyne incognita* juveniles. Growth response of plants to neem and aldicarb was better than groundnut cake and unamended control. In the early period of plant growth, neem and aldicarb treatments were at par but at the later phase, neem superseded aldicarb. Similarly, groundnut showed improvement over control which were earlier at par. In root and soil populations, least nematode number was recorded in aldicarb followed by neem, groundnut and control. Different treatments showed differential rates of development with fastest in control followed by groundnut, aldicarb and neem. Treatments also affected fecundity of the females and hatching of eggs.

The use of neem extracts for pest control is less common in nematology than in entomology. The purpose of this paper is to make a short review of the agronomical potential of the neem tree, with particular emphasis on its role for the control of deleterious nematodes. A specific case for the control of *Meloidogyne,* which was carried out in Benin, and was presented by Colin and Pussemier, (1992).

Musabyimana and Saxena, (1999) studied the soil applications of powdered neem seed or neem cake at 100 g/plant at planting and, subsequently, at 3-month intervals, reduced the populations of *Pratylenchus goodeyi* Sher & Allen and *Meloidogyne* spp. on par with Furadan 5G (carbofuran) applied at 40 g/plant at planting and then at 6-month intervals to banana plants grown in 100-/containers with controlled levels of banana nematode infestations. Eight months after planting, banana plants treated with powdered neem cake, seed or kernel or with neem oil had 4 to 95 times fewer parasitic nematodes than the untreated control. However, only neem cake powder or neem seed powder applied to unpared banana plants kept the nematode population below the economic threshold.

Bharadwaj and Trivedi, (2000) conducted a study to determine the individual and concomitant effect of neem cake and nematophagous fungi *Paecilomyces lilacinus and Verticillium chlamydosporium* so as to evaluate their compatibility in the nematode management programme. Experimental fungi and neem cake were added to the steam sterilized soil filled in 15 ern diameter clay pots separately in two dosages and in combinations Seven days old cowpea plants were inoculated with the freshly hatched juveniles of *Heterodera cajani* @ 1000 larvae/kg soil. Observations were taken ninety days after nematode inoculation. It was observed that *P. lilacinus* along with neem cake gave better results when compared to *Verticillium* + neem cake (V+NC) treated plants. Inoculum levels of both neem cake and fungi influenced the nematode multiplication greatly. The plants were better in growth and with lesser nematode infection in the higher doses of *P. lilacinus* and *V. chlamydosporium.* Neem cake alone reduced the number of cysts developed per plant to a certain extent. Combination of *P. lilacinus* with neem cake treated roots showed results comparable to the higher dose of *Paecilomyces* alone treated plants. Marked reduction in the cyst production was observed in this treatment. Neem cake also gave satisfactory results when added along with the nematophagous fungus *V. chlamydosporium*.The addition of organic amendment to the soil due to oil cake, direct parasitizing effect of the fungus on the nematode and guarding of root surface by both fungus and the organic matter so as to provide biological protection could be the possible reason for such findings. Neem products enhance nematode biocontrol efficiency of the fungus *P. lilacinus.* These results were further confirmed by Ahmad and Alam . Thus it could be deduced from the results that the combination of the nematophagous fungi and neem cake can be of great help in the integrated pest management as it not only reduces the nematode population efficiently, it is also economical at the same time.

Hasan and Khan, (2004) studied interaction of neem cake, VAM fungus, *Glomus fasciculatum,* and the root-knot nematode, *Meloidogyne incognita,* on floral growth characters, mycorrhizal root colonization and the developnient of root-knot disease in gladiolus under green-house conditions. Both the neem cake and the VAM fungus increased the spike length, number of florets/spike and the floret diameter whereas the root-knot nematode reduced these floral growth characters. The neem cake at higher doses of 1 and 2% and the VAM fungus significantly increased the floral growth characters and suppressed root galls. These effects were significantly greater in the presence of neem cake/VAM fungus around nematode infected plants. Sporulation and mycorrhizal root colonization was suppressed at higher doses of the cake. Nematode multiplication was suppressed at low cake doses but was greatest at higher doses. Spore viability was lowest and nematode mortality was highest at higher doses of the cake after six weeks of exposure in amended soil. Lower doses of cake in combination with G. *fasciculatum* is suggested as a means to protect gladiolus from root-knot damage.

Patel *et al.,* (2005) evaluated the effects of organic cakes and nematicides for the management of root-knot nematode (*Meloidogyne javanica*) on fennel (*Foeniculum vulgare*) at Kapadvanj (Gujarat) indicated that all the treatments including organic amendments and nematicide either alone or in combination significantly reduced root-knot disease and increased the grain yield over control. Maximum grain yield (2762 kg ha-1) was obtained with the treatment neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}, which was on par with Neemguard 20 kg ha^{-1} + phorate 1 kg ha^{-1} (2566 kg ha^{-1}). Minimum root-knot index (1.64) was recorded in the combined treatment of neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}, which was on par with castor cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}. Maximum net returns (Rs. 22,775 ha^{-1}) was obtained in the treatment neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}.

Fatema and Ahmad, (2005) conducted an experiment using six treatments with organic amendments like neem oil cake, mustard oil cake, til oil cake, garlic extract and a chemical Furadan-3G including control were tested against root-knot on two local varieties of groundnut caused by *Meloidogyne javanica*. Treatment with Furadan-3G as side-dressing after 7 and 14 days of inoculation gave the best response in plant growth characters including nodulation correspondingly with the lowest number of galls, adult females and different juvenile stages of the nematode within the treated plants. Neem oil cake gave better effect with the reduction of galls and nematode population like that of Furadan-3G. Garlic bulb extract showed comparatively higher response in promoting plant growth and suppressing the nematode.

Olabiyi *et al.,* (2007) conducted a field experiment to study the effect of different organic manure on the certain nematode pests on cowpea cv. Ife brown. Both decomposed and un-decomposed manure applied as organic amendment caused significant reduction in the soil population of *Meloidogyne spp., Helicotylenchus sp.* and *Xiphinema sp.* on cowpea. The result of the field experiment showed that organic manure significantly increased growth and yield of cowpea. Moreover, organic manure enhanced soil nutrient status that invariably increased the growth rate of cowpea. All these gave resultant high cowpea yield.

Abolusoro and Oyedunmade, (2007) studied the toxic effects of neem, *Azadirachta indica* fruit powder against a root-knot nematode, *Meloidogyne incognita* on tomato was investigated in the field in the year 2002. Tomato Roma var. Uf was planted on a ploughed and harrowed field. Each plant stand was inoculated with 2000 *Meloidogyne incognita* juveniles. The treatments were made up of four levels; 0.5, 1.0, 1.5 and 2.0 tonnes/ha of neem fruit powder, while there was an untreated control denoted by 0 tonne/ha. The experiment lasted for a period of sixteen weeks. The results from the experiment showed that neem fruit powder brought about a significant increase in growth and yield of nematode-infected tomato as compared with the control. At 10 and 12 WAP, plant height and number of leaves/plant were significantly higher in the treated plants. The number and weight of tomato fruits were also significantly higher in the treated plants than in the untreated control. The nematode multiplication rate and damage caused by the nematode on tomato roots (root gall index) were significantly lower in the treated plants than in the control. The higher concentrations of the neem powder were significantly more effective than the lower concentrations in controlling the nematode and consequently improving the growth and yield of treated tomato plants.

Javed *et al.,* (2008) observed the effects of neem formulations applied as soil drenching on the development of second stage juveniles (J2) of *Meloidogyne javanica* on roots of susceptible tomato cv. Tiny-Tim at controlled environment consisted of photoperiod of 16 h light/8 h dark at 30^{o}C during light and 24.1^{o}C during dark. Thirty day old seedlings were transplanted singly in 15cm diam., pots filled with autoclaved proprietary based loam. Beginning 7-days after transplant, three neem formations viz., neem cake, aza 5 mg and 10 mg were drenched @ 10 ml per pot. Water and 4% ethanol treated plants were included as check for comparison. Three days after the application, plants were inoculated with freshly hatched 250 J2 suspended in 10 ml of water surrounding root zone of each plant. Each treatment consisted of 5 replications. The experimental plants were completely randomized on a bench in a growth room. The roots of tomato plants drenched with three neem formulations and ethanol equal numbers of J2 penetrated but significantly less than that of water check plants. Three neem treatments including aza (5mg), aza (10mg) arrested the development of J2 over that of water check. The roots of plants treated with aza (10mg) allowed less number of J2 to develop into immature females than on roots of ethanol check plants. The plants treated with all three neem formulations and ethanol responded less in terms of root gall formation over that of water check. Aza at 10mg was found most effective in protecting the roots against nematode infection. These findings warrant the use of neem as biocide to manage the nematode populations.

Oka, (2009) showed application of organic soil amendments, a traditional control method for plant–parasitic nematodes and it is considered a part of nematode-management programs. A variety of organic amendments, such as animal and green manures, compost, nematicidal plants and proteinous wastes, are used for this purpose, but nematode control efficacy is not always satisfactory. Elucidation of nematode-control mechanisms in amended soil may lead to improved efficacy or the development of more effective control techniques, although the effects of organic amendments on nematodes, microbial communities, plants and soil environments are very complex. Possible mechanisms involved in nematode suppression are:

(1) release of pre-existing nematicidal compounds in soil amendments, (2) generation of nematicidal compounds, such as ammonia and fatty acids, during degradation, (3) enhancement and/or introduction of antagonistic microorganisms, (4) increase in plant tolerance and resistance, and (5) changes in soil physiology that are unsuitable for nematode behavior. Combinations of these mechanisms, rather than a single one, appear to produce nematode suppression in amended soils.

Azim *et al.*, (2011) evaluated the impact of oil cake amendments (argan; neem; castor cake and ground castor leaves) on the control of root-knot nematodes (*Meloidogyne spp*.), affecting cucumber and melon; on soil fertility; on agronomic parameters of cucumber under greenhouse in south-western Morocco. In cucumber growing-greenhouse, experimental results showed a reduction of gall formation, soil nematodes density, root rot infestation, and improvement of plant height and yield as compared to the control. Argan cake improved yield 112% more than the control. Generally, argan cake gave better results compared to the other treatments. In pots experiment on melon, maximum suppression (100%) of root knots and soil larvae population were found with argan; castor cake and ground argan shoot; while neem cake was less effective. Argan cake resulted in 24% increase in fresh weight compared to the infested control, while ground argan shoot enormously decreased both height and weight.

Trifonova and Atanasov, (2011) conducted an experiment under glass-house conditions to test the effects of five plants products in the form of drenches on the growth of potato and population density of potato cyst nematode *Globodera rostochiensis*. All the tested formulations improved plant growth, yield and suppressed the nematode multiplication. Neem oil+extract of *Nicotiana tabacum* 0.5% or *Veratrum album* 1.0% were the most effective in reducing the disease incidence (77.7 – 77.8%), followed by neem Azal 0.3% (66.6%) and neem oil 0.3% (50.0%). None of the formulations was phytotoxic even at the tested concentration.

Singh *et al.,* (2011) carried out a survey during 2008-09 to observe nematode infestation at IIVR research Farm and found that brinjal crop was heavily infested with root-knot nematode, *Meloidogyne incognita* (5 J2/g soil). Keeping this fact in view a trial under field condition was laid out the for the management of root-knot disease of chili caused by *M. incognita* with integration of summer ploughing, biological control agents (*Pochonia chlamydosporia* and *Trichoderma viride*) and organic amendment (Neem cake). Three summers (May to June) ploughing at the interval of two weeks caused 48% reduction in *M. incognita* population density and dropped the initial inoculums level to 2.4 J2/g soil. The best protection of root-knot disease of chili was achieved through combined use of neem cake, *P. chlamydosporia* and *T. viride* that gave statistically significant ($p<0.05$) increase in plant growth, Biomass, and fruit yield (69%, 61% and 80% respectively) compared to control. A significant reduction (at $p<0.05$) in *M. incognita* multiplication and development in terms of root galling, egg masses and soil population (58%, 46 and 85% respectively) was also achieved in the treatment where all the three components were applied compared to control. Both the fungal biocontrol agents were successfully established in the rhizosphere of chili plants up to the termination of experiment. It can be concluded that application of summer ploughing followed by combined application of fungal biocontrol agents + neem cake increased not only plant health and yield but also reduced nematode multiplication and development on chili cv. Pusa Sadabahar.

Nwanguma *et al.,* (2011) carried out field trials in 2007 and 2008 planting seasons to evaluate the efficacy of different sources of organic manure in the control of *Meloidogyne incognita* infection on four varieties of pepper, *Capsicum fruitscens.* The organic manure (poultry manure, pacesetter organic fertilizer and *Chromolacna odoratum* based compost) were each incorporated 15cm deep, within the pepper plant rhizosphere, into the soil at the rates of 0, 5, 10 and 20 tha 1 . Each of the organic manure was allowed to undergo full decomposition period of 4 months prior to application time. Untreated plots served as the control treatment. Different pepper cultivars were NHV1A, NHV1B, NHV1F and "Sombo". Seedlings of four varieties of pepper raised in sterilized sandy-loam top soil were transplanted 0.5m x 0.75m apart in plots of sizes 2.50m x 1.50m. The experimental field was naturally infested with *Meloidogyne incognita, Pratylenchus brachyurus* and *Hoplolaimus* species. The experiment was a factorial design fitted into a randomized complete block design with four replications. Data obtained during the two years field trial were pooled together and analyzed. The results showed that the pepper varieties displayed varying levels of susceptibility to the nematode infection. Tolerance to the nematode attack was highest in NHV1A while susceptibility to infection was significantly high in “Sombo” variety. Poultry manure had the most significant suppressive effect on soil and root nematode populations, number of egg mass per plant and gall index. Nematode populations in *C. odoratum* based compost amended soil were the highest. There were inverse relationships between nematode populations and rate of each organic amendment. Yield of pepper were positively correlated with increase in the rate of applied treatment. Poultry manure significantly influenced the number and weight of pepper fruit with the highest yield in plots where 20t/ha poultry manure was applied. The interactive effects between manure and pepper variety, types of organic fertilizer and application rate of organic fertilizer and application rate of organic fertilizer and pepper variety on the growth and yield of pepper showed similar trends. Regardless of the pepper variety, all interactions involving 20t/ha of poultry manure recorded outstanding results on the growth and yield of pepper. These results suggest that exploitation of organic soil amendment in nematode management would be a useful control measure in organic pepper production in southwest Nigeria.

Tobacco (Nicotiana *tabacum L.*) is one of the most important commercial crops of tropical countries and it is being cultivated in most of the countries. Tobacco is susceptible to several diseases caused by fungi, viruses, Bacteria, root parasites and nematodes, which affect the yield and quality of tobacco both in nursery as well as field. This experiment was conducted to test the efficacy of organic amendment (neem), bio-control agent (*Trichiderma viride*), trap crop (*Tagetes patula*) and chemicals (carbofuran and phorate) as individual treatments and in combinations on the growth of tobacco plants and on the development and multiplication of root-knot nematode *M. incognita*. Among individual treatments, the maximum shoot height, shoot weight, number of leaves (75.66 cm,169.50 g, 12.66 respectively) were recorded in T4 carbofuran treatment where as minimum shoot height, shoot weight and number of leaves (70.50 cm, 156.00 g, 17.33 respectively) were recorded in T3 marigold treatment. Further, maximum root length and rtoot weight (22.33 cm, 45.66 g) were recorded in T4 carbofuran treatment where as minimum was recorded (17.33 cm, 40.66 g) in T3 marigold treatment respectively. The bio-control agent, *Trichoderma viridae* T2 significantly increased the plant growth with respect to plant height; (70.83 cm) shoot weight (158.22 g), number of leaves (10.66) root length and root weight (18.10 cm and 42.16 g) of tobacco plant infested with the *M. incognita*. From the present study, it may be concluded that the improved plant growth is obtained in combination treatments than in individual treatments, which might be due to the additive and interactive effect of the treatment on tobacco plants. This was studied by Raveendra *et al.,* (2011).

Mohan, (2011) evaluated the efficacy of organic nematicides such as neem cake, press mud, groundnut oil cake, neem mark and cotton seed oil and inorganic nematicides such as carbofuron, phorate and aldicarb have been found to have inhibitory effect against the soil nematodes including plant parasitic nematodes of sugarcane crop. The percent reductions of nematode population with the organic and chemical nematicides were studied. Among the organic amendments neem cake recorded the maximum reduction of nematode population density of 89.36 per cent and the cotton seed oil cake the minimum 60.84 per cent compared with control plots. Among the chemical nematicides, carbofuron reduced the population density of nematodes to the maximum, i.e. being 100 per cent followed by phorate while aldicarb recorded the minimum compared to the population density of control.

Rehman *et al.,* (2011) conducted a pot experiment to evaluate the efficacy of different oil cakes against the root knot nematode. Root knot nematodes are the major agricultural pest of wide range of crops worldwide. Root knot nematodes are one of the major biological constraint that reduces per capita yield of this pulse crops. In the present investigation, studies were made to determine the efficacy of different oil cakes viz. *Azadirachta indica* (Neem), *Brassica campestris* (Mustard) and *Gossypium hirsutum* (Cotton). Two doses (50 and 100 g) of each neem, mustard and cotton oil cakes were applied to reduce nematode infestation in chickpea. Results revealed that root gall development due to *Meloidogyne incognita* were significantly reduced in all the treatments and enhance all the plant growth characters of *C.arietinum*. Higher dose of neem oil cake was found to be most effective as compared to other treatments. Hence, it may be concluded that oil cakes are better substitute against nematicide for the effective control of root-knot nematode and reduce environmental hazards for ecologically safe environment.

Trifonova, (2012) conducted an experiment under glasshouse conditions to test the effects of neem-based product in the form of drenches and potato tuber treatments on the growth of potato and population density of the potato cyst nematode *Globodera rostochiensis*. The soil applications of the bio preparation improved the plant growth and yield of potato, being greatest with 1% Neem Azal. The biggest increase in the yield occurred in the Oxamyl application (15.8%). The bio preparation in concentrations from 0.2% to 1% increased the yield of potatoes from 0.3% to 9.7% compared to the untreated inoculated control. The soil application was relatively more effective in increasing of the yield (0.3%-9.7%) than the potato tuber treatments (0.3%-2.3%). The nematode reproduction was reduced 83.3% with Oxamyl and from 59.8% to 71.0% with Neem Azal treatments.

Seenivasan *et al.,* (2013) undertook studies to determine the efficacy of different bio-rationale approaches in managing the incidence of burrowing nematode, *Radopholus similis* and spiral nematode, *Helicotylenchus multicinctus* in banana under field conditions. The bio-rationale treatments included sucker dip with neem oil (1.5 %), soil application of pressmud at the rate of 5 kg/plant, neem cake at the rate of 500 g/plant, vermicompost at the rate of 250 g/plant, growing marigold (*Tagetes errecta*) around the basin and growing coriander (*Coriandrum sativum*) around the basin which were compared with chemical check carbofuran 3G at the rate of 40 g/plant and untreated control. The study revealed the superiority of the marigold and neem cake treatments in reducing nematode population significantly and increasing banana bunch yield on par with chemical check with 18.3 - 24.6 per cent over the untreated control. High rate of multiplication of bacterial feeding nematodes *Rhabditis* spp. and predatory nematode, *Mononchus* spp. were observed in these treatments. The economic returns were also higher with incremental benefit- cost ratio of 16.8 and 12.5 in marigold and neem cake treatments respectively.

Serfoji *et al.,* (2013) studied the management of *Meloidogyne incognita* on tobacco var. VR2 (*Nicotiana tabaccum* L.) through arbuscular mycorrhizal fungus (AMF) *Glomus aggregatum* Schenck and Smith in combination with oil cakes were conducted. Amending the soil with *G. aggregatum* in combination with different oil cakes was effective in reducing root-knot nematode in chewing tobacco var. VR2. Combination of *G. aggregatum* and neem cake significantly increased plant growth characters *viz*., shoot and root length, plant biomass and leaf yield of tobacco followed by application of *G. aggregatum* plus peanut cake. Similarly, reduction in root-knot nematode population, egg mass production, root galling and root-knot index was recorded in *G. aggregatum* plus neem cake.

Meloidogyne incognita is one of the major disease causing agents of Mulberry. This pathogen causes root knot disease in mulberry which causes 12-25% yield loss. There are a number of management techniques for the management of nematode but no single method alone can control this problem. So, in the present study an integration of different ecofriendly biocontrol methods were selected to know their efficacy on the management of root knot nematode in different mulberry varieties viz.Tr10, DD,V1RFS175,K2 and MS8. It was found that this integrated nematode management method can control nematode problem up to 83.30 % in Tr10 variety which is highest among the six varieties selected. And the less percentage of reduction and growth of plants was observed in MS8 variety. Highest percentage of growth and yield was observed in Tr10 variety. This was reported by Vijaya Kumari and Sujathamma, (2014).

Kshetrimayum and Das, (2014) investigated on efficacy of different bio-agents (*Trichoderma viride*, *T. harzianum*, Biofor- pf and neem cake) against root-knot nematode, *Meloidogyne incognita* in green gram (*Vigna radiata*) revealed that soil application of neem cake @ 2 tones/ ha significantly increased the shoot length, fresh and dry weight of shoot of green gram, followed by soil application of *T. viride* @ 2.5 kg/ha as compared to untreated control. Among the different bio-agents, Biofor-pf @ 100 kg/ ha exhibited the best result in reducing the galls, egg masses and final soil nematode population followed by neem cake @ 2 tones/ ha. However, application of Carbofuran @ 1 kg a.i./ha was very effective in reducing the galls, egg masses as well as soil nematode population.

Rizvi *et al.*, (2015) conducted a pot experiment during winter season of 2009–2010 in the department of Botany, AMU, Aligarh, India, to determine the nematicidal potential of organic matter, neem cake at third level of dose, and bioagent, *Glomus fasciculatum* in terms of various growth parameters of tomato, when inoculated individually as well as concomitantly with respect to root-knot development. Neem cake and *G. fasciculatum* showed potential for sustainable management while providing nutrient sources for proper plant growth. Disease intensity of root-knot nematode decreased while increasing the doses of neem cake along with the *G. fasciculatum*. Chlorophyll contents have been found to be increased in single and combined application as well. There is a progressive increase in growth parameters raised in soil amended with 10, 20, and 30 g neem cake/kg soil and inoculated with *G. fasciculatum*. Significant improvement in the plant growth was observed when *G. fasciculatum* and neem cake were inoculated simultaneously. Neem cake plus *G. fasciculatum* reduced the nematodes' multiplication and root-galling, and increased the plant growth of tomato as compared to unamended and *Meloidogyne incognita*-inoculated plants. Mycorrhyzation and agronomic parameters were increased due to application of *G. fasciculatum* alone, but enhanced further when inoculated with neem cake.

2.3. Effect of vermiwash :

Banu and Iyer, (2006) reported Burrowing nematode, *Radopholus similis*, root-knot nematode, *Meloidogyne incognita,* root lesion nematode, *Pratylenchus coffeae* and spiral nematode, *Helicotylenchus multicinctus* are the major nematode pests of crops in coconut based high-density multispecies cropping system. Vermiwash at different dilutions were tested against these nematodes under *in vitro* conditions and were found to be deleterious to varying extent. Juvenile hatching of *M. incognita* was greatly inhibited by vermiwash. Undiluted vermiwash caused maximum nematode mortality and inhibition in hatching. Among four nematodes tested, *M. incognita* and *H.multicinctus* were found to be highly susceptible to vermiwash, followed by *R. similis* and *P. coffeae.*

Edwards *et al.,* (2007) experimented the production and use of aqueous extracts of thermophilic composts and vermicomposts, commonly termed 'teas', has expanded rapidly in the last 2-3 years. The effects of vermicompost 'teas' on nematodes were studied in the laboratory and greenhouse, in soils that had been artificially infested with the root knot of nematode (*Meloidogyne incognita*), which is a very serious pest of a wide range of crops all over the world. Six-week-old tomato seedlings were transplanted into 10 cm diameter pots containing a sand:loam (1:3) soil mixture to which the test 'tea' treatments were applied. Drench treatments of 'teas' were applied at seedling transplanting, and every two weeks thereafter. One week after transplanting 10,000 *Meloidogyne hapla* eggs were added to each plant pot in suspension in tap water. Each treatment was replicated four times. Pots into which tomato plants had been transplanted were arranged on benches in a completely randomized design and the greenhouse was maintained at 25˚ C. Thirty days after infestation with nematodes, soil was removed from the pots and the roots were washed to assess the extent of root damage and the numbers of root knots. The washed roots were rated for numbers of root knot galls and the numbers of galls per unit wet weight of roots counted. The effects of the nematodes on plant height were determined by growth measurements, including heights, leaf areas, fresh and the dry weights of leaves from plant tops and the dry weights of all above-ground tissues at the end of the experiment.The differences in growth between treatments, in response to the vermicompost 'teas' were spectacular, and the reductions in numbers of root knot galls on the tomato roots in response to the vermicompost 'tea' applications was considerable.These effects of vermicompost 'teas' on plant parasitic nematode attacks were very similar to those in experiments that used solid vermicompost substituted into Metro-Mix 360 in the greenhouse. It was investigated by Arancon *et al.*, (2003).

Edwards *et al.,* (2007) reported that vermicompost 'teas' have dramatic effects on the suppression of attacks by plant parasitic nematodes such as Meloidogyne on tomatoes both in terms of reducing the number of root cysts significantly and increasing root and shoot growth.Vermicompost has enormous economic potential for increasing crop yields and suppressing attacks by nematodes.

Gopalakrishnan *et al.,* (2010) observed that the biowash of herbal vermicompost suppress the population of plant parasitic nematode (*Meloidogyne incognita*)

Edwards *et al.,* (2010) demonstrated significant suppression of plant parasitic nematodes by soil drenches of aqueous extracts, (vermiwash) produced from vermicomposts.

Adhikary, (2012) observed the effective reduction in population of root-knot nematode (*Meloidogyne incognita*) in tomato plants after the application of vermiwash liquid (vermicompost teas).

Gopal *et al.,* (2012) experimented that coconut leaf vermiwash application also had significant impact on the suppression of the nematode *Meloidogyne incognita* infestation in okra. It was observed that vermiwash application significantly reduced the gall index, egg mass g-1 of root, and nematode population g-1 of root and per 250 cc soil Upon uprooting the okra for dry weight analysis,the absence or reduction in the number of root galls was clearly seen in the vermiwash applied plants compared to the large number of galls in the control plants. The coconut leaf vermiwash contains very high counts of fluorescent pseudomonads known for plant growth promotion activities. it is possible that these microorganisms present in the vermiwash could have played an important role in the suppression of the nematode population and activities in the rhizosphere of okra.

Sinha *et al.,* (2014) Proved vermiwash as both ‘growth promoters and protectors’ for crop plants and reported positive role of vermiwash in lowering population of plant parasitic nematodes (*Meloidogyne incognita*).

Short-term vegetable crop production often involves frequent tillage and other farm activities that resultsin disturbed soil food web communities. A less disturbed soil community would have a more structuredsoil food web which contains soil fauna higher up in the food web hierarchy, thus higher integrity insoil nutrient cycling. The objective of this study is to examine if strip-till cover cropping and drenchingsoil with vermicompost tea could improve soil food web structure in a short-term agroecosystem. Twofield trials were conducted in Waialua, HI, USA to evaluate the effect of strip-till planting of sunn hemp(SH, Crotalaria juncea) or crimson clover (Trifolium incarnatum) cover crops in a zucchini (Cucurbita pepo)cropping system. At zucchini planting, each cover crop plot was split to receive four soil treatments:fertilizer (F, chicken pellet), compost tea (CT), fertilizer plus compost tea (F + CT), and none. Composttea was prepared from chicken manure based vermicompost aerated overnight in water at 1:10 (v:v).Planting of SH increased bacterivorous nematodes and suppressed plant-parasitic nematodes throughoutboth zucchini cropping cycles, but did not enhance the numbers of omnivorous or predatory nematodes.Crimson clover did not enhance beneficial nematodes nor suppress plant-parasitic nematodes. AddingCT to F suppressed the key plant-parasitic nematodes only at the initial stage of the zucchini growth,increased percentage of predatory or omnivorous nematodes only toward the end of zucchini crops, andincreased the structure index at harvest in the first trial. Zucchini yield was increased by planting ofSH but not by drenching of CT. Despite the benefits of CT in improving the soil food web structure, acorrelation analysis revealed that zucchini yields were correlated to the reduction in the percentage offungivorous nematodes at planting, an increase in the percentage of bacterivorous nematodes at harvest,and to reduction in the percentage of plant-parasitic nematodes at harvest. It was presented by Wang *et al.,* (2014).

In this study, solid (Vermicompost) and liquid products (Liquid Vermicompost, Vermiwash and Coelomic fluid) of the earthworm species Eisenia fetida were tested against root-knot nematode, *Meloidogyne javanica* in vitro and greenhouse conditions. Results showed that Liquid Vermicompost, Coelomic fluid and Vermiwash had the greatest effect on egg hatching inhibition, respectively, and Coelomic fluid, Vermiwash and Liquid Vermicompost had the highest effect on mortality of larvae (J2), respectively, in vitro. All earthworm-based products were added to the cucumber pots and then a root-knot disease as well as plant growth indices was recorded. Results showed that all products could reduce the number of nematode juveniles and gall index in greenhouse conditions. The best combination for controlling disease was Vermicompost +10 % Liquid Vermicompost and the highest rates of growth related to plants were treated with Vermicompost + 10 % Vermiwash. This was reported by Rostami *et al.,* (2014).

3. MATERIALS AND METHODS

The experiment in the net house of the Department of Nematology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. during 2014-15. The entire experiment was conducted under natural environmental condition. During the period of investigation, the various materials used and methods followed, are briefly categorized and discussed as follows.

3.1. MATERIALS

3.1.1. Laboratory materials:

The laboratory appliances and other materials required to conduct and investigate the experiment are as follows

Glass wares

Glass beakers, Petridishes, Measuring cylinder, Counting dish, Glass slides, Pipettes, 25 ml Volumatric Flasks, 100 ml Conical Flasks, Cover slips, Cavity Slides, Hand tally counter

Laboratory chemicals

Formalin (40 % formaldehyde), Sodium hypochlorite (NaOCl), (5N) Hydrochloric acid (HCl), Acid fuchsin, Lactic acid, Glycerol, Phenol, Distilled water.

Other materials

Aluminium pans, Aluminium wire gauge, Tissue paper, Filter paper, Polythene bags, Micropipette, Rubber band, Sieve, Bamboo stick, Needle, Electric heater, Meter scale, Threads, Envelops, Gunny bags and Earthen pots, Peak, Spades, Rubber bands, Bucket, Hand sprayer, Vermiwash extraction unit, Earth worms / Verms (*Eudrillus euginae*), Bottels.

3.1.2. Equipments:

Binocular stereoscopic microscope, Binocular research microscope, Hot air oven, Electronic balance, Earthern pots of 15cm diameter and Autoclave.

3.1.3. Tomato Variety:

Tomato seeds *(Solanum esculentum* L.*) cv*. Pusa Ruby (susceptible variety of *M. incognita*) was collected from Vegetable Improvement Scheme, OUAT, Bhubaneswar.

3.1.4. Root knot Nematode, *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949**:**

It was the test nematode species for the experiment. The population, multiplied on Brinjal from a single egg mass progeny was used for the experiment.

3.1.5. Use of organic amendments:

According to the requirement three different types of organic amendments i.e. Vermicompost, Vermiwash and Neem cake (*Azadirachta indica*) were used .

3.2. METHODS

3.2.1. Experimental site:

The experiment was conducted during 2014-15 and was entirely carried out under pot culture condition in the Department of Nematology, College of Agriculture,

Bhubaneswar. All investigations and analysis were also done in the P.G. laboratory of the department.

3.2.2. Preparation of soil & pots:

For experimental purpose as well as for culturing of nematodes, well pulverised sandy loam soil free from plant debris and gravels were collected from the University Central Farm. The soil was mixed thoroughly with sand and FYM in the ratio of 2:1:1 which was filled in gunny bag and autoclaved at 1.1kg/cm^2 pressure for one hour daily for two consecutive days. The sterilized soil was spread on a clean polythene sheet for 24 hours for renaturation of soil. In the mean time earthen pots of 15cm diameter were cleaned and surface sterilized in 1% formaldehyde solution and made air dry. Pots were then filled with aerated sterilized soil. Neem cake / vermicompost alone or in combination in different doses were added to the pot soil as per the experimental needs. After watering the pots, a waiting period of 15 days was given for proper decomposition of amendments.

3.2.3. Sowing of seeds:

Tomato cv. Pusa Ruby seeds were surface sterilized in 2.5% Sodium hypochlorite solution for two minutes followed by rinsing seeds thrice with distilled water and air dried in shade. Three to 4 seeds were sown in each pot and lightly covered with sterilized soil. Light watering was done to keep the soil moist. Seeds when germinated and attained 3-4 leaves stage, thinning was done keeping one plant per pot. Same procedure was used in thermocol cups containing above prepared soil mixture @ 200g per cup for penetration study.

3.2.4. Method of collection of vermiwash;

A stainless steel vessel measuring about fifteen liters capacity was taken and a hole was made at the bottom of vessel .The hole of vessel was sealed with paraffin wax. The vessel was filled with pebbles, sand and over this microbial infested old dampened cow dung was added. *Eudrilus eugeniae* earthworms were heavily introduced into the vessel. The setup was left undisturbed for about 20days. The water was sprayed every day to maintain moisture required for the worm bed. On the twenty first day 1 liter of distilled water was poured over the worm bed and the liquid was collected by opening the seal at the bottom of the vessel. The collected vermiwash was stored in tightly closed 500ml bottle. It was then used for the penetration study. Each thermocol pot soil was then drenched with vermiwash @ 20ml / pot.

3.2.5. Nematode culture:

Egg masses of *Meloidogyne incognita* was collected from brinjal root and the population was multiplied on a susceptible Brinjal variety (BB-54) grown in pots containing sterilized soil. This was done two months prior to the start of the experiment. From the culturing pots, egg masses were collected from roots and were allowed to hatch in distilled water to give rise to second stage juveniles for inoculation purpose

3.2.6. Standardizing nematode number in stock solution:

The nematode suspension containing second stage juveniles was taken in a beaker. This was thoroughly stirred before taking a 10 ml suspension in a rectangular counting dish to count the nematodes, under a stereoscopic microscope thrice. The average of total number of nematodes present in the 10 ml stock sample was determined.

Figure 2: Vermiwash extraction unit

3.2.7. Inoculation of nematode:

Fifteen days after the sowing of seeds in the pots, infective J_2 of root knot nematode were inoculated @ 2000 J_2/kg soil. Two small holes of 2 cm depth were made in the soil close to base of the plant, into which a measured volume of nematode suspension (10ml) was slowly poured to release 2000 young females per pot in all the treatments and close the holes immediately. More over for penetration study, *Meloidogyne incognita* juveniles were inoculated in vermiwash treated thermocol cups @ 200 J_2 per thermocol cup 30 days after sowing of seeds.

3.3. Experiment 1: Effect of vermicompost and neem cake on root knot nematode, *Meloidogyne incognita* infecting tomato

3.3.1. Experimental details:

The experiment was laid out in 15 cm size earthen pots following Complete Randomised Design (CRD) with ten treatments, each replicated thrice. The treatments were as follows:

T_1 - Vermicompost alone @ 500g/m²

T_2 - Vermicompost alone @ 250g/m²

T_3 - Neem cake alone @ 100g/m²

T_4 - Neem cake alone @ 50g/m²

T_5 - $T_1 + T_3$

T_6 - $T_1 + T_4$

T_7 - $T_2 + T_3$

T_8 - $T_2 + T_4$

T_9 - Carbofuran as standard check @ 0.3g a.i./m²

T_{10}- Untreated Check

3.3.2. Recording of observations

Sixty days after sowing, the crop was harvested and the following experimental data were recorded.

3.3.2.1. Shoot length:

The length of the shoot from the base of the plant to the top most crown was measured with the help of a meter scale.

3.3.2.2. Fresh weight of shoot:

Fresh weight of shoot of individual plant was recorded. This was further labelled and kept for recording of dry weight of shoot.

3.3.2.3. Dry weight of shoot:

In order to determine the dry weight of shoot, this was cut from the ground level and root portion was separated. The shoot portion was labelled properly; first sun dried and subsequently dried in the hot air oven at 80°c with periodical observations at 24 hours interval till constant weight was observed.

3.3.2.4. Root length:

Prior to taking root length the pot was irrigated lightly to drench the soil just sufficiently. The pot was taken in a large (30 cm dia) plastic pan and inverted with a jerk, so that the whole soil came out easily from the pot along with the plant. Further water was given to loosen the soil and allow the plant come out easily along with the root system. The roots were carefully washed so as to remove all the adhering soil. The root length was measured with the help of a meter scale from the base of the plant up to the end of the main root.

3.3.2.5. Fresh weight of root:

Fresh weight of root of individual plant was recorded. This was further labelled and kept for recording of dry weight of root.

3.3.2.6. Dry weight of root:

Five gram roots were first dried under sun and then in a hot air oven at 80°C for 2 days till constant weight was obtained. The weight of the root system was extrapolated from 5g root. Rest quantity of root were used for determination of nematode population in roots.

3.3.2.7. Fruit weight:

Fruits from each plant were plucked and later fruit weight of individual plant was recorded.

3.3.2.8. Number of Galls:

During harvest of the plants, number of galls were counted in the roots and recorded.

3.3.2.9. Estimation of *Meloidogyne incognita* population in soil:

At the time of harvest, the soil sample was processed following Cobb's sieving and decantation method (Cobb,1918). Population estimation of *M. incognita* was done as per Sl. no. 3.2.6.

3.3.2.10. Estimation of *Meloidogyne incognita* population in root:

At the time of harvest, roots of tomato plants inoculated with *M. incognita* were lifted carefully. 2g infected root from each replication of different treatments were tied separately with cotton threads and labelled accordingly. These roots were stained in Acid fuchsin stained lactophenol solution (lactic acid, phenol, glycerol and distilled water in 1:1:2:1 proportion and added with 0.05% acid fuchsin stain). A glass beaker upto $1/4^{th}$ of its capacity was filled with freshly prepared stained lactophenol solution. The glass beaker was placed on a hot plate for boiling of the solution. When the solution started boiling, labelled roots tied with cotton threads were plunged into the solution for 3minutes and then cooled to room temperature. After draining the stained lactophenol, stained roots were rinsed with running tap water to wash off the excess stain taken by the root. Then the roots were placed in another beaker containing lactophenol solution for destaining of roots. After destaining, roots were examined under stereoscopic microscope. Different stages of root knot nematodes were counted.

3.4. Experiment 2: Effect of vermiwash on penetration of *Meloidogyne incognita* juveniles in tomato roots.

3.4.1. Experimental details:

To study the effect of vermiwash on penetration of juveniles of root knot nematode, *Meloidogyne incognita* in tomato roots an experiment was laid out in thermocol cups following Complete Randomised Design (CRD) with six treatments, each replicated thrice. For each treatment an untreated check was maintained. The treatments were as follows:

T_1 - Juveniles penetration at 4 hours

T_2 - Juveniles penetrated at 8 hours

T_3 - Juveniles penetrated at 12 hours

T_4 - Juveniles penetrated at 24 hours

T_5 - Juveniles penetrated at 48 hours

T_6 - Juveniles penetrated at 72 hours

3.4.2. Recording of observations

3.4.2.1. Staining of plant roots and estimation of penetrated juveniles:

Roots of 4 weeks old tomato seedlings inoculated with *M. incognita* were lifted carefully from the thermocol cups. Infected root from each replication of different treatments viz. T_1 (4hrs after inoculation), T_2 (8hrs after inoculation), T_3 (12hrs after inoculation), T_4 (24hrs after inoculation), T_5 (48hrs after inoculation) and T_6 (72hrs after inoculation) were tied separately with cotton threads and labelled accordingly. These roots were stained in Sodium Hypochlorite Acid fuchsin stained solution (3.5g Acid fuchsin stain in 250ml Acetic acid and 750ml distilled) following Byrd's method. Infected roots were washed carefully and were placed in a 150ml glass beaker. Roots were then cleaned by adding 50ml of tap water and 20ml of 5.25% NaOCl (Chlorine bleach) . Roots were soaked for about 4 minutes in the above solution with occasional agitation. Then the roots were rinsed for approximately 45 seconds in running tap water and then soaked in tap water for 15 minutes to remove any residual NaOCl. Water was then drained and roots were tranfered to a beaker with 30 – 50ml of tap water. To it 2ml of stock acid fuchsin stain was added. The solution was boiled for about 30 minutes on a hot plate. Solution was then cooled to room temperature and drained from the roots. Roots were then rinsed in running tap water and placed in 20 – 30ml glycerol acidified with a few drops of 5N HCl and heated to boiling for destaining. After destaining, roots were examined under stereoscopic microscope. Number of root knot nematodes penetrated were counted.

3.5. Statistical analysis and interpretation of data:

Statistical analysis of different plant growth parameters, nematode were carried out following Fisher's (1970) 'F' test and analysis of variance in a complete randomized design. Further $S.E_{(m)}$ and L.S.D for different factors were calculated to test the significance of means in the following manner.

$S.E_{(m)}$ for treatment = = $\sqrt{2}EMS/r$

L.S.D at 0.05= $S.E_{(m)} \times t_{0.05}$ at error d.f., where,

d.f.= degree of freedom

r= replication

EMS= Error means sum of square

$S.E_{(m)}$ = Standard error mean

L.S.D $_{(0.05)}$ = Least significant difference at 5% level.

The difference between two treatment means if greater than the LSD value indicated the significant difference between the treatments. In this way, comparison between the treatments was made.

4. RESULTS

An attempt was made to carry out a pot culture experiment to test the response of neem cake and vermicompost along with a nematicide as standard check with the primary objective of determining the efficacy of various organic amendments against *Meloidogyne incognita* in tomato,. The effect of various treatments alone and in combination was compared with the inoculated check by recording the data relating to various growth parameters and nematode multiplication. More over effect of vermiwash on nematode penetration in tomato roots at different time interval was also studied. The observed data were compiled in a tabular form and were subjected to statistical analysis in order to test the significance of various treatments. Finally the mean data for each growth parameter and nematode multiplication were arranged in tables and presented in this chapter.

4.1. Plant Growth Parameters:

4.1.1. Shoot length (Table -1; Fig. 5):

As shoot length is the index of plant growth, the effect of different treatments on this important aspect was studied. It was evident from the tabulated data, that there was increase in shoot length in all treatments, as compared to inoculated check (T_{10}), But statistical analysis of data revealed that there was no significant difference in shoot length in T_2 over check. Shoot length was maximum in T_5 (T_1 + T_3) with 86.17% increase in plant height over T_{10}. This was followed in descending order as T_7 (75.43%), T_6 (66.43%), T_8 (63.62%), T_9 (49.09%), T_3 (43.63%), T_1 (42.71%), T_4 (35.45%) and T_2 (27.27%) over T_{10}. Moreover T_1, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 were found statistically significant over check. However, among all treatments, T_5 (combination of Vermicompost @ 500g/m² and Neem cake @ 100g/m²) exhibited highest increase in shoot length.

4.1.2. Fresh Shoot Weight (Table -1; Fig. 6):

The data indicated increase in fresh weight in all treatments over check (T_{10}). T_5 exhibited highest fresh weight (61.60g) with 50.24% increase over check which was closely followed by T_7 (44.39%), T_6 (40.41%), T_8 (28.22%), T_9 (21.88%), T_3 (20.32%), T_1 (14.15%), T_4 (8.05%) increase in fresh weight of shoot over check, the lowest being 3.90% increase in T_2. Fresh shoot weight in T_5 was found significantly at par with T_7, T_6 and T_8. However, T_3, T_5, T_6, T_7, T_8 and T_9 were found significantly superior over check.

Figure 3: Effect of vermicompost and neem cake on shoot growth of tomato infected by *Meloidogyne incognita*

Figure 4: Effect of vermicompost and neem cake on root growth of tomato infected by *Meloidogyne incognita*

T_1 – Vermicompost @ 500g/m^2
T_2 – Vermicompost @250g/m^2,
T_3 – Neem cake @ 100g/m^2
T_4 – Neem cake @ 50g/m^2,
T_5 – T_1 + T_3
T_6 – T_1 + T_4,
T_7 – T_2 + T_3
T_8 – T_2 + T_4
T_9 – Carbofuran @ .3g a.i. /m^2
T_{10} – Untreated check

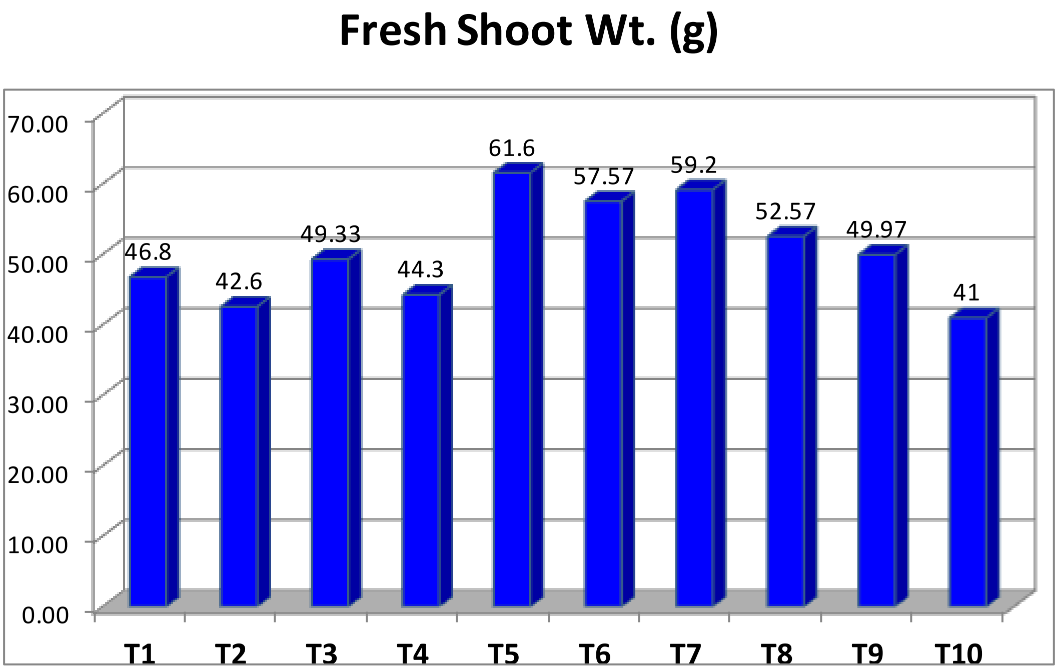
Table-1.Influence of *M. incognita*, vermicompost and neem cake either alone or in combination on shoot growth parameters of tomato cv. pusa ruby

(Average of 3 replications)

Treatments	**Shoot Length (cm)**	**% increase**	**Fresh Shoot Weight (g)**	**% increase**	**Dry Shoot Weight (g)**	**% increase**
T_1 = Vermicompost @ 500g/m²	52.33	42.71	46.80	14.15	10.10	24.69
T_2 = Vermicompost @250g/m²	46.67	27.27	42.60	3.90	8.80	8.64
T_3 = Neem Cake @ 100g/m²	52.67	43.63	49.33	20.32	10.70	32.10
T_4 = Neem @ 50g/m²	49.67	35.45	44.30	8.05	9.40	16.05
$T_5 = T_1 + T_3$	68.27	86.17	61.60	50.24	13.90	71.60
$T_6 = T_1 + T_4$	61.03	66.43	57.57	40.41	12.40	53.09
$T_7 = T_2 + T_3$	64.33	75.43	59.20	44.39	13.10	61.73
$T_8 = T_2 + T_4$	60.00	63.62	52.57	28.22	11.80	45.68
T_9 = Carbofuran @ 0.3g a.i./m²	54.67	49.09	49.97	21.88	11.00	35.80
T_{10} = Untreated Check	36.67	0.00	41.00	0.00	8.10	0.00
S.E. (m)	**3.39**	**-**	**2.71**	**-**	**0.45**	-
L.S.D. (0.05)	**10.02**	**-**	**8.02**	**-**	**1.34**	-

Figure 5: Effect of vermicompost and neem cake on shoot length of tomato infected by *Meloidogyne incognita*

Figure 6: Effect of vermicompost and neem cake on fresh shoot weight of tomato infected by *Meloidogyne incognita*.



T_1 - VC @ 500g/m², T_2 - VC @ 250g/m², T_3- NC @ 100g/m², T_4- NC @ 50g/m², T_5 - (T_1 + T_3), T_6 - (T_1 + T_4), T_7 – (T_2 + T_3), T_8 – (T_2 + T_4), T_9 - Carbofuran @ 0.3g a.i./m², T_{10} - Untreated Check

4.1.3. Dry Shoot Weight (Table -1; Fig. 7):

There was increase in mean dry shoot weight in all treatments over check (T_{10}). The percentage of increase in dry shoot weight over check ranged from 8.64% (T_2) to 71.60% in T_5. Mean dry shoot weight in T_5 (13.90g) was found statistically non-significant with T_7 (13.1g) but significantly different from rest of the treatments. Combined application of vermicompost & neem cake in T_5, T_6, T_7 and T_8 as well as T_1 (Vermicompost @ 500g/m^2) and T_3 (Neem cake @ 100g/m^2) exhibited significant increase in mean dry shoot weight over check. However, combined application of vermicompost @ 500g/m² and Neem cake @ 100g/m² indicated highest increase in dry shoot weight (13.90g).

4.1.4. Root Length (Table -2; Fig. 8):

Perusal of data on mean root length revealed that root length in all treated tomato plants increased over check. T_5 registered highest root length (25.53cm) followed by T_7 (23.00cm), T_6 (22.00cm), T_8 (21.00cm), T_9 (19.67cm), T_3 (19.60cm), T_1 (16.53cm), T_4 (15.30cm) and T_2 (14.50cm). Barring T_1, T_2 and T_4, all other treatments were observed significantly superior over check (T_{10}). T_5 was found to be statistically insignificant with T_6, T_7 and T_8 but superior over rest of the treatments. Percentage increase of mean root length was observed highest in T_5 (82.36%), followed by T_7 (64.29%), T_6 (57.14%), T_8 (50%), T_9 (40.50%), T_3 (40.00%), T_1 (18.07%), T_4 (9.29%) and the lowest being recorded in T_2 (3.57%).

4.1.5. Fresh Root Weight (Table -2; Fig. 9):

While observing the data on fresh root weight, it was noticed that T_5 recorded the highest fresh root weight (19.20g) followed by T_7 (18.30g), T_6 (16.10g), T_8 (14.2g), T_9 (13.9g), T_3 (13.75g), T_1 (12.2g), T_4 (11.6g) and the lowest being in T_2 (11.00g) . There was no significant difference in fresh root weight among T_1, T_2 and T_4 over check (T_{10}). But T_5 exhibited significant difference in fresh root weight from T_1, T_2, T_3, T_4, T_6, T_8, T_9 and T_{10}. But T_5 was found to be statistically insignificant with T_7. Percentage of increase in fresh root weight was recorded highest in T_5 (79.44%) followed by T_7 (71.03%), T_6 (50.47%), T_8 (32.71%), T_9 (29.91%), T_3 (28.50%), T_1 (14.02%), T_4 (8.41%) and T_2 (2.80%) over check.

Figure 7: Effect of vermicompost and neem cake on dry shoot weight of tomato infected by *Meloidogyne incognita.*

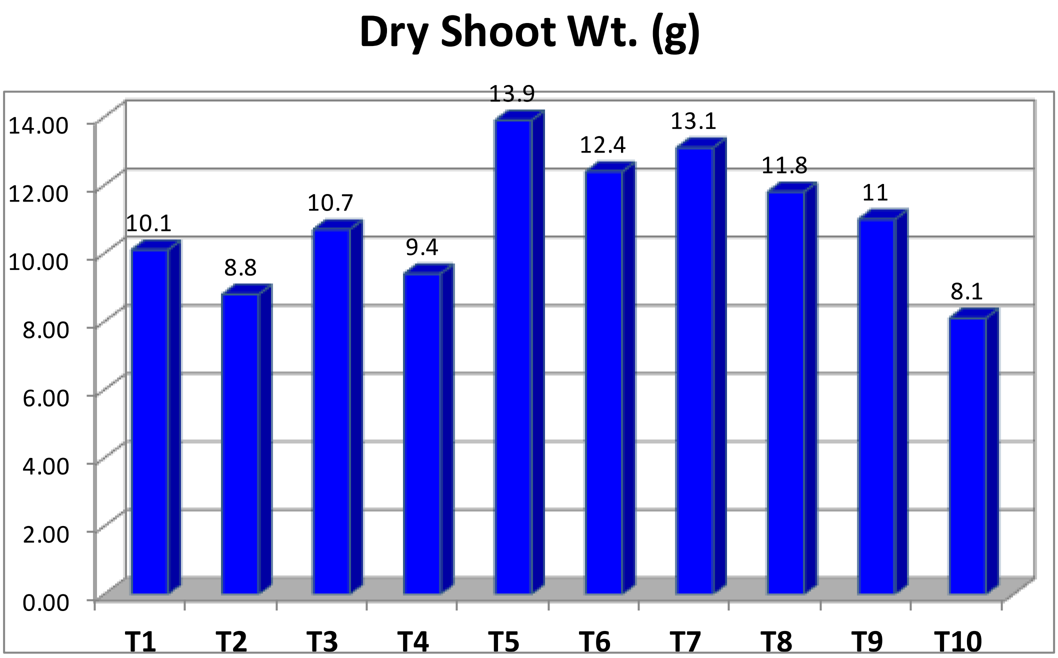
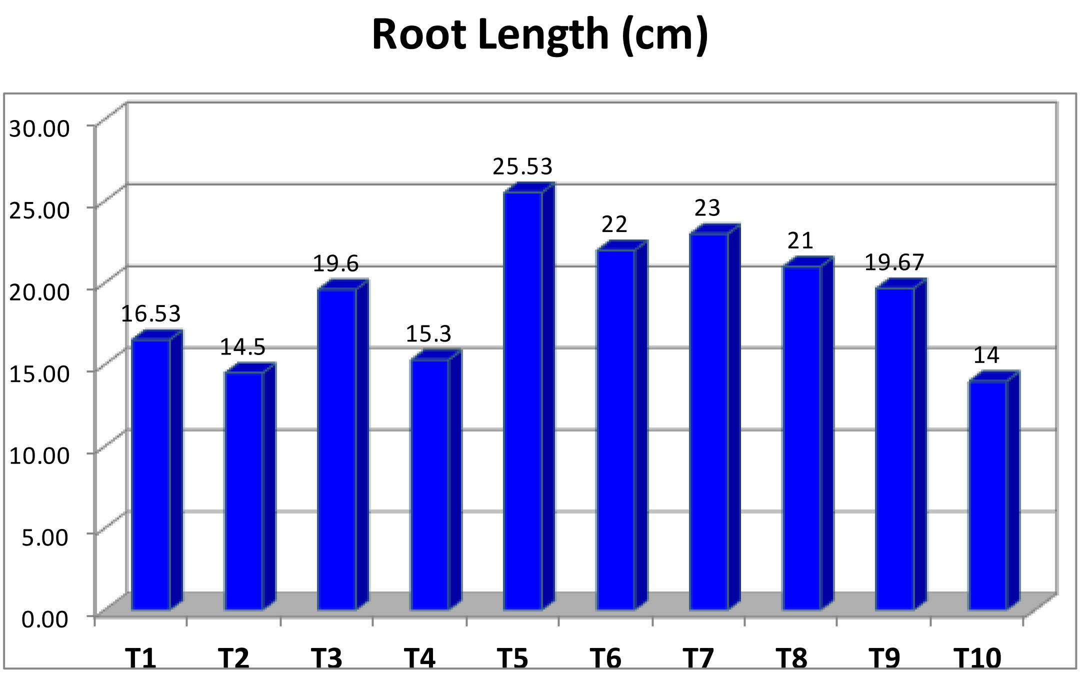


Figure 8: Effect of vermicompost and neem cake on root length of tomato infected by *Meloidogyne incognita.*



T_1 - VC @ 500g/m², T_2 - VC @ 250g/m², T_3- NC @ 100g/m², T_4- NC @ 50g/m², T_5 - (T_1 + T_3), T_6 - (T_1 + T_4), T_7 – (T_2 + T_3), T_8 – (T_2 + T_4), T_9 - Carbofuran @ 0.3g a.i./m², T_{10} - Untreated Check

Table–2.Influence of *M. incognita*, vermicompost and neem cake either alone or in combination on root growth parameters and fruit weight of tomato cv. pusa ruby

(Average of 3 replications)

Treatments	Root length (cm)	% increase	Fresh Root Weight (g)	% increase	Dry Root Weight(g)	% increase	Fruit weight (g)	% increase
T_1 = Vermicompost @ 500g/m²	16.53	18.07	12.20	14.02	6.80	21.43	80.26	13.36
T_2 = Vermicompost @ 250g/m²	14.50	3.57	11.00	2.80	5.90	5.36	73.30	3.53
T_3 = Neem @ 100g/m²	19.60	40.00	13.75	28.50	7.10	26.79	85.83	21.23
T_4 = Neem @ 50g/m²	15.30	9.29	11.60	8.41	6.40	14.29	76.40	7.91
$T_5 = T_1 + T_3$	25.53	82.36	19.20	79.44	9.10	62.50	120.70	70.48
$T_6 = T_1 + T_4$	22.00	57.14	16.10	50.47	8.20	46.43	109.97	55.32
$T_7 = T_2 + T_3$	23.00	64.29	18.30	71.03	8.60	53.57	115.50	63.14
$T_8 = T_2 + T_4$	21.00	23.07	14.20	32.71	7.90	41.07	101.40	43.22
T_9 = Carbofuran @ 0.3g a.i./m²	19.67	40.50	13.90	29.91	7.60	35.71	91.83	29.70
T_{10} = Untreated	14.00	0.00	10.70	0.00	5.60	0.00	70.80	0.00

Check								
S.E. (m)	**1.80**	**-**	**0.92**	**-**	**0.34**	**-**	**4.11**	**-**
L.S.D. (0.05)	**5.32**	**-**	**2.71**	**-**	**1.04**	**-**	**12.13**	**-**

Figure 9: Effect of vermicompost and neem cake on fresh root weight of tomato infected by *Meloidogyne incognita.*

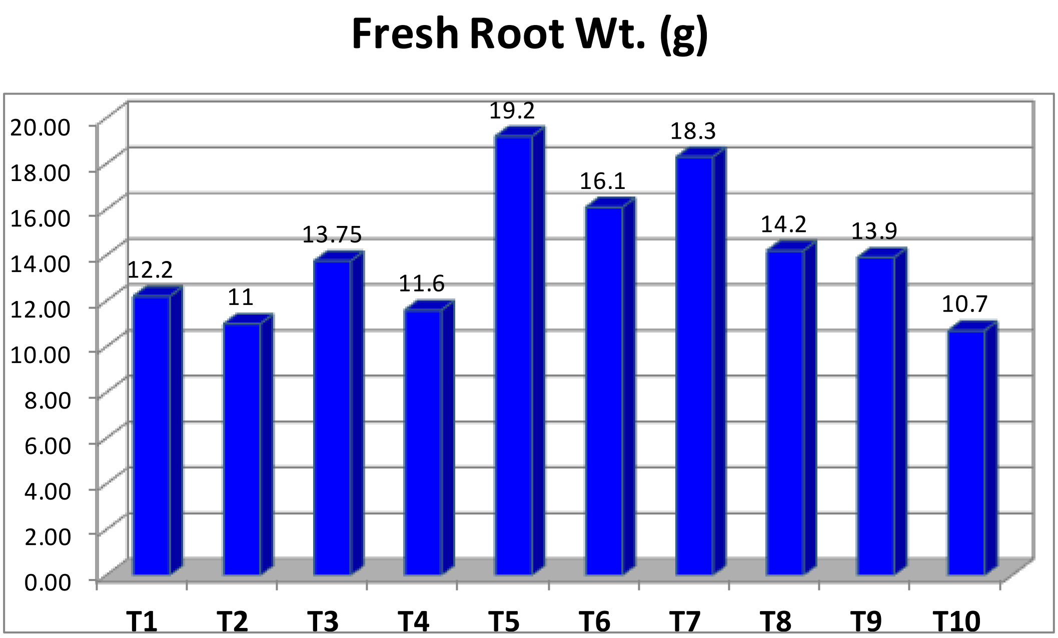
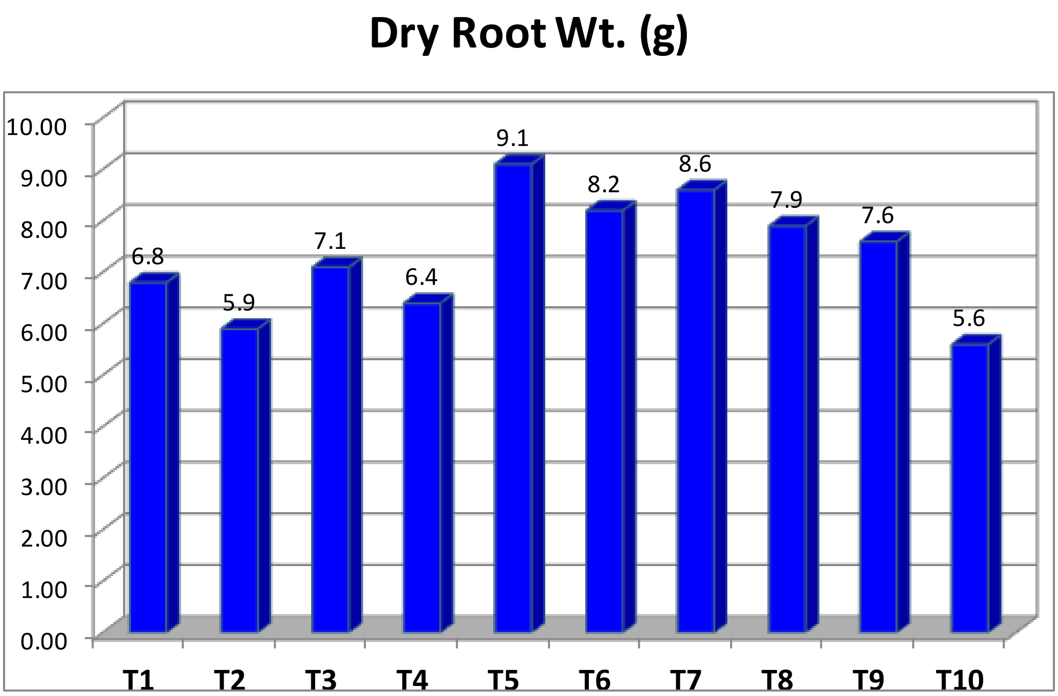


Figure 10: Effect of vermicompost and neem cake on dry root weight of tomato infected by *Meloidogyne incognita.*



T_1 - VC @ 500g/m², T_2 - VC @ 250g/m², T_3- NC @ 100g/m², T_4- NC @ 50g/m², T_5 - (T_1 + T_3), T_6 - (T_1 + T_4), T_7 – (T_2 + T_3), T_8 – (T_2 + T_4), T_9 - Carbofuran @ 0.3g a.i./m², T_{10} - Untreated Check

4.1.6. Dry Root Weight (Table -2; Fig. 10):

Dry root weight in different treatments ranged from 5.60g in T_{10} to highest 9.10g in T_5. Dry root weight in T_5 was found statistically at par with T_6, T_7 and T_8 but was significantly different from rest treatments. Moreover, percentage of increase in dry root weight ranged from 5.36% in T_2 to 62.50% in T_5 over check. T_5 was followed by T_7 (53.57%), T_6 (46.43%), T_8 (41.07%), T_9 (35.71%), T_3 (26.79%), T_1 (21.43%), T_4 (14.29%) and T_2 (5.36%) over check (T_{10}).

4.1.7. Fruit Weight (Table -2; Fig. 11):

There was increase in mean fruit weight in all treatments over check (T_{10}). The percentage of increase in fruit weight over check ranged from as low as 3.53% (T_2) to 70.48% in T_5. Mean fruit weight in T_5 (120.70g) was found statistically non-significant with T_7 (115.50g) and T_6 (109.97g) but significantly different from rest of the treatments. Combined application of vermicompost & neem cake in T_5, T_6, T_7 and T_8 as well (Neem cake @ 100g/m^2) and T_9 (Carbofuran .3g a.i/m^2) exhibited significant increase in mean fruit weight over check. But T_1, T_2 and T_4 were found to be statistically insignificant with check. However, combined application of vermicompost @ 500g/m^2 and Neem cake @ 100g/m^2 indicated highest increase in fruit weight (120.70g).

4.2. Root Knot Nematode infection parameters and its population:

4.2.1. Number of Galls/ plant (Table -3; Fig. 12):

Analysis of data on number of galls produced by root knot nematode revealed that there was significant reduction in number of galls in different treatments over check (T_{10}). There was highest reduction in number of galls in T_5 (78.99%) followed by T_7 (68.07%), T_9 (62.35%), T_6 (50.33%), T_8 (47.60%), T_3 (45.45%), T_1 (38.83%), T_4 (32.57) and T_2 (8.72%) over check in descending order. Number of galls in T_5 was found statistically significantly superior from all of the treatments. Also it was noticed that treatments where vermicompost and neem cake were applied alone, the number of galls produced by root knot nematode were comparatively more than the corresponding treatments where vermicompost and neem cake were applied together.

Figure 11: Effect of vermicompost and neem cake on fruit weight of tomato infected by *Meloidogyne incognita*

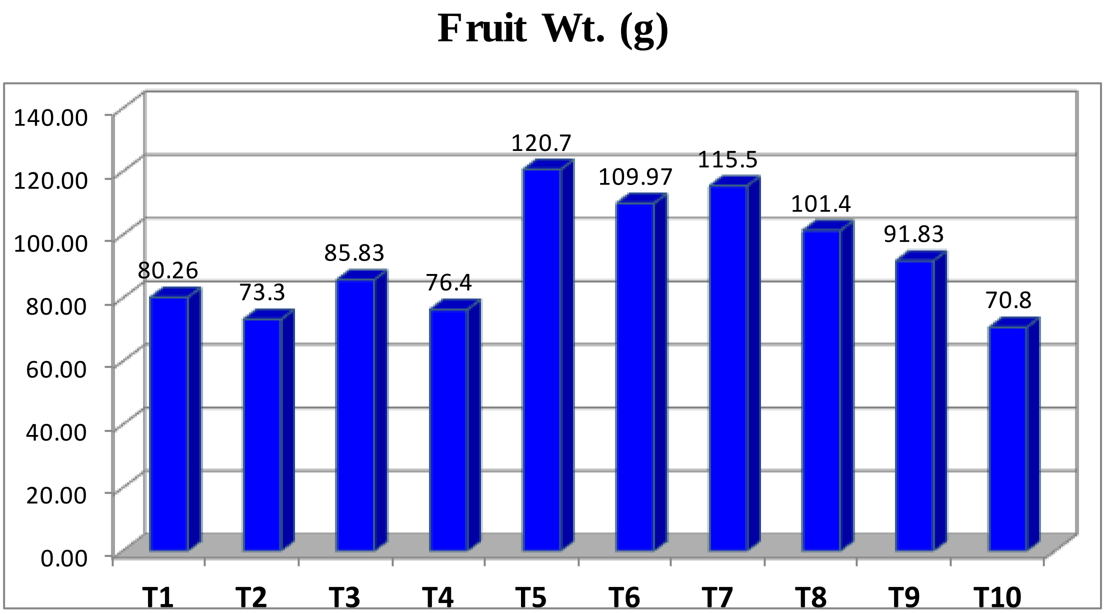
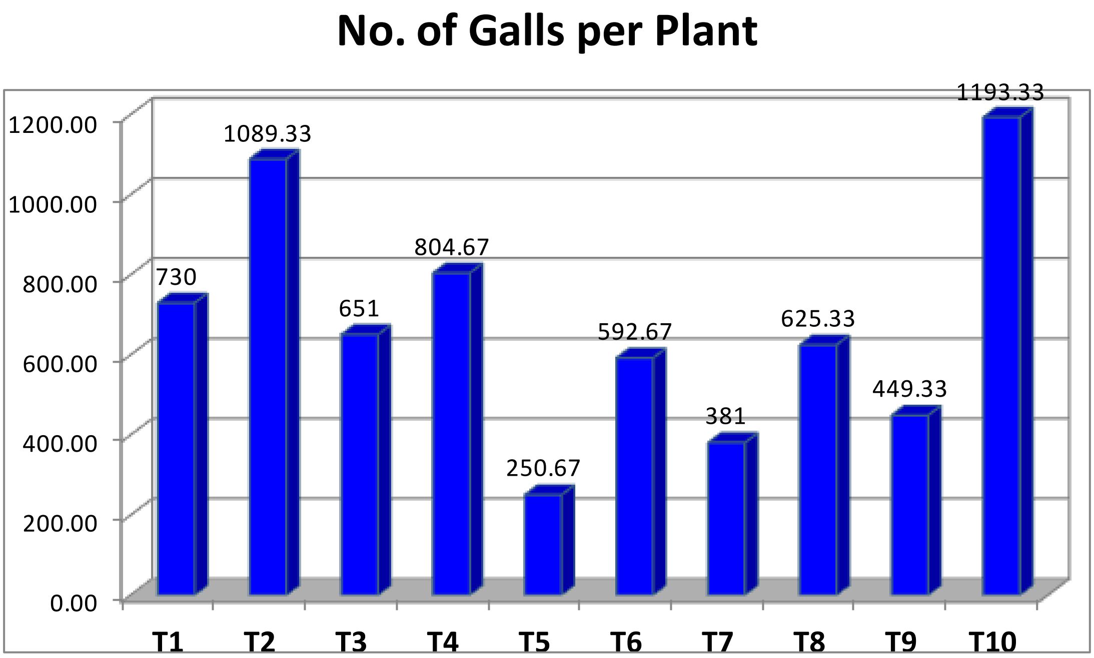


Figure 12: Effect of vermicompost and neem cake on no. of galls per plant of tomato infected by *Meloidogyne incognita*.



T_1 - VC @ 500g/m², T_2 - VC @ 250g/m², T_3- NC @ 100g/m², T_4- NC @ 50g/m², T_5 - (T_1 + T_3), T_6 - (T_1 + T_4), T_7 – (T_2 + T_3), T_8 – (T_2 + T_4), T_9 - Carbofuran @ 0.3g a.i./m², T_{10} - Untreated Check

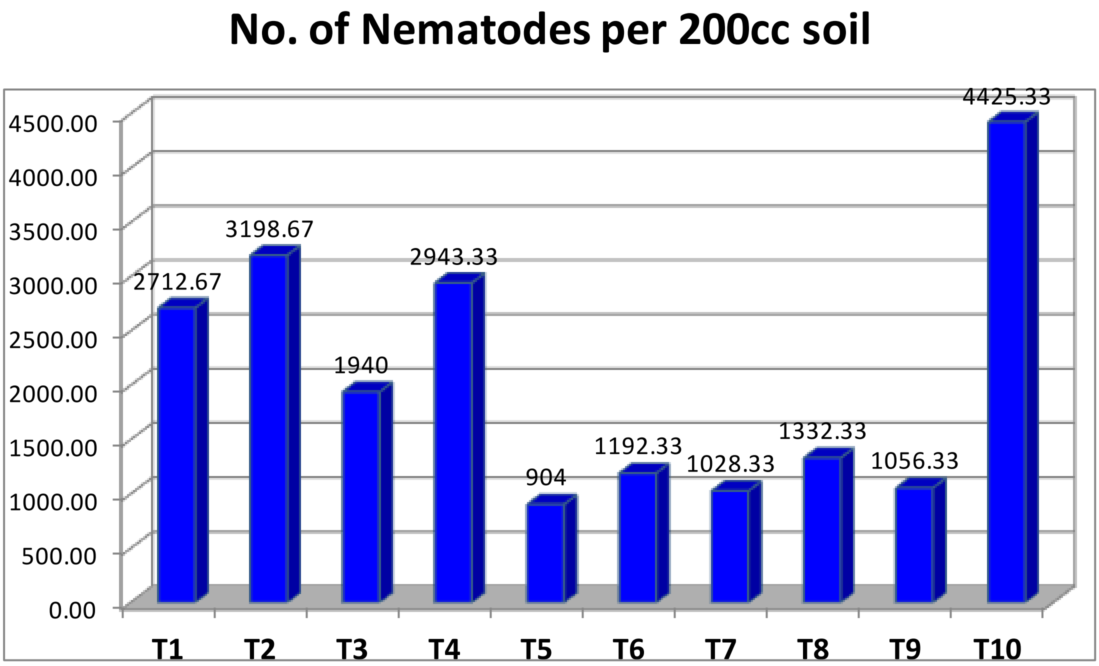
Table-3.Root Knot Nematode (*Meloidogyne incognita*) infection parameters and its population growth in tomato cv. pusa ruby

(Average of 3 replications)

Treatments	**Number of Galls**	**% decrease**	**Root knot nematode population (soil and roots)**	**% decrease**
T_1 = Vermicompost @ 500g/m²	730.00 (2.86)*	38.83	2712.67 (3.43)*	38.70
T_2 = Vermicompost @ 250g/m²	1089.33 (3.04)	8.72	3198.67 (3.50)	27.72
T_3 = Neem @ 100g/m²	651.00 (2.81)	45.45	1940.00 (3.29)	56.16
T_4 = Neem @ 50g/m²	804.67 (2.90)	32.57	2943.33 (3.47)	33.49
$T_5 = T_1 + T_3$	250.67 (2.40)	78.99	904.00 (2.96)	79.57
$T_6 = T_1 + T_4$	592.67 (2.77)	50.33	1192.33 (3.08)	73.06
$T_7 = T_2 + T_3$	381.00 (2.57)	68.07	1028.33 (3.12)	76.76
$T_8 = T_2 + T_4$	625.33 (2.79)	47.60	1332.33 (3.12)	69.89
T_9 = Carbofuran @ 0.3g a.i./ha	449.33 (2.65)	62.35	1056.33 (3.02)	76.13
T_{10} = Untreated Check	1193.33 (3.08)	0.00	4425.33 (3.64)	0.00
S.E. (m)	**0.03**	**-**	**0.02**	**-**
L.S.D. (0.05)	**0.10**	**-**	**0.06**	**-**

***Figures in parentheses are log transformed values.**

Figure 13: Effect of vermicompost and neem cake on total nematode population per 200cc soil of tomato infected by *Meloidogyne incognita.*



T_1 - VC @ 500g/m², T_2 - VC @ 250g/m², T_3- NC @ 100g/m², T_4- NC @ 50g/m²,

T_5 - (T_1 + T_3), T_6 - (T_1 + T_4), T_7 – (T_2 + T_3), T_8 – (T_2 + T_4),

T_9 - Carbofuran @ 0.3g a.i./m², T_{10} - Untreated Check

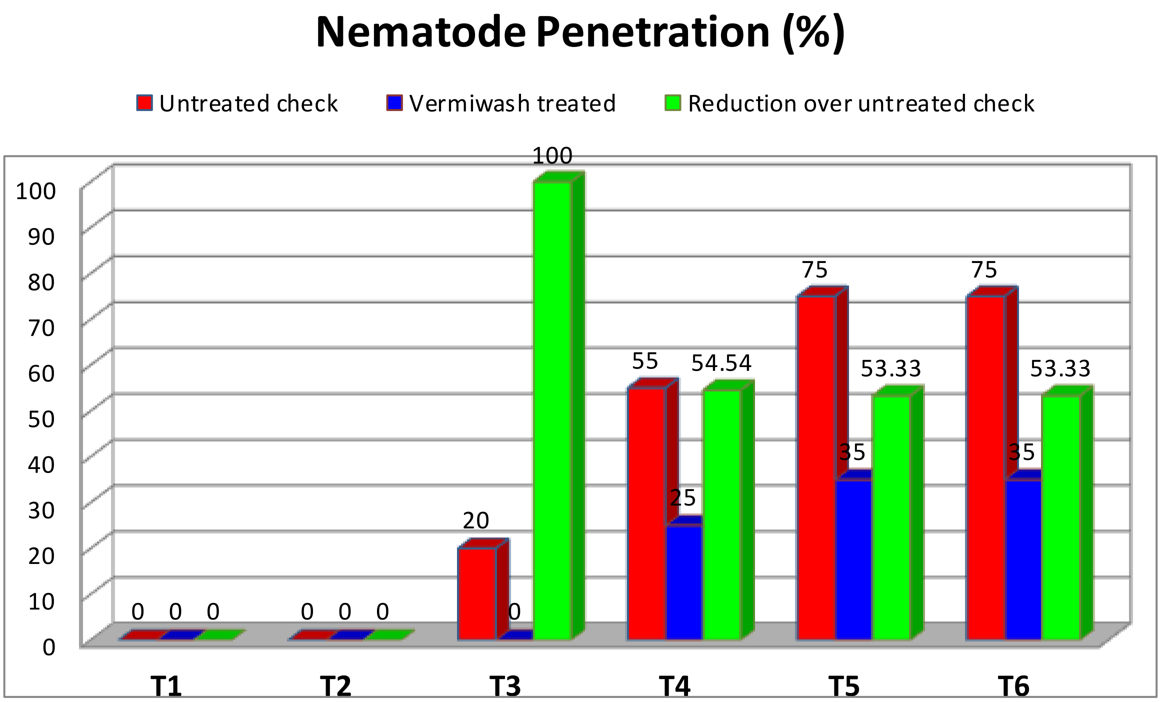
4.2.2. Root Knot Nematode Population/ 200cc soil (Table -3; Fig. 13):

From the data on mean nematode population in soil and root, it was evident that T_5 exhibited the lowest root knot nematode population (904.00) with highest reduction (79.57%) in nematode population over check (T_{10}) followed by T_7 (76.76%), T_9 (76.13%), T_6 (73.06%), T_8 (69.89%), T_3 (56.16%), T_1 (38.70%), T_4 (33.49%) and T_2 (27.72%) in descending order over check (T_{10}). As compared to check, all treatments significantly contributed in reducing the root knot nematode population.

4.3. Root knot nematode penetration (Table -4; Fig. 14):

From the data on mean nematode penetration in tomato roots, it is evident that penetration was not recorded up to 8hours neither in vermiwash treated roots nor in corresponding untreated roots (T_1 and T_2). Penetration of juveniles of *Meloidogyne incognita* started at 12 hours after inoculation (T_3) in untreated seedlings to the tune of 20% where as there was no penetration of nematodes at the same time interval in the corresponding vermiwash treated tomato roots. Thus the penetration reduction percentage over untreated check was 100% at 12 hours interval. Penetration of J_2 of *Meloidogyne incognita* at 24 hours interval (T_4) increased upto 55% of inoculated nematodes in the roots of untreated seedlings as against 25% in vermiwash treated roots. Here 54.54% of nematode penetration reduction was found over the corresponding untreated check. At 48 hours interval (T_5) maximum juveniles (75%) of inoculated nematodes penetrated to untreated tomato roots as against of 35% in vermiwash treated roots. In this case nematode penetration was reduced by 53.33% over untreated check. At 72 hours interval (T_6) no further penetration was recorded and was same as that of 48hrs interval (T_5) and no further observations were noted.

Figure 14: Effect of vermiwash on penetration of juveniles of *Meloidogyne incognita* in tomato roots.



T_1 – Penetration @ 4hours interval.

T_2 – Penetration @ 8hours interval.

T_3 – Penetration @ 12hours interval.

T_4 – Penetration @ 24hours interval.

T_5 – Penetration @ 48hours interval.

T_6 – Penetration @ 72hours interval.

Table-4.Penetration of root knot nematode (*Meloidogyne incognita*) in tomato roots

(Average of 3 replications)

Treatments	Hours Interval	Nematode penetration				% penetration reduction over untreated check
		Untreated check		Vermiwash treated		
		Number	% penetration	Number	% penetration	
T_1	4 hours	0	0	0	0	0
T_2	8 hours	0	0	0	0	0
T_3	12 hours	40	20	0	0	100
T_4	24 hours	110	55	50	25	54.54
T_5	48 hours	150	75	70	35	53.33
T_6	72 hours	150	75	70	35	53.33

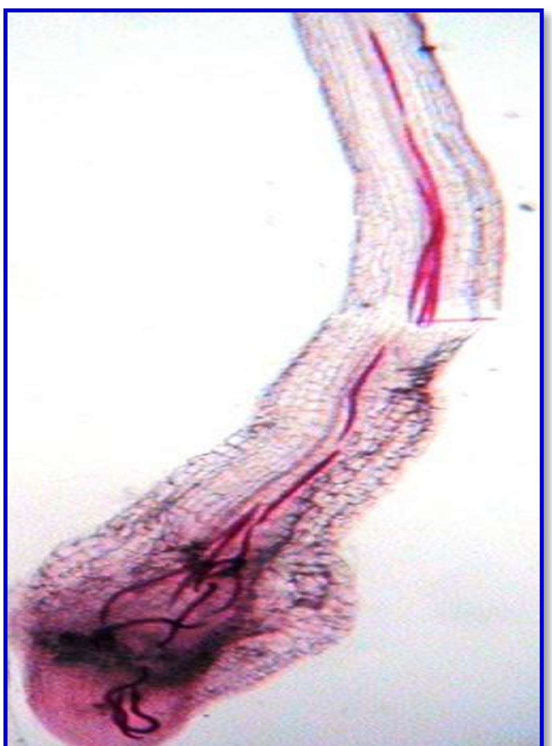
EFFECT OF VERMIWASH ON NEMATODE PENETRATION

Figure 15: At 12 hours interval

Figure 16: At 24 hours interval

Figure: 17At 48 hours interval

Figure 18: At 72 hours interval



. **5.**

DISCUSSION

Plant parasitic nematodes are the major limiting factors in crop production and are considered as hidden enemies of farmers. Among various plant parasitic nematodes, root knot nematode (*Meloidogyne incognita*) is a polyphagous nematode species affecting wide range of crops. This nematode species causes great menace to profitable production of vegetable crops in general and tomato crop in particular. Keeping in view the magnitude of loss sustained by *Meloidogyne incognita* in tomato, farmers usually take immediate measure in applying nematicides for quick knock down of nematode population without considering its consequences. In view of multifaceted difficulties encountered with chemical control and unattractiveness of other methods of management by the farmers, there was reorientation in thinking among nematologists to create an eco-friendly environment of the habitat of beneficial micro flora and fauna by use of organic amendments like vermicompost, vermiwash, neem cake etc. so that rise in the population of natural enemies of phytonematodes and release of pre-existing nematicidal compounds would suppress the noxious phytonematode population. It is at present an important strategy to harness the potentiality of organic amendments and bio fertilizers like oilcakes (neem cake), vermicompost, vermiwash etc. which can be prepared by the farmers and can also be availed in market in commercial form being produced by different companies. Organic manure alone or in combination with oilcakes is at present used by farmers to boost the yield of various crops.

Organic manures not only provide nutrition to the plant but also their role in reducing the population of phytonematodes has been reported by various workers affecting various crops. Keeping abreast of the finding of some of the workers, the first experiment was carried out on "Effect of vermicompost and neem cake on rootknot nematode, *Meloidogyne incognita* infecting tomato". In this pot culture experiment effect of vermicompost and neem cake each alone and their combination were studied. It comprised of 8 treatments. Besides a nematicide (carbofuran) as standard check was included in the experiment. All these treatments were compared with an untreated check. Hence, the experiment comprised a total number of 10 treatments. From the results of this experiment it was evident that there was progressive increase in plant growth parameters in respect of fresh and dry shoot and root weight, shoot and root length, fruit weight etc. in all treatments over untreated check (T_{10}). But among all treatments T_5 (combined effect of vermicompost @500g/m^2 and neemcake @ 100g/m^2) registered highest increase in plant growth parameters over check (shoot length – 86.17%, root length – 82.36%, fresh shoot and root weight – 79.44 and 50.24% respectively, etc. possibly because of the increase in the population of nematode antagonistic microbial organisms in the soil, which might have suppressed the population of *Meloidogyne incognita*. This is in agreement with findings of Arancon *et al.*, 2002. They reported heavy depression of plant parasitic nematode population by vermicomposts in soils planted with tomatoes, peppers, strawberry and grapes. They also revealed, increased competition from fungivorous and bacterivorous nematodes resulting from increased availability of food sources after vermicompost application successfully suppressed the population of plant parasitic nematodes. Kerry, 1998 also opined plant parasitic nematodes are attacked by cyst fungi and nematode-trapping fungi, populations of which could have increased in response to addition of organic matter due to vermicompost application. This is in conformity with the findings of Pathma and Sakthivel, 2012 who reported that organic matter addition to the soil by application of vermicompost stimulates the population of bacterial and fungal antagonist of nematodes (e.g., *Pasteuria penetrans*, *Pseudomonas spp*., chitinolytic bacteria and *Trichoderma spp*.), and other typical predators including predatory and omnivorous nematodes, nematophagous mites viz., *Hypoaspis calcuttaensis*, collembola, bacteria and/or protozoa (*Dendrobaena octaedra*) other arthropods which selectively feeds on plant parasitic nematodes. This corroborates the finding of other workers who have noted high population reduction of soil nematode pests because of biological competition, antagonism and predation (Arancon et al., 2003; Bilgrami, 1996 and Hyvonen et al., 1994). More over Sivananthi and John Paul, 2014 reported statistically significant suppression of plant-parasitic nematodes and increase in plant root and shoot growth in field trials with tomato and justified the concept behind it as, high levels of agronomically beneficial microbial population in vermicompost protects plants by out-competing parasitic nematodes for available food resources, water, etc. i.e. by starving them. They also found that the ability of plant parasitic nematode suppression disappeared when the vermicompost was sterilized, convincingly indicating that the biological mechanism of disease suppression involved was "microbial antagonism".

More over presence of earthworms in vermicompost might have a predatory nature on the plant parasitic nematodes present in the soil, which ultimately reduced the population of *Meloidogyne incognita* in tomato soils thereby reducing the severity of attack by the nematode pest. This is in agreement with findings of Dominguez et al., 2003 who reported that the decrease in nematode numbers in the presence of earthworms suggests direct grazing of nematodes by earthworms. Further Dash *et al.*, 1980 in this regard have also observed the predatory effect of earthworms on nematodes may be due to direct ingestion, digestion and consequent effects on the fertility, viability and germination of cysts present in casts. They also reported earthworms can decrease plant parasitic nematode population by up to 64%. Roessner, 1986 has also opined that earthworm *Eisenia fetida* reduced plant parasitic nematode abundance by more than 60% in soil cultures. Nath and Singh, 2011 also explained that earth worms feed on the egg and larvae of soil nematode pests which ultimately reduced the soil nematode population. This corroborates the findings of other workers who have observed reduction of nematode pest population in presence of earthworms (Gupta, 2005 and Shield and Earl, 1982).

Apart from the aforesaid mechanisms in reducing nematode population, release of nemato toxic substances from vermicompost also may be contributing in suppressing the population of plant parasitic nematodes in the soil. This is in conformity with the findings of Rodriguez-Kabana, 1986 who have reported that vermicompost on decomposition release toxic substances like hydrogen sulphide, ammonia and nitrites which kills the plant parasitic nematodes. Apart from that vermicompost promotes colonization of rhizobacteria in plant roots which kills the plant parasitic nematodes by producing enzymes and toxins that are toxic to them and thereby induces biological resistance in plants against nematodes (Siddiqui and Mahmood, 1999).

One of the factors involved in nematode suppression by the use of vermicompost may be increased tolerance of plants to nematode attack due to growth promoting effects of vermicompost. This is in accordance with the report of Arancon *et al.*, 2003 that vermicompost are natural way to add nutrients and plant-growth regulators to the soil, control diseases and prevent soil contamination. Ami and Sipes, 2008 have also reported that application vermicompost increased plant growth and shoot weight in cowpea, which also helps in reducing nematode population.

So far the population growth of *Meloidogyne incognita* is concerned, it was found that there was reduction in population of *Meloidogyne incognita* both in soil and root along with decline in number of root galls in all treatments over untreated check. But there was highest reduction in the nematode population, number of galls in T_5 where combination of vermicompost @500g/m^2 and neem cake @100g/m^2 were applied. In this treatment number of galls reduced by 78.99% and total nematode population decreased by 79.57% over untreated check. This might be due to ability of vermicompost in hindering the penetrating ability of parasitic nematodes into plant roots. This coincides with investigations of Ami and Sipes, 2008 who reported that vermicompost may act on nematode by affecting nematode ability to penetrate the host. This corroborates with the finding of other workers like (Sivananthi and John Paul, 2014; Ramesh Kumar *et al.*, 2011). More over Serfoji *et al.*, 2010 have also investigated that maximum plant height, biomass, nutrient uptake and other improved plant growth characters was recorded in tomato plant c.v. Pusa ruby treated with vermicompost due to presence of growth hormones, micronutrients, phenolic compounds like carotenoids, flavones etc. causing significant reduction in nematode population, gall index of root knot nematode, nematode reproduction rate and number of egg masses. In addition to that the suppressive effect of vermicompost on the parasitic effect root-knot nematode was well pronounced by significant elevation in the number of flowers and fruits, shoot length, leaf length and leaf area of Okra (*Hibiscus esculentus*) grown in nematode inoculated soil with vermicompost (Babidha and Ramaswamy, 2012). Further Swathi *et al.*, 1998 demonstrated that 1kg/m^2 of vermicompost suppressed attacks of *Meloidogyne incognita* in tomato plants. More over Morra *et al.,* (1998) demonstrated partial control of *Meloidogyne incognita* by vermicomposts in a tomato-zucchini rotation.

Further it was found that application of neem cake suppressed the root knot nematode (*Meloidogyne incognita*) population roots of tomato seedlings by 56.16% in T_3 (Neem cake alone @100g/m^2). This might be due to the nematicidal effect of neem cake that render them unsuitable for nematode penetration and development. This may be because of the fact that on decomposition it releases certain limonoids (Azadirachtin, nimbidin, phenolics, aldehydes etc.) which are nematicidal in action.This is in accordance with the findings of other workers (Alam, 1991; Haseeb *et al.*, 2005; Musabyimana and Saxena, 1999; Javed *et al.*, 2007 and Mojumder, 1995). More over Abolusoro and Oyedunmade, 2007 reported that the nematode (*Meloidogyne* *incognita*) multiplication rate and root gall index was significantly lower in the neem cake treated tomato plants

. In the second experiment inhibitory effect of vermiwash on *Meloidogyne incognita* infecting tomato plant was assessed. In T_1 and T_2 i.e. at 4 hours and 8 hours interval no penetration of nematodes occurred in the tomato roots. Nematode penetration was reduced by 100% at 12 hours interval (T_3) as compared to the corresponding untreated check. Decline in nematode penetration was reduced by about 54.54% in vermiwash treated tomato seedlings over untreated check at 24 hours interval (T_4). In (T_5) at 48 hours interval in vermiwash treated tomato roots only 35% on inoculated nematodes penetrated as compared to 75% in corresponding untreated check. Here the percentage reduction in penetration in vermiwash treated roots was 53.33% over the untreated check. Similar results were found at 72 hours interval (T_6) as that of T_5. Hence the experiment was stopped at 72 hours interval (T_6) due to no further penetration of nematodes. It might be because of the toxic effects of vermiwash on nematodes to varying degrees. This is in agreement with the reports of various workers who have experimented significant reduction in egg mass hatching and larval mortality of *Meloidogyne incognita* due to ovicidal effect of vermiwash (Edwards *et al.*, 2007; Pandey and Kalra, 2010; Gopalakrishnan *et al.*, 2010; Adhikary, 2012; Gopal *et al.*, 2012; Sinha *et al.*, 2014 and Renco and Kovacik, 2015). More over Gulsar Banu and Iyer, 2006 tested the efficacy of vermiwash at different dilutions against *Meloidogyne incognita, Radopholus similis, Pratylenchus coffeae and Helicotylenchus multicinctus* under in vitro conditions and found vermiwash to be deleterious to varying extent. More over Elumalai *et al.*, 2013 reported that vermiwash exhibited growth promoting effects on the exo-morphological characters such as plant height, length and diameter of the internodes, number of leaves, leaf surface area, root length, wet and dry weight of the shoot and root of *Abelmoschus esculentus*. Similarly, Ansari, 2008 showed that the yield of spinach was significantly higher in plots treated with vermiwash (1:5 v/v in water). The yield of onion was significantly higher in plots treated with vermiwash (1:10 v/v in water)

So, combined effect of vermicompost @ 500g/m^2 and neem-cake @ 100g/m^2 and use of vermiwash provided better option of management of *Meloidogyne incognita* infecting tomato. However it is worthwhile to investigate the efficiency of this treatment in field condition for more meaningful result in managing root knot nematode.

6. SUMMARY AND CONCLUSION

An investigation was carried out in pot culture under net house condition in the Department of Nematology during Rabi season 2014-15 to study the effect of vermicompost and neem cake on root knot nematode (*Meloidogyne incognita*) infecting tomato c.v. Pusa ruby. The experiment comprising of 10 treatments, each replicated thrice in complete randomized design, viz. vermicompost @ 500g/m^2 (T_1), neem cake @ 100g/m^2 (T_2), vermicompost + neem cake at different doses (T_3 – T_8), Carbofuran @ 1kg a.i./ha (T_9) and an untreated check (T_{10}). Pots were then filled with 2 kg steam sterilized soil. Neem cake, vermicompost alone or in combination in different doses were added to the pot soil as per the experimental needs. After watering the pots, a waiting period of 15 days was given for proper decomposition of amendments. Fifteen days old tomato seedlings were transplanted one in each pot, following which 2000 J_2 of *Meloidogyne incognita* were inoculated in each replicated pot. Intercultural operation and watering were attended in time. The experiment was terminated at 60 days of inoculation and final observation on plant growth parameters such as root and shoot length, fresh shoot and root weight, dry shoot and root weight, fruit weight as well as infection parameters in respect of number of root galls and total nematode population in soil and root were recorded. Recorded tabular data were subjected to statistical analysis for each parameter for comparison of different treatments. From the experimental findings it was evident that barring the untreated check, all other nine treatments increased the plant growth parameters and reduced the infection parameters and nematode multiplication. But combined application of vermicompost @ 500g/m^2 along with neem cake @ 100g/m^2 (T_5) performed the best by increasing the root and shoot length (82.36 and 86.17%), fresh shoot and root weight (50.24 and 79.44%), fruit weight (70.48%) significantly with corresponding decrease in root galls (78.99%) and root knot nematode population in soil (79.57%) over untreated check followed by combined application of vermicompost @250g/m^2 along with neem cake @100g/m^2 (T_7) where the nematode population reduced by 76.76% over untreated check.

Another experiment was carried out to test the efficacy of vermiwash on penetration of juveniles of *Meloidogyne incognita* in tomato roots at different time intervals. The stainless steel vessel measuring about fifteen liters capacity was taken and a hole was made at the bottom of vessel .The hole of vessel was sealed with paraffin wax. The vessel was filled with pebbles, sand and over this microbial infested old dampened cow dung was added. *Eudrilus eugeniae* earthworms were heavily introduced into the vessel. The setup was left undisturbed for about 20days. The water was sprayed every day to maintain moisture required for the worm bed. On the twenty first day 1 liter of distilled water was poured over the worm bed and the liquid was collected by opening the seal at the bottom of the vessel. The collected vermiwash was stored in tightly closed 500ml bottle. It was then used for the experiment. 24 thermocol plastic cups were prepared by adding 200g sieved soil mixture in each cup. Four weeks old tomato seedlings were raised one in each cup and 200 J_2 of *Meloidogyne incognita* were released into each cup. 18 cups consisting of six treatments, each replicated thrice were treated with vermiwash and 6 cups not treated with vermiwash (untreated check) were prepared. Three tomato plants were uprooted each at 4, 8, 12, 24, 48 and 72 hours of nematode inoculation and were labelled as T_1, T_2, T_3, T_4, T_5 and T_6 respectively. treated with vermiwash,. An untreated check was maintained for each treatment (6 untreated cups). Tomato roots were uprooted and following observations were noted. No penetration occurred up to 8 hours (T_1 and T_2). Penetration of nematodes stared at 12 hours interval (T_3) and vermiwash was found to be quite effective where no penetration of nematode was observed in vermiwash treated tomato roots as against 20% penetration of inoculated nematodes in the corresponding untreated tomato roots (untreated check of T_3), signifying 100% reduction in nematode penetration in vermiwash treated tomato roots over the corresponding untreated check. At 24 hours interval (T_4) the penetration percentage of nematode was reduced by 54.44% as compared to the corresponding untreated check. At 48 hours interval (T_5), nematode penetration reduced by 53.33% in vermiwash treated tomato roots as against the corresponding untreated check. Similar result was obtained at 72 hours interval (T_6) as that of T_5 and no further penetration was noticed and hence the experiment was terminated. Therefore it can be summarized from the above data that maximum penetration of nematodes was recorded at T_5 at 48 hours interval where 75% of inoculated nematodes penetrated the untreated check as against only 35% in the corresponding vermiwash treated tomato roots and maximum reduction in nematode penetration i.e. 100%, was found in vermiwash treated tomato roots of T_3 (at 12 hours interval) over the corresponding untreated check. Basing on the present result there is need for further study of these treatments in micro plots as well as field trials for more meaningful result.

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