Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation

संरक्षित खेती में जड़गाँठ सूत्रकृमि, *मेलॉइडोगाइनी इनकोग्निटा* का खीरा (*कुकुमिस सेटाइवस* एल.) पर वितरण, हानि और प्रबन्धन

SHAKTI SINGH BHATI

Thesis

Doctor of Philosophy in Agriculture

(Nematology)

2020

DEPARTMENT OF NEMATOLOGY
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY
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THESIS

Submitted to the

Maharana Pratap University of Agriculture and Technology, Udaipur

in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

(Nematology)

By

SHAKTI SINGH BHATI

2020

Rajasthan College of Agriculture

Maharana Pratap University of Agriculture & Technology, Udaipur

CERTIFICATE – I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis entitled **"Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation"** submitted for the award of degree of **Doctor of Philosophy** in Agriculture in the subject of **Nematology,** to Maharana Pratap University of Agriculture and Technology, Udaipur (Raj.) is original and bonafide record of research work carried out by me under the supervision of **Dr. B. L. Baheti,** Professor & Head, Department of Nematology, Rajasthan College of Agriculture. The content of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or University for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my words and where other's ideas have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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(Shakti Singh Bhati)

RAJASTHAN COLLEGE OF AGRICULTURE
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CERTIFICATE - II

Dated: 29/ 08/ 2020

This is to certify that the thesis entitled **"Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation"** submitted for the degree of **Doctor of Philosophy** in Agriculture in the subject of **Nematology,** embodies bona fide research work carried out by **Mr. Shakti Singh Bhati** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 30/06/2020.

The manuscript has been subjected to plagiarism check by software Urkund.

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Dated: 28/11/2020

This is to certify that this thesis entitled "**Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation"** submitted by **Mr. SHAKTI SINGH BHATI** to the Maharana Pratap University of Agriculture & Technology, Udaipur in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Nematology** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination held on 27/11/2020 was found satisfactory; we therefore, recommend that the thesis be approved.

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CERTIFICATE - IV

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This is to certify that **Mr. SHAKTI SINGH BHATI** student of **Doctor of Philosophy in Agriculture,** Department of Nematology, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled "**Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation"** which were suggested by the external examiner and the advisory committee in the oral examination held on 27/11/2020. The final copies of the thesis duly bound and corrected were submitted on 01/12/2020.

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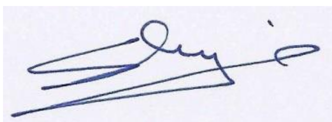

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a widely cultivated crop belongs to family - Cucurbitaceae. It is originated from Southern Asia and currently grown all over the world. It is a creeping vine with thin and spiral tendrils. Cucumber plant has large leaves that form a canopy over the fruit. The fruit of the cucumber is cylindrical, elongated with tapered ends. They are eaten as salad and vegetables. It is also commercially processed as pickle in western countries. Cucumber is used as an additive in confectionery and cosmetic products. It is highly nutritive vegetable and a good source of vitamins and minerals (Vitamin K, Vitamin C, pantothenic acid, biotin, molybdenum, potassium, phosphorus, copper and magnesium).

India enjoys a unique status in the cultivation of cucumber in the world because of congenial climatic conditions for crop growth. It has been cultivated in 80.00 thousand ha of area with the production and productivity of 1261.00 thousand million tons and 15762.00 kg/ha, respectively during 2018-19 in India (Anon,2018-19a). It is mainly cultivated in Rajasthan, Punjab, U.P., M.P., Andhra Pradesh, Karnataka, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Tamil Nadu, Kerla and Haryana states of the country. In Rajasthan, the area under Cucumber is 1184.00 ha with production of 5239 million tons and productivity of 4423 kg/ha during 2018-19 (Anon, 2018-19 b).

Protected cultivation is a cultivation of crops under controlled environmental conditions which provides most congenial environment for crop growth and gives manifold increase in yield per unit of area. The application of poly house technology is feasible in almost in all the agro-climatic conditions of India for the cultivation of high value vegetable and ornamental crops. Under protected cultivation due to high productivity, better quality produce, large number of protected units are being installed and increase day by day through out the country.

In India estimated area under protected cultivation is around 40,000 ha. The major portion under protected cultivation mostly in Himachal Pradesh, Haryana, Punjab, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Bihar, Assam, Andhra Pradesh, Telngana, Tamil Nadu and Maharashtra. In Rajasthan, Udaipur, Jaipur, Alwar, Bharatpur, Ajmer, Chittorgarh, Rajasmand, Kota, Baran, Banswara, Sawai Madhopur, Jodhpur, Nagaur, Sikar, Bikaner, Hanumangarh and Sriganganagar are the major districts where protected cultivation units have been established and increased day by day (Anonymous, 2018-19b).

Due to favourable environmental conditions in Poly houses / Protected cultivation, multiplication of insect pest and pathogens including plant parasitic nematodes are very high and significantly reduce the quantity and quality of production (Greco & Esmenjaud, 2004; Desaeger and Csinos, 2006). Plant parasitic nematodes *viz*. *Meloidogyne* spp., *Rotylenchulus reniformis, Heterodera* spp., *Pratylenchus* spp., *Helicotylenchus* spp. and *Hoplolaimus* spp. are associated with vegetable crops in India. Among these nematodes, root-knot nematodes, *Meloidogyne incognita* and *M. javanica* are most important and causing great damage to crops grown under poly-houses including cucumber (Desaeger *et al.*, 2004; Rao *et al.*, 2015). Plant parasitic nematode causes 21.3% crop losses amounting to Rs.102,039.79 million (1.58 billion USD) annually in India. Among nematodes, root-knot nematode, *Meloidogyne* spp. is responsible for 75.83% of the estimated losses. It causes 12.00 % losses on cucumber with estimated monetary loss of Rs. 110.46 million per annum in India (Kumar *et al.*, 2020).

In view of disease severity and crop losses caused by these micro-organisms in field as well as in poly-houses, attempts were made to test various insecticides for the management of root-knot nematodes on vegetables (Jain and Gupta, 1986; Ahmad *et al*., 2007) and found effective, but due to residual toxicity, high cost, health hazards and environmental pollution their use at farmer's level has been very limited. Therefore, investigations have been emphasized to evolve economical and eco-friendly methods for the management of root-knot nematode, *Meloidogyne* spp. on vegetable crops (Patel and Patel, 1998; Mishra *et al.*, 2003) including Cucumber under protected cultivation. To fill this gap of knowledge, present investigations have been proposed with following objectives:-

1. To find out population status and occurrence of root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation.

2. To estimate avoidable losses caused by root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.

3. To study seasonal fluctuations of root-knot nematode, *M. incognita* on cucumber under protected cultivation.

4. To develop management strategies against root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.

Plate 1: Healthy and root-knot nematode infested root of cucumber in poly-house

Plate 2 : Visit at different poly-houses during survey

Plate 3 : Farmer's awareness activities about nematodes during studies

2. REVIEW OF LITERATURE

Root-knot nematode is one of the most important polyphagous nematode and attack on almost all the cultivated crop plants of economic importance throughout the world (Sasser, 1980). However, due to their small size, shorten life cycle and higher fecundity rate, root-knot nematodes are more serious to others. Root-knot disease was first reported by Berkeley (1855) on cucumber grown in glasshouses from England. Thereafter, it was reported from all parts of the world. Barber (1901) firstly find out root-knot nematode infested roots of tea plants from Kerala, in India, Arya (1957) first time reported it on *Lycopersicum esculentum* from Jodhpur in Rajasthan. It is found to infect not only tomato, but almost all the vegetable crops of Rajasthan (Yadav and Naik, 1966). Vegetables are considered to be most favoured host for root-knot nematode. Tomato, brinjal, chilli, okra, carrot, potato, cucumber, bottle gourd, yam, pointed gourd, lettuce, etc., suffer due to their attack and responsible to causes significant economic losses (Bhatti and Jain, 1977; Parvatha Reddy and Singh, 1981; Deka and Rahman, 1997).

The literature available on root-knot nematode infecting vegetables including cucumber under protected cultivation with special reference to survey, estimation of avoidable losses, seasonal fluctuations and its management is reviewed as under:

1. Survey:-

A survey was conducted by Rao *et al.* (2007) in Andhra Pradesh and recorded the presence of nematodes specially plant parasitic like root-knot (*Meloidogyne incognita* and *M. javanica),* reniform *(Rotylenchulus reniformis),* spiral *(Helicotylenchus sincises*), Lesion *(Pratylenchus delattrei), Tylenchorhynchus capitatus, Xiphinemae sp., Tylenchus sp., Criconema sp.* and *Aphelenchus sp.* infecting vegetables like chilli tomato, brinjal, okra, cucurbits and cluster bean.

A survey was conducted by Chandel *et al.* (2010) to find out qualitative and quantitative analysis of major plant parasitic nematodes in 214 greenhouses associated with main crops (Sweet pepper, carnation, cucurbits, tomato and cauliflower) and 19 nurseries (various vegetables and citrus) was done in Himachal Pradesh. Study revealed the presence of three plant parasitic nematodes including *Meloidogyne incognita*, *Helicotylenchus dihystera* and *Pratylenchus* spp. in the main crops with their populations ranging from 8 to 5604, 15 to 2560 and 5 to 795/200 cc soil, respectively. In roots, considerably high population of *M. incognita* (15-4288/5g) was recorded as compared to *Pratylenchus* spp. (2 to 221/5g roots).

A survey was conducted by Sharma (2010) in 15 poly-houses and samples were collected in Solan district of Himachal Pradesh. It was found that in capsicum the main nematode species were: *M. incognita*, *T. mashhoodi* and *H. dihystera* the latter being present in only a few poly-houses and in low numbers. All the poly-houses growing tomato and cucumber were found heavily infested with *M. incognita*. In some cases, up to 80 percent of the plants were found loaded with nematode galls, retarding the crop growth.

Survey carried out by Anamika *et al.* (2011) to assess the incidence and intensity of root-knot disease on field crops especially rice and vegetable crops in 21 districts, representing the major production centre in Uttar Pradesh (India). Based on incidence, population density and associated damage on affected crops, *Meloidogyne* species were considered to be the most important parasites of the crops under local condition. The increasing occurrence and damage of this nematode to tomato, rice, brinjal, okra, cowpea, cucurbits, onion, pumpkin and bitter gourd grown in northern India was recently documented. Heavy galling was caused in many crops including tomato, okra, cowpea, onion, brinjal and cucurbits.

Ismail *et al.* (2012) conducted a survey in vegetable growing area, to determine the incidence and distribution of root-knot nematodes, *Meloidogyne* spp. in open-field and plastic tunnel planted cucumber crop. Two root-knot nematode species. *M. incognita* and *M. javanica*, were identified from 200 samples. *M. incognita* was predominantly found species and was detected in 95% of all the fields surveyed. The average incidence was 46% and ranged from 30 to 60% on open-field planted cucumber crop, whereas on tunnel planted crop it was 35% and ranged from 20 to 50%. The average gall and egg mass indices on scale of 0 to 5 with average of 2.6 on roots of open-field planted crop. Roots of plants within tunnels had 3.85 % and 7.14 % greater gall and egg mass indices over that of open-field plants.

Singh *et al.* (2012) conducted a survey of okra fields for the occurrence of economically important plant parasitic nematodes in some localities of Jammu and Samba district of J&K. Among the different plant parasitic nematodes, *Meloidogyne* spp. was more frequently encountered in maximum localities of Jammu and Samba districts.

A survey was carried out by Anes and Gupta (2014) to study the distribution of plant parasitic nematodes in the soybean growing areas of India. Soil samples were collected from the rhizospheres of soybean across the country. Population analysis of 58 soil samples representing 23 districts of 14 states revealed the presence of *Meloidogyne* spp., *Rotylenchulus reniformis*, *Pratylenchus* spp., *Heterodera* spp., *Helicotylenchus* spp., *Hoplolaimus* spp., *Tylenchorhynchus* sp., *Hirschmanniella* sp., and *Trichodorus* sp. with varying population densities.

Bem *et al.* (2014) conducted an experiment to assess the distribution of root-knot nematode in some tomato fields. Tomato plants were surveyed for infection based on symptoms such as stunted growth, yellowing of leaves and wilting in farmers' farm for determining disease incidence. Number of knots and root-knot index (RKI) was used for disease severity. Result showed incidence range from 20%-80%. Gall Index (GI) ranged from 1.0 - 4.0. *M. incognita* and *M. javanica* were identified to be the causes of infection.

Gautam *et al.* (2014) conducted a survey to determine status of root-knot nematode (*M. incognita*) in Chhattisgarh state and an estimated yield loss of 5 to 43 % in vegetable crops. An overall incidence of root- knot nematode infection was 54.54 %. The percent incidence of disease range between 30 and 80 % in five districts. The most frequently occurring spices was *M. incognita* (63.33 %) followed by *M. areneria* (20 %) and *M. javanica* (16.67 %). The mean population density of J2 ranged between 766-9076 nematodes per 200 cc soil sample.

Survey conducted by Manju and Subramanian (2015) in the different districts of Tamil Nadu in order to determine the most important plant parasitic nematodes species associated with gerbera under polyhouse conditions. The analysis of soil and root samples collected from the rhizosphere of gerbera in each district revealed the presence of only five species of plant-parasitic nematodes. These were *Meloidogyne incognita, Helicotylenchus multicinctus, Pratylenchus coffeae, Tylenchorhynchus* spp. and *Rotylenchulus reniformis*. Root-knot nematode, *M. incognita* is one of the serious limiting factors in commercial cultivation of gerbera under polyhouse conditions.

Singh and Khanna (2015) carried out survey to determine the status of phyto-parasitic nematodes associated with vegetable crops under polyhouse conditions. About 81 poly houses from 52 localities of different districts of Himachal Pradesh were surveyed. Study revealed the presence of different genera of plant parasitic nematodes viz. *Meloidogyne incognita, M. hapla, Pratylenchus sp., Helicotylenchus spp., Mesocriconema sp., Tylenchorhynchus sp.* and *Hoplolaimus sp.* Out of these nematodes *M. incognita* was predominant with population range (37- 1200/200cc soil) followed by *Helicotylenchus dihystera* (28-832/200cc soil).

Singh *et al.* (2015) carried out to find out status of phytoparasitic nematodes associated with vegetable crops (French bean, cucurbits, tomato, crucifers and potato) under poly-house conditions. They observed plant parasitic nematodes *viz*. *Meloidogyne* sp., *Pratylenchus* sp., *Helicotylenchus* sp., *Mesocriconema* sp., *Tylenchorhynchus* sp. and *Hoplolaimus* sp. Out of these nematodes, *Meloidogyne incognita* was predominant with population range (37-2547/200 cc soil) followed by *Helicotylenchus dihystera* (28-838/200 cc soil), *Pratylenchus coffeae* (30-540/200 cc soil) and *Mesocriconema xenoplax* (30-260/200 cc soil) respectively, *M. incognita* was found to be most alarming. They also found that tomato-cabbage-cowpea and tomato-cucumber-mustard were found to have maximum suppressive effect on *M. incognita*.

2. Estimation of avoidable losses:

Bhatti and Jain (1977) assessed yield losses of okra, tomato, and brinjal 90.9, 46.2 and 2.3%, respectively, due to *Meloidogyne incognita* infestation at 3-4 larvae/g soil under field conditions. Parvatha Reddy and Singh (1981) estimated crop losses caused by root-knot nematode to be 28.08 per cent in okra, 33.68 per cent in brinjal, 43.48 per cent in French bean, 28.60 per cent in cowpea and 20.0 per cent in peas.

Sasser and Freckman (1987) estimated overall annual yield loss of world’s major crops due to damaged by phyto-parasitic nematodes reported to the extent of 12.3%. Sharma and Baheti (1992) conducted field trials to estimate losses caused by root-knot nematode, *M. incognita* and *M. javanica* on pea, okra, tomato and bottle gourd and reported 46.0, 46.7, 47.8 and 55.4% losses, respectively.

Jain *et al*. (1994) reported 71.9 per cent avoidable yield losses in tomato due to *M. incognita* (INP 385 J_2/250 g soil). However, at other site having *M. javanica* infestation, the per cent avoidable losses in yields of tomato, brinjal and okra were 47.3, 41.8 and 29.9 per cent, respectively. Jain *et al*. (2007) estimated annual yield losses in okra (14.1%), brinjal (16.67%), chilli (12.05%), tomato (27.21%) and cucurbits (18.2%) due to root-knot nematode, *M. incognita* in all India.

Chandel *et al*. (2010) conducted an experiment for qualitative and quantitative analysis of plant parasitic nematodes in 214 greenhouses associated with main crops (Sweet pepper, carnation, cucurbits, tomato and cauliflower) and 19 nurseries (various vegetables and citrus). Plant parasitic nematodes *viz. Meloidogyne incognita*, *Helicotylenchus dihystera* and *Pratylenchus* spp. were dominant in the main crops with population range from 8 to 5604 J2, 15 to 2560 and 5 to 795/200 cc soil, respectively. Avoidable losses due to nematode in greenhouse were estimated to the tune of 11.31 per cent on tomato.

Gautam *et al.* (2014) conducted a survey to determine status of root-knot nematode (*M. incognita*) disease in various vegetable crops in the central plain region of Chhattisgarh state and an estimated yield loss of 5 to 43% in vegetable crops. An overall incidence of root- knot nematode was 54.54%. The percent incidence of disease range between 30 and 80% in five districts. Most frequent occurring spices was *M. incognita* (63.33%) followed by *M. areneria* (20%) and *M. javanica* (16.67%).

Baheti and Bhati (2017) studied avoidable crop yield losses caused by root-knot nematode on okra under varied soil conditions. Trials were carried out on farmer's field with the application of carbofuran at 2 kg/ha in light, medium and heavy textured soils naturally infested with root-knot nematode, *M. incognita* having initial inoculums of 430-500 larvae/100 cc oil. Results revealed that application of carbofuran at 2 kg /ha at the time of sowing significantly reduced nematode population (22.98- 49.48 %) and avoided yield losses to the tune of 41.30-45.50 %, 37.50-41.52 % and 22.45-25.38 % in light, medium and heavy soils, respectively.

Hema and Khanna (2018) conducted a two years trial to estimate the severity of damage in terms of crop yield losses by root knot nematode (*Meloidogyne incognita*) on tomato (*Solanum lycopersicum* L.). In this field experiment some of the plots were treated with Carbofuran and remaining were kept as untreated check. Results showed 35.2 and 37.4 per cent avoidable yield losses during the years 2016 and 2017. Significant differences were also observed in plant heights, fresh and dry weights of plants between treated and untreated plants. The treatment with Carbofuran resulted in 77.7, 79.7 percent reduction in final nematode population (soil), 40.0 and 36.8 percent (root), 37.5, and 29.1 percent in root knot index during 2016 and 2017, respectively.

Kumar *et al.* (2020) estimated 21.3% over all crop losses caused by plant-parasitic nematodes and amounting to Rs. 102,039.79 million (1.58 billion USD) annually; the losses in 19 horticultural crops were assessed at Rs. 50,224.98 million, while for 11 field crops it was estimated at Rs. 51,814.81 million. Rice root-knot nematode, *Meloidogyne graminicola*, was economically most important causing yield loss of Rs. 23,272.32 million in rice. Citrus (Rs. 9828.22 million), banana (Rs. 9710.46 million) among fruit crops; and tomato (Rs. 6035.2 million), brinjal (Rs. 3499.12 million) and okra (2480.86 million) among the vegetable crops suffered comparatively more losses due to various nematodes. They recorded 12% yield loss and estimated Rs.110.46 million monetary losses in cucumber due to *Meloidogyne* spp. in India.

3. Population fluctuation:

Vincx (1989) carried out experiment to find out the seasonal fluctuations of the nematode community of Belgian and its east coast was examined based on the monthly samples. The mean density of the total nematode population of 32 species were found in between 55 IJs/l0 cm2 (Feb. 1983) and 5610 IJs/10 cm2 (Jun. 1985.) and increase in their reproductive activity appeared in spring and autumn. Lucas (1992) conducted a two years trial in kiwi orchard to find out the seasonal population fluctuations of the root-knot nematodes, *Meloidogyne incognita, M. Arenaria* and *M. hapla.* and were monitored monthly. Nematode numbers in soil fluctuated little, but there was a trend toward reduced numbers at the end of the study, with higher numbers in winter than in summer.

Eapen (1993) studied on population dynamics of root knot nematodes *(Meloidogyne* spp.) in a cardamom plantation for three years. It was found that number of J_2 of root knot nematodes in soil was highest during March-April. Nematode population in roots increased rapidly during the post monsoon period, declined gradually during summer and was lowest in monsoon months. Crop phenology appears to be the major factor influencing the fluctuations in nematode populations than ecological factors like rainfall and soil temperature.

A study on the seasonal fluctuation of nematode population was conducted during three vegetation periods from 2005 to 2007 at 20 and 40 cm soil depth from May to October in a hop garden. The seasonal fluctuation of the nematode population was related to temperature and rainfall. At 20 cm soil depth of each year, the largest nematode population was recorded in July and the smallest from July to October. At 40 cm soil depth, a decrease of nematode flow was observed from May to October (Renco *et al.,* 2010).

Cerevkova and Cagan (2012) studied on the seasonal changes of nematode population during May to September in maize field. The identified nematode species belonged mainly to the orders Dorylaimida, Tylenchida and Rhabditida. Dominant species were *Acrobeloides nanus*, *Cephalobus persegnis* and *Eucephalobus striatus*. In May, it was found dominance of *Rhabditis* spp. (almost 80 % of total nematode fauna) but this dominance dropped during the rainy season. On the other hand, dominance of *C. persegnis, Aphelenchoides minimus, Bitylenchus dubius* increased during the rainy season. The highest abundance of nematodes was found in May and the lowest abundance was found in September.

Ghonaimy *et al.* (2015) conducted an experiment based on two cropping sequences including pepper-cucumber-common bean-sesame and green bean-cucumber- onion-sesame for controlling root-knot nematode, *Meloidogyne incognita* under protected conditions. Results showed that the population density of root-knot nematode fluctuated with respective plants in both two sequences after 2 and 4 months from planting each crop. Cucumber and common bean in the first sequence were found to be the best hosts for root knot nematode. The least number of nematodes were found on sesame. No galls or egg masses were found on onion. It is concluded that use of poor hosts or non-host crops may be beneficial for controlling root-knot nematode population densities in intensive cropping system and reducing the dependence on nematicides in protected cultivation.

Surega and Ramakrishanan (2017) cultivated turmeric under conventional and drip irrigation methods to study the effect of seasonal changes of the population of plant parasitic nematodes. Population densities were monitored at monthly intervals throughout the crop season. It was observed that seasonal fluctuations have a direct effect on the nematode population. The predominant genera of phytoparasitic nematodes recovered from rhizospheric soil samples were *Meloidogyne incognita, Pratylenchus delattrei, Radopholus similis, Longidorus elongatus, Xiphinema elongatum, Hoplolaimus seinhorstii, Helicotylenchus multicinctus, Tylenchorhynchus martini* and *Rotylenchulus reniformis.* Among Root-knot nematode population gradually started to built up right from the time of planting of turmeric and reached its peak around sixth month and declined towards crop maturity.

Sen (2017) carried out work in a guava orchard and results revealed that the maximum populations of nematodes were observed during monsoon with a population of 4169 IJS/250 gm soil in the month of July. During monsoon low soil temperature (30.10^{0}C – 31.80^{0}C) and high soil moisture (20% - 26%) in the month of July were also observed. The minimum population (204 IJs/250 gm soil) of soil nematodes was observed during pre- and post-monsoon with a wide range of low to high soil temperature (18^{0}C - 34^{0}C) and low soil moisture (10% - 13%). This reveals a direct effect of these two climatic factors of soil on the population of soil nematodes.

4. Nematode Management:

Berkeley (1855) was the first ever to discover root-knot nematode, *Meloidogyne incognita,* when he reported it from glass house grown cucumbers in England. Mankau (1975) demonstrated biological control of root-knot nematode through *Bacillus penetrans*. In glass house test, air dried soil infested with spores of *B. penetrans* were planted with tomato seedlings to which 10,000 root-knot nematode larvae were added. After 70 days, plants in the air-dried spores infested soil appeared healthier and roots had less nematode galling as compared to other treatments.

Jatala *et al.* (1979) reported the parasitization of eggs and females of *M. incognita* by *P. lilacinus* on potato. Mankau (1980) carried out an experiment to evaluate the fungal antagonist of nematodes consist of nematode trapping fungi and endo-parasitic fungi. They observed that fungi can be effectively be used as bio-control agents for nematodes and may be an alternative to chemicals.

Parvatha Reddy and Khan (1991) tested finely powdered oil cakes [neem, castor, groundnut and honge (karanj)] each at 1.0 t/ha as single and 0.5 t/ha as combined application and carbofuran (2 kg a.i./ha as single and 1.0 kg a.i./ha as combined application) for the management of root-knot nematode, *M. incognita* infecting okra. Results revealed that plots treated with karanj cake, neem cake + carbofuran, groundnut cake + carbofuran, gave highest yield of okra. However, all the oil cakes in combination with carbofuran gave least root-knot index (2.92-3.32) as compared to control (4.35) followed by single application of neem cake (1 t/ha) and carboruan (2kg a.i./ha). These treatments were at par with each other in regards to root-knot index. Jain and Gupta (1993) reported that summer ploughing in infested filed coupled with seed treatment (carbosulfan 3 %) proved most effective in management of root-knot nematode, *M. javanica* and increasing okra yield over untreated check. At harvest, treated seeds had a significantly lower root-knot index and final soil population than untreated seeds.

Barman and Das (1996) reported that seed treatment with carbosulfan 25 DS @ 3 % (w/w) and organic amendments *viz*; neem cake, mustard cake and poultry manure each at 2 t/ha alone and combined application of seed dressing with organic amendments @ 1 t/ha were found effective in improving plant growth and yield of green gram. Reduction in number of galls, egg masses and final nematode population of root-knot nematode was also noticed over untreated control. Best results were obtained with poultry manure applied @ 2 t/ha followed by combined application of seed dressing + neem cake @ 1 t/ha.

Rao *et al*. (1997) evaluated neem cake and a bio-control fungus (*T. harzianum)* either singly or in combination for the management of root-knot nematode, *M. incognita* on tomato. Significant increase in plant growth and reduction in root gall and final population of *M.*

incognita were observed in tomato seedlings transplanted in neem cake amended soil incorporated with *T. harzianum*. It was also noticed that neem cake amendment enhances the activity of *T. harzianum*.

Patel and Patel (1998) carried out field experiments on chickpea against root-knot nematode using seed treatment with carbosulfan 25 ST @ 0.75% coupled with soil application of organic amendments *viz*., pressmud (3.0 t/ha), poultry manure (3.0 t/ha), neem cake (1.0 t/ha) and mustard cake (1.0 t/ha). Results revealed that seed treatment and organic amendments had no adverse effect on germination and significantly enhanced height of plants, grain and fodder yield and reduced root-knot index as well as final population in soil. Neem and mustard cakes were the most effective treatments followed by pressmud and poultry manure as organic amendments.

Rangasamy *et al.* (2000) reported that *Trichoderma viride* alone and in combination with either neem or castor cake was most effective in parasitizing egg masses of the root-knot nematode, *M. incognita* infecting tomato.

Brcka *et al* (2000) examined effects of hot water treatments on populations of the root-knot nematode (*Meloidogyne incognita*) in four experiments to determine a temperature and time combination capable of lowering nematode populations on caladium (Caliadium x hortulanum) tubers without damaging plant performance. In a preliminary experiment, tubers were grouped by weight and immersed in a water bath at 50^0C for 30 min, 52^0C for 20 min, 54^0C for 10 min, and a control (24^0C for 1 min). After treatment, tubers were planted in the greenhouse for evaluation of plant growth. Emergence and leaf growth were fastest in the treatment using 50^0C for 30 minutes and the control group. In experiments II and III, the effectiveness of four similar hot water treatments in lowering nematode numbers on tubers infected with *Meloidogyne incognita* was determined. All tubers receiving a hot water treatment did not carry root-knot nematodes to sterile soil and produced more plant mass than the control group. Immersion of tubers in a hot water bath maintained at 50°C for 30 min lowered extractable nematode numbers to zero and improved plant performance.

A greenhouse study was carried out by Zareen and Zaki (2001) to evaluate the *P. lilacinus, T. harzianum* and *T. flavus* as seed treatment and soil drench on tomato. Seed treatment by *P. lilacinus* reduced gall formation, egg mass production, soil and root population as compared to control. In another experiment where soil was treated with conidial suspension, maximum plant height and shoot weight was achieved by *P. lilacinus* over control. Maximum suppression in gall formation and egg mass production was obtained with *P. lilacinus.*

An experiment conducted by Asawalam and Adesiyan (2001) to compare the nematicidal potential of Carbofuran (Furadan) and *Azadirachta indica* (neem) leaf extract against root-knot nematode (*M. incognita*) on okra and found that nematicidal potential of *A. indica* and carbofuran in terms of reduction of root galls in okra was similar. *A. indica* and carbofuran significantly reduced root galls and increased mean fruit number and weight.

Devi and Sharma (2002) studied the efficacy of *Trichoderma viride* and *T. harzianum* against root-knot nematode, *M. incognita* on tomato. They observed improvement in plant growth (shoot length, shoot weight, root length and root weight) and reduced nematode population as compared to untreated control. Rao *et al.* (2003) evaluated the efficacy of bio-control agents for the management of *M. incognita* on egg plant. They found that integration of *V. chlamydosporium* and *Glomus fasciculatum* proved significantly better to increase plant growth and reduced the root galling and nematode population. They further reported significant increase in parasitization of nematode eggs by *V. chlamydosporium.* The results suggest the potential use of these eco friendly components for management of root- knot nematode on egg plant.

Patel *et al.* (2003) found that the application of neem, castor, mahua, mustard, piludi and karanj cakes, farm yard and poultry manures, dry and fresh *Azolla* pressmud and urea significantly increased the plant growth and decreased the host infestation by *Rotylenchulus reniformis* over control in cotton.

Mishra *et al.* (2003) reported that seed treatment with bio-pesticides (neem seed powder, latex of *Calotropis procera* and Neemark), chemicals (dimethoate, triazophos, chlorpyriphos and carbofuran) and bio-agents (*Trichoderma viride, Aspergillus niger* and *Paecilomyces lilacinus*) effectively control root-knot nematode infestation and increased plant growth and yield of chickpea. Soil treatment with carbofuran at 2 kg./ha was found equally effective as neem seed powder (50 kg/ha), but plant growth parameters were better under neem seed powder treatment. *Trichoderma viride* could reduce the nematode population to almost the same extent as observed in case of other bio-agents.

An experiment was carried out by Krishnaveni and Subramanian (2004) to test the efficacy of seed and soil treatments with *Pseudomonas fluorescens* (10 g/seed and 2.5 kg/ha), vasicular arbuscular mycorrhizal fungi (VAM, at 10 g /kg seed and 10 g /kg soil) and *Trichoderma viride* (at 5 g / kg seed and 2.5 kg / ha, respectively) along with Carbofuran at 1 kg a.i./ha was also applied for comparison in the control of *M. incognita* infesting cucumber cv. Green Long. Among the biological control treatments, *P. fluorescens* was the most effective in controlling nematode population in the soil and root and in improving cucumber growth.

Jagdale and Grewal (2004) studied effectiveness of a hot water drench for the control of *Aphelenchoides fragariae* infesting hosta (*Hosta* sp.) and ferns (*Matteuccia pensylvanica*). Drenching with hot water at 70 °C and 90 °C in October reduced *A. fragariae* in the soil but not in the leaves relative to the control (25 °C) 300 days after treatment (DAT). Plants drenched with 90 °C water had lower numbers of nematode-infected leaves per plant than those treated with 25 °C and 70 °C water. Hot water treatments had no adverse effect on the growthparameters of hosta. Boiling water (100 °C) caused a 67% reduction in *A. fragariae* population in hosta leaves, 50% in fernfronds, and 61% to 98% in the soil over the control 150 DAT. A boiling water drench had no effect on the fern growth but caused 49% and 22% reduction in the number and size of hosta leaves, respectively, over the control. 90 °C watersoil drench in the autumn or early spring could prove effective in managing foliar nematodes on hosta in nurseries and landscapes.

Pandey *et al.* (2005) studied the effects of bio-agents and neem cake on *Meloidogyne incognita* infesting chickpea cv.H-208. The treatments comprised neem cake, *Trichoderma harzianum*, *T.viride*, *Paecilomyces lilacinus*, *Aspergillus niger* and *Verticillum chlamydosporium*. The combined application of neem cake and bio-agents significantly increased shoot weight, root weight and chlorophyll content. Root and shoot length were highest in integrated application of bio-agents with neem cake.

Das and Sinha (2005) studied the efficacy of *Paecilomyces lilacinus*, carbofuran (as seed treatment), poultry manure, FYM alone and in combination for the management of *Meloidogyne incognita* on okra. Maximum increase in growth parameters and decrease in number of galls, egg masses per root system and final nematode population in soil was observed in the combine treatment with *P. lilacinus* at 4 g/ kg soil + carbosulfan 25 EC at 0.2 % + poultry manure at 2.5 t/ha + FYM at 2.5 t/ha over untreated check.

Begum and Sivakumar (2005) applied carbofuran at 3 kg/ha (as soil application), *Pseudomonas fluorescens* (seed treatment) + neem cake (soil application) and *Trichoderma* *viride* (seed treatment) + neem cake (soil application) for the management of disease complex involving *Heterodera cajani* and *Macrophomina phaseolina* on greengram. Highest reduction in the nematode population was recorded with carbofuran at 3 kg/ha followed by combined application of *P. fluorescens* + neem cake and *T. viride* + neem cake.

Giannakou and Anastasiadis (2005) conducted experiments in three fields of methyl bromide to compare management tactics on tomato and cucumber in commercial greenhouses naturally infested with root-knot nematodes (*Meloidogyne* spp.) Methyl bromide was used as a reference treatment and was consistently superior to all the other treatments and combinations of other fumigants with contact nematicides. A significant reduction of nematode juveniles and root-galling index was observed in plots treated with either metham sodium and cadusafos or 1,3-dichloropropene and cadusafos. Nematode decrease was greater when these three chemicals were applied in the same plots. Good nematode control based on the use of different chemicals combinations can be achieved only for one cropping season and therefore nematode management measures must be employed for the next cropping season.

Goswami *et al.* (2006) carried out an experiment to study the effect of fungal bio-agents along with mustard cake and furadan against root-knot nematode *Meloidogyne incognita* infecting tomato under greenhouse condition. Bio-agents *viz*., *Paecilomyces lilacinus* and *Trichoderma viride* alone or in combination with mustard cake and furadan boost up plant growth, reduced number of galls/plant, egg masses/root system and eggs/egg mass. The fungal bio-agents along with mustard cake and nematicide showed least nematode reproduction as compared to untreated check. Haseeb and Vipin Kumar (2009) reported the effect of bio-agents (*P. fluorescens* and *T. viride* at 10 g/kg seed having 2×10^{8} cfu/g of talc based formulation), neem seed powder at 10 g/kg seed and carbosulfan at 3.0% w/w as seed treatment alone and in combination against root-knot nematode, *M. incognita* on lentil. Highest improvement in grain yield (44.6%) and lowest root-knot index (0.45) was observed in plots treated with P. *fluorescens* + *T. viride* + neem seed powder + carbosulfan.

Sharma *et al.* (2007) studied Hi-Tech polyhouse cultivation of tomato, sweet pepper and cucumber. Crop management practices such as fumigation (formaldehyde 250 litre/ha) of polyhouse every year, removal/changing of top soil and regular supplement of pesticides (carbofuran 3G 1 kg a.i./ha) were regularly used against *M. incognita*. Results revealed that all the treatments reduced the nematode population and enhanced plant growth of sweet pepper, tomato and cucumber.

Yucel *et al.* (2007) conducted greenhouse experiments to found the effectiveness of soil disinfestation by solarization in combination with low doses of metham-sodium (500, 750, 1000 and 1250 l ha^{-1}) or dazomet (400 g ha^{-1}) against soilborne pathogens and nematodes. In the greenhouse with a low level of *Forl*, all the treatments tested reduced disease incidence, and were therefore considered to be applicable for soil disinfestation. In addition, root-knot nematode density decreased with all the treatments tested in both of the greenhouses.

Oloo *et al.* (2009) conducted a field study to manage weeds and nematodes for two seasons under polyethylene covered growth tunnels. The treatments tested were: Dazomet (83.3 g/m^2), Metham sodium (0.12g/l) *Brassica napus* and *Brassica juncea* applied at 2, 3 and 4 kg/m^2. The biofumigants reduced the number of nematodes by between 25% and 62% compared to the non-treated plots. However, the highest reduction of the 2^{nd} juvenile stage of root-knot nematodes of between 42% and 81% and up to 88% reduction in the emergence of some weeds were observed in the plots treated with Metham sodium at 0.12 g/l. The findings of this study clearly show that, metham sodium and dazomet still remain the most effective means of controlling weeds and nematodes under enclosed environment.

Sharma *et al.* (2009) reported that in controlled environmental conditions and continuous growing of crops, the root-knot nematode (*Meloidogyne* spp.) has emerged as a major problem, causing enormous yield loss. The damage progressively increases if proper sanitation control measures are not followed during the polyhouse cultivation of crops. In the absence of Methyl Bromide other fumigants like metham sodium and Dazomet have been found quite effective when used under plastic mulch for single season, Non-fumigants, cadusaphos and oxamyl have also been used alone or in combination to protect 3-4 crops in protected cultivation. Combined use of bioagents, neem products and dazomet have shown promise to reduce the nemic population.

A study was conducted to investigate the effectiveness of *Pseudomonas fluorescens* and *Trichoderma viride* and two botanicals; neem seed and tobacco waste dust for the control of root-knot nematodes in tobacco. Results indicated that all bio-preparations and neem seed treatment have suppressed the RKN to the best level expressing least number of root-knot and other parasitic nematodes followed by tobacco waste and *P. fluorescens* (Motha *et al.*, 2010).

A study was conducted by Nchore *et al.* (2011) in greenhouse as well as in field to determine the efficacy of agro-industrial waste and organic amendments for the management of root-knot nematodes on *Solanum nigrum.* Treatments included cattle manure, goat manure, *Tithonia diversifolia* and agro-industrial wastes of tea [*Camellia sinensis* residue] pyrethrum, pymarc and vegetable waxy resins. The results revealed suppression of RKN population and reproduction by the various amendments compared to control in both field and greenhouse. Plant growth was improved in all the amendments. However, higher levels of tea waste and VWR application caused significant reductions in gall index, Rf and J2 populations. These organic amendments can be used as an alternative in eco-friendly management of plant parasitic nematodes including *Meloidogyne incognita*.

Cabos *et al*. (2012) evaluated continuous hot water drench treatment for disinfesting potted dracaena of reniform nematodes, *Rotylenchulus reniformis*. Modifications were made to a hot water shower container to allow the delivery of a continuous stream of hot water directly to the media and roots of infested plants. Reniform nematodes were successfully eliminated in dracaena of marketable age treated at 50°C for 10 minutes or longer. No evidence of thermal damage was observed on plants drenched with hot water even at 52°C for 14 minutes. Continuous drenching for 15 minutes at 50°C is recommended to ensure effective penetration of water.

Das and Choudhary (2012) conducted field experiments for the management of rice root-knot nematode (*Meloidogyne graminicola*) and rice-root nematode (*Hirschmsnniella oryzae*) with Cartap hydrochloride and Phosphonothioate as nursery bed treatment. Results revealed that application of Phosphonothioate 10 G at 1 kg a.i./ha at 7 days prior to uprooting plus main field application after 45 days of transplanting at 1 kg a.i./ha exhibited maximum reduction of *M. graminicola* and *H. oryzae* population. Maximum yield of rice was also recorded in above said treatments.

Joshi *et al.* (2012) carried out an experiment under glasshouse conditions for management of *Meloidogyne incognita* infecting *Lycopersicum esculentum* by using fungal bio-agents namely *Pochonia chlamydosporia, Paceliomyces lilacinus* and *Trichoderma harzianum* @ 1 and 2 g/kg soil as soil application along with chemical (Carbofuran 3G @ 1kg a.i./ha) and untreated control. Result showed that fungal bio-agents, *P. lilacinus* @ 2 g/kg soil were found best treatment in increasing plant growth and in reducing nematode reproduction over other fungal bio-agents**.**

An experiment was carried out by Rajvanshi and Bishnoi (2012) on cowpea and Mungbean with eight treatments *viz* Neem cake 5 q/ha (Soil application), Neem oil 10 ml/kg seed (Seed dresser), Neem seed kernel powder 10% (seed dresser), Neem baan 10% (seed dresser), *Trichoderma viride* 2.5 kg/ha (soil application), Carbosulfan 2% (seed soaking) along with chemical treated check (Carbofuran 1.5 kg ai/ha as soil application) and untreated check. The maximum grain yield of cowpea (7.08 q/ha) was recorded in carbofuran with reducing nematode counts from 18.16 to 9.90 followed by carbosulfan and over untreated check (Grain yield 2.11 q/ha). All the treatments significantly increased grain yield and reduced root-knot population over control. It was also found that the grain yield in carbosulfan treatment (8.64 q/ha) was found at par with the neem seed kernel powder (8.50 q/ha). The highest yield was recorded in carbofuran treated plots in mungbean.

Chaudhary and Kaul (2012) investigated the cumulative effect of two bio-agents *viz.*, *Pasteuria penetrans* and *Paecilomyces lilacinus* against *M. incognita*. Two doses of *P. penetrans* i.e. 50g/kg and 100g/kg infested soil were applied either alone or in combination with two doses of *P. lilacinus* i.e. 4g and 6g spore culture/kg of soil. Application of *P. penetrans* with *P. lilacinus* resulted better improvement in various growth attributes of chilli when compared with the individual application. Amongst various treatments, combined application at higher dose of bio-agents (100g *P. penetrans* with 6g of *P. lilacinus*/kg soil) showed maximum improvement in fresh and dry weight of shoot and root.

Khan *et al.* (2012) tested the efficacy of bio-control fungi and dry neem leaves powder against root-knot nematode, *Meloidogyne incognita* on Eggplant cv. Pusa Purple Round. They used *Pochonia chlamydosporia, Paecilomyces lilacinus, Trichoderma harzianum* (1.5 g fungi/ seedling), neem leaves (100 g /seedling) along with chemical check (aldicarb 4 g a.i. /ha.). Neem leaves induced a 19% increase in the weight of fruits/plant. Similar results were obtained using *P. chlamydosporia*, *P. lilacinus*, *T. harzianum* and aldicarb treatments, with increases over the inoculated control of 11%, 14%, 6% and 8%, respectively. The percentages of infection in adult nematode females and egg masses with *P. chlamydosporia*, *P. lilacinus* and *T. harzianum* applied to plants were considerably greater in the presence of neem leaves (77%-92% and 43%-57%) than in their absence (69%-87% and 33%-47%).

Taye *et al*., (2012) assessed nematicidal potential of baker tree (*Milletia ferruginea*), Bitter leaf (*Vernonia amygodalina*), parthenium (*Parthenium hysterophorus*), lantana (*Lantana camara*), Mexican marigold (*Tagetes minuta*), Mexican tea (*Chenopodium ambrosioides*), Neem (*Azadirachta indica*) and Pyrethrum (*Chrysanthemum cinerariafolium*) against *M. incognita* on tomato under field conditions. Aqueous extracts of the plants (20 g/100 ml w/v) were evaluated at 3 and 5% concentrations which was applied as soil drench one day after transplanting the seedling. All the plant extracts were highly effective in reducing root-knot index when compared with untreated plants. Bitter leaf, lantana, Mexican marigold, neem seed and parthenium leaves at 5% conc. reduced galling significantly and were found at par with chemical nematicide.

Kavitha *et al.* (2013) conducted an experimemt on carnation in nematode sick plot in farmers poly-house at Nelamangala, Bengaluru by using six commercially available bio-agents. *Paecilomyces lilacinus* treated plots recorded reduced soil and root population of *M. incognita*, number of galls/root system, number of egg masses/root system, increased plant height, root length, fresh and dry root weight, early emergence of flower bud, maximum number of flowers and increased flower yield of carnation.

Sivakamasundari and Usharani (2013) carried out an experiment to study the effect of endophytic *P. fluorescens* and *G. fasciculatum* on the growth and yield of maize. Maximum germination percentage, vigour index, plant height, dry matter production, yield and yield attributes were recorded in the treatment T7 (Endophytic *Pseudomonas fluorescens* + *Glomus fasciculatum* + 75% P). Minimum growth and yield parameters were recorded in the treatment T3 (*Glomus fasciculatum alone*).

Chandel *et al*. (2014) observed that plant parasitic nematodes in general and root knot nematodes (*Meloidogyne* spp.) in particular have become a serious threat for crop production under protected cultivation. Soil fumigation with metham sodium alone and in combination with neem cake enriched with bio-agents (*Paecilomyces lilacinus*, *Pseudomonas fluorescence*) has been found effective against root- knot nematode infecting tomato, capsicum and carnation.

Ramakrishnan *et al*. (2014) tested poultry manure against root-knot nematodes in FCV tobacco nursery for three years. Results revealed that there was no adverse effect of poultry manure on tobacco seed germination. At 60 DAS, Poultry manure at 200 g/m2 was at par with poultry manure at 250 g/m2 in recording reduced RKI of 1.36 and 1.34, respectively and also was at par with neem cake + soil solarization (1.40) and dazomet at 30 g/m2 (1.22). Similarly application of Poultry manure at 200 g/m2 in FCV tobacco nursery beds resulted in 40% reduction in number of root galls /g root, 34% reduction in number of root knot nematode adult females/g root, 43% reduction in number of root knot nematode egg masses/g root and 36.9% reduction in root knot nematode soil population/100g soil as compared to untreated check.

To avoid excess use of chemicals, Prasad *et al*. (2014) carried out an experiment to manage *M. incognita* infecting carrot by using bio-agents *viz.*, *Trichoderma harzianum* (indigenous and commercial) and *Pseudomonas fluorescens* (commercial) under field conditions. Among bio-agents, the lowest nematode population in soil was recorded in isolated *T. harzianum* at 25g/m^2 (2×10^6 cfu/g) treated plot than commercial *T. harzianum* at 20g/m^2.

The effectiveness of different bacterial and fungal genera against *M. javanica* on eggplant evaluated by Mokbel and Alharbi (2014) under laboratory and greenhouse conditions. Among the bacterial bio-agents, *P*. *fluorescens* caused 75.3% inhibition on *M. javanica* egg-hatch and 2^{nd} stage juveniles (J_2) activity and showed 81.3% reduction in number of galls, 81.8% in egg-masses/plant, 72% in number of J_2/250 cc soil and increased in root (65.8%) and shoot (63.3%) dry weight of eggplant. Among the fungal bio-agents, *P*. *lilacinus* caused significant reductions in number of galls (83.6%), egg-masses/plant (84.2%) and number of J_2/250 cc soil (89.5%) and showed increase in root (59.7%) and shoot (55.8%) dry weight of eggplant. The potential of *P*. *lilacinus* in colonization *M. javanica* egg masses and eggs formed on eggplant roots ranged from 45.2- 99.2% as compared to the control.

Hanawi (2014) conducted a greenhouse experiment to study the effect of bio-agents *viz.*, *Paecilomyces lilacinus*, *Trichoderma harzianum*, *T. viride* with *G*. *mosseae* and nematicide furfural against root knot nematode, *Meloidogyne javanica* infecting tomato (*Lycopersicon esculentum*). Result showed that *T*. *harzianum* was the best biocontrol agent in increasing shoot length and root length 16.2% and 26.1%, respectively. The *P*. *lilacinus* was the best bio-agent in reduction of root galls (57.53%).

Ramezani and Ebrahimi (2014) conducted an experiment for biological control of reniform nematode on sunflower through bio-agents. This study made to consider the effectiveness of commercial formulation of VAM fungus (*Glomus mosseae*), bacterial agent (*Pseudomonas fluorescens*) and antagonistic fungus (*Trichoderma viride*) against reniform nematode, *R. reniformis* on sunflower under greenhouse condition. Three bio-agents each subsequently were representing *G. mosseae* as soil application and *P. fluorescens* as seed treatment improved the plant growth and yield of sunflower. As soil application, *G. mosseae* produced maximum reduction of nematode population in roots (65.1 %) and soil (73.1 %) which was at par with seed treatment of *P. fluorescens*.

Singh *et al.* (2014) carried out field trials to manage root-knot disease caused by *Meloidogyne incognita* infesting okra through integration of bio-agents *(Paecilomyces lilacinus*) and plant growth promoting rhizobacteria, *Pseudomonas fluorescens* as seed treatment (10 g/kg seed) as well as soil application (10 kg/ha) and 1.5 t/ha farm yard manure (FYM). Besides untreated control, chemical nematicide, carbofuran was also kept as control for comparison. Integration of all management components improved plant height (20%) and enhanced marketable yield (71%) compared with individual treatments and controls. Also, the best protection of root-knot disease of okra in terms of reduction of root-knot index (1.0) and reproduction factor (Pf/Pi = 0.4) was achieved through integration of seed treatment and soil application of bio-agents, *P. lilacinus* and *P. fluorescens* and FYM.

Yankova *et al.* (2014) conducted greenhouse experiments to establish the biological activity of BioAct WG *Paecilomyces lilacinus* and *Trichoderma viride* strain T6 applied alone and in combination against root-knot nematodes *M. incognita* in cucumber variety Defense F1. All tested variants suppressed nematode reproduction and root galling and result in plant growth improvement as compared to the control. The lowest rate of infestation and the highest total yield were established in the combination of BioAct WG and *Trichoderma viride* strain T6.

Sellaperumal *et al*. (2015) applied hot-water with three temperatures (45, 50, 55^{o}C) and time (15, 30, 45 min) combinations to reduce the infection of root-knot nematode on tuberose bulbs. Results showed an improvement in plant growth and a good reduction of nematode population in all the treatments. Hot water treatment at 50^{o}C for 45 minutes gives a reduction of 43, 36 and 57% in galls, egg masses and soil population of nematodes, respectively.

Mehta *et al*. (2015) carried out an experiment to evaluate the efficacy of neem (*Azadirachta indica*), aak (*Calotropis procera*) and water hyacinth (*Eichhornia crassipes*) leaf powder at 1, 2 and 4 g/plant as soil amendment for the management of maize cyst nematode, *H. zeae* on maize. Results revealed maximum increase in plant growth character when neem leaf powder applied at 4 g/plant followed by aak and water hyacinth leaf powders at 4 g/ plant. Significant reduction in nematode population (cyst/plant, cyst /100 cc soil, eggs and larvae / cyst and larvae/100 cc soil) was observed with neem leaf powders at 4 g/plant over control.

Baheti *et al.* (2015) evaluated bio-agents for management of maize cyst nematode, *Heterodera zeae* on sweet corn (*Zea mays* L. *Saccharata*). Result showed that seed treatment with *P. lilacinus* at 4 % was found most effective followed by *P. chlamydosporia* at 4 % and *P. lilacinus* at 2 % to enhance plant growth and to reduce the infection of *Heterodera zeae* on maize.

Mehta *et al.* (2016) planned an integrated nematode management trial and applied bio-agents (*Paecilomyces lilacinus*, *Trichoderma harzianum* and *Pseudomonas fluorescens* at 2% w/w as seed treatment) with leaves powder (*Azadirachta indica*, *Calotropis procera and Eichhornia crassipes* at 4g/plant as soil application) for the management of maize cyst nematode, *Heterodera zeae* on maize. Results exhibited that among bio-agent and plant product combinations, *P. lilacinus* at 2% coupled with neem leaves powder at 4g/plant was found most effective followed by *T. harzianum* at 2% + neem leaves powder at 4g/plant and *P. lilacinus* at 2% + aak leaves powder at 4g/plant for the management of *H. zeae* and to enhanced plant growth parameters of maize.

Gocher *et al.* (2018) investigated on three chemicals *viz.* Dimethoate, Triazophos & Chlorpyrifos @ 0.5 and 1 ml/lit of water as seed soaking to find out their efficacy against *Meloidogyne incognita* infecting cucumber in polyhouse. Triazophos @ 1 ml/lit water was found very promising to improve plant growth characters and reducing nematode reproduction over Chlorpyrifos and Dimethoate. Giriraj *et al.* (2018) find out the efficacy of soil fumigants (STTC and Metham Sodium) against *M. incognita* on tomato in poly-house. Result showed that Metham Sodium at 40 ml/m^2 was recorded most effective fumigant followed by Metham Sodium at 30 ml and STTC 40 ml/m^2. Metham Sodium at 40 ml/m2 reduce maximum nematode reproduction and enhance plant growth over control.

Baheti *et al.* (2019) tested neem, karanj and mustard oil-cakes for the management of root-knot nematode, *M. incognita* infecting okra on farmer‟s field naturally infested with test nematode. These were applied @ 2, 4 and 6 q/ha maintaining chemical treated (carbofuran 2 kg a.i./ha) and untreated control for comparing the experimental results. Results showed that neem cake @ 6 q/ha was proved to be most effective for the management of *M. incognita*, while karanj cake @ 6 q/ha was found best to enhanced crop yield (49.18-53.51 %) followed by neem cake @ 6 q/ha (40.98-45.61%) and karanj cake @ 4 q/ha (39.34-43.86 %) over untreated control. Higher yield was obtained with the application of karnaj cake @ 6 q/ha as compared to carbofuran @ 2 kg a.i./ha during both the years.

Bhati *et al.* (2019) conducted an experiment for testing of bio-agents *viz*., *Paecilomyces lilacinus*, *Pochonia chlamydosporia* and *Glomus fasiculatum* as seed treatment @ 6 and 12 g/kg for the management of root-knot nematode, *M. incognita* on bitter gourd. A standard (*Trichoderma viride* at 12 g/kg seed) and untreated check was also maintained for comparison. Results of experiment revealed that *Paecilomyces lilacinus* at 12 g/kg seed was found most effective followed by *Pochonia chlamydosporia* at 12 g/kg seed and *Glomus fasiculatum* at 12 g/kg seed to enhancing plant growth of bitter gourd and to reduce the infection of *M. incognita*.

Mahalik and Sahoo (2019) evaluate the efficacy of oil cakes (neem and jatropha oil) and bio control agents (*Purpureocillium lilacinum, Trichoderma viride* and *Pseudomonas flourescens*) and Carbofuran 3G against *Meloidogyne incognita* on okra. The experimental results showed that soil application of jatropha oil cake @ 1.0 t/ha + seed treatment with *T. viride* and *P. fluorescens*, each @ 5g/kg seed + soil application of *P. lilacinum* @ 2.5kg/ha resulted maximum increase in plant growth with highest reduction in nematode population over control followed by soil application of neem oil cake @ 1.0 t/ha+ seed treatment with *T.viride* & *P.fluorescens*, each @ 5g/kg seed + soil application of *P.lilacinum*@ 2.5kg/ha, which were statistically at par. But soil application of neem oil cake @ 1 t/ha + seed teatment with *T. viride* & *P. fluoroscence* @ 5 g each/kg seed + soil application of *P. lilacinum* @ 2.5 kg/kg having the highest B: C ratio (2.12).

3. MATERIALS & METHODS

The root-knot nematode, *Meloidogyne* spp. has been frequently associated with cucumber and responsible for severe economic losses in open field as well as in poly-houses. Therefore, it is necessary to study about root-knot nematode, *Meloidogyne incognita* infecting cucumber and to find out it's suitable means of management. To fulfill the said objectives, present investigations have been carried out in poly-houses establish on farmer's field against root-knot nematode, *M. incognita* on cucumber. Following points were mainly considered:-

A. GENERAL PROCEDURES:

I. Selection of Experimental Site:

Survey was under taken to identified and locate root-knot nematode, *M. incognita* infested polyhouse before laying out of different experimental trials. Utmost care was taken for selection of suitable sites. Cucumber growing progressive farmer's was selected which have well established poly house infested with *Meloidogyne incognita*. Plant protection, irrigation and other required facilities have been fully ensured for planning, monitoring and layout of experimental trials. After thorough discussion with farmers, experiments were conducted on poly-houses of Sh. Shivrao Maratha, Nimbahera (2016) and Sh. Jitendra Kumar, Surajpol, Chittorgarh (2017).

II. Collection and processing of samples:

Soil samples were collected from various poly-houses, labelled properly and processed in laboratory. Processed samples were thoroughly examined under microscope to estimate population of root-knot nematode, *M. incognita*..

III. Identification of root-knot nematode species:

Root samples were brought to the laboratory and washed carefully in running tap water to remove adhering soil particles. Egg masses with females were detached from infected roots with the help of teasing needle and forceps under stereoscopic binocular microscope. Egg masses were kept in water atleast for 24 hrs for hatching and females were picked up for identification of nematode species. Perineal patterns of these females were cut with the help of scalpel and the body contents were removed gently with camel brush No.1 as described by Taylor and Netscher , 1974.Observations of such several patterns was recorded and the nematode species was identified as *M. incognita* (Eisenback *et al*.,1981).

Plate 4 : Collection of soil and root samples of cucumber in poly-house during survey

IV. Filling of poly bags:

In all the experiments poly bags of 12"x18" size were taken. Selection of poly bags were made in such a way that all the poly bags were of almost same size and volume for proper growth of cucumber (Approximately 5 kg naturally root-knot nematode infested soil/poly bag). Each of these have a hole at bottom which was covered with a piece of broken clay pots before filling the soil to fascilitate drainage. Each poly bags then filled with equal quantity of infested soil. Some space from the above was left unfilled for irrigation.

V. Sowing:

After layout and proper treatment, sowing of cucumber variety “Mini-angle” which is highly susceptible and used by poly house growers was done in the month of July with dibbling method and labeled properly. Spacing for each poly bag was maintained as recommended for better growth of the plants under protected cultivation. Some seeds also sown in pro trays for gap filling, if required.

VI. Aftercare:

Care was taken right from sowing till harvest of experiments. To avoid pest and pathogens damage, the recommended pesticide/fungicides were applied as and when required. Weeding and hoeing was done from time to time and irrigation was given as per requirement through drip system. The recommended fertigation schedules have been adopted at the time of sowing and in standing crop for proper growth of cucumber crop.

VII. Estimation of initial and final nematode population:

For estimation of initial nematode population, soil samples were collected from the poly houses selected for experimentation during both the years (2016 and 2017).Samples were brought to the laboratory and thoroughly mixed by using coring and quartering method. Hundred cc soil was taken and processed by using Cobb’s Sieving and Decanting Technique (Cobb, 1918) followed by Baermann’s funnel technique (Christie and Perry, 1951). After 24 hours, the nematode suspension was drawn from the funnel in a beaker and kept for some time as such to allow the nematodes to settle down at the bottom. Nematode suspension was drawn for counting of population with the help of a pipette after thorough bubbling and poured over a counting disc. Population was counted under stereoscopic binocular microscope. Same procedure was also adopted to estimate final nematode population at harvest from experimental poly bags.

Plate 5 : Processing of soil and root samples in laboratory

VIII. Counting of galls and egg masses:

After harvesting, root samples were collected from each experiment, labelled properly and brought to the laboratory. Roots were gently washed in running tap water to remove adhering soil particles. Well cleaned roots were cut into small pieces and 5g samples were taken to observed thoroughly under microscope for counting of galls and egg masses.

IX. Counting of eggs and larvae per egg mass:

After counting of galls and egg masses, roots were stained with 0.1% acid fuchsin lactophenol solution, rinsed in water to remove excess amount of stain and kept in clear lactophenol at least for 24 hours before examination (McBeth *et al*., 1941). Egg masses were randomly selected, detached from stained roots, put in a drop of clear lactophenol on glass slide, covered with cover slip and press gently so that contents of egg mass spread thoroughly. Thereafter, eggs & larvae were counted under stereoscopic binocular microscope.

X. Yield record:

Picking was done time to time whenever required and collected separately treatment wise from each poly bag in well labeled cloth bags, cleaned and weighed to obtained yield record data with the help and co-operation of growers.

XI. Statistical analysis:

After completion of experiments, data were statistically analysed for interpretation of findings (Nelson, 1978). The critical difference was found out for comparison of treatments where the 'F' test was found significant at 5 per cent level of significance. Summary tables along with SEm± and CD were worked out and presented in the text of the chapter entitled "Experimental Results" and analysis of variance for different parameters were appended in "Appendices".

B. EXPERIMENT WISE METHODOLOGY:

Following experiments were conducted during the course of investigation to fulfill the objectives of investigation:-

1. Population status and occurrence of root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation.

2. Estimation of avoidable losses caused by root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.
3. Seasonal fluctuation of root-knot nematode, *M. incognita* on cucumber under protected cultivation.
4. Effect of hot water treatment on root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.
5. Management of root-knot nematode, *M. incognita* through different organic amendments on cucumber under protected cultivation.
6. Effect of bio-agents as soil application on root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.
7. Management of root-knot nematode, *M. incognita* infecting cucumber under protected cultivation through different chemicals.
8. Eco-friendly management of root-knot nematode, *M. incognita* infecting cucumber under protected cultivation.
9. Integrated management of root-knot nematode, *M. incognita* infecting cucumber under protected cultivation

1. Occurrence and population status of *Meloidogyne incognita* on cucumber in protected cultivation of Rajasthan:

To find out distribution and population status of *Meloidogyne incognita*, soil and root samples were collected from poly-houses and brought to the laboratory and kept in refrigerator till processing. Soil samples were processed by using Cobb's Sieving and Decanting Technique (Cobb, 1918) followed by Baermann's Funnel Assembly (Christie and Perry, 1951). Roots were stained in 0.1% acid fuchsin lactophenol solution at 80ºC for 2-3 minutes (McBeth *et al*., 1941). Then roots were rinsed in the tap water and kept in clear lactophenol at least for 24 hrs. Thereafter, roots were examined under stereoscopic binocular microscope. The observations on no. of galls/5 g roots, egg masses/5 g roots, nematode larvae/100 cc soil and Occurrence (%) were recorded.

2. Estimation of avoidable losses caused by *M. incognita* infecting cucumber under poly-house:

The experiment was carried out in naturally infested poly house established at farmer's field. Two treatments *viz.*, treated (Phorate 2 kg a.i./ha) and untreated check were taken. The experiment was laid out in completely randomized design. Both the treatments were replicated fifteen times and observations on initial nematode population/100cc soil, no. of galls/5 g roots, egg masses/5 g roots, eggs & larvae /egg mass, final nematode population/100cc soil and yield (kg/plant) were recorded. Avoidable yield losses caused by *M. incognita* on cucumber in poly houses was determined. The data were statistically analyzed to interpretate the experimental findings.

3. Population fluctuation of *M. incognita* on cucumber under protected cultivation:

Soil and root samples of cucumber were collected from polyhouse, during crop season at fifteen days interval from rhizosphere of cucumber and brought to the laboratory. The samples were kept in refrigerator till processing. Nematodes were extracted from soil by using Cobb's Sieving and Decanting Technique (Cobb, 1918) followed by Baermann's Funnel Assembly (Christie and Perry, 1951). Thereafter, nematode suspension was examined under stereoscopic binocular microscope. Roots were gently washed in running tap water to remove adhering soil particles. Well cleaned roots were cut into small pieces, samples taken and observed thoroughly under microscope for counting of galls, egg masses and eggs and larvae/egg mass. Observations on no. of galls/5 g roots, egg masses/5 g roots, eggs and larvae/egg mass and initial & final larvae population/100 cc soil were recorded. After completion of experiment, data were statistically analyzed for interpretation of findings.

4. Effect of hot water treatment on *M. incognita* infecting cucumber in poly-house:-

The experiment was carried out in polyhouse to find out the effect of hot water treatment on root-knot nematode, *Meloidogyne incognita* on cucumber. The hot water (approx. 100^0C) was applied at 0.5, 1.0 and 1.5 litre/poly bag filled with nematode infested soil alongwith check (normal water) to interpretate the experimental findings. The experiment was laid out in completely randomized design and all the treatments were replicated seven times. Atmost care was taken right from sowing to till harvest of experiment for proper growth and development of cucumber plants. Initial nematode population/100 cc soil was determined before sowing and other observations such as no. of galls/5 g root, egg masses/5 g root, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded at the time of harvest. Yield (kg/plant) was recorded from first picking to till harvest of experiments. After completion of experiments, data were analyzed for interpretation of experimental findings.

Plate 6 : Application of Hot-water treatment and soil fumigations

5. Effect of organic amendments against root-knot nematode, *M. incognita* on cucumber in poly-house:

An experiment was carried out to test the effect of tea waste, tobacco churi, poultry manure, water hyacinth and lantana leaf powder as organic amendments at 20 and 40 g/plant for the management of root-knot nematode, *Meloidogyne incognita* on cucumber in poly house. A standard check (neem cake 50 g/plant) and untreated check was also taken for comparison. The experiment was laid out in completely randomized design and all the treatments were replicated five times. Atmost care were taken right from sowing till harvest of experiment for proper growth and development of plants. Initial nematode population/100 cc soil was determined before sowing and other observations on no. of galls/5 g root, egg masses/5 g root, eggs & larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded. Yield (kg/plant) was recorded from first picking to harvest of experiment.

6. Efficacy of bio-agents as soil application on *M. incognita* infecting cucumber in poly-house:

An experiment was carried out to test the efficacy of bio-agents *i.e. Paecilomyces lilacinus*, *Trichoderma harzianum, Pochonia chlamydosporia*, *Pseudomonas fluorescens* and *Glomus fasiculatum* (VAM) for the management of root-knot nematode, *Meloidogyne incognita* on cucumber. Bioagents were applied at 2.5 and 5.0 g/plant. Treated (*Trichoderma viride* 5.0 g/plant) and untreated checks were also maintained for comparison of results. The experiment was laid out in completely randomized design with five replications. Atmost care was taken right from sowing till harvest of experiment for proper growth and development of plants. Initial nematode population/100 cc soil was determined before sowing and observations such as no. of galls/5 g root, egg masses/5 g root, eggs & larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield (kg/plant) were recorded to interpretate the results.

7. Effect of chemicals as pre-sowing application against root-knot nematode, *M. incognita* on cucumber under poly-house:

An experiment was carried out to test the efficacy of various chemicals *i.e.* formalin 10, 20, 30 ml/plant, metham sodium and sodium tetra thio-carbonate (STTC) at 2.5, 5.0 and 10 ml/plant for the management of root-knot nematode, *Meloidogyne incognita* on cucumber under polyhouse conditions. Treated (Phorate 2 g a.i./plant) and untreated checks were also taken

Plate 7 : Application of organic amendments and bio-agents

for comparison. The required quantity of chemical was measured separately for each replication. The experiment was laid out in completely randomized design with five replications. Initial nematode population/100 cc soil was determined before sowing and other observations *viz.* no. of galls/5 g root, egg masses/5 g root, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded at the time of harvest.Yield(kg/plant) was taken from first picking to till harvest of experiments. After completion of experiments, data were statistically analyzed to interpretate experimental findings.

8. Influence of eco-friendly management strategies on root-knot nematode, *M. incognita* infecting cucumber under poly-house:-

The experiment was carried out to find out suitable integrated nematode management module for root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation. The hot water at 1.0 litre/polybag along with organic amendments *i.e.* tea waste, tobacco churi, poultry manure, water hyacinth powder, lantana leaf powder was used at 20 g/plant and bio-agents *Paecilomyces lilacinus* and *Trichoderma harzianum* at 2.5 g/plant. A treated check (Hot water 1.0 litre/polybag + Neem cake 50 g/plant + *Trichoderma viride* 5.0 g/plant) and untreated check were also maintained for comparison of different treatments. The experiment was laid out in completely randomized design with five replications. Initial nematode population/100 cc soil was determined just before sowing. Observations on no. of galls/5 g root, egg masses/5 g root, eggs & larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded. Yield (kg/plant) was recorded from first picking to till harvest of experiment.

9. Effect of integrated nematode management on *M. incognita* infecting cucumber under poly-house:

An experiment was carried out to find out integrated nematode management module against root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation. The hot water at 1.0 litre/polybag with organic amendments (tea waste, tobacco churi, poultry manure, water hyacinth powder, lantana leaf powder at 20 g/plant) along with carbofuran (0.25 and 0.50 g a.i./plant) were used in combinations. A treated check (Hot water 1.0 litre/polybag + Neem cake 50g/plant + phorate at 0.50 g a.i./plant) and untreated check was also taken and maintained for comparison of various treatments .

Plate 8 : View of seedling stage of cucumber in poly-house

The experiment was laid out in completely randomized design with five replications. Initial nematode population/100 cc soil was determined before sowing and other observations that is no. of galls/5 g root, egg masses/5 g root, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded at the time of harvest. Yield (kg/plant) was recorded from first picking to till harvest of experiments. After harvest, data were analyzed to interpretate research findings.

4. EXPERIMENTAL RESULTS

Root-knot nematode, *Meloidogyne* spp. is one of the most widespread nematode pest limiting world's agricultural productivity and almost all the crop plants that accounts for worlds food supply have been found susceptible to infection by this pest (Taylor *et al*., 1982). Root-knot nematode, *M. incognita* has being distributed throughout India and associated with number of economically important crops specially vegetables. Keeping this in view, present investigation was undertaken to estimate the losses caused by root-knot nematode, *M. incognita* on cucumber under protected cultivation and to evolve its suitable management options. To fulfill the said objectives, various trials were conducted during 2016 and 2017 and the results are being described below:-

1. Occurrence and population status of root-knot nematode, *Meloidogyne incognita* on cucumber in Poly houses of Rajasthan:-

Survey was carried out to determine the occurrence and population status of root-knot nematode in poly-houses of different districts of Rajasthan (Udaipur, Chittorgarh, Rajsamand, Hanumangarh, Jaipur, Dausa, Nagaur and Jodhpur). One hundred fifty eight samples were collected from forty poly-houses during 2016 and 17. Observations on occurrence (%), galls per 5 g roots, egg masses per 5 g roots and larvae per 100cc soil were recorded. Occurrence of root-knot nematode was noticed 100 % in surveyed poly houses. Results (Table-1) showed that not a single poly house was observed free from presence of root-knot nematode, *Meloidogyne* spp.

I. Udaipur:-

During survey, thirty eight samples collected from nine different locations. All samples containing root-knot nematode, *Meloidogyne* spp. and on an average 90.77 galls per 5 g roots, 80.44 egg masses per 5 g roots and 937.55 larvae per 100cc soil were recorded on cucumber. Results revealed that maximum galls/5g roots (107), egg masses/5g roots (102) and nematode larvae/100 cc soil (1220) recorded from poly-house of Bikarni followed by Nandoli and Maharaj ki khedi village. Minimum galls/5g roots (68), egg masses/5g roots (49) and nematode larvae/100cc (695) observed from poly-house established at Jalkhedi-III.

II. Chittorgarh:-

A total of fifty eight samples collected from 12 different locations of Chittorgarh. As per results revealed 93.25 galls/ 5 g roots, 82.75 egg masses/ 5 g roots and 1033.75 larvae per 100cc soil were recorded on cucumber from different poly-houses. Maximum galls/5g roots (142), egg masses/5g roots (135) and larvae/100 cc soil (1460) were recorded from poly-house situated at Tana followed by Surajpole and Munda Gulfroshan village. Minimum galls/5g roots (47), egg masses/5g roots (36) and larvae/100cc (580) were observed from poly-house of Krishna Nursery of Chittorgarh. All samples were collected from poly house containing root-knot nematode, *Meloidogyne* spp.

III. Rajsamand:-

Forty samples were collected from different poly-houses during survey and all samples containing root-knot nematode population. On an average 81.72 gall/5 g roots, 70.81 egg masses per 5 g roots and 955.90 larvae/100cc soil were recorded on cucumber from poly-houses. Maximum galls/5g roots (118), egg masses/5g roots (107) and juveniles/100 cc soil (1325) were recorded from poly-house established at Bhim-Karera road followed poly houses of Nedi and Amet . Minimum galls/5g roots (40), egg masses/5g roots (26) and larvae/100 cc soil (545) found in poly-house of Badola farm.

IV. Hanumangarh:-

Four samples were collected from two different poly-houses and an average 113 gall per 5 g roots, 100 egg masses per 5 g roots and 1358.00 larvae/100cc soil recorded on cucumber. Maximum galls/5g roots (124), egg masses/ 5 g roots (112) and nematode larvae / 100cc soil (1410) were recorded from poly house established at Nohar-I.

V. Jaipur:-

Four samples were collected from Shahpura and Chomu location. An average 95 gall per 5 g roots, 83.50 egg masses per 5 g roots and 1172.50 larvae/100cc soil were recorded on cucumber. Maximum galls/5g roots (116), egg masses per 5 g roots (105) and larvae per 100 cc soil (1205.00) obtained from poly house of Chomu village. All samples collected from Jaipur district were containing root-knot nematode on cucumber grown under poly house.

VI. Dausa:-

Two samples were collected from poly house of Gijgarh location with 104 galls/5g roots, 93 egg masses/5 g roots and 980 larvae/100cc soil on cucumber in poly-house.

Table-1: Occurrence and Population status of root-knot nematode, *Meloidogyne* spp. on cucumber under protected cultivation in Rajasthan

S. No.	Location	No. of samples Collected	Number of samples containing *Meloidogyne* spp.	Galls/ 5g roots	Egg masses/ 5g roots	Larvae/ 100cc soil	Occurrence (%)
I.	**Udaipur:**						
1.	Maharaj ki khedi	8	8	104	97	1156	100
2.	Jalkedi-I	4	4	88	78	875	100
3.	Jalkhedi-II	4	4	72	57	705	100
4.	Jalkhedi-III	5	5	68	49	695	100
5.	Nandoli	4	4	105	99	1192	100
6.	Narayanpura	6	6	87	73	720	100
7.	Piladar, Jaisamand road	2	2	91	83	925	100
8.	Bikarni, Chirva	2	2	107	102	1220	100
9.	CTAE Campus, Udaipur	3	3	95	86	950	100
	Total*/Mean	**38***	**38***	**90.77**	**80.44**	**937.55**	**100**
II.	**Chittorgarh:**						
10.	Tana via Dundiya, Teh. Bhopalsagar	18	18	142	135	1460	100
11.	Manda gulfroshan, Nimbahera	6	6	130	118	1350	100
12.	Choti sadri road, Nimbahera	8	8	109	101	1235	100
13.	Ghosunda	2	2	80	74	1025	100
14.	Rithola	2	2	126	115	1255	100
15.	Jaisingh pura	2	2	82	75	1105	100
16.	Krishna nursery- Chittorgarh	2	2	47	36	580	100
17.	Surajpole-Chittorgarh	4	4	132	120	1375	100
18.	Kashmor	2	2	65	52	725	100
19.	Near to Kapasan	4	4	68	55	785	100
20.	Kheri, kapasan road-Chittorgarh	4	4	76	64	850	100
21.	Kapasan road-Chittorgarh	4	4	62	48	660	100
	Total*/Mean	**58***	**58***	**93.25**	**82.75**	**1033.75**	**100**
III.	**Rajasamand:**						
22.	Odan, Nathdwara road	2	2	84	72	930	100
23.	Badola farm house Near rameshwaram temple-Rajsamand	4	4	40	26	545	100
24.	Bhana-Kankroli	4	4	97	83	1115	100

25.	Bagana-Devgarh	4	4	72	67	840	100
26.	Kirado ka badiya, Kamlighat, Devgarh	4	4	85	75	1005	100
27.	Bhim	4	4	88	77	1095	100
28.	Karera road-Bhim	4	4	118	107	1325	100
29.	Nedi, Karera road-Bhim	4	4	102	94	1155	100
30.	Selma, Bhim	4	4	63	49	725	100
31.	Lasani	4	4	52	44	660	100
32.	Amet	2	2	98	85	1120	100
	Total*/Mean	**40***	**40***	**81.72**	**70.81**	**955.90**	**100**
IV.	**Hanumangarh:**						
33.	Nohar-I	2	2	124	112	1410	100
34.	Nohar-II	2	2	102	88	1306	100
	Total*/Mean	**4***	**4***	**113**	**100**	**1358**	**100**
V.	**Jaipur:**						
35.	Mahar khurd, Shahapura	2	2	74	62	1140	100
36.	Nindola, Khejroli, Chomu	2	2	116	105	1205	100
	Total*/Mean	**4***	**4***	**95**	**83.50**	**1172.50**	**100**
VI.	**Dausa:**						
37.	Gijgarh	2	2	104	93	980	100
	Total*/Mean	**2***	**2***	**104**	**93**	**980**	**100**
VII	**Nagaur**						
38.	Dabada, Maulasar	4	4	79	61	760	100
39.	Maulasar	4	4	59	48	912	100
	Total*/Mean	**8***	**8***	**69**	**54.5**	**836**	**100**
VIII.	**Jodhpur:**						
40.	Agarwal farm, Osian	4	4	64	54	956	100
	Total*/Mean	**4***	**4***	**64**	**54**	**956**	**100**
	Grand Total*/Mean	**158***	**158***	**88.87**	**77.38**	**1028.96**	**100**

VII. Nagaur:-

Eight samples collected from two different locations. On an average 69 galls/5g roots, 54.50 egg masses per 5 g roots and 836.00 larvae per 100cc soil were recorded on cucumber. The maximum galls/5g roots (79), egg masses/ 5 g roots (61) and nematode larvae/ 100cc soil (760) were observed from poly house established at Dabada (Maulasar).

VIII. Jodhpur:-

Four samples were collected from poly-house of Agrawal farm-Osian with population of 64 galls/5g roots, 54 egg masses/5 g roots and 956.00 larvae per 100cc soil on cucumber. All samples collected from Jodhpur district shows presence of root-knot nematode on cucumber in poly house.

2. Estimation of avoidable losses caused by root-knot nematode, *M. incognita* on cucumber in poly-house:-

Plant parasitic nematodes are hidden enemies of agri-horticultural crops and cause losses directly as well as indirectly. Amongst nematodes, the root-knot nematode, *M. incognita* is being considered to be the most damaging and responsible to causes severe losses to vegetables including cucumber. Therefore, an attempt was made to estimate the avoidable losses caused by root-knot nematode, *M. incognita* on cucumber (*var.* Mini Angle) under protected cultivation with the application of phorate at 2 kg a.i./ha. The trial was carried out in poly-houses naturally infested with *M. incognita* during 2016 and 2017 at farmer's field. Observations on no. of galls/5g roots, no. of egg masses/5g roots, no. of eggs and larvae/egg mass, final nematode population/100 cc soil and yield kg/plant were recorded. Avoidable losses were estimated caused by root-knot nematode, *M. incognita* on cucumber in poly-house. Experimental results are being presented in Table-2 and illustrated through Fig.1 and Plate 9.

I. Number of galls per 5g roots:

Results revealed that soil application of phorate at 2 kg a.i./ha at the time of sowing significantly reduced galls/5 g roots. Galls/5g roots (15.26) was recorded minimum in plants treated with phorate at 2 kg a.i./ha (Pooled 2016 and 2017) as compared to untreated check (72.79). Reduction in galls was determined to the tune of 79.03 per cent in treated plants over untreated check (Table-2).

Table-2: Estimation of avoidable losses caused by root-knot nematode, *M. incognita* infecting cucumber under poly-house

Treatments	Galls/ 5 g roots			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Nematode population/ 100cc soil			Yield (kg/plant) and Avoidable loss (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Phorate 2 kg a.i./ha (T_1)	16.66 (77.76)	13.86 (80.38)	15.26 (79.03)	12.80 (79.39)	09.66 (82.97)	11.23 (81.10)	178.86 (31.29)	175.66 (30.53)	177.26 (30.91)	855.57 (56.47)	847.33 (56.60)	851.45 (56.54)	3.824 (67.31)*	4.260 (66.43)*	4.042 (66.84)*
Untreated check (T_2)	74.93	70.66	72.79	62.13	56.73	59.43	260.33	252.86	256.59	1965.73	1952.66	1959.19	1.250	1.430	1.340

Figures in parentheses are per cent decrease over untreated check

Data are the average value of fifteen replications

*Avoidable loss (%)

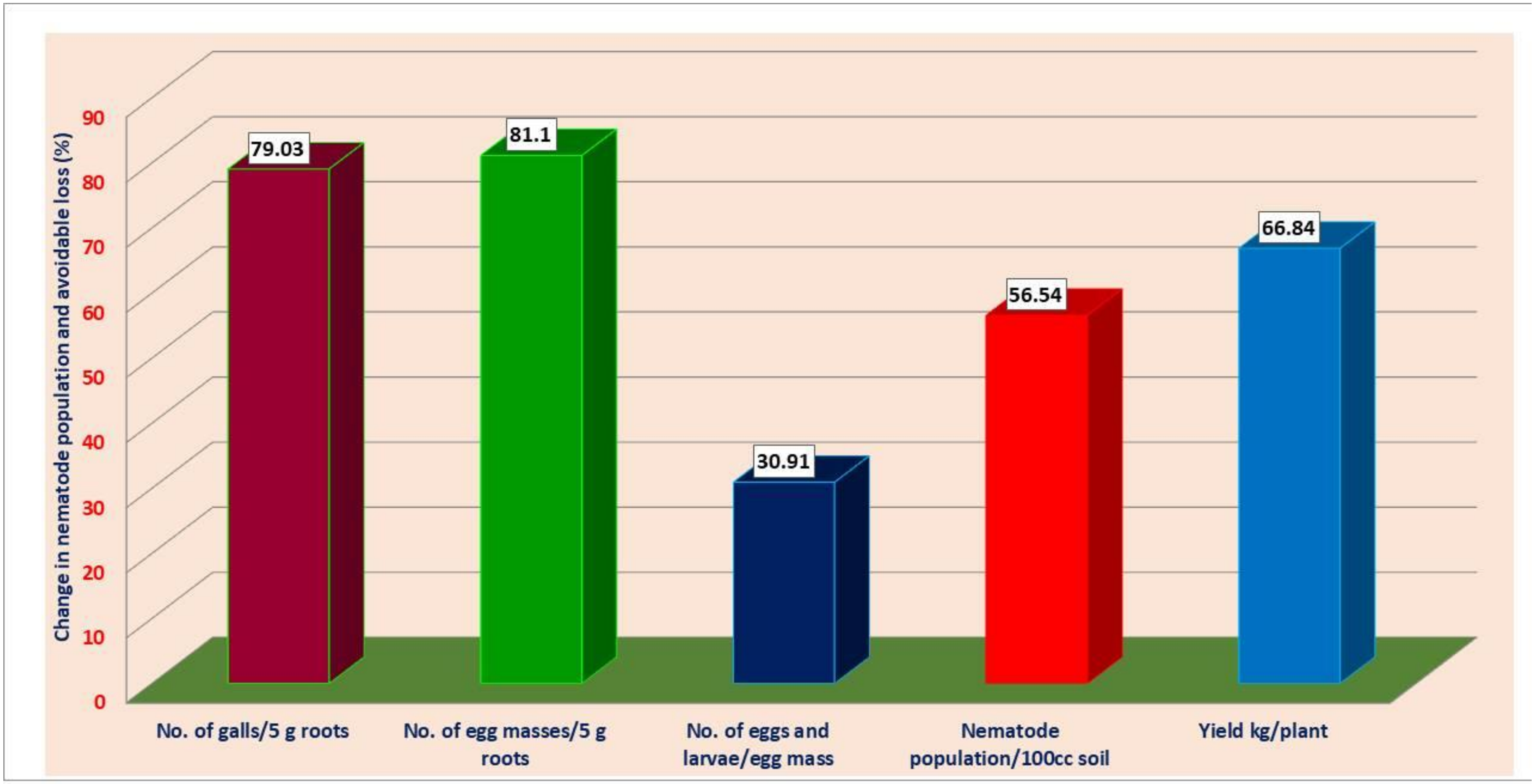

Figure 1: Estimation of avoidable losses caused by root-knot nematode, *M. incognita* infecting cucumber in poly-house

Plate 9 : Estimation of avoidable losses caused by *M. incognita* on cucumber in poly-house

II. Number of egg masses per 5g roots:

Results showed minimum egg masses/5 g roots (11.23) recorded in plants treated with phorate at 2 kg a.i./ha. The treatment significantly reduced egg masses of root-knot nematode on cucumber. It was observed 59.43 egg masses/5 g roots in untreated check. Reduction in egg masses/5 g roots was noticed 81.10 % with phorate at 2 kg a.i./ha (Pooled 2016 and 2017) over untreated check on cucumber grown in poly house.

III. Number of eggs and larvae per egg mass:

Soil application of phorate at 2 kg a.i./ha at the time of sowing significantly reduced eggs and larvae per egg mass. In the experimental results, minimum number of eggs and larvae per egg mass (177.26) on cucumber was observed with phorate at 2 kg a.i./ha whereas, it was observed 256.59 eggs and larvae per egg mass in untreated check. The per cent decrease in eggs & larvae/egg mass was obtained 30.91 with phorate at 2 kg a.i./ha over untreated check.

IV. Final nematode population per 100 cc soil:

Results showed that final nematode population significantly decreased at the time of harvest with the application of phorate at 2 kg a.i./ha over untreated check in cucumber under protected cultivation. It was obtained minimum (851.45 larvae per 100 cc soil) with chemical treated application, while maximum population per 100 cc soil (1959.19) was recorded in untreated check. Final nematode population was reduced 56.54 per cent with application of phorate at 2 kg a.i./ha over untreated check (Fig.1).

V. Yield (kg/plant) and Avoidable Yield Loss (%):

Results revealed that soil application of phorate at 2 kg a.i./ha at the time of sowing significantly increased yield of cucumber in poly house infested with *M. incognita*. It was recorded 4.042 kg/plant with application of phorate at 2 kg a.i./ha and 1.340 kg/plant in untreated check. The avoidable yield loss was estimated to be 66.84 per cent on cucumber in poly houses by root-knot nematode, *M. incognita* in present investigation (Table-2).

3. Population fluctuation of root-knot nematode, *M. incognita* on cucumber in Poly house:

Studies on population fluctuations of root-knot nematode, *M. incognita* on cucumber was carried out in poly house at different locations during 2016 and 2017. Population fluctuations of root-knot nematode, *M. incognita* was monitored at fifteen days interval throughout the crop season up to 120 days on cucumber under protected cultivation. Observations on number of galls/5g roots, number of egg masses /5g roots, number of eggs & larvae/egg mass and number

Table-3: Population fluctuation of root-knot nematode, *M. incognita* on cucumber at different time interval in poly-house

Days after Sowing	Galls/ 5 g roots			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Final nematode larvae / 100 cc soil		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
15	2.20	3.00	2.60	0.00	0.00	0.00	0.00	0.00	0.00	1350.60	1345.20	1347.90
30	5.00	7.20	6.10	3.20	4.60	3.90	313.60	321.20	317.40	1540.20	1556.60	1548.40
45	19.60	22.80	21.20	14.40	16.40	15.40	304.20	307.80	306.00	1667.80	1672.40	1670.10
60	26.40	28.60	27.50	21.80	22.40	21.10	282.80	285.60	284.20	1720.20	1734.40	1727.30
75	38.80	41.20	40.00	30.40	33.20	31.80	277.20	278.40	277.80	1885.40	1876.80	1881.10
90	44.20	48.40	46.30	37.60	39.60	38.60	270.60	274.20	272.40	1956.60	1965.20	1960.90
105	58.40	59.60	59.00	45.20	48.40	46.80	267.80	270.40	269.10	2032.80	2043.40	2038.10
120	72.80	75.20	74.00	64.80	62.60	63.70	262.60	265.80	264.20	2245.20	2268.60	2256.90
SEm ±	1.782	2.041	1.911	1.297	1.523	1.410	13.501	15.560	14.530	68.502	67.420	67.961
CD at 5%	5.161	5.912	5.536	3.759	4.413	4.086	39.111	45.076	42.093	198.443	195.309	196.876

Data are the average value of five replications

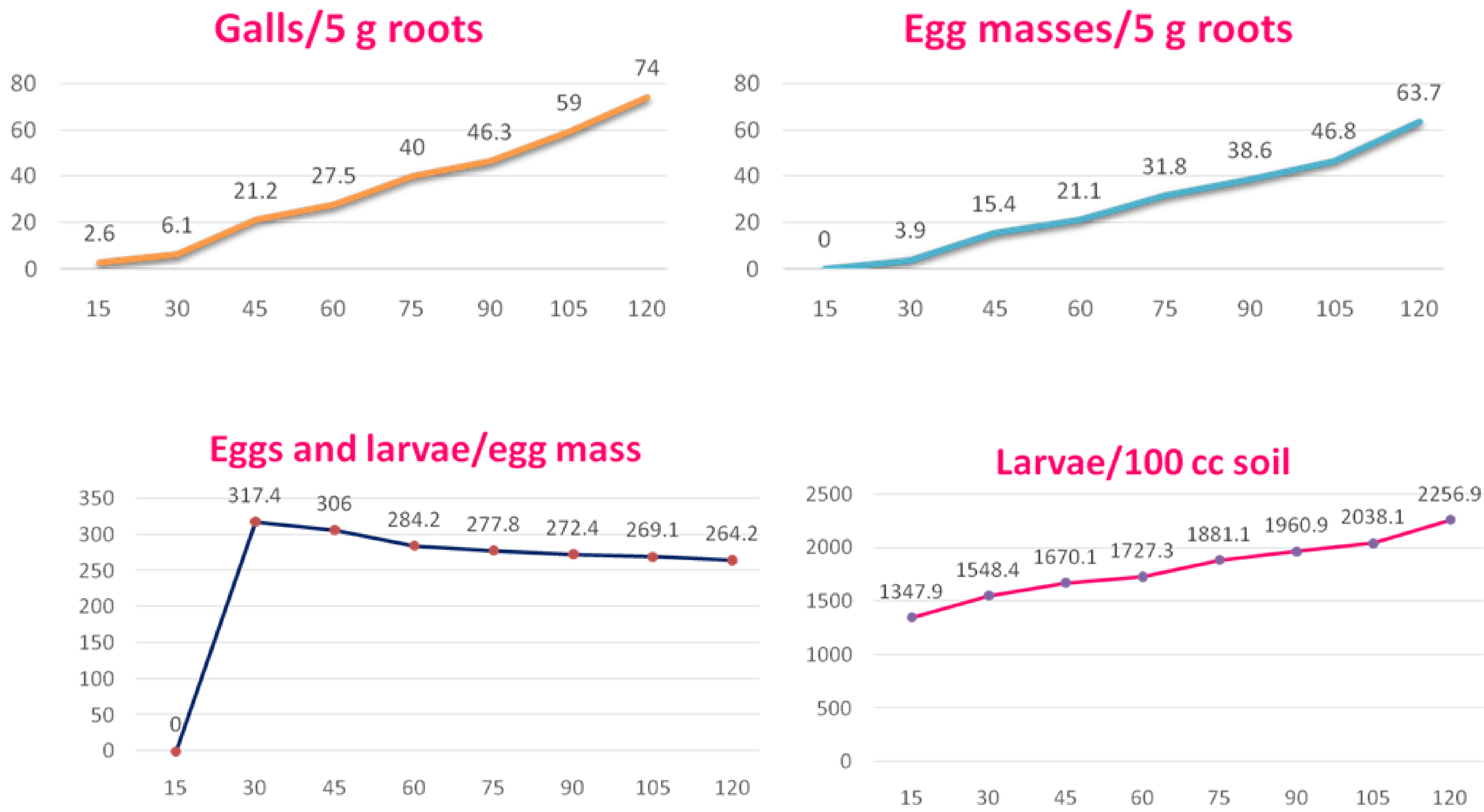

Figure 2: Population fluctuation of root-knot nematode, *M. incognita* on cucumber at different time interval in poly-house

Plate 10 : Effect of population fluctuation of *M. incognita* infecting cucumber in poly-house

of larvae/100 cc soil were recorded during investigation. Results were analysed, presented in Table 3 and illustrated through Fig.-2 and Plate-10.

I. Number of galls per 5g roots:

Results showed that number of galls increased with the increase of crop time. Results of pool analysis (2016 and 2017) revealed that minimum galls (2.60 galls/5g root) on cucumber was found at 15 days after sowing followed by 30 (6.10) and 45 (21.20) days of sowing. The number of galls was found significantly higher at 120 days after sowing (74.00 galls/5g roots) over rest of time interval of crop growth.

II. Number of egg masses per 5g roots:

Experimental findings showed that number of egg masses per 5g roots differed significantly at different time interval of cucumber growth. Results revealed that no egg mass of root-knot nematode was observed at 15 days of sowing of cucumber. Minimum 3.90 egg masses/5 g roots were obtained at 30 days after sowing of cucumbers under protected cultivation. It was also observed 15.40 and 21.10 egg masses/5 g roots at 45 and 60 days of sowing, respectively. Maximum 63.70 egg masses/5 g roots were recorded at 120 days after sowing of cucumber in protected cultivation (Fig.-2).

III. Number of eggs and larvae per egg mass:

In the experimental results maximum 317.40 eggs & larvae per egg mass was observed at 30 days followed by 45 (306.00) and 60 (284.20) days of sowing of cucumber under protected cultivation (Fig.-2). These time intervals found at par with each other with respect to eggs & larvae per egg mass. Minimum 264.20 eggs & larvae per egg mass were obtained at 120 days after sowing. Results showed that number of eggs & larvae per egg mass decreased with the increase of crop growth.

IV. Final nematode population per 100cc soil:

Results exhibited that final nematode population increase gradually with the increase of cucumber growth. Results showed that final nematode population recorded maximum (2256.90 per 100 cc soil) in cucumber under protected cultivation at 120 days of sowing followed by 105 (2038.10) and 90 (1960.90) days of sowing. It was obtained minimum (1347.90 larvae per 100 cc soil) at 15 days of sowing cucumber in poly-house and differed significantly over rest of time period (Fig-2).

4. Effect of hot water treatment on root-knot nematode, *M. incognita* infecting cucumber in poly-house:-

Hot water treatment is a very effective and low cost physical method of nematode management. Looking to the importance of physical method of nematode management, 0.5,1.0, 1.5 litre of hot water was used in poly bags filled with nematode infested soil having an initial inoculum of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. After treatment, poly bags were kept for 15 days as such for maturation of soil and then sowing was made to find out the effect on nematode multiplication and crop growth parameters under poly house. Observations on number of galls/5g roots, egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield kg/plant were recorded and presented in Table 4-5 and illustrated with Fig. 3-4 and Plate-11.

I. Number of galls per 5g roots:

Results revealed that application of hot water as soil treatment was found effective and significantly decrease number of galls produced by *M. incognita* on cucumber. It has been observed that the treatment with hot water at 1.5 litre /poly bag produced minimum 12.79 galls/5g roots on cucumber followed by 15.57 and 21.93 galls/5g roots with 1.0 and 0.5 litre of hot water, respectively under protected cultivation. These treatments significantly decreased galls over untreated check. Maximum 61.14 galls/5g roots were found in untreated check (Pooled 2016 and 2017) and it was significantly higher over rest of the treatments.

With the application of hot water at 1.5 litre / polybag, a 79.08 per cent galls reduction was noticed on cucumber under protected cultivation followed by 74.54 and 64.14 per cent reduction with 1.0 and 0.5 litre of hot water, respectively.

II. Number of egg masses per 5g roots:

Results of pool analysis showed that hot water treatment significantly decreased egg masses of *M. incognita* on cucumber under protected cultivation over check. It has been observed that minimum egg masses (9.00 per 5g roots) were recorded with hot water at 1.5 litre per poly bag followed by 1.0 (11.86) and 0.5 (16.93) litre of hot water treatment. Maximum egg masses per 5 g roots (46.28) produced on cucumber in untreated check. Maximum reduction in egg masses/5g roots (80.55%) was noticed with hot water treatment at 1.5 litre/polybag followed by 1.0 (74.34) and 0.5 (63.42) litre of hot water /poly bag.

Table-4: Effect of hot water treatment on root-knot nematode, *M. incognita* infecting cucumber in poly-house

Treatments	Galls/ 5 g root			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Final Nematode population/100 cc soil			Vine length (m)			Vine weight (kg)			Yield (kg/plant)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Hot Water at 0.5 litre/poly bag (T_1)	22.57	21.29	21.93	17.29	16.57	16.93	233.86	228.29	231.07	1261.86	1246.14	1254.00	2.097	2.177	2.137	0.479	0.485	0.482	1.850	1.844	1.847
Hot Water at 1.0 litre/poly bag (T_2)	16.57	14.57	15.57	12.86	10.86	11.86	220.71	214.86	217.78	806.29	798.86	802.57	2.619	2.719	2.669	0.592	0.578	0.585	2.402	2.420	2.411
Hot Water at 1.5 litre/poly bag (T_3)	12.29	13.29	12.79	09.43	8.57	9.00	209.00	211.57	210.28	622.14	658.57	640.35	3.207	3.257	3.232	0.641	0.648	0.644	3.205	3.185	3.195
Check (T_4)	62.43	59.86	61.14	48.57	44.00	46.28	247.29	252.00	249.64	1770.71	1780.00	1775.35	1.251	1.241	1.246	0.380	0.390	0.385	1.150	1.120	1.135
SEm ±	1.577	1.347	1.460	1.177	1.275	1.226	8.849	6.582	7.715	38.317	17.272	27.794	0.069	0.064	0.066	0.021	0.014	0.017	0.045	0.035	0.040
CD at 5%	4.687	4.001	4.344	3.496	3.788	3.642	26.290	19.555	22.922	113.846	51.319	82.582	0.204	0.190	0.197	0.064	0.040	0.052	0.133	0.105	0.119

Data are the average value of seven replications

Table-5: Influence of plant growth and nematode reproduction with the application of hot water treatment on root-knot nematode, *M. incognita* on cucumber under poly-house

Treatments	Per cent decrease over control												Per cent increase over control								
	Galls/5 g root			Egg masses/5 g roots			Eggs and larvae/egg mass			Final Nematode population/100 cc soil			Vine length			Vine weight			Yield/plant		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Hot Water at 0.5 litre/poly bag (T_1)	63.85	64.45	64.14	64.41	62.34	63.42	5.43	9.52	7.49	28.74	29.99	29.36	67.64	75.58	71.61	26.02	24.47	25.24	60.83	64.63	62.73
Hot Water at 1.0 litre/poly bag (T_2)	73.46	75.67	74.54	73.53	75.25	74.34	10.75	15.07	12.93	54.47	55.11	54.79	109.32	119.24	114.28	55.79	48.32	52.05	108.91	116.08	112.49
Hot Water at 1.5 litre/poly bag (T_3)	80.32	77.80	79.08	80.59	80.52	80.55	15.48	16.26	15.87	64.86	63.00	63.93	156.37	162.67	159.52	68.76	66.19	67.47	178.67	184.39	181.53
Check (T_4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

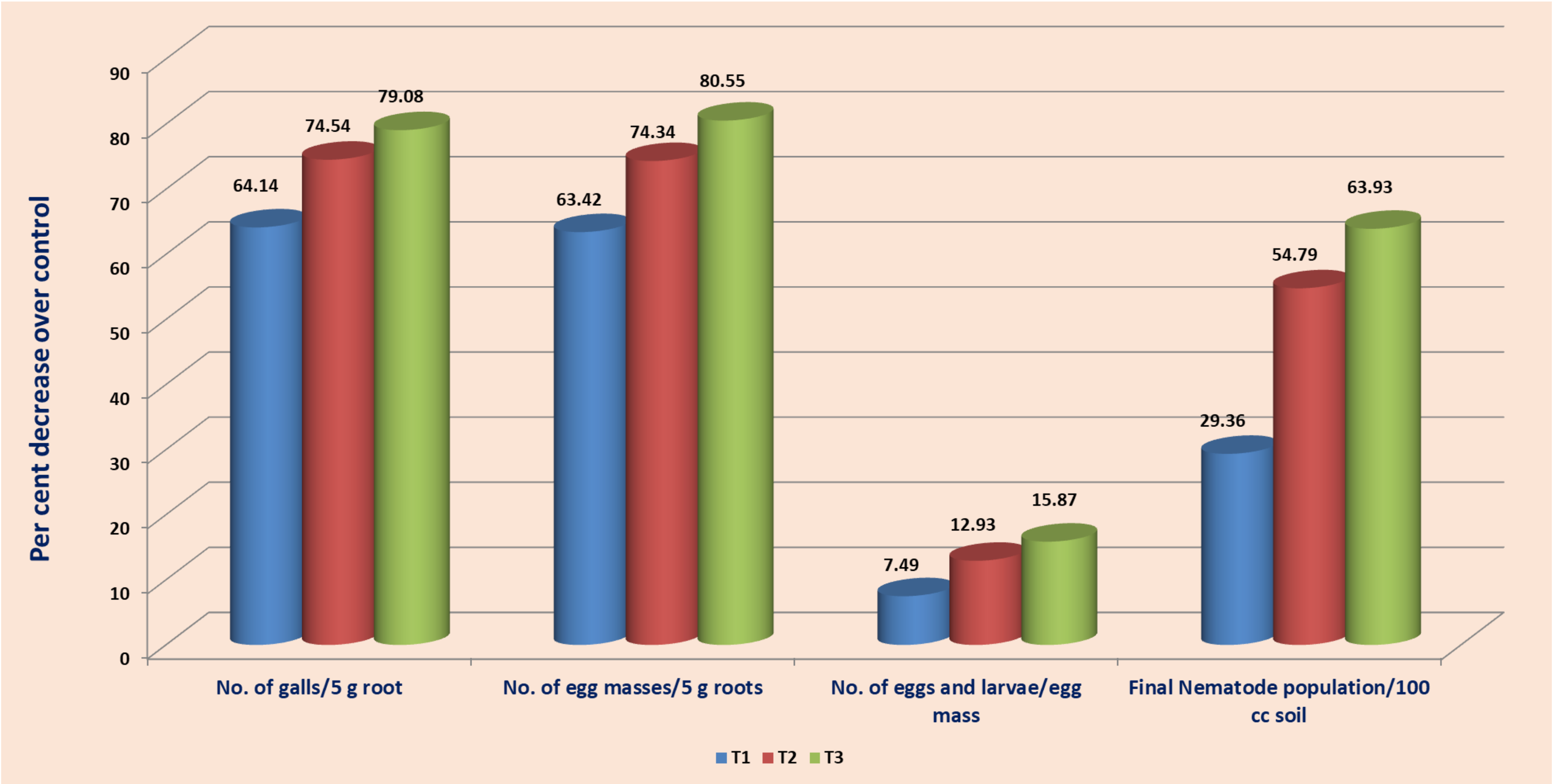

Figure 3: Influence of nematode reproduction with the application of hot water on *M. incognita* infecting cucumber in poly-house

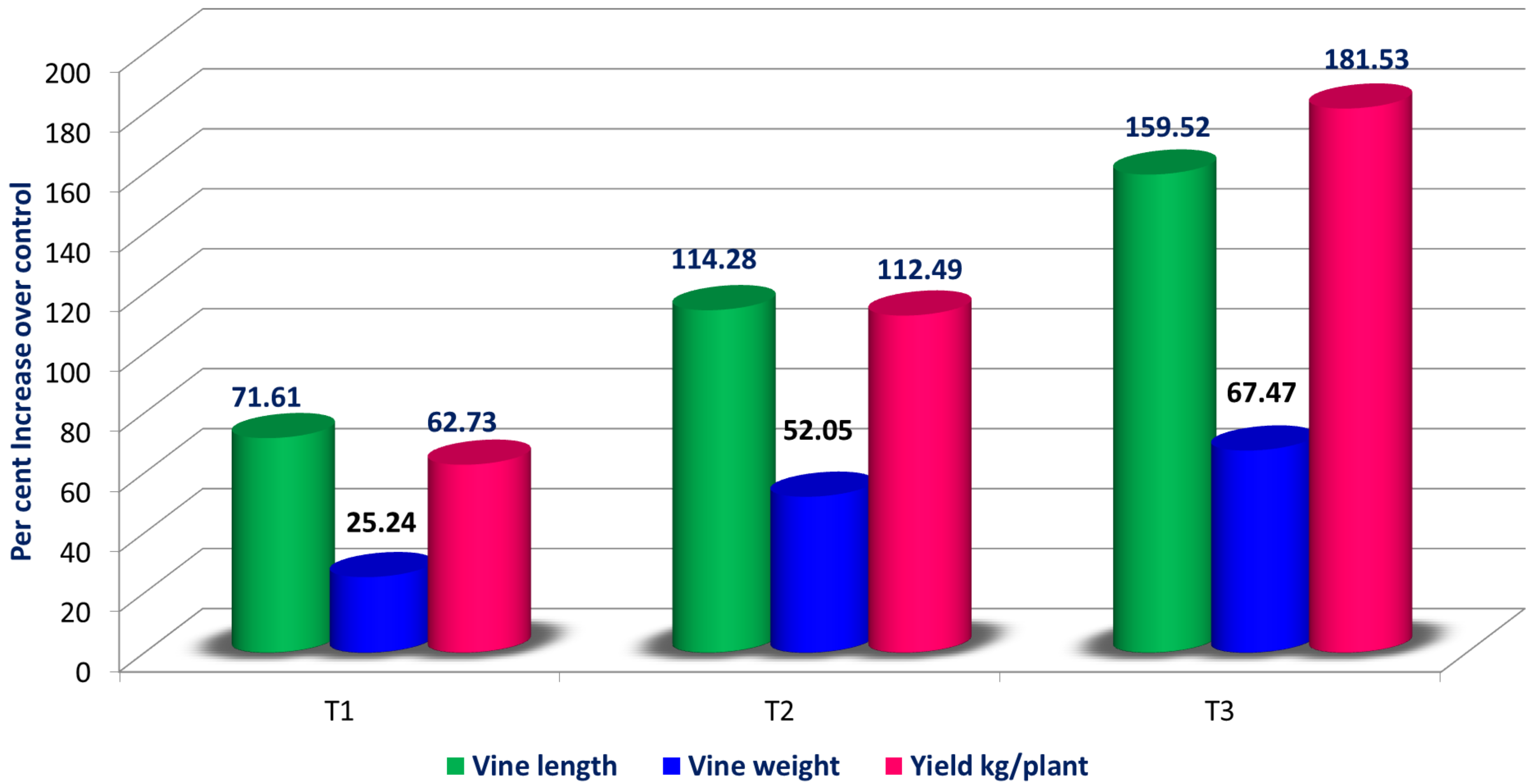

Figure 4: Influence of plant growth of cucumber with the application of hot water treatment on *M. incognita* under poly-house

III. Number of eggs and larvae per egg mass:

Results exhibited that minimum (210.28) eggs & larvae per egg mass was found with hot water treatment at 1.5 litre per poly bag followed by 1.0 (217.78) and 0.5 (231.07) litre of hot water under protected cultivation. These treatments significantly reduced eggs and larvae per egg mass over untreated check. Maximum (249.64) eggs and larvae per egg mass found in untreated check (normal water). Results illustrated in Fig.-3 showed that maximum (15.87 %) reduction in egg mass contents was found when hot water was applied at 1.5 litre/ poly bag. Reduction was observed 12.93 and 7.49 % in the hot water treatment when applied at 1.0 and 0.5 litre/poly bag.

IV. Final nematode population per 100 cc soil:

All the treatments significantly reduced final nematode population as compared to untreated check. Results revealed that nematode population/100 cc soil at harvest decreases significantly with the application of hot water treatment. It was observed to be minimum (640.35) with the application of hot water at 1.5 litre per poly bag followed by 1.0 (802.57 larvae per 100 cc soil) and 0.5 (1254.00 larvae/100 cc soil) litre of hot water. These treatments significantly differ from each other. Maximum final nematode population was obtained in untreated check (1775.35 larvae per 100 cc soil). Results presented in Table-5 showed that all the treatments reduce nematode population in soil at crop harvest. However, maximum per cent reduction (63.93) in nematode population was registered with the application of hot water at 1.5 litre followed by 1.0 (54.79 %) and 0.5 (29.36 %) litre hot water /poly bag.

V. Vine length (m):

Results revealed that application of hot water found effective and significantly increased vine length of cucumber. Highest vine length (3.232 m) was obtained in 1.5 litre of hot water/ poly bag followed by 2.669 m (1.0 litre hot water/ poly bag) and 2.137 m (0.5 litre hot water/ poly bag) under protected cultivation in comparison to untreated check (1.246 m). All the treatments significantly increased vine length of cucumber over untreated check. Application of hot water at 1.5 litre per polybag exhibited 159.52 per cent increase in vine length of cucumber under protected cultivation. Minimum (71.61 %) increase in the vine length of cucumber observed with hot water treatment at 0.5 litre per polybag in protected cultivation over check.

VI. Vine weight (kg):

Results of pool analysis showed that hot water treatment significantly increased vine weight (kg) of cucumber under protected cultivation over untreated check. It has been noticed

Plate 11 : Effect of hot water treatment against *M. incognita* infecting cucumber in poly-house

that maximum vine weight (0.644 kg) was recorded with hot water at 1.5 litre per polybag followed by 1.0 (0.585 kg) and 0.5 (0.482 kg) litre of hot water treatment. Minimum vine weight (0.385 kg) of cucumber was obtained in the untreated check. Maximum enhance in vine weight (67.47 %) was noticed with hot water treatment at 1.5 litre/poly bag followed by 1.0 (52.05 %) and 0.5 (25.24 %) litre of hot water /poly bag.

VII. Yield (kg/plant):

All the treatments significantly increased yield of cucumber as compared to untreated check. Results of pool analysis (Table 4) showed that highest yield (3.195 kg/plant) was obtained with application of hot water 1.5 litre per poly bag followed by hot water 1.0 litre/polybag (2.411 kg/plant) and at 0.5 litre/polybag (1.847 kg/plant) as compared to untreated check (1.135 kg/plant). These treatments significantly differ from each other with respect to enhancing yield. Per cent yield increase over control was also calculated and presented in Table 5. Results exhibited that maximum (181.53 %) increase in yield was observed with the application of hot water at 1.5 litre per polybag followed by 112.49 and 62.73 % with hot water at 1.0 litre and 0.5 litre/poly bag, respectively.

5. Effect of organic amendments against root-knot nematode, *M. incognita* on cucumber in poly-house:-

Organic amendment plays an important role to improve physical, biological and chemical properties of soil which enhance plant growth of agri-horticultural crops and to reduce pest and soil pathogens including nematodes. Looking to the attributes of organic amendment tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder have been tested at 20 and 40 g/plant for the management of root-knot nematode, *M. incognita* on cucumber in poly house establish at farmer’s field. Neem cake at 50g/plant as standard check and untreated check was also maintained to compare the experimental results. Experiments were conducted in poly house having an initial nematode inoculum of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. The observations on number of galls/5g roots, egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield kg/plant were recorded and presented in Table 6-9 and illustrated with Fig. 5-6 and Plate 12.

I. Number of galls per 5g roots:

Results of pool analysis (2016 and 2017) revealed that number of galls per 5g roots significantly reduced with the organic amendment over untreated check. Among organic amendments, tobacco churi applied at 40g/plant was found to produced minimum galls (34.80 / 5g roots) followed by tea waste at 40g/plant (36.00 galls/ 5g roots) and poultry manure at 40g/plant (38.00 galls/5g roots) as compared to untreated check (73.70 galls per 5g roots). Soil application of neem cake at 50 g/plant (33.20 galls per 5g roots) which was kept as standard check found superior and at par with tobacco churi at 40g/plant in reducing the no. of galls.

Results presented in Table 8 revealed that application of tobacco churi at 40g/plant reduced galls to the tune of 52.78 % whereas tea waste and poultry manure at 40 g/plant reduced galls 51.14 and 48.44 %, respectively over untreated check. Maximum reduction in galls per 5g roots (54.95 %) was noticed with the application of neem cake at 50 g/plant.

II. Number of egg masses per 5g roots:

Results showed that egg masses of root-knot nematode, *M. incognita* significantly reduced on cucumber with the application of organic amendment as compared to untreated check. Among organic amendments, minimum number of egg masses per 5g roots (27.00) were obtained with the application of tobacco churi at 40g/plant followed by tea waste at 40g/plant (28.40) and poultry manure at 40 g/plant (29.90) as compared to untreated check (62.80). Minimum egg masses/5 g roots were obtained in neem cake at 50 g/plant (26.00) on cucumber. It was found at par with tobacco churi at 40 g/plant. Experimental results exhibited that soil amendment with tobacco churi at 40 g/plant decrease egg masses to the tune of 56.94% over untreated check followed by tea waste (54.71 %) and poultry manure (52.36 %) at 40 g/plant. Maximum reduction (58.54 %) in egg masses per 5 g roots was obtained with the application of neem cake at 50 g/plant.

III. Number of eggs and larvae per egg mass:

Experimental findings showed that contents of egg masses on cucumber significantly reduced with the organic amendments over untreated check. Among different organic amendments, minimum eggs and larvae per egg mass (189.00) was observed in tobacco churi when applied at 40 g/plant followed by tea waste (189.50) and poultry manure at 40 g/plant (196.50) over untreated check (251.00). On the whole, minimum eggs and larvae per egg mass

Table-6: Effect of organic amendment against root-knot nematode, *M. incognita* on cucumber in poly-house

Treatments		Galls/5 g root			Egg masses/5 g roots			Eggs and larvae/egg mass			Final Nematode population/100 cc soil		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Tea waste at 20 g/plant	43.20	44.00	43.60	37.40	38.60	38.00	219.00	213.40	216.20	735.80	728.40	732.10
T_2	Tea waste at 40 g/plant	35.80	36.20	36.00	28.00	28.80	28.40	191.00	188.00	189.50	667.80	672.20	670.00
T_3	Tobacco churi at 20 g/plant	41.00	42.60	41.80	35.40	36.80	36.10	211.80	214.80	213.30	721.80	734.80	728.30
T_4	Tobacco churi at 40 g/plant	34.20	35.40	34.80	26.40	27.60	27.00	186.00	192.00	189.00	660.00	666.60	663.30
T_5	Poultry manure at 20 g/plant	45.20	46.20	45.70	39.20	40.00	39.60	224.80	221.60	223.20	770.00	764.20	767.10
T_6	Poultry manure at 40 g/plant	37.40	38.60	38.00	30.20	29.60	29.90	198.80	194.20	196.50	682.20	686.80	684.50
T_7	Water hyacinth powder at 20 g/plant	47.20	48.00	47.60	40.60	41.40	41.00	222.00	225.20	223.60	788.00	794.40	791.20
T_8	Water hyacinth powder at 40 g/plant	38.80	39.40	39.10	32.20	31.60	31.90	202.00	205.00	203.50	694.00	698.60	696.30
T_9	Lantana leaf powder at 20 g/plant	48.20	49.80	49.00	41.00	42.80	41.90	232.00	234.20	233.10	804.00	807.20	805.60
T_{10}	Lantana leaf powder at 40 g/plant	39.00	41.80	40.40	34.40	35.80	35.10	207.60	209.80	208.70	707.60	702.80	705.20
T_{11}	Neem cake at 50 g/plant	32.80	33.60	33.20	25.60	26.40	26.00	181.60	175.60	178.60	651.80	644.40	648.10
T_{12}	Check	72.80	74.60	73.70	64.80	60.80	62.80	246.00	256.00	251.00	1885.00	1893.60	1889.30
SEm ±		2.116	2.029	2.072	2.078	2.046	2.062	11.230	11.210	11.22	32.566	32.080	32.323
CD at 5%		6.030	5.783	5.906	5.924	5.830	5.877	32.009	31.952	31.980	92.819	91.434	92.126

Data are the average value of five replications

Table-7: Effect of organic amendment on plant growth of cucumber infected with root-knot nematode, *M. incognita* in poly-house

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Tea waste at 20 g/plant	2.536	2.496	2.516	0.675	0.678	0.676	2.600	2.552	2.576
T_2	Tea waste at 40 g/plant	2.908	2.938	2.923	0.771	0.768	0.769	3.050	3.070	3.060
T_3	Tobacco churi at 20 g/plant	2.670	2.640	2.655	0.680	0.685	0.682	2.660	2.638	2.649
T_4	Tobacco churi at 40 g/plant	2.960	2.990	2.975	0.776	0.771	0.773	3.150	3.210	3.180
T_5	Poultry manure at 20 g/plant	2.532	2.482	2.507	0.651	0.647	0.649	2.424	2.408	2.416
T_6	Poultry manure at 40 g/plant	2.828	2.858	2.843	0.746	0.741	0.743	2.920	2.860	2.890
T_7	Water hyacinth powder at 20 g/plant	2.468	2.418	2.443	0.631	0.626	0.628	2.338	2.316	2.327
T_8	Water hyacinth powder at 40 g/plant	2.768	2.738	2.753	0.715	0.720	0.717	2.850	2.812	2.831
T_9	Lantana leaf powder at 20 g/plant	2.328	2.286	2.307	0.591	0.596	0.593	2.178	2.080	2.129
T_{10}	Lantana leaf powder at 40 g/plant	2.720	2.700	2.710	0.694	0.699	0.696	2.755	2.710	2.732
T_{11}	Neem cake at 50 g/plant	3.024	3.054	3.039	0.779	0.783	0.781	3.405	3.375	3.390
T_{12}	Check	1.410	1.370	1.390	0.369	0.374	0.371	1.228	1.202	1.215
SEm ±		0.085	0.088	0.086	0.025	0.015	0.020	0.079	0.059	0.069
CD at 5%		0.241	0.251	0.246	0.070	0.044	0.057	0.225	0.167	0.196

Data are the average value of five replications

Table-8 : Changes in reproduction parameters of root-knot nematode, *M. incognita* on cucumber under poly-house through organic amendment

Treatments		Galls/ 5 g root*			Egg masses/ 5 g roots*			Eggs and larvae/ egg mass*			Final Nematode population/100 cc soil*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Tea waste at 20 g/plant	40.66	41.02	40.84	42.28	36.51	39.40	10.98	16.64	13.81	60.97	61.53	61.25
T_2	Tea waste at 40 g/plant	50.82	51.47	51.14	56.79	52.63	54.71	22.36	26.56	24.46	64.57	64.50	64.54
T_3	Tobacco churi at 20 g/plant	43.68	42.90	43.29	45.37	39.47	42.42	13.90	16.09	15.00	61.71	61.20	61.46
T_4	Tobacco churi at 40 g/plant	53.02	52.55	52.78	59.26	54.61	56.94	24.39	25.00	24.70	64.99	64.80	64.90
T_5	Poultry manure at 20 g/plant	37.91	38.07	37.99	39.51	34.21	36.86	9.76	12.03	10.90	59.15	59.64	59.40
T_6	Poultry manure at 40 g/plant	48.63	48.26	48.44	53.40	51.32	52.36	19.19	24.14	21.67	63.82	63.73	63.78
T_7	Water hyacinth powder at 20 g/plant	35.16	35.66	35.41	37.35	31.91	34.63	8.62	13.44	11.03	58.20	58.05	58.13
T_8	Water hyacinth powder at 40 g/plant	46.70	47.18	46.94	50.31	48.03	49.17	17.89	19.92	18.91	63.18	63.11	63.15
T_9	Lantana leaf powder at 20 g/plant	33.79	33.24	33.51	36.73	29.61	33.17	5.69	8.52	7.11	57.35	57.37	57.36
T_{10}	Lantana leaf powder at 40 g/plant	46.43	43.97	45.20	46.91	41.12	44.02	15.61	18.05	16.83	62.46	62.89	62.68
T_{11}	Neem cake at 50 g/plant	54.95	54.96	54.95	60.49	56.58	58.54	26.18	31.41	28.80	65.42	65.97	65.70
T_{12}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table-9: Changes in plant growth parameters of cucumber under poly-house infested with *M. incognita* through organic amendment

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Tea waste at 20 g/plant	79.86	82.19	81.03	82.74	81.00	82.09	111.73	112.14	111.93
T_2	Tea waste at 40 g/plant	106.24	114.45	110.35	108.66	104.96	107.13	148.37	155.40	151.85
T_3	Tobacco churi at 20 g/plant	89.36	92.70	91.03	83.98	82.66	83.71	116.61	119.46	118.02
T_4	Tobacco churi at 40 g/plant	109.93	118.25	114.09	109.90	105.76	108.20	156.51	167.05	161.72
T_5	Poultry manure at 20 g/plant	79.57	81.17	80.37	76.14	72.68	74.69	97.39	100.33	98.84
T_6	Poultry manure at 40 g/plant	100.57	108.75	104.66	101.95	97.81	100.13	137.80	137.93	137.86
T_7	Water hyacinth powder at 20 g/plant	75.04	76.50	75.77	70.83	67.13	69.17	90.39	92.67	91.52
T_8	Water hyacinth powder at 40 g/plant	96.31	99.85	98.08	93.56	92.00	93.13	132.08	133.94	133.00
T_9	Lantana leaf powder at 20 g/plant	65.11	66.86	65.99	60.01	58.96	59.75	77.35	73.04	75.22
T_{10}	Lantana leaf powder at 40 g/plant	92.91	97.08	95.00	87.82	86.39	87.48	124.32	125.45	124.89
T_{11}	Neem cake at 50 g/plant	114.47	122.92	118.70	110.77	109.02	110.22	177.26	180.78	179.01
T_{12}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

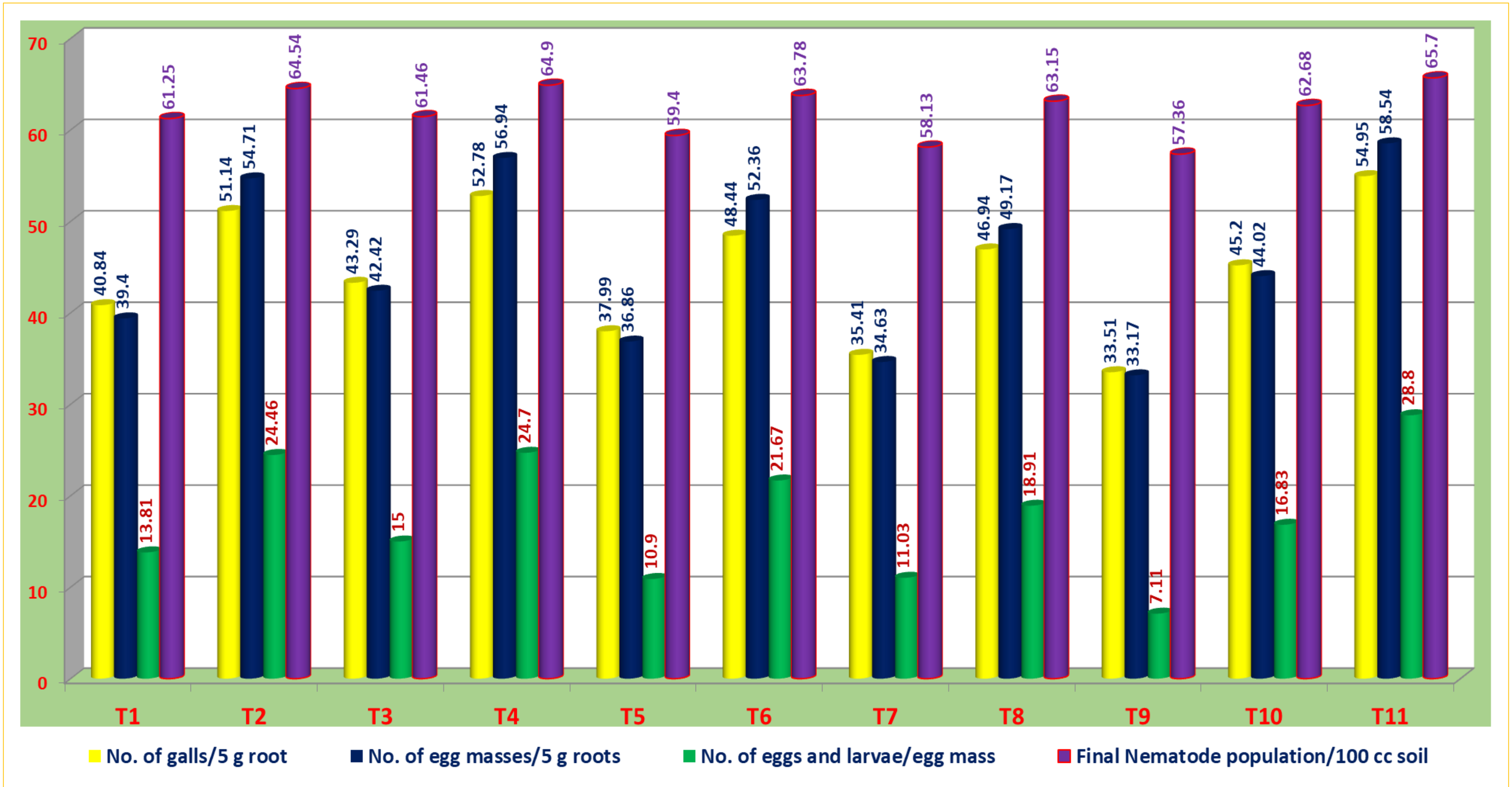

Figure 5: Changes in reproduction parameters of root-knot nematode, *M. incognita* on cucumber under poly-house through organic amendment

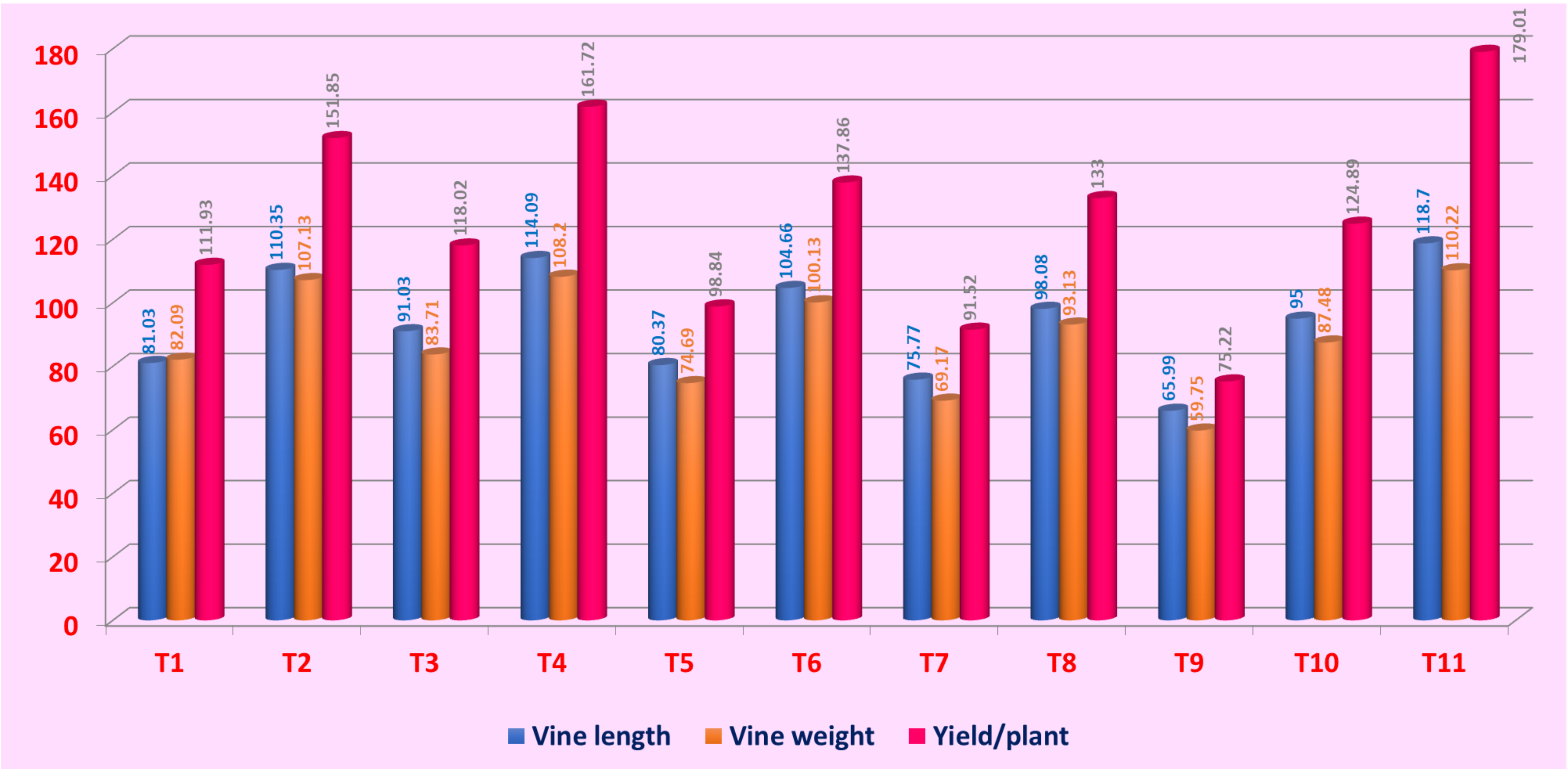

Figure 6: Changes in plant growth parameters of cucumber under poly-house infested with *M. incognita* through organic amendment

(178.60) were obtained with soil application of neem cake at 50 g/plant. All the treatments significantly reduced eggs mass contents over untreated check.

Results showed that application of tobacco churi at 40 g/plant reduced egg mass contents to the tune of 24.70%, whereas, it was 24.46 and 21.67 % with tea waste and poultry manure at 40 g/plant, respectively over untreated check. Maximum reduction in egg mass contents (28.80 %) was noted with the application of neem cake at 50 g/plant (Fig.5).

IV. Final nematode population per 100 cc soil:

Results presented in Table-6 revealed that final soil population of root-knot nematode decrease significantly when treated with the organic amendments over untreated check. Among organic amendments, minimum nematode population (663.30) was recorded with the application of tobacco churi at 40 g/plant followed by tea waste (670.00) and poultry manure (684.50) at 40 g/plant as compared to untreated check (1889.30). These treatments were found at par with each other. However, soil application of neem cake at 50 g/plant was found to be the best with respect to reducing final soil population of nematode (648.10) and was at par with tobacco churi at 40 g/plant. All the treatments significantly decreased final nematode population over check.

Soil amendment with tobacco churi at 40 g/plant decreased final nematode population /100cc soil to the tune of 64.90 % over untreated check. It was observed 64.54 % with tea waste and 63.78 % with poultry manure at 40 g/plant. Highest reduction (65.70 %) in final nematode population was noticed with application of neem cake at 50 g/plant.

V. Vine length (m):

All the treatments significantly increased vine length over untreated check. Results exhibited that maximum 2.975 meter vine length of cucumber in protected cultivation was recorded with tobacco churi at 40 g/plant followed by 2.923 and 2.843 m. vine length observed with tea waste and poultry manure at 40 g/plant, respectively. Minimum vine length (1.390 m) was noticed in untreated check. Among all the treatments, neem cake at 50 g/ plant (3.039 m.) give better response to increase vine length of cucumber over other treatments.

Results illustrated in Fig. 6 revealed that maximum (114.09 %) increase in vine length was found when tobacco churi was applied at 40 g per plant followed by tea waste (110.35 %) and poultry manure at 40 g/plant (104.66 %) in comparison to untreated check. Highest increase in vine length was recorded with application of neem cake at 40 g/plant.

Plate 12 : Effect of organic amendments on plant growth of cucumber infested with *M. incognita* in poly-house

VI. Vine weight (kg):

Statistical analysis showed that all the treatments significantly increased vine weight over untreated check. Experimental results revealed that application of organic amendments found effective and increase vine weight of cucumber infected with *M. incognita*. Vine weight 0.773 kg of cucumber was observed with the application of tobacco churi at 40 g/plant followed by 0.769 and 0.743 kg with tea waste and poultry manure at 40 g/plant, respectively in protected cultivation as compared to untreated check (0.371 kg). Neem cake was found at par with tobacco churi. The application of tobacco churi at the rate of 40 g / plant increase vine weight 108.20% of cucumber under protected cultivation followed by 107.13 and 100.13% with tea waste and poultry manure at 40 g/plant, respectively.

VII. Yield (kg/plant):

Yield of cucumber was significantly increased with the organic amendment treatments over untreated check in root-knot nematode infested cucumber in poly house. Among treatments, maximum yield (3.180 kg/plant) was obtained with the application of tobacco churi at 40 g/plant followed by tea waste (3.060 kg/plant) and poultry manure (2.890 kg/plant) at the rate 40 g per plant as compared to untreated check (1.215 kg/plant). Among all the treatments, highest yield (3.390 kg/plant) was recorded with soil application of neem cake at 50 g/plant. It was observed that all the treatments significantly enhanced yield of cucumber over untreated check. Per cent yield increase over control was also calculated with the application of various treatments to interpretate the experimental findings. It was registered highest when tobacco churi was applied at 40 g/plant (161.72 %), followed by tea waste (151.85 %) and poultry manure (137.86 %) at 40 g/plant over untreated check (Fig. 6). However, highest increase in yield of cucumber was recorded with application of neem cake at 50 g/plant which was kept as standard check.

On the whole, soil amendment with tobacco churi at 40 g/plant was observed superior for the management of root-knot nematode and proved most effective to enhance yield of cucumber under protected cultivation.

6. Efficacy of bio-agents on root-knot nematode, *M. incognita* infecting cucumber in poly-house:-

Biological nematode management in relation to crop production system is a subject of considerable current interest, because of a perceived urgency to develop and adopt environmentally safe, economic and efficient method for managing nematodes in agri-horticultural crops. Looking to the importance of bio-agents in present scenario, an experimental trial was carried out to test the efficacy of bio-agents *i.e. Trichoderma harzianum*, *Pochonia chlamydosporia*, *Pseudomonas fluorescens, Paecilomyces lilacinus* (now known as *Purpureocillium lilacinum*) and *Glomus fasiculatum* for the management of *M. incognita* on cucumber during 2016 and 2017. Bio-agents were applied at 2.5 and 5.0 g/plant. Bio-agent, *Trichoderma viride* applied at 5.0 g/plant as standard check and untreated check was also maintained to compare results. The experiment was conducted in poly house having an initial inoculum of 1350 and 1360 larvae/100 cc soil during 2016 & 2017, respectively. The observations on number of galls/5g roots, egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield (kg/plant) were recorded. Data were analyzed to interpretate research findings and presented in Table 10-13 and illustrated through Fig. 7-8 and Plate 13.

I. Number of galls per 5 g roots:

Pool analysis of results exhibited that all bio-agents significantly reduced galls over untreated check. Data presented (Table-10) revealed that number of galls per 5 g roots significantly decreased on cucumber in protected cultivation with the application of bio-agents. Among bio-agents, minimum number of galls per 5 g roots (33.10) were obtained with *Pacilomyces lilacinus* at 5.0 g/plant followed by *Trichoderma harzianum* (37.10) and *Pseudomonas fluorescens* (38.80) over untreated check (76.70). Among treatments, maximum number of galls per 5g roots (47.80) were observed with *Glomus fasiculatum* at 2.5 g/plant and differed significantly with check. However, *Trichoderma viride* at 5 g /plant (30.20) was found to be the best among bio-agents which was kept as standard check.

Experimental findings (Table-12) showed that *P. lilacinus* (5.0 g/plant) reduced galls to the tune of 56.85 % while in *T. harzianum* (5.0 g/plant) it was observed to be 51.63 % over untreated check on cucumber under protected cultivation. Maximum reduction in galls (60.63 %) was recorded with *T. viride* at 5 g/plant. *Glomus fasiculatum* at 2.5 g/plant (37.68%) was found least effective with regards to galls/5g roots.

II. Number of egg masses per plant:

Experimental results presented in Table 10 indicated that all the treatments were found significantly superior over untreated check to reduce egg mass formation by root-knot nematode, *M. incognita* on cucumber in poly-house. Among bio-agents tested, *P. lilacinus* at 5.0 g/plant

Table-10: Efficacy of bio-agents on root-knot nematode, *M. incognita* infecting cucumber in poly-house

	Treatments	Galls/5 g root			Egg masses/5 g roots			Eggs and larvae/egg mass			Final Nematode population/100 cc soil		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	42.80	43.40	43.10	33.40	34.80	34.10	205.60	202.40	204.00	715.80	712.40	714.10
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	32.60	33.60	33.10	27.80	26.60	27.20	183.00	179.80	181.40	669.60	665.20	667.40
T_3	*Trichoderma harzianum* at 2.5 g/plant	43.80	45.60	44.70	35.80	37.00	36.40	208.80	210.60	209.70	737.40	739.80	738.60
T_4	*Trichoderma harzianum* at 5.0 g/plant	36.80	37.40	37.10	28.20	28.80	28.50	187.40	189.00	188.20	683.40	685.60	684.50
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	45.60	47.80	46.70	38.00	39.20	38.60	215.80	218.20	217.00	773.20	771.80	772.50
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	39.80	40.60	40.20	30.20	31.20	30.70	193.80	191.80	192.80	693.80	688.20	691.00
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	44.60	46.40	45.50	37.20	38.80	38.00	211.80	210.60	211.20	757.00	752.60	754.80
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	38.20	39.40	38.80	29.60	29.40	29.50	189.60	193.80	191.70	688.60	684.60	686.60
T_9	*Glomus fasiculatum* at 2.5 g/plant	47.40	48.20	47.80	39.40	40.20	39.80	221.40	224.20	222.80	795.80	791.80	793.80
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	40.20	41.60	40.90	32.80	31.20	32.00	198.60	201.60	200.10	703.20	698.40	700.80
T_{11}	*Trichoderma viride* at 5.0 g/plant	29.80	30.60	30.20	25.60	27.40	26.50	178.80	175.40	177.10	658.60	652.20	655.40
T_{12}	Check	76.20	77.20	76.70	58.00	61.00	59.50	242.60	246.20	244.40	1941.00	1947.60	1944.30
	SEm ±	2.151	2.140	2.145	1.894	1.888	1.891	6.010	5.220	5.615	16.603	6.993	11.798
	CD at 5%	6.131	6.100	6.115	5.398	5.381	5.389	17.129	14.877	16.003	47.320	19.930	33.625

Data are the average value of five replications

Table-11: Efficacy of bio-agents on plant growth and yield of cucumber against root-knot nematode, *M. incognita* in poly-house

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	2.562	2.502	2.532	0.649	0.632	0.640	2.199	2.182	2.190
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	2.984	2.954	2.969	0.780	0.776	0.778	2.950	2.860	2.905
T_3	*Trichoderma harzianum* at 2.5 g/plant	2.510	2.550	2.530	0.624	0.645	0.634	2.102	2.220	2.161
T_4	*Trichoderma harzianum* at 5.0 g/plant	2.880	2.860	2.870	0.760	0.754	0.757	2.822	2.776	2.799
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	2.378	2.354	2.366	0.592	0.585	0.588	1.819	1.798	1.808
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	2.760	2.740	2.750	0.714	0.702	0.708	2.532	2.508	2.520
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	2.438	2.468	2.453	0.605	0.622	0.613	1.952	2.010	1.981
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	2.810	2.776	2.793	0.734	0.725	0.729	2.645	2.618	2.631
T_9	*Glomus fasiculatum* at 2.5 g/plant	2.250	2.208	2.229	0.574	0.568	0.571	1.738	1.702	1.720
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	2.664	2.688	2.676	0.692	0.699	0.695	2.399	2.426	2.412
T_{11}	*Trichoderma viride* at 5.0 g/plant	3.096	3.160	3.128	0.792	0.828	0.810	3.102	3.220	3.161
T_{12}	Check	1.280	1.298	1.289	0.352	0.364	0.358	1.178	1.085	1.131
	SEm ±	0.075	0.041	0.058	0.020	0.007	0.013	0.058	0.018	0.038
	CD at 5%	0.213	0.116	0.164	0.057	0.019	0.038	0.166	0.050	0.108

Data are the average value of five replications

Table-12: Changes in reproduction characters of root-knot nematode, *M. incognita* on cucumber in poly-house using bio-agents

Treatments		Galls/ 5 g root*			Egg masses/ 5 g roots*			Eggs and larvae/ egg mass*			Final Nematode population/100 cc soil*		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	43.83	43.78	43.81	42.41	42.95	42.69	15.25	17.79	16.53	63.12	63.42	63.27
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	57.22	56.48	56.85	52.07	56.39	54.29	24.57	26.97	25.78	65.50	65.85	65.67
T_3	*Trichoderma harzianum* at 2.5 g/plant	42.52	40.93	41.73	38.28	39.34	38.82	13.93	14.46	14.20	62.01	62.01	62.01
T_4	*Trichoderma harzianum* at 5.0 g/plant	51.71	51.55	51.63	51.38	52.79	52.08	22.75	23.23	23.00	64.79	64.80	64.79
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	40.16	38.08	39.12	34.48	35.74	35.13	11.05	11.37	11.21	60.16	60.37	60.27
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	47.77	47.41	47.59	47.93	48.85	48.40	20.12	22.10	21.11	64.26	64.66	64.46
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	41.47	39.90	40.69	35.86	36.39	36.13	12.70	14.46	13.58	61.00	61.36	61.18
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	49.87	48.96	49.42	48.97	51.80	50.42	21.85	21.28	21.56	64.52	64.85	64.69
T_9	*Glomus fasiculatum* at 2.5 g/plant	37.80	37.56	37.68	32.07	34.10	33.11	8.74	8.94	8.84	59.00	59.34	59.17
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	47.24	46.11	46.68	43.45	48.85	46.22	18.14	18.12	18.13	63.77	64.14	63.96
T_{11}	*Trichoderma viride* at 5.0 g/plant	60.89	60.36	60.63	55.86	55.08	55.46	26.30	28.76	27.54	66.07	66.51	66.29
T_{12}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table-13: Changes in plant growth characters of cucumber under poly-house infested with root-knot nematode, *M. incognita* using bio-agents

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	100.16	92.76	96.46	84.33	73.48	78.91	86.69	101.14	93.92
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	133.13	127.58	130.36	121.52	113.12	117.32	150.44	163.59	157.02
T_3	*Trichoderma harzianum* at 2.5 g/plant	96.09	96.46	96.28	77.17	76.99	77.08	78.42	104.63	91.53
T_4	*Trichoderma harzianum* at 5.0 g/plant	125.00	120.34	122.67	115.73	106.92	111.33	139.59	155.87	147.73
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	85.78	81.36	83.57	67.97	60.74	64.36	54.38	65.75	60.07
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	115.63	111.09	113.36	102.73	92.86	97.80	114.97	131.12	123.05
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	90.47	90.14	90.31	71.72	70.90	71.31	65.72	85.29	75.51
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	119.53	113.87	116.70	108.46	99.12	103.79	124.53	141.33	132.93
T_9	*Glomus fasiculatum* at 2.5 g/plant	75.78	70.11	72.95	62.98	55.85	59.42	47.57	56.90	52.24
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	108.13	107.09	107.61	96.59	91.98	94.29	103.65	123.61	113.63
T_{11}	*Trichoderma viride* at 5.0 g/plant	141.88	143.45	142.67	124.87	127.46	126.17	163.29	196.74	180.02
T_{12}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

(27.20) proved to be most effective followed by *T. harzianum* (28.50) and *P. fluorescens* at 5.0 g/plant (29.50) as compared to untreated check (59.50). Among all the treatments, *T. viride* at 5 g/plant (26.50) was found better over rest of bio-agents (treated check). Bio-agent, *Glomus fasiculatum* at 2.5 g/plant was found least effective with regards to egg mass formation by root-knot nematode, *M. incognita* on cucumber.

It was observed that soil treatment with *P. lilacinus* at 5.0 g/plant reduced egg masses to the tune of 54.29 % whereas with *T. harzianum* at 5.0 g/plant, it was recorded 52.08 % over untreated check (Fig. 7). Maximum reduction in egg masses /5 g roots were obtained with *T. viride* at 5 g/plant (55.46 %) and minimum with *Glomus fasiculatum* at 2.5 g/plant.

III. Number of eggs and larvae per egg mass:

Results revealed that bio-agents significantly decreased egg mass content over untreted check. Minimum egg mass contents (181.40) were recorded at 5.0 g/plant dose of *P. lilacinus* followed by *T. harzianum* (188.20) and *P. fluorescens* (191.70) at 5.0 g/plant as compared to untreated check (244.40). Among all the treatments, egg mass contents (177.10) was found least in *T. viride* at 5 g/plant and was observed at par with *P. lilacinus* (5 g/plant).

Experimental findings showed that soil application of bio-agents, *P. lilacinus* (5 g/plant) reduces egg mass contents 25.78 % over untreated check (Fig. 7). It was observed to be 23.00 and 21.56 % with *T. harzianum* and *P. fluorescens* at 5 g/plant, respectively. Highest reduction in egg mass contents (27.54 %) was obtained with *T. viride* at 5 g/plant and lowest was registered with *Glomus fasiculatum* at 2.5 g/plant.

IV. Final nematode population per 100 cc soil:

Data showed that nematode population at harvest decreased significantly from all the bio-agent treatments over untreated check. It was obtained minimum (667.40) in soil treatment with *P. lilacinus* at 5 g/plant dose followed by *T. harzianum* at 5 g/plant (684.50) and *P. fluorescens* at 5 g/plant (686.60) as compared to untreated check (1944.30). Soil treatment with bio-agents significantly reduced final nematode population /100 cc soil over untreated check. However, *T. viride* at 5 g/plant was found best over rest of bio-agents.

Bio-agents, *P. lilacinus*, *T. harzianum* and *P. fluorescens* at 5 g/plant decreased final nematode population in soil to the tune of 65.67, 64.79 and 64.69 %, respectively. Among all the treatments, maximum reduction (66.29 %) in final nematode population/100 cc soil was noticed with *T. viride* at 5 g/plant and minimum was obtained with *G. fasiculatum* at 2.5 g/plant.

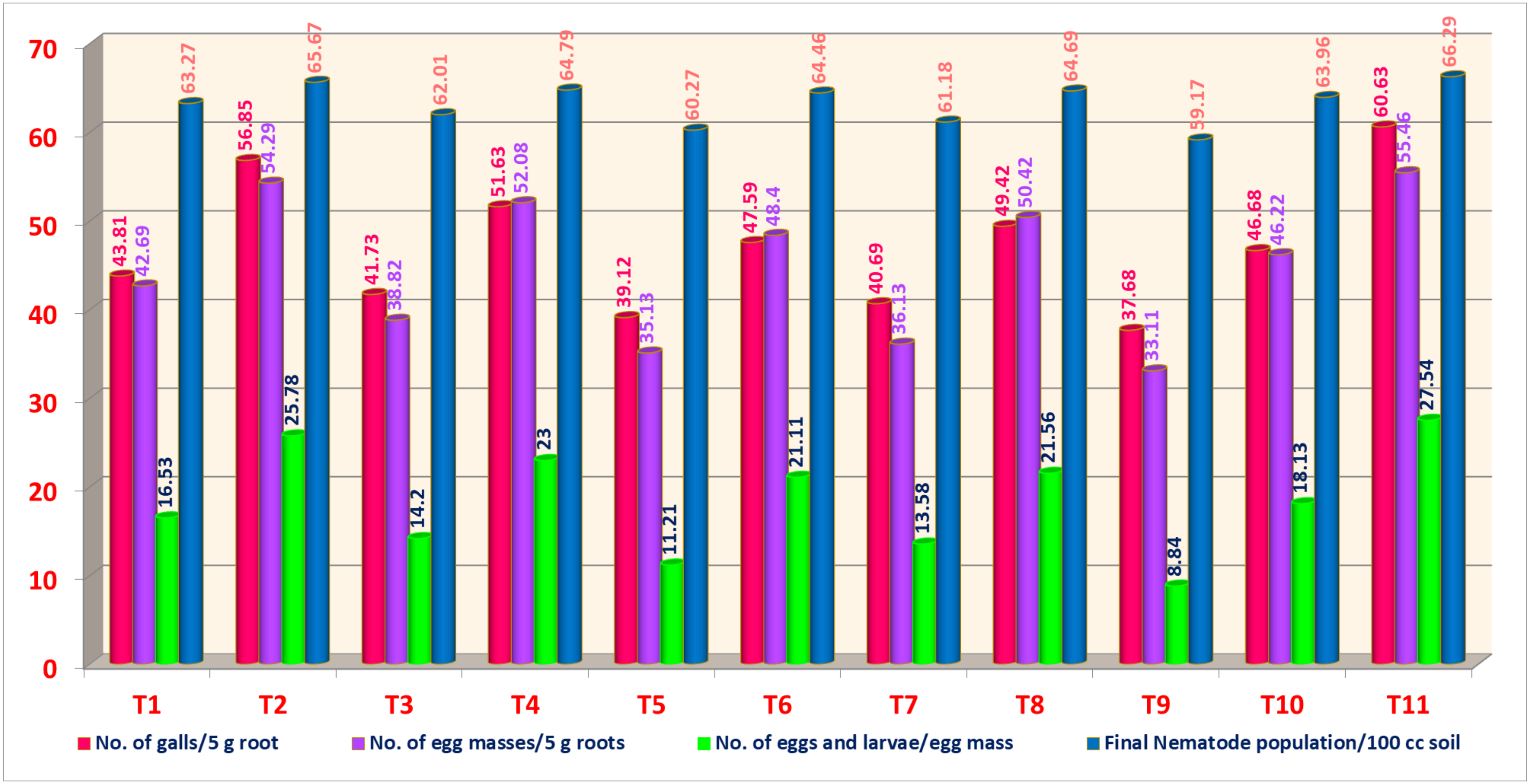

Figure 7: Changes in reproduction characters of root-knot nematode, *M. incognita* on cucumber in poly-house using bio-agents

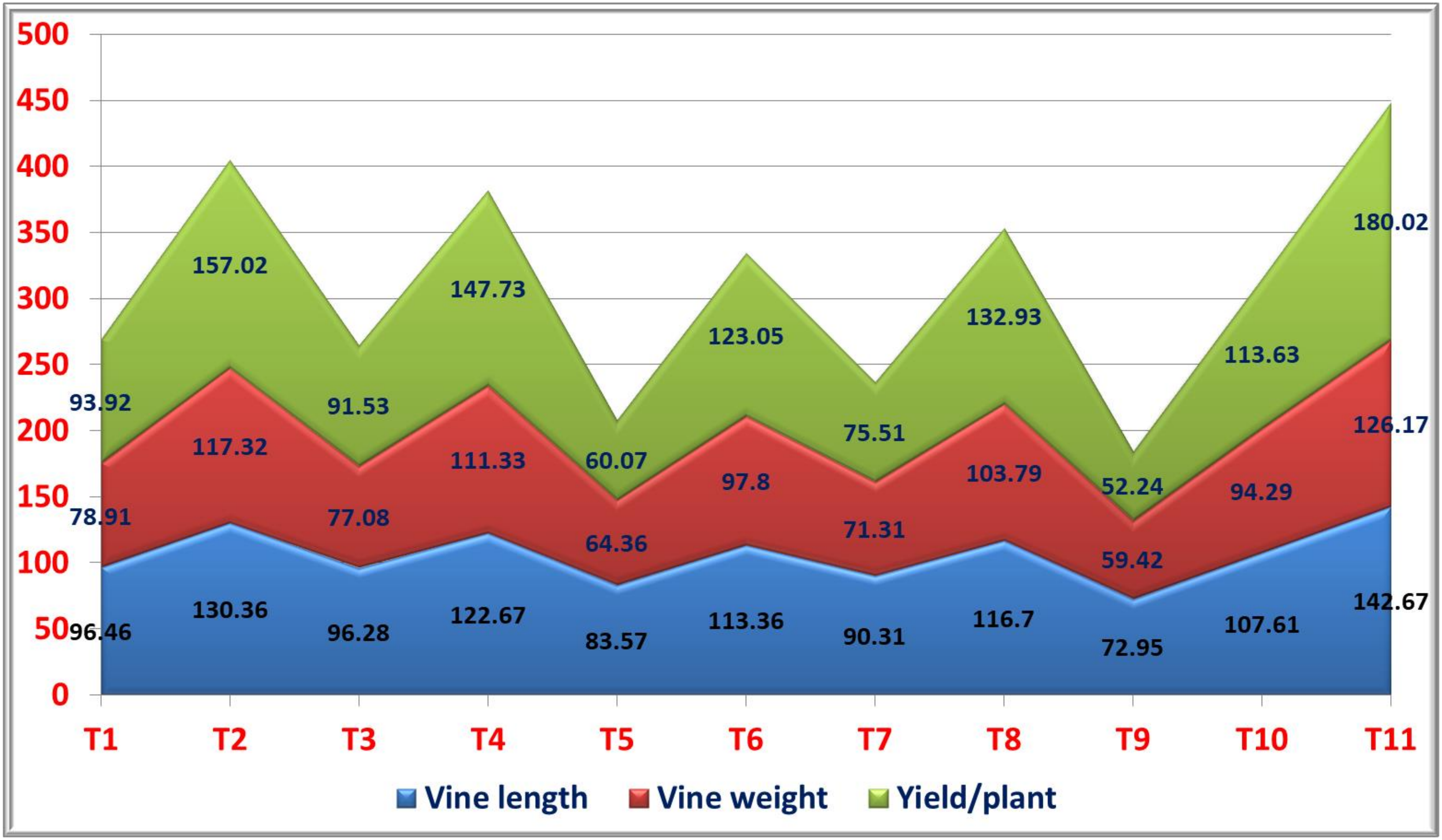

Figure 8: Changes in plant growth characters of cucumber under poly-house infested with root-knot nematode, *M. incognita* using bio-agents

V. Vine length (m):

Results revealed that soil treatment with bio-agents significantly increased vine length of cucumber over untreated check. Results exhibited that among bio-agents, maximum vine length (2.969 m.) was recorded with *P. lilacinus* at 5.0 g/plant followed to *T. harzianum* (2.870 m.) and *P. fluorescens* (2.793 m.) at 5.0 g/plant. Vine length was recorded 3.128 m. in *T. viride* at 5 g/plant and was at par with *P. lilacinus* at 5.0 g/plant. Among treatments, minimum vine length was obtained with bio-agent, *G. fasiculatum* at 2.5 g/plant.

Experimental findings showed that soil application of bio-agents, *P. lilacinus* (5 g/plant) increased vine length 130.36 % over untreated check (Fig. 8). It was observed to be 122.67 % and 116.70 % in *T. harzianum* (5 g/plant) and *P. fluorescens* (5 g/plant), respectively. Among all the treatments, highest increase in vine length (142.67 %) was obtained with *T. viride* at 5 g/plant.

VI. Vine weight (kg):

Data revealed (Table-11) that vine weight of cucumber with the application of bio-agents significantly enhanced over untreated check. Among bio-agents, maximum vine weight (0.778 kg) was obtained with *P. lilacinus* at 5.0 g/plant followed by *T. harzianum* at 5.0 g/plant (0.757 kg) and *P. fluorescens* at 5.0 g/plant (0.729 kg) as compared to untreated check (0.358 kg). Results showed that all bio-agents significantly increased vine weight over untreated check. However, *T. viride* at 5 g /plant (0.810 kg) was found to be best. Among bio-agents, *G. fasiculatum* at 2.5 g/plant was found to be least effective but significantly better over untreated check.

Experimental findings showed that *P. lilacinus* (5.0 g/plant) increased vine weight to the tune of 117.32 % while in *T. harzianum* (5.0 g/plant), it was observed 111.33 % over untreated check. Maximum increase in vine weight (126.17 %) was recorded with treatment of *T. viride* at 5 g/plant which was maintained as standard check.

VII. Yield (kg/plant):

Results revealed that yield of cucumber increase significantly with the application of bio-agents over untreated check in root-knot nematode *M. incognita* infested cucumber in poly-house. Amongst different bio-agents tested, maximum yield (2.905 kg/plant) was obtained with *P. lilacinus* at 5.0 g/plant followed by *T. harzianum* at 5.0 g/plant (2.799 kg/plant) and *P. fluorescens* at 5.0 g/plant (2.631 kg/plant) as compared to untreated check (1.131 kg/plant). However, maximum yield was noticed with *T. viride* at 5 g/plant (3.161 kg/plant) and was found

Plate 13 : Efficacy of bio-agents on plant growth of cucumber infested with *M. incognita* in poly-house

at par with *P. lilacinus* at 5.0 g/plant (Table-11). Among bio-agents, minimum yield was recorded with *G. fasiculatum* at 2.5 g/plant but differed significantly over untreated check.

Data presented in Table 13 exhibited that soil treatment with *P. lilacinus* (5.0 g/plant) increases yield 157.02 % followed by *T. harzianum* at 5.0 g/plant (147.73 %) and *P. fluorescens* at 5.0 g/plant (132.93 %) over untreated check. It was observed to be 180.02 % with *T. viride* at 5 g/plant (Fig.-8).

On the whole, bio-agent, *Trichoderma viride* followed by *Paecilomyces lilacinus* and *Trichoderma harzianum* at 5.0 g/plant found effective to reduced the infection of root-knot nematode, *M. incognita* and to enhance yield of cucumber in poly houses.

7. Effect of chemicals as pre-sowing application against root-knot nematode, *M. incognita* on cucumber in poly-house:-

Management of nematodes through chemicals under protected cultivation is need of hour due to highly susceptible cropping pattern and rapid build up of nematode population due to favorable and most congenial environment. Looking to this attribute, an experiment was design and conducted to find out the efficacy of chemicals as soil fumigation against *M. incognita* on cucumber under protected cultivation. For this trial, chemicals *viz*. Formalin at 10, 20 and 30 ml/plant, Metham Sodium at 2.5, 5.0 and 10 ml/plant and Sodium tetra thio-carbonate (STTC) at 2.5, 5.0 and 10 ml/plant were used for the management of root-knot nematode infecting cucumber in poly-house during 2016 and 2017. Phorate 2 g a.i./plant (as a standard check) and untreated check were also maintained for comparison of experimental findings. The experiment was conducted in poly house having an initial nematode population of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. Observations on nematode reproduction (number of galls per 5g roots, egg masses per 5g roots, eggs and larvae per egg mass and final nematode population/100cc soil) and on plant growth characters (vine length, vine weight and yield) were recorded. After completion of experiments, data were analyzed and presented in Table 14-17 and illustrated with Fig. 9-10 and Plate-14.

I. Number of galls per 5g roots

Results of pool analysis revealed that application of formalin, metham sodium and Sodium tetra thio-carbonate as soil fumigant at all dose were found effective and significantly decrease galls produced by *M. incognita* on cucumber under protected cultivation. It was observed that minimum number of galls per 5 g roots (13.90) found in soil fumigated with

Table-14: Effect of chemicals as pre-sowing application against root-knot nematode, *M. incognita* on cucumber under poly-house

Treatments		Galls/ 5 g root			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Final Nematode population /100 cc soil		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	Formalin at 10 ml/plant	25.40	25.80	25.60	21.80	22.20	22.00	216.20	214.60	215.40	738.40	732.60	735.50
T_2	Formalin at 20 ml/plant	20.40	21.80	21.10	16.80	17.40	17.10	197.20	195.40	196.30	686.20	691.40	688.80
T_3	Formalin at 30 ml/plant	13.60	14.20	13.90	8.60	9.20	8.90	169.80	166.20	168.00	644.40	638.00	641.20
T_4	Metham Sodium at 2.5 ml/plant	29.40	28.60	29.00	23.00	24.00	23.50	221.00	223.20	222.10	756.20	760.60	758.40
T_5	Metham Sodium at 5.0 ml/plant	22.80	23.60	23.20	19.60	18.60	19.10	207.40	204.80	206.10	698.20	703.60	700.90
T_6	Metham Sodium at 10.0 ml/plant	18.00	19.00	18.50	15.00	14.20	14.60	181.20	185.40	183.30	662.60	666.20	664.40
T_7	Sodium Tetra Thio- Carbonate at 2.5 ml/plant	31.60	32.00	31.80	25.00	26.60	25.80	224.00	226.60	225.30	776.40	782.20	779.30
T_8	Sodium Tetra Thio- Carbonate at 5.0 ml/plant	23.60	24.40	24.00	20.20	21.40	20.80	212.20	210.20	211.20	712.40	717.40	714.90
T_9	Sodium Tetra Thio-Carbonate at 10.0 ml/plant	20.20	21.60	20.90	15.60	15.20	15.40	191.80	189.60	190.70	674.00	678.60	676.30
T_{10}	Phorate at 2 g a.i./plant	14.40	13.80	14.10	11.40	10.60	11.00	172.00	179.00	175.50	652.80	646.60	649.70
T_{11}	Check	79.30	82.00	80.65	68.00	71.00	69.50	254.00	246.60	250.30	1780.40	1768.00	1774.20
	SEm ±	1.136	1.591	1.3635	1.145	1.279	1.212	8.064	6.505	7.2845	24.408	26.176	25.292
	CD at 5%	3.247	4.549	3.898	3.271	3.656	3.4635	23.049	18.594	20.8215	69.763	74.816	72.2895

Data are the average value of five replications

Table-15: Effect of chemicals as pre-sowing application on plant growth and yield of cucumber against *M. incognita* in poly-house

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Formalin at 10 ml/plant	2.610	2.570	2.590	0.675	0.688	0.681	2.425	2.406	2.415
T_2	Formalin at 20 ml/plant	2.804	2.754	2.779	0.766	0.758	0.762	2.754	2.735	2.744
T_3	Formalin at 30 ml/plant	3.310	3.390	3.350	0.828	0.836	0.832	3.640	3.675	3.657
T_4	Metham Sodium at 2.5 ml/plant	2.522	2.472	2.497	0.637	0.652	0.644	2.337	2.318	2.327
T_5	Metham Sodium at 5.0 ml/plant	2.720	2.700	2.710	0.725	0.732	0.728	2.611	2.598	2.604
T_6	Metham Sodium at 10.0 ml/plant	2.986	2.906	2.946	0.794	0.797	0.795	3.255	3.305	3.280
T_7	Sodium Tetra Thio- Carbonate at 2.5 ml/plant	2.436	2.386	2.411	0.606	0.617	0.611	2.170	2.192	2.181
T_8	Sodium Tetra Thio- Carbonate at 5.0 ml/plant	2.640	2.660	2.650	0.689	0.698	0.693	2.552	2.568	2.560
T_9	Sodium Tetra Thio- Carbonate at 10.0 ml/plant	2.862	2.828	2.845	0.782	0.774	0.778	2.906	2.960	2.933
T_{10}	Phorate at 2 g a.i./plant	3.156	3.242	3.199	0.805	0.817	0.811	3.473	3.492	3.482
T_{11}	Check	1.356	1.262	1.309	0.361	0.347	0.354	0.939	1.050	0.994
	SEm ±	0.113	0.113	0.113	0.020	0.021	0.021	0.085	0.083	0.084
	CD at 5%	0.322	0.323	0.323	0.056	0.060	0.058	0.243	0.237	0.240

Data are the average value of five replications

Table-16: Changes in nematode reproduction parameters of root-knot nematode, *M. incognita* infected cucumber in poly-house through chemicals

Treatments		Galls/5 g root*			Egg masses/5 g roots*			Eggs and larvae/egg mass*			Final Nematode population/100 cc soil*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Formalin at 10 ml/plant	67.97	68.54	68.26	67.94	68.73	68.35	14.88	12.98	13.93	58.53	58.56	58.54
T_2	Formalin at 20 ml/plant	74.27	73.41	73.84	75.29	75.49	75.40	22.36	20.76	21.56	61.46	60.89	61.18
T_3	Formalin at 30 ml/plant	82.85	82.68	82.77	87.35	87.04	87.19	33.15	32.60	32.88	63.81	63.91	63.86
T_4	Metham Sodium at 2.5 ml/plant	62.93	65.12	64.04	66.18	66.20	66.19	12.99	9.49	11.24	57.53	56.98	57.25
T_5	Metham Sodium at 5.0 ml/plant	71.25	71.22	71.23	71.18	73.80	72.52	18.35	16.95	17.65	60.78	60.20	60.49
T_6	Metham Sodium at 10.0 ml/plant	77.30	76.83	77.06	77.94	80.00	78.99	28.66	24.82	26.74	62.78	62.32	62.55
T_7	Sodium Tetra Thio- Carbonate at 2.5 ml/plant	60.15	60.98	60.57	63.24	62.54	62.88	11.81	8.11	9.96	56.39	55.76	56.08
T_8	Sodium Tetra Thio- Carbonate at 5.0 ml/plant	70.24	70.24	70.24	70.29	69.86	70.07	16.46	14.76	15.61	59.99	59.42	59.71
T_9	Sodium Tetra Thio- Carbonate at 10.0 ml/plant	74.53	73.66	74.09	77.06	78.59	77.84	24.49	23.11	23.80	62.14	61.62	61.88
T_{10}	Phorate at 2 g a.i./plant	81.84	83.17	82.52	83.24	85.07	84.17	32.28	27.41	29.85	63.33	63.46	63.40
T_{11}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table-17: Changes in plant growth parameters of cucumber infected by root-knot nematode, *M. incognita* in poly-house through chemicals

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Formalin at 10 ml/plant	92.48	103.65	98.07	86.62	98.16	92.39	158.03	129.16	143.60
T_2	Formalin at 20 ml/plant	106.78	118.23	112.51	111.61	118.43	115.02	193.04	160.50	176.77
T_3	Formalin at 30 ml/plant	144.10	168.62	156.36	128.75	140.67	134.71	287.36	249.98	268.67
T_4	Metham Sodium at 2.5 ml/plant	85.99	95.88	90.94	76.06	87.73	81.90	148.69	120.76	134.73
T_5	Metham Sodium at 5.0 ml/plant	100.59	113.95	107.27	100.33	110.83	105.58	177.80	147.47	162.64
T_6	Metham Sodium at 10.0 ml/plant	120.21	130.27	125.24	119.57	129.61	124.59	246.35	214.80	230.58
T_7	Sodium Tetra Thio- Carbonate at 2.5 ml/plant	79.65	89.06	84.36	67.55	77.65	72.60	130.90	108.78	119.84
T_8	Sodium Tetra Thio- Carbonate at 5.0 ml/plant	94.69	110.78	102.74	90.44	101.09	95.77	171.55	144.57	158.06
T_9	Sodium Tetra Thio- Carbonate at 10.0 ml/plant	111.06	124.09	117.58	116.14	122.93	119.54	209.17	181.94	195.56
T_{10}	Phorate at 2 g a.i./plant	132.74	156.89	144.82	122.39	135.20	128.80	269.53	232.61	251.07
T_{11}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (18.50) and sodium tetra thio-carbonate at 10 ml/plant (20.90) as compared to untreated check (80.65). Among fumigants, formalin exhibited better response over metham sodium and STTC with respect to galls/5 g roots. Among all the treatments, phorate 2 g a.i./plant (14.10) also proved better but found at par with formalin 30 ml/plant. These treatments found significantly superior over rest of the treatments. Formalin at 30 ml/plant and phorate 2 g a.i./plant differed significantly to other treatments. Sodium tetra thio-carbonate at 2.5 ml/plant was found least effective.

All the treatments reduced number of galls per 5 g root. However, maximum reduction in galls (82.77 %) was recorded with formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (77.06 %) and sodium tetra thio-carbonate at 10 ml/plant (74.09 %) over untreated check (Fig. 9). Reduction in galls/5 g roots (82.52 %) was noticed with the application of phorate 2 g a.i./plant.

II. Number of egg masses per 5g roots:

On the basis of results presented in Table 14, minimum egg masses/5 g root (8.90) was observed with the application of formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (14.60) and sodium tetra thio-carbonate at 10 ml/plant (15.40) compared to untreated check (69.50). All the treatments were found significantly better over untreated check with regards to reducing egg mass/5 g roots. Among chemicals sodium tetra thio-carbonate at 2.5 ml/plant (25.80) was found least effective to minimise *M. incognita* egg masses on cucumber. Application of phorate 2 g a.i./plant (11.00) as soil treatment also reduce egg mass effectively but found at par with formalin 30 ml/plant.

Results showed that all the treatments reduced number of egg masses. However, maximum reduction in egg masses (87.19 %) was noticed with application of formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (78.99 %) and sodium tetra thio-carbonate at 10 ml/plant (77.84 %) over untreated check. Reduction in egg masses/5 g roots was noticed 84.17 % with the application of phorate 2 g a.i./plant (standard check).

III. Number of eggs and larvae per egg mass:

Results exhibited that during present investigation chemicals when applied as soil treatment significantly decrease egg mass contents of *M. incognita* as compared to untreated check. Minimum eggs and larvae per egg mass (168.00) was recorded by fumigation of formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (183.30 eggs and larvae/egg mass) and

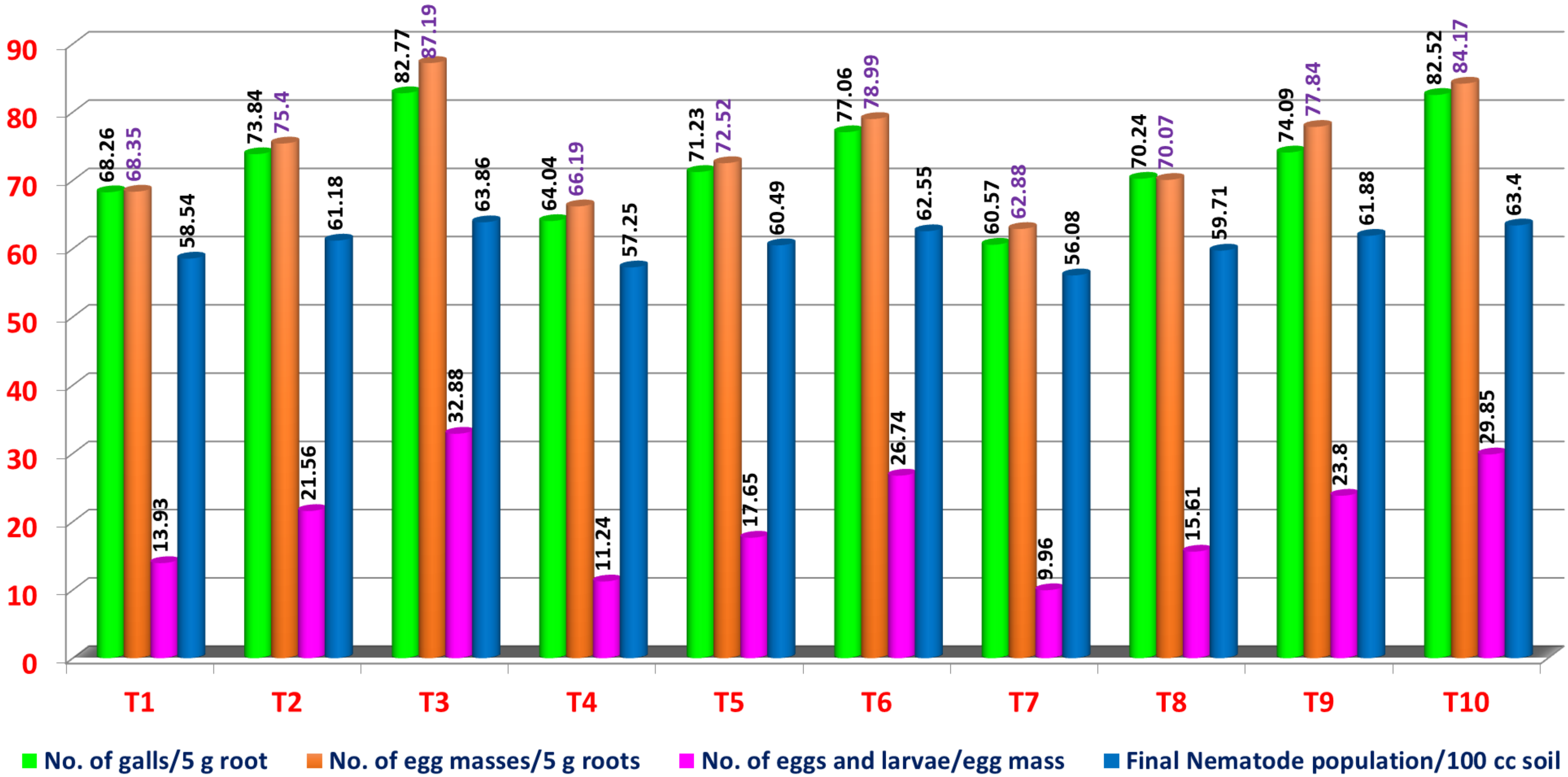

Figure 9: Changes in nematode reproduction parameters of root-knot nematode, *M. incognita* infected cucumber in poly-house through chemicals

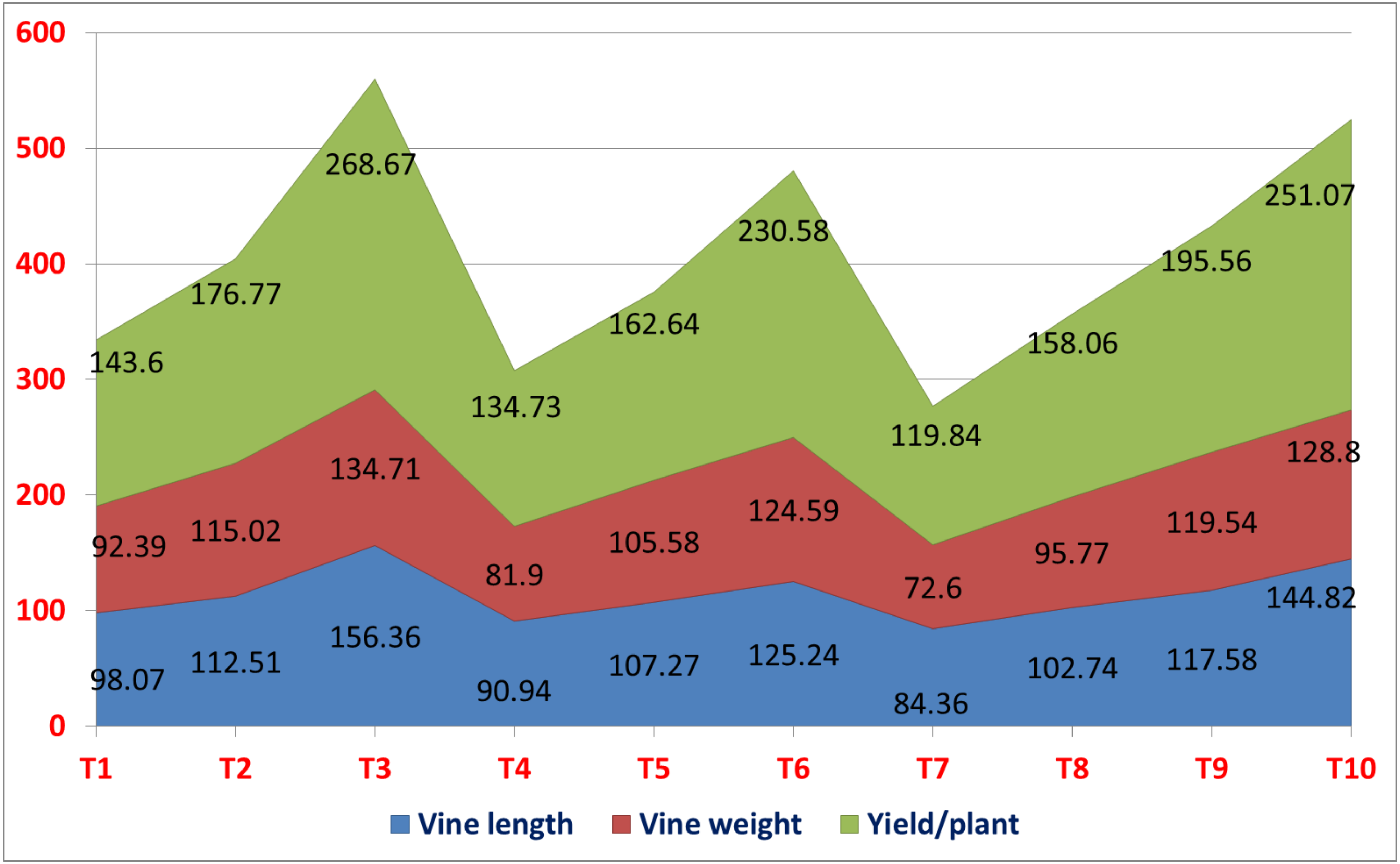

Figure 10: Changes in plant growth parameters of cucumber infected by root-knot nematode, *M. incognita* in poly-house through chemicals

sodium tetra thio-carbonate at 10 ml/plant (190.70 eggs and larvae/egg mass) over untreated check (250.30 eggs and larvae/egg mass). Among chemicals, formalin exhibited better response over metham sodium and STTC with respect to reduce egg mass contents of *M. incognita*.

Results illustrated in Fig. 9 showed maximum reduction in egg mass contents (32.88 %) found when formalin was applied at 30 ml/plant. Reduction was observed to be 26.74 % and 23.80 % in metham sodium and STTC at 10 ml per plant, respectively over untreated check. Reduction (29.85%) in eggs & larvae/egg masses was noticed with the application of phorate at 2 g a.i./plant.

IV. Final nematode population per 100 cc soil:

Results presented in Table 14 revealed that nematode population/100 cc soil decline significantly with the application of chemical treatments. It was observed to be minimum (641.20) in formalin at 30 ml/plant followed by fumigation of metham sodium (664.40) and STTC (676.30) at 10 ml per plant before sowing. These treatments significantly decreased final nematode population over untreated check (1774.20). Sodium tetra thio-carbonate at 2.5 ml/plant was found least effective but significantly superior over untreated check. Among all chemicals, formalin and phorate exhibited significantly better over rest of the treatments to reduce nematode population in soil at harvest.

Results showed (Table 16) that all the treatments reduce nematode population in soil at harvest however, maximum reduction (63.86 %) in nematode population was registered with the application of formalin 30 ml/plant followed by metham sodium (62.55 %) and sodium tetra thio-carbonate (61.88 %) at 10 ml/plant over untreated check . It was registered 63.40 % in phorate at 2 g a.i./plant.

V. Vine length (m):

All the treatments found significantly superior over untreated check with regards to enhance vine length of cucumber in poly house. Soil fumigation with formalin at 30 ml/plant showed maximum vine length (3.350 m.) followed by metham sodium (2.946 m.) and sodium tetra thio-carbonate (2.845 m.) at 10 ml/plant. It was observed 3.199 m. in phorate at 2 g a.i./plant as soil treatment. Sodium tetra thio-carbonate at 2.5 ml/plant (2.411 m.) was found least effective with regards to vine length over other chemicals.

Experimental findings showed that soil application of chemicals under protected cultivation in cucumber with formalin at 30 ml/plant increased vine length (156.36 %) over

Plate 14 : Efficacy of fumigants against *M. incognita* infecting cucumber in poly-house

untreated check (Fig. 10). It was observed 125.24 % and 102.74 % with metham sodium (10 ml/plant) and STTC (10 ml/plant), respectively. Sodium tetra thio-carbonate at 2.5 ml/plant found least effective to enhance vine length (84.36 %) of cucumber.

VI. Vine weight (kg):

Data presented in Table 15 revealed that vine weight of cucumber in poly house significantly increase with the application of chemicals over untreated check. Among chemicals, maximum vine weight (0.832 kg) was obtained with application of formalin at 30.0 ml/plant followed by metham sodium at 10.0 ml/plant (0.795 kg) and sodium tetra thio-carbonate at 10.0 ml/plant (0.778 kg) over untreated check (0.354). All the chemicals significantly increased vine weight over untreated check. Soil application of Phorate at 2 g a.i./plant (0.811 kg) was also found better but at par with formalin at 30 ml/ plant. Among treatments, vine weight of cucumber was found minimum with Sodium tetra thio-carbonate at 2.5 ml/plant.

Experimental findings (Table-17) showed that soil treatment with formalin (30.0 ml/plant) increased vine weight to the tune of 134.71 % while in metham sodium and sodium tetra thio-carbonate (10.0 ml/plant), it was observed 124.59 and 119.54 %, respectively over untreated check. Sodium tetra thio-carbonate at 2.5 ml/plant found least effective among chemicals to enhance vine weight (72.60%).

VII. Yield (kg/plant):

The results pertaining to cucumber yield in poly-house presented in Table 15 and illustrated through Fig. 10 revealed that all the treatments were found significantly better over untreated check with regards to enhance yield of cucumber in poly house. Formalin 30 ml/plant was found to be the most effective followed by metham sodium and STTC. Maximum yield (3.657 kg/plant) was obtained with application of formalin 30 ml/plant followed by metham sodium (3.280 kg/plant) and sodium tetra thio-carbonate (2.933 kg/plant) at 10.0 ml/plant as compared to untreated check (0.994 kg/plant). These treatments significantly enhanced yield over untreated check. Application of phorate at 2 g a.i./plant (3.482 kg/plant) as soil treatment also found better but at par with formalin 30 ml/plant to enhance yield of cucumber in poly house.

Yield increased over control was also calculated and presented in Table 17. Results exhibited that maximum (268.67 %) increase in yield was registered with the application of formalin at 30 ml/plant in comparison to untreated check. It was observed to be 230.58 and 195.56 % with the application of metham sodium and STTC at 10.0 ml/plant (Fig. 10). Sodium tetra thio-carbonate at 2.5 ml/plant (119.84%) found to be least effective among all the treatments to enhance yield of cucumber in poly house.

Among chemicals, formalin 30 ml/plant, phorate 2 g a.i./plant, metham sodium and sodium tetra thio-carbonate at 10 ml/plant significantly reduced infection of *M. incognita* and increased yield of cucumber under protected cultivation.

8. Influence of eco-friendly management strategies against root-knot nematode, *M. incognita* infecting cucumber in poly-house:-

Economic losses to vegetable production under protected cultivation is very high due to plant parasitic nematodes, specially by root-knot nematodes justify the use of various measures for their management. All the individual methods have their own advantage and disadvantages. Therefore, in present scenario, it is needed to develop and focus on such management measures which are effective, efficient and low cost with the attributes of least environmentally disruptive. With this view, in present investigation physical method (Hot water at 1.0 lit./plant), organic amendments (Tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder at 20 g/plant) and bio-control agents (*Pacilomyces lilacinus* and *Trichoderma harzianum* at 2.5 g/plant) were used in combination for the management of root-knot nematode, *M. incognita* on cucumber under protected cultivation . A treated (Hot water at 1.0 lit./plant + Neem cake at 50 g/plant + *Trichoderma viride* at 5 g/plant) and untreated check was also maintained for comparison of the experimental findings. The experiment was conducted in poly house of farmer's field having an initial nematode population of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. Observations on number of galls/5g roots, number of egg masses/5g roots, number of eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield kg/plant were recorded. The results presented in Table 18-21 and illustrated with Fig. 11-12 and Plate 15 and have been described below:-.

I. Number of galls per 5g roots:

Results of pool analysis revealed that all the treatments significantly reduced number of galls/5 g roots as compared to untreated check (Table-18). Among various combinations, minimum number of galls per 5 g roots (11.60) was recorded in Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (14.10) and Hot water + Tobacco churi + *T. harzianum* (17.80) in comparison to untreated check (77.30).These treatments significantly differed from rest of the treatment combinations. Minimum galls (9.30) was

Table-18: Influence of eco-friendly management strategies against root-knot nematode, *M. incognita* infecting cucumber in poly-house

Treatments		Galls/ 5 g root			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Final Nematode population/100 cc soil		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	14.40	13.80	14.10	09.00	10.40	9.70	165.60	168.40	167.00	575.80	568.60	572.20
T2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	19.40	18.60	19.00	15.00	16.20	15.60	176.20	179.20	177.70	604.00	597.20	600.60
T3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	12.00	11.20	11.60	07.00	6.20	6.60	163.00	161.80	162.40	560.40	548.20	554.30
T4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	17.40	18.20	17.80	14.20	13.80	14.00	171.60	174.20	172.90	592.20	588.40	590.30
T5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	21.20	20.40	20.80	17.00	18.40	17.70	180.40	182.40	181.40	628.40	622.60	625.50
T6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	26.40	24.80	25.60	20.80	19.80	20.30	182.80	183.60	183.20	651.60	644.20	647.90
T7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	28.20	26.60	27.40	22.80	23.20	23.00	189.40	188.20	188.80	673.80	665.60	669.70
T8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	33.20	32.20	33.70	26.40	27.60	27.00	196.20	199.80	198.00	698.60	686.00	692.30
T9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	30.00	28.80	29.40	24.80	25.40	25.10	191.40	193.60	192.50	682.40	674.20	678.30
T10	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	35.40	34.20	34.80	29.00	30.20	29.60	201.40	204.40	202.90	708.40	698.40	703.40
T11	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + *Trichoderma viride* 5 g/plant	10.00	8.60	9.30	06.20	5.40	5.80	159.00	156.60	157.80	535.00	529.00	532.00
T12	Check	74.40	80.20	77.30	62.40	65.60	64.00	239.60	244.20	241.90	1844.4	1788.2	1816.30
	SEm ±	1.140	1.035	1.088	0.930	1.177	1.054	4.460	5.718	5.089	26.609	7.761	17.185
	CD at 5%	3.240	2.950	3.095	2.644	3.354	2.999	12.700	16.296	14.498	75.841	22.119	48.980

Data are the average value of five replications

Table-19: Influence of eco-friendly management strategies on plant growth and yield parameters of cucumber against *M. incognita* in poly-house

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	3.284	3.358	3.321	0.825	0.838	0.831	3.619	3.762	3.690
T_2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	3.052	3.168	3.110	0.785	0.796	0.790	3.388	3.412	3.400
T_3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	3.448	3.486	3.467	0.850	0.864	0.857	3.805	3.925	3.865
T_4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	3.192	3.258	3.225	0.805	0.820	0.812	3.437	3.546	3.491
T_5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	2.878	2.918	2.898	0.765	0.778	0.771	2.986	3.108	3.047
T_6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	2.760	2.836	2.798	0.754	0.766	0.760	2.736	2.886	2.811
T_7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	2.620	2.748	2.684	0.740	0.758	0.749	2.619	2.742	2.680
T_8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	2.402	2.510	2.456	0.649	0.662	0.655	2.374	2.412	2.393
T_9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	2.520	2.626	2.573	0.689	0.676	0.682	2.422	2.580	2.501
T_{10}	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	2.332	2.376	2.354	0.620	0.632	0.626	2.250	2.294	2.272
T_{11}	Hot Water 1 lit/poly bag + Neem Cake 50 g/plant + *Trichoderma viride* 5 g/plant	3.540	3.616	3.578	0.875	0.886	0.880	4.021	4.136	4.078
T_{12}	Check	1.422	1.348	1.385	0.410	0.384	0.397	0.906	1.060	0.983
	SEm ±	0.071	0.076	0.074	0.023	0.010	0.017	0.096	0.108	0.102
	CD at 5%	0.202	0.218	0.210	0.066	0.029	0.048	0.274	0.308	0.291

Data are the average value of five replications

Table-20: Changes with eco-friendly combinations on population of *M. incognita* infecting cucumber under poly-house

Treatments		Galls/5 g root*			Egg masses/5 g roots*			Eggs and larvae/egg mass*			Final Nematode population/100 cc soil*		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant+ *Paecilomyces lilacinus* at 2.5 g/plant	80.65	82.79	81.76	85.58	84.15	84.84	30.88	31.04	30.96	68.78	68.20	68.50
T_2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	73.92	76.81	75.42	75.96	75.30	75.63	26.46	26.62	26.54	67.25	66.60	66.93
T_3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	83.87	86.03	84.99	88.78	90.55	89.69	31.97	33.74	32.86	69.62	69.34	69.48
T_4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	76.61	77.31	76.97	77.24	78.96	78.13	28.38	28.67	28.52	67.89	67.10	67.50
T_5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	71.51	74.56	73.09	72.76	71.95	72.34	24.71	25.31	25.01	65.93	65.18	65.56
T_6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	64.52	69.08	66.88	66.67	69.82	68.28	23.71	24.82	24.27	64.67	63.97	64.33
T_7	Hot water at 1 litre/polybag+ Water Hyacinth Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	62.10	66.83	64.55	63.46	64.63	64.06	20.95	22.93	21.95	63.47	62.78	63.13
T_8	Hot water at 1 litre/polybag+ Water Hyacinth Powder at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	55.38	59.85	57.61	57.69	57.93	57.81	18.11	18.18	18.15	62.16	61.64	61.90
T_9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	59.68	64.09	61.97	60.26	61.28	60.78	20.12	20.72	20.42	63.00	62.30	62.65
T_{10}	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant+ *Trichoderma harzianum* at 2.5 g/plant	52.42	57.36	54.98	53.53	53.96	53.75	15.94	16.30	16.12	61.59	60.94	61.26
T_{11}	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + *Trichoderma viride* 5 g/plant	86.56	89.28	87.97	90.06	91.77	90.94	33.64	35.87	34.77	70.99	70.42	70.71
T_{12}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table-21: Changes on plant growth parameters of cucumber infested with *M. incognita* under poly-house with eco-friendly treatment combinations

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	130.94	149.11	140.03	101.07	118.28	109.68	299.45	254.94	277.20
T_2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	114.63	135.01	124.82	91.23	107.24	99.24	274.00	221.92	247.96
T_3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	142.48	158.61	150.55	107.16	124.90	116.03	319.98	270.28	295.13
T_4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	124.47	141.69	133.08	96.15	113.54	104.85	279.32	234.49	256.91
T_5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	102.39	116.47	109.43	86.45	102.60	94.53	229.54	193.17	211.36
T_6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	94.09	110.39	102.24	83.72	99.53	91.63	201.94	172.30	187.12
T_7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	84.25	103.86	94.06	80.36	97.45	88.91	189.07	158.64	173.86
T_8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	68.92	86.20	77.56	58.24	72.45	65.35	162.03	127.55	144.79
T_9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + *Paecilomyces lilacinus* at 2.5 g/plant	77.22	94.81	86.02	67.93	75.99	71.96	167.33	143.40	155.37
T_{10}	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + *Trichoderma harzianum* at 2.5 g/plant	63.99	76.26	70.13	51.12	64.58	57.85	148.34	116.42	132.38
T_{11}	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + *Trichoderma viride* 5 g/plant	148.95	168.25	158.60	113.21	130.68	121.95	343.80	290.21	317.01
T_{12}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

obtained in combination with Hot water (1.0 litre/plant) + Neem cake (50 g/plant) + *Trichoderma viride* (5 g/plant) which was kept as standard check but it was found at par with Hot water + Tobacco churi + *P. lilacinus*. All the treatments significantly reduced galls over untreated check. Hot water + lantana leaf powder + *T. harzianum* was found least effective among all the combinations but found significantly better over check.

Reduction in gall was calculated and presented in Table 20. Maximum reduction (84.99 %) in galls was noticed in Hot water + Tobacco churi + *P. lilacinus*. It was found to be 81.76 % (Hot water + Tea waste + *P. lilacinus*) and 76.97 % (Hot water + Tobacco churi + *T. harzianum*) on cucumber in poly-house. The highest reduction (87.97 %) found with standard check (Hot water + Neem cake + *Trichoderma viride*) as compared with untreated check. Lowest reduction in galls was noticed with Hot water + lantana leaf powder + *T. harzianum.*

II. Number of egg masses per 5g roots:

Results pertaining to egg masses showed that all the treatments significantly decreased egg mass formation of *M. incognita* on cucumber under protected cultivation as compared to untreated check. Among treatments, minimum egg masses per 5 g roots (6.60) on cucumber in poly-house were recorded with Hot water + Tobacco churi + *P. lilacinus* combination followed by Hot water + Tea waste + *P. lilacinus* (9.70) and Hot water + Tobacco churi + *T. harzianum* (17.80) over untreated check (64.00). Minimum egg masses per 5 g roots (5.80) were obtained with Hot water + Neem cake + *Trichoderma viride* combination (as standard check) and it was found at par with Hot water + Tobacco churi + *P. lilacinus* combination. It was observed that these treatment combinations significantly reduced galls over untreated check. Hot water + lantana leaf powder + *T. harzianum* was found least effective with respect to egg masses/5g roots (29.60).

Results revealed that maximum reduction (89.69 %) in egg masses was noticed with combination of Hot water + Tobacco churi + *P. lilacinus* followed by 84.84 % (Hot water + Tea waste + *P. lilacinus*) and 78.13 % (Hot water + Tobacco churi + *T. harzianum*) on cucumber in poly-house. Highest reduction (90.94 %) was recorded with Hot water + Neem cake + *Trichoderma viride* combination over untreated check. Lowest reduction was noticed with Hot water + lantana leaf powder + *T. harzianum* (53.75%).

III. Number of eggs and larvae per egg mass:

Results shows that eggs & larvae per egg mass decrease significantly with the application of treatments over untreated check. Minimum eggs and larvae/egg mass (162.40) was obtained with the combination of Hot water + Tobacco churi + *P. lilacinus*. It was observed 167.00 and

172.90 with Hot water + Tea waste + *P. lilacinus* and Hot water + Tobacco churi + *T. harzianum*, respectively as compared to check (241.90 eggs & larvae/egg mass). Combination of Hot water + Neem cake + *Trichoderma viride* (156.60 eggs & larvae/egg mass) was found to be the best over all other treatments tested. Hot water + lantana leaf powder + *T. harzianum* was found least effective with respect to eggs and larvae/egg mass (202.90).

Among treatments, maximum (32.86 %) reduction in egg mass contents was noticed with the application of Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (30.96 %) and Hot water + Tobacco churi + *T. harzianum* (28.52 %). However, highest reduction (34.77 %) was observed with Hot water + Neem cake + *Trichoderma viride* over untreated check (Fig.11). Lowest reduction in eggs and larvae/egg mass was observed with Hot water + lantana leaf powder + *T. harzianum* (16.12 %).

IV. Final Nematode Population per 100 cc soil:

Nematode population in soil at harvest is an important parameter to judge the effect of any treatment applied to manage plant parasitic nematodes. Therefore, final nematode population per 100 cc soil was observed and presented in Table-18.

Results exhibited that final nematode population decreased significantly with the application of different treatment combinations. Among combinations, minimum nematode population (554.30) was obtained with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (572.20) and Hot water + Tobacco churi + *T. harzianum* (590.30) over untreated check (1816.30). These treatments were found at par with each other in respect to final nematode population. Among all the treatments, minimum nematode population (532.00 larvae/100 cc soil) was observed with Hot water + Neem cake + *T. viride* combination used as a standard check. Combination of Hot water + lantana leaf powder + *T. harzianum* was found least effective with regards to final nematode population/100 cc soil.

Results revealed that maximum reduction (69.48 %) was registered with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (68.50 %) and Hot water + Tobacco churi + *T. harzianum* (67.50 %). It was found to be 70.71 % with Hot water + Neem cake + *T. viride* combination over untreated check. Lowest reduction in final nematode population/100 cc soil was obtained in Hot water + lantana leaf powder + *T. harzianum* treatment.

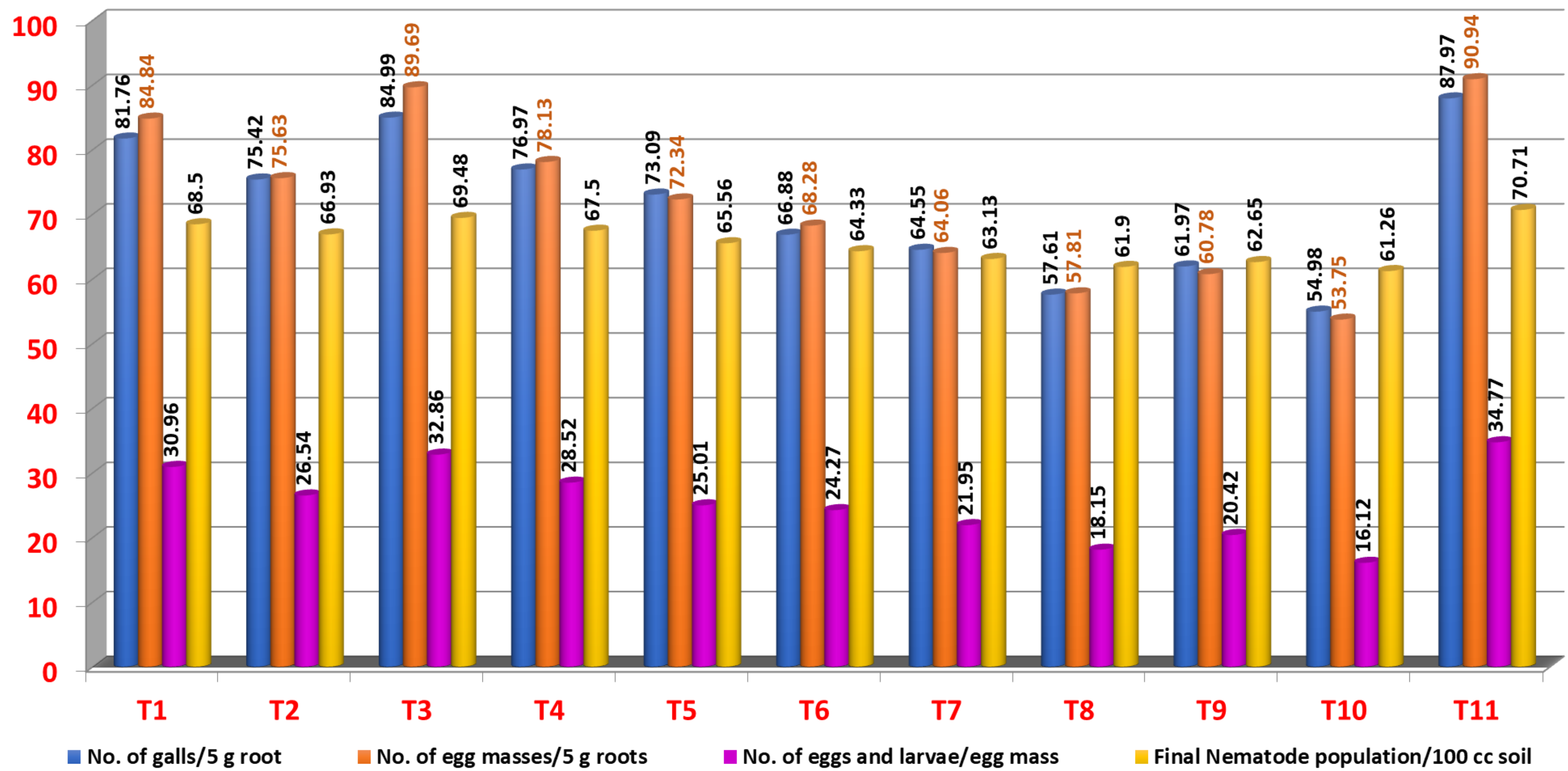

Figure 11: Changes with eco-friendly combinations on population of *M. incognita* infecting cucumber under poly-house

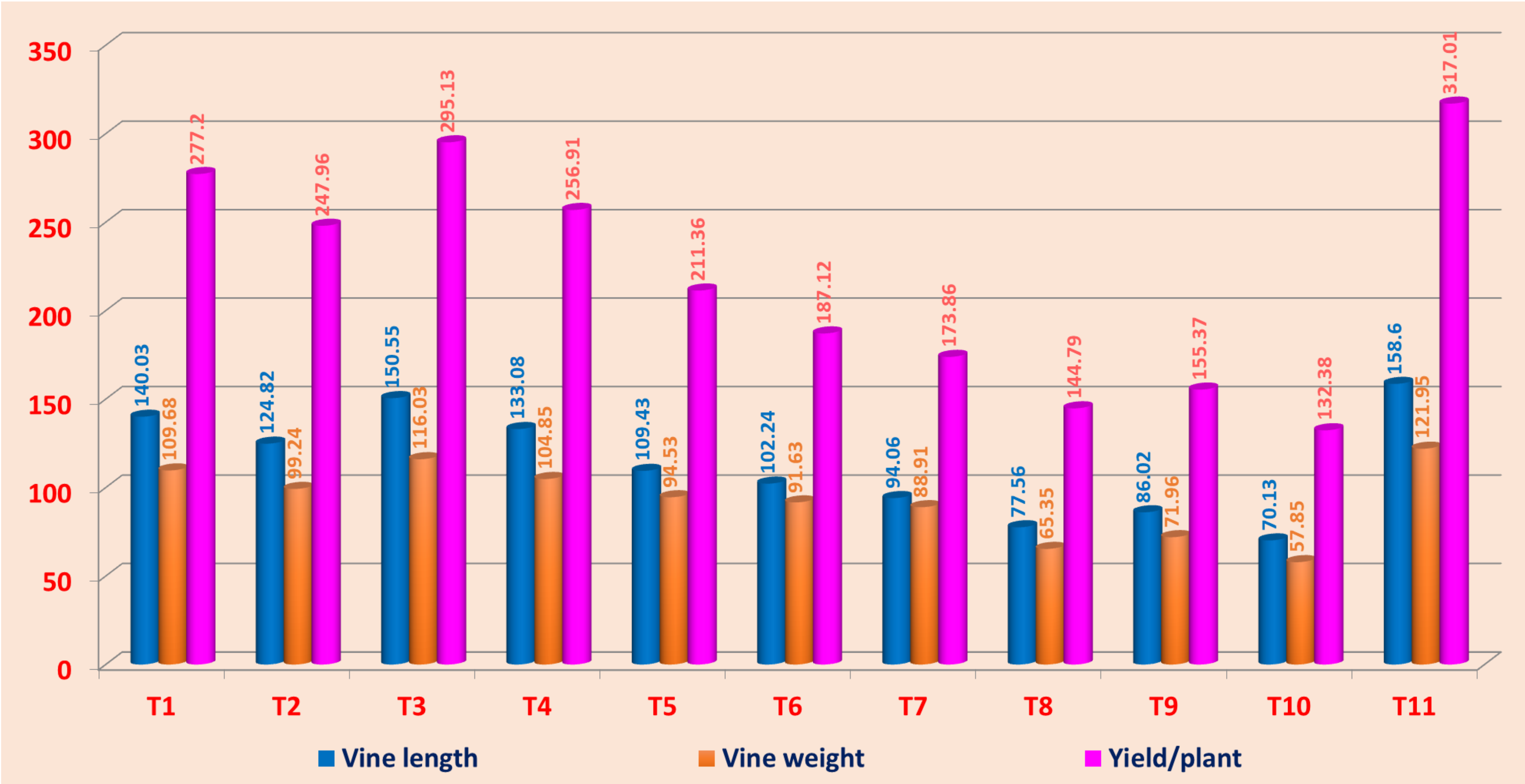

Figure 12: Changes on plant growth parameters of cucumber infested with *M. incognita* under poly-house with eco-friendly treatment combinations

V. Vine length (m):

Results showed that all the treatments were found significantly superior to increase vine length of cucumber under protected cultivation as compared to untreated check. Maximum vine length (3.467 m.) was observed with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (3.321 m) and Hot water + Tobacco churi + *T. harzianum* (3.225 m). These treatments were found significantly superior with regards to increase vine length as compared to untreated check (1.385 m). It was obtained 3.578 m in standard check (Hot water + Neem cake + *T. viride*).

Experimental findings revealed that soil application of different combinations of hot water, organic amendments and bio-agents under protected cultivation significantly increased vine length of cucumber. Maximum vine length increased with the treatment of Hot water + Tobacco churi + *P*. lilacinus (150.55 %) followed by 140.03 % and 133.08 % with Hot water + Tea waste + *P. lilacinus* and Hot water + Tobacco churi + *T. harzianum*, respectively (Fig.-12). It was observed to be 158.60 % with Hot water + Neem cake + *T. viride* (standard check) over untreated check. Minimum increase in vine length was noticed with Hot water + lantana leaf powder + *T. harzianum* treatment combination.

VI. Vine weight (kg):

Data presented in Table-19 revealed that vine weight of cucumber under protected cultivation adversely affected by *M. incognita* and increased significantly with the application of different combinations over untreated check. Among treatments, maximum vine weight (0.857 kg) was obtained with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (0.831) and Hot water + Tobacco churi + *T. harzianum* (0.812 kg) over untreated check (0.397). However, Hot water + Neem cake + *T. viride* (0.880 kg) was found to be better than other treatments but found at par with Hot water + Tobacco churi + *P. lilacinus*. Hot water + lantana leaf powder + *T. harzianum* combination was found least effective with regards to increase in vine weight.

Experimental findings presented in Table-21 showed that Hot water + Tobacco churi + *P. lilacinus* increased vine weight to the tune of 116.03 % while in Hot water + Tea waste + *P. lilacinus* and Hot water + Tobacco churi + *T. harzianum*, it was observed to be 109.68 and 104.85 %, respectively as compared to untreated check. Vine weight was increased highest with standard check combination of Hot water + Neem cake + *T.* viride (121.95 %) and lowest in Hot water + lantana leaf powder + *T. harzianum* combination.

Plate 15 : Effect of eco-friendly management on plant growth of cucumber infested with *M. incognita* in poly-house

VII. Yield (kg/plant):

Results pertaining to yield (kg/plant) data have been presented in Table 19 and illustrated with Fig. 12. Pool analysis of results revealed that yield was enhanced significantly with the application of treatments over untreated check. Among treatments, maximum (3.865 kg/plant) yield was obtained with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (3.690 kg/plant) and Hot water + Tobacco churi + *T. harzianum* (3.491 kg/plant) as compared to untreated check (0.983 kg/plant). Results revealed that all the combinations enhanced yield over untreated check. However, highest yield (4.078 kg/plant) was obtained with Hot water + Neem cake + *T. viride* kept as standard check and it was at par with Hot water + Tobacco churi + *P. lilacinus* combination. Hot water + lantana leaf powder + *T. harzianum* was found least effective with regards to cucumber yield but differed significantly from untreated check.

Results exhibited that among combinations, maximum increase in yield was noticed with Hot water + Tobacco churi + *P. lilacinus* (295.13 %) followed by Hot water + Tea waste + *P. lilacinus* (277.20 %) and Hot water + Tobacco churi + *T. harzianum* (256.91 %) over untreated check. However, highest increase in yield (317.01%) was obtained with the application of Hot water + Neem cake + *T. viride* and lowest was recorded with Hot water + lantana leaf powder + *T. harzianum* combination.

9. Effect of integrated nematode management on root-knot nematode, *M. incognita* infecting cucumber in poly-house:-

Agri-horticultural production was adversely affected greatly by plant parasitic nematodes in present scenario due to climate change. Variety of cultural, physical, biological and chemical methods of nematode control have been tested individually and found effective to some extent but all the methods have their own merits and demerits. With this view, in present investigation integration of hot water (1 litre/poly bag), organic amendment (tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder at 20 g/plant) and carbofuran (0.25 g a.i./plant and 0.50 g a.i./plant) have been tried for the management of root-knot nematode, *M. incognita* on cucumber in poly house. A standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) and untreated check was also maintained to compared experimental findings. Experimental trial was carried out in poly house at farmer’s field having an initial nematode population of 1350 and 1360 larvae/100 cc soil (2016 & 2017). Observations on galls/5 g roots, egg masses/5 g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield (kg/plant) was recorded. The results are presented in Table 22-25 and illustrated with Fig. 13-14 and Plate-16.

I. Number of galls per 5g roots:

Results revealed that all the treatments significantly reduced number of galls/ 5 g roots as compared to untreated check. Among various combinations, minimum number of galls per 5 g roots (9.00) was recorded with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (10.80) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (13.00) in comparison to untreated check (70.10) . These treatments were found significantly better with regards to decrease galls on cucumber over check. On the whole, minimum galls per 5 g roots (7.80) were obtained with standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) but it was found at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant.

Per cent reduction in gall was calculated and presented in Table 24. Maximum reduction in galls per 5 g roots (87.16 %) was noticed with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant. It was found to be 84.59 % and 81.46 % with Hot water + Tea waste + carbofuran at 0.5 g a.i./plant and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant, respectively. However, maximum reduction (88.87 %) was noticed with combination of Hot water at 1 litre + Neem cake at 50 g/plant + phorate at 0.5 g a.i./plant (standard check).

II. Number of egg masses per 5g roots:

Results pertaining to egg masses per 5 g roots showed that all the treatments significantly decreased egg mass formation of *M. incognita* on cucumber under protected cultivation in comparison to untreated check. Among various combinations tested, minimum egg masses per 5 g roots (4.90) was observed with the application of Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (6.80) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (9.00) over untreated check (61.40). These combinations differed significantly with regards to decrease in egg masses per 5 g roots on cucumber over check. Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant was found to be the best over others and produced 4.10 egg masses per 5 g roots. It was found at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant.

Results revealed that maximum reduction in egg masses per 5 g roots (92.02 %) was registered with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (88.93) and Hot water + Poultry manure + carbofuran at

Table-22: Effect of integrated nematode management on multiplication of root-knot nematode, *M. incognita* infecting cucumber in poly-house

Treatments		Galls/ 5 g root			Egg masses/ 5 g roots			Eggs and larvae/ egg mass			Final Nematode population/100 cc soil		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.25 g a.i./plant	20.00	19.40	19.70	15.40	15.00	15.20	186.80	179.80	183.30	616.40	612.00	614.20
T2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.5 g a.i./plant	11.40	10.20	10.80	07.20	6.40	6.80	168.60	161.40	165.00	510.60	502.40	506.50
T3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + Carbofuran 0.25 g a.i./plant	18.40	17.80	18.10	13.00	12.20	12.60	181.80	175.60	178.70	596.00	584.20	590.10
T4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + Carbofuran 0.5 g a.i./plant	09.20	8.80	9.00	05.20	04.60	4.90	161.20	158.40	159.80	494.80	486.80	490.80
T5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.25 g a.i./plant	21.00	20.40	20.70	16.60	15.60	16.10	191.00	184.20	187.60	640.60	628.60	634.60
T6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.5 g a.i./plant	13.40	12.60	13.00	09.20	08.80	9.00	172.40	169.20	170.80	538.20	526.60	532.40
T7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	25.00	24.60	24.80	17.80	16.20	17.00	191.80	188.40	190.10	668.00	660.40	664.20
T8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	15.00	14.20	14.60	10.40	09.80	10.10	175.20	171.60	173.40	560.20	556.80	558.50
T9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	25.80	25.40	25.60	19.00	18.40	18.70	195.00	191.20	193.10	682.20	675.20	678.70
T10	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	15.60	15.20	15.40	12.20	11.60	11.90	178.40	173.60	176.00	577.80	564.60	571.20
T11	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + Phorate 0.50 g a.i./plant	08.00	7.60	7.80	04.40	03.80	4.10	153.80	146.20	150.00	480.20	472.40	476.30
T12	Check	67.80	72.40	70.10	59.60	63.20	61.40	238.20	242.40	240.30	1826.8	1842.4	1834.6
	SEm ±	0.937	0.752	0.845	0.883	0.591	0.737	7.655	2.776	5.216	28.692	14.086	21.389
	CD at 5%	2.671	2.143	2.407	2.518	1.683	2.101	21.818	7.911	14.865	81.777	40.147	60.962

Data are the average value of five replications

Table-23: Effect of integrated nematode management on plant growth characters of cucumber infected with *Meloidogyne incognita* under poly-house

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.25 g a.i./plant	2.604	2.664	2.634	0.684	0.695	0.689	2.664	2.738	2.701
T2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.5 g a.i./plant	3.252	3.272	3.262	0.810	0.828	0.819	3.744	3.818	3.781
T3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + Carbofuran 0.25 g a.i./plant	2.746	2.840	2.793	0.707	0.718	0.712	2.800	2.880	2.840
T4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + Carbofuran 0.5 g a.i./plant	3.390	3.422	3.406	0.840	0.854	0.847	3.902	3.946	3.924
T5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.25 g a.i./plant	2.434	2.402	2.418	0.655	0.665	0.660	2.396	2.460	2.428
T6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.5 g a.i./plant	3.096	3.156	3.126	0.782	0.796	0.789	3.504	3.564	3.534
T7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	2.318	2.292	2.305	0.642	0.656	0.649	2.250	2.376	2.313
T8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	2.962	3.042	3.002	0.758	0.764	0.761	3.220	3.340	3.280
T9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	2.312	2.242	2.277	0.629	0.648	0.638	2.200	2.260	2.230
T10	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	2.912	2.942	2.927	0.712	0.724	0.718	2.910	2.970	2.940
T11	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + Phorate 0.50 g a.i./plant	3.538	3.562	3.550	0.860	0.872	0.866	4.146	4.196	4.171
T12	Check	1.326	1.446	1.386	0.390	0.374	0.382	1.104	1.080	1.092
	SEm ±	0.087	0.042	0.065	0.021	0.016	0.019	0.099	0.104	0.102
	CD at 5%	0.248	0.119	0.184	0.059	0.046	0.053	0.281	0.297	0.289

Data are the average value of five replications

Table-24: Changes in reproduction parameters of root-knot nematode, *M. incognita* with the integrated treatments on cucumber in poly-house

Treatments		Galls/ 5 g root*			Egg masses/ 5 g roots*			Eggs and larvae/ egg mass*			Final Nematode population/100 cc soil*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.25 g a.i./plant	70.50	73.20	71.90	74.16	76.27	75.24	21.75	25.83	23.80	66.26	66.78	66.52
T_2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.5 g a.i./plant	83.19	85.91	84.59	87.92	89.87	88.93	29.22	33.42	31.34	72.05	72.73	72.39
T_3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + Carbofuran 0.25 g a.i./plant	72.86	75.41	74.18	78.19	80.70	79.48	23.68	27.56	25.63	67.37	68.29	67.83
T_4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + Carbofuran 0.5 g a.i./plant	86.43	87.85	87.16	91.28	92.72	92.02	32.33	34.65	33.50	72.91	73.58	73.24
T_5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.25 g a.i./plant	69.03	71.82	70.47	70.13	75.32	73.78	19.82	24.01	21.93	64.93	65.88	65.40
T_6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.5 g a.i./plant	80.24	82.60	81.46	84.56	86.08	85.34	27.62	30.20	28.92	70.54	71.42	70.98
T_7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	63.13	66.02	64.62	72.15	74.37	72.31	19.48	22.28	20.89	63.43	64.16	63.80
T_8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	77.88	80.39	79.17	82.55	84.49	83.55	26.45	29.21	27.84	69.33	69.78	69.56
T_9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	61.95	64.92	63.48	68.12	70.89	69.54	18.14	21.12	19.64	62.66	63.35	63.01
T_{10}	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	76.99	79.01	78.03	79.53	81.65	80.62	25.10	28.38	26.76	68.37	69.36	68.87
T_{11}	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + Phorate 0.50 g a.i./plant	88.20	89.50	88.87	92.62	93.99	93.32	35.43	39.69	37.58	73.71	74.36	74.04
T_{12}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table-25: Influence of integrated nematode management on plant growth parameters of cucumber infested with *M. incognita* in poly-house

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.25 g a.i./plant	96.38	84.23	90.31	75.38	85.94	80.66	141.30	152.58	146.94
T_2	Hot water at 1 litre/poly bag+Tea Waste at 20 g/plant + Carbofuran 0.5 g a.i./plant	145.25	126.28	135.77	107.69	121.50	114.60	239.13	252.21	245.67
T_3	Hot water at 1 litre/poly bag+Tobacco churi at 20 g/plant + Carbofuran 0.25 g a.i./plant	107.09	96.40	101.75	81.28	92.09	86.69	153.62	165.68	159.65
T_4	Hot water at 1 litre/poly bag+ Tobacco churi at 20 g/plant + Carbofuran 0.5 g a.i./plant	155.66	136.65	146.16	115.38	128.34	121.86	253.44	264.02	258.73
T_5	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.25 g a.i./plant	83.56	66.11	74.84	67.90	77.81	72.86	117.03	126.94	121.99
T_6	Hot water at 1 litre/poly bag+ Poultry Manure at 20 g/plant + Carbofuran 0.5 g a.i./plant	133.48	118.26	125.87	100.46	112.94	106.70	217.39	228.78	223.09
T_7	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	74.81	58.51	66.66	64.62	75.29	69.96	103.80	119.19	111.50
T_8	Hot water at 1 litre/poly bag+ Water Hyacinth Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	123.38	110.37	116.88	94.36	104.28	99.32	191.67	208.12	199.90
T_9	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.25 g a.i./plant	74.36	55.05	64.71	61.23	73.37	67.30	99.28	108.49	103.89
T_{10}	Hot water at 1 litre/poly bag+ Lantana Leaf Powder at 20 g/plant + Carbofuran 0.5 g a.i./plant	119.61	103.46	111.54	82.56	93.58	88.07	163.59	173.99	168.79
T_{11}	Hot Water 1 litre/poly bag + Neem Cake 50 g/plant + Phorate 0.50 g a.i./plant	166.82	146.33	156.58	120.51	133.16	126.84	275.54	287.08	281.31
T_{12}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

0.5 g a.i./plant (85.34) over untreated check. It was observed highest (93.32 %) with standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant).

III. Number of eggs and larvae per egg mass:

Results of pool analysis (2016-17) showed that eggs & larvae/egg mass decrease significantly with all the treatments over untreated check. It was observed minimum (159.80) with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (165.00) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (170.80) as compared to untreated check (240.30).These combinations differed significantly with regards to decrease egg masses contents over check. On the whole, Hot water 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant (150.00 egg mass contents) was found to be the best and at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant.

Maximum reduction in egg mass contents was noticed with the application of Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant (33.50 %) followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (31.34 %) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (28.92 %) over untreated check (Fig. 13). Highest reduction (37.58 %) was recorded with the integration of Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant which was kept as standard check.

IV. Final Nematode Population per 100 cc soil:

Final nematode population at harvest is an important parameter to judge the effect of any treatment applied for the management of plant parasitic nematodes. Therefore, final nematode population per 100 cc soil was recorded and presented in Table 22. Results exhibited that final nematode population /100 cc soil decreased significantly with the application of different treatment combinations. Minimum nematode population per 100 cc soil (490.80) was obtained with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (506.50) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (532.40) over untreated check (1834.60). These treatments were found significantly superior over check with respect to the reduction in final nematode population. On the whole, minimum nematode population (476.30) was observed with Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant (standard check). All the treatments significantly reduced nematode population at harvest over untreated check.

Result showed (Table-24), maximum reduction in final soil population (73.24 %) was registered with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water +

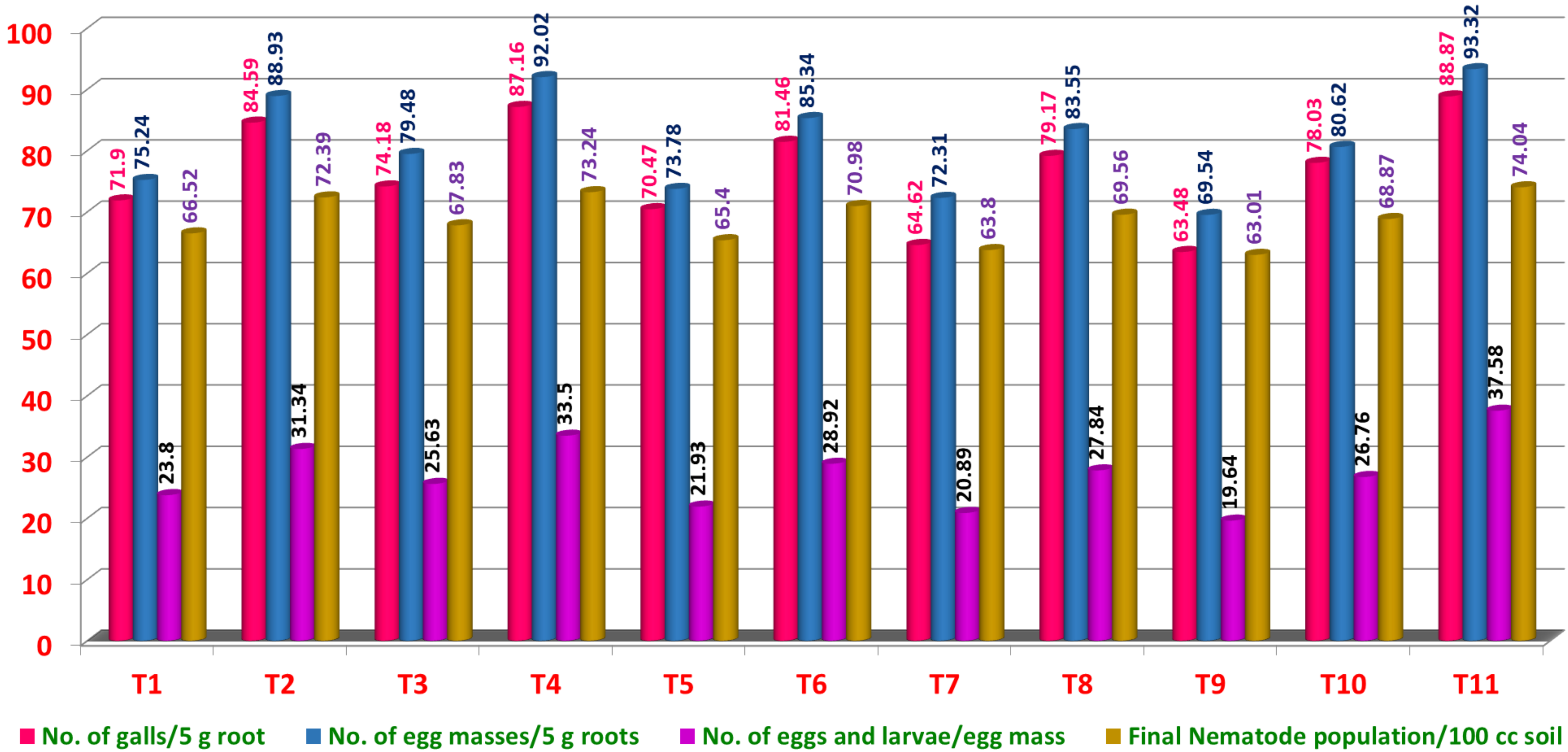

Figure 13: Changes in reproduction parameters of root-knot nematode, *M. incognita* with the integrated treatments on cucumber in poly-house

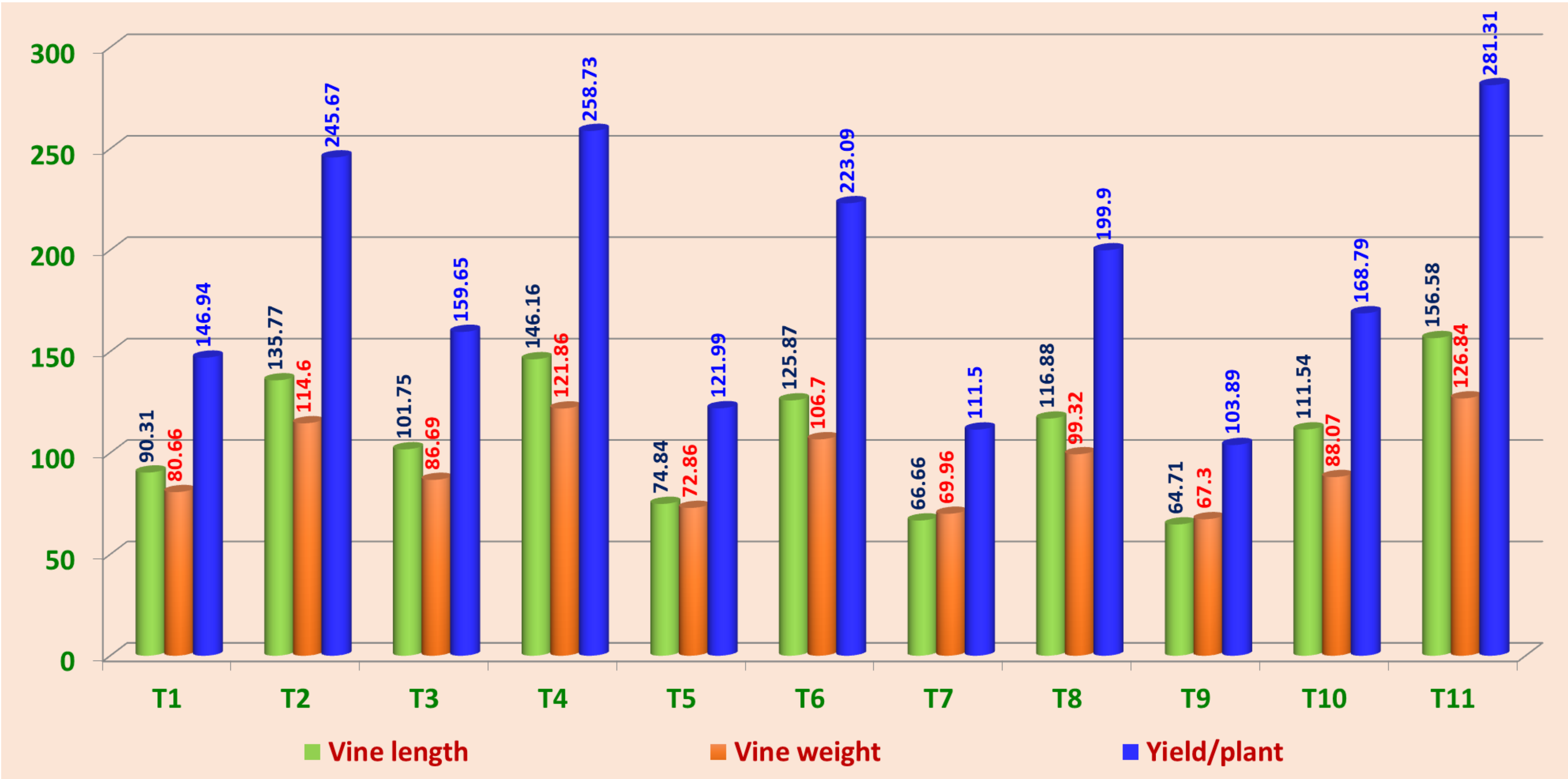

Figure 14: Influence of integrated nematode management on plant growth parameters of cucumber infested with *M. incognita* in poly-house

Tea waste + carbofuran at 0.5 g a.i./plant (72.39%) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (70.98%) over untreated check. It was observed highest (74.04 %) with standard check.

V. Vine length (m):

Vine length of cucumber increased significantly with the application of integrated treatments over untreated check. Results showed maximum increase in the vine length with the application of Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant (3.406 m.) followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (3.262 m.) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (3.126 m) over untreated check (1.386 m). However, it was registered 3.550 m. with Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant and was found at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant.

Experimental findings showed that soil application of different treatment combinations under protected cultivation increase vine length of cucumber. Maximum increase (146.16 %) was observed with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant over untreated check (Fig. 14). It was observed to be 135.77 % and 125.87 % with Hot water + Tea waste + carbofuran at 0.5 g a.i./plant and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant, respectively. Highest increase in vine length was noticed with Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant which was maintained as standard check.

VI. Vine weight (kg):

Data presented (Table 23) revealed that vine weight of cucumber under protected cultivation increased significantly with the application of treatments over untreated check. Among combinations, maximum vine weight (0.847 kg) was obtained when treated with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (0.819 kg) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (0.789 kg) as compared to untreated check (0.382 kg). All the treatments significantly increased vine weight over untreated check. However, Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant (0.866 kg) found the best over other treatments but at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant. Among various treatments, minimum vine weight (0.638 kg) was obtained with Hot water + lantana leaf powder + carbofuran at 0.25 g a.i./plant

Experimental findings (Table-25) showed maximum increase in vine weight with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant (121.86 %) followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant(114.60 %) and Hot water + Poultry manure + carbofuran at

Plate 16 : Effect of integrated nematode management on plant growth of cucumber infested with *M. incognita* in poly-house

0.5 g a.i./plant (106.70 %) over untreated check. However, it was registered highest (126.84 %) with standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant).

VII. Yield (kg/plant):

Results pertaining to yield have been presented in Table 23 and illustrated with Fig. 14. Pool analysis revealed that yield was enhanced significantly with the application of integrated treatments over untreated check. Among treatment combinations, maximum (3.924 kg/plant) yield was obtained with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by in Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (3.781 kg/plant) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (3.534 kg/plant) as compared to untreated check (1.092). These treatment combinations differed significantly over check. Minimum yield (2.230 kg) was recorded with integration of Hot water at 1 litre + lantana leaf powder at 20 g/plant + carbofuran at 0.25 g a.i./plant but it was significantly better over check. Highest yield (4.171 kg/plant) was obtained with the standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) and was observed at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant combination.

Results exhibited that among combinations, maximum increase (258.73 %) in yield was noticed with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (245.67 %) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (223.09 %) over untreated check . However, highest increase in yield (281.31 %) was obtained with the application of standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant).Minimum increase in yield was observed with combination of Hot water at 1 litre + lantana leaf powder at 20 g/plant + carbofuran at 0.25 g a.i./plant over untreated check.

Plate 17 : Fruiting of cucumber in poly-house

5. DISCUSSION

In present scenario protected cultivation is the most adoptable technology in agriculture for vegetable production and cucumber is the most favourable vegetable crop grown under protected cultivation. Cucumber is highly valuable crop among all vegetables, it is a rich source of minerals, which are essential for human diet. Plant parasitic nematodes take a heavy tribute of this crop throughout the world. The losses due to nematodes were observed to the 10 per cent extending up to 80 per cent, depends on the nematode population and other factors of poly-house. Though, number of plant parasitic nematodes have been found associated with vegetables in India, but root-knot nematode is considered to be the most damaging one (Prasad, 1960; Seshadri, 1970). In terms of disease severity and crop losses caused by *M. incognita* on vegetables including cucumber, attempts were made for management of nematode through chemicals (Sivakumar *et al*., 1973; Mahajan, 1978; Subramanian, 1996). Chemical control of nematode, though quick and effective, but has certain disadvantages such as prohibitive cost, pollution hazards and unsafe for human and domestic animals. Therefore, the present investigations were taken up to study various aspects such as survey, population fluctuation, estimation of losses caused by root-knot nematode with their eco-friendly management on cucumber in poly-house. The experiments wise findings have been discussed below:

I. OCCURRENCE AND POPULATION STATUS:

Survey was carried out to determine the occurrence and population status of root-knot nematode in poly-house of different districts of Rajasthan (Udaipur, Chittorgarh, Rajsamand, Hanumangarh, Jaipur, Dausa, Nagaur and Jodhpur). One hundred fifty eight samples were collected from forty poly-houses during 2016 and 17. Observations on occurrence (%), galls per 5 g roots, egg masses per 5 g roots and larvae per 100cc soil were recorded. Occurrence of root-knot nematode was noticed 100 % in surveyed poly houses. Results showed that not a single poly house during survey was observed free from root-knot nematode, *Meloidogyne* spp. presence.

During survey, thirty eight samples collected from nine different locations of Udaipur. All samples containing root-knot nematode, *Meloidogyne* spp. and on an average 90.77 galls per 5 g roots, 80.44 egg masses per 5 g roots and 937.55 larvae per 100cc soil were recorded on cucumber. Results revealed that maximum galls/5g roots (107), egg masses/5g roots (102) and nematode larvae/100 cc soil (1220) recorded from poly-house of Bikarni followed by Nandoli and

Maharaj ki khedi villages. Fifty eight samples were collected from 12 different locations of Chittorgarh. Results revealed 93.25 galls/ 5 g roots, 82.75 egg masses/ 5 g roots and 1033.75 larvae per 100cc soil were recorded on cucumber from different poly-houses. Maximum galls/5g roots (142), egg masses/5g roots (135) and larvae/100 cc soil (1460) recorded from poly-house situated at Tana followed by Surajpole and Munda Gulfroshan villages. From Rajsamand, forty samples collected from different poly-houses and all samples containing root-knot nematode population. On an average 81.72 gall/5 g roots, 70.81 egg masses per 5 g roots and 955.90 larvae/100cc soil were recorded on cucumber from poly-houses. Maximum galls/5g roots (118), egg masses/5g roots (107) and juveniles/100 cc soil (1325) recorded from poly-house established at Bhim-Karera road followed poly houses of Nedi and Amet. Four samples were collected from two different poly-houses of Hanumangarh and maximum galls/5g roots (124), egg masses/ 5 g roots (112) and nematode larvae / 100cc soil (1410) recorded from poly house of Nohar-I. Four samples were collected from Shahpura and Chomu villages of Jaipur. Maximum galls/5g roots (116), egg masses per 5 g roots (105) and larvae per 100 cc soil (1205.00) obtained from poly house of Chomu village. All samples collected from Jaipur district containing root-knot nematode on cucumber grown under poly house. Two samples were collected from poly house of Gijgarh district of Dausa with 104 galls/5g roots, 93 egg masses/5 g roots and 980 larvae/100cc soil on cucumber. Eight samples collected from Nagaur and on an average 69 galls/5g roots, 54.50 egg masses per 5 g roots and 836.00 larvae per 100cc soil were recorded on cucumber. The maximum galls/5g roots (79), egg masses/ 5 g roots (61) and nematode larvae/ 100cc soil (760) were observed from poly house established at Dabada (Maulasar).Four samples were collected from poly-house of Agrawal farm-Osian with population of 64 galls/5g roots, 54 egg masses/5 g roots and 956.00 larvae per 100cc soil on cucumber of Jodhpur.

The results of investigation are in accordance with the findings or earlier workers. Rao *et al.* (2007) who found the association of plant parasitic nematodes *viz.*, *Meloidogyne incognita, M. javanica, Rotylenchulus reniformis, Helicotylenchus sincises, Pratylenchus delattrei, Tylenchorhynchus capitatus, Xiphinema sp., Tylenchus sp., Criconema sp.* and *Aphelenchus sp.* on vegetables including chilli tomato, brinjal, okra, cucurbits and cluster bean. Chandel *et al.* (2010) conducted a trial in Himachal Pradesh for find out the population of plant parasitic nematodes in 214 greenhouses associated with Sweet pepper, carnation, cucurbits, tomato and cauliflower. Study revealed the presence of *Meloidogyne incognita, Helicotylenchus dihystera* and

Pratylenchus spp. ranging from 8 to 5604, 15 to 2560 and 5 to 795/200 cc soil, respectively. Similarly, Sharma (2010) collected samples from 15 poly-houses of Himachal Pradesh and found association of nematodes *viz., M. incognita, T. mashhoodi* and *H. dihystera* with capsicum in poly-houses. Tomato and cucumber were found heavily infested with *M. incognita* up to 80 per cent.

Ismail *et al.* (2012) also conducted a survey to determine the incidence and distribution of root-knot nematodes, *Meloidogyne* spp. infecting cucumber in open-field as well as plastic tunnel and found two dominant root-knot nematode species. *M. incognita* and *M. javanica* in samples. Similar findings were also recorded by Singh *et al.* (2012), Bem *et al.* (2014), Gautam *et al.* (2014), Manju and Subramanian (2015) and found that root-knot nematode is most prevalent and dominant in poly-houses. Singh and Khanna (2015) carried out survey on poly-houses from 52 localities of different districts of Himachal Pradesh and reported that *Meloidogyne incognita, M. hapla, Pratylenchus* sp., *Helicotylenchus* spp., *Mesocriconema* sp., *Tylenchorhynchus sp.* and *Hoplolaimus* sp. are major plant parasitic nematodes of poly-houses. Out of these nematodes *M. incognita* (37- 1200/200cc soil) was found most dominant over others.

These findings revealed that root-knot nematode was the most dominant and found in all poly-houses. However, population of nematodes have been observed highly variable, may be due to the age of poly-houses, cropping pattern, crop and it's variety, soil type and other abiotic conditions as well as different management practices adopted by the poly-house growers.

II. ESTIMATION OF AVOIDABLE LOSSES:

Root-knot nematode is a major biological factor for decrease agricultural production under protected cultivation throughout world and associated with number of economically important crops including vegetables. Keeping this in view, present investigation was undertaken to estimate the avoidable losses caused by root-knot nematode, *M. incognita* on cucumber under protected cultivation during 2016 & 2017 with the application of phorate at 2 kg a.i./ha. Observations on galls/5g roots, egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil and yield kg/plant was recorded. Experimental results showed a reduction of 79.03 per cent in galls/5 g roots, 81.10 per cent in egg masses/5 g roots, 30.91 per cent in the eggs and larvae per egg mass, 56.54 per cent in the nematode population with application of phorate at 2 kg a.i./ha. Use of chemical avoided, 66.84 per cent yield loss caused by root-knot nematode, *M. incognita* on cucumber in poly houses.

The results of present investigation are also agreement with the findings of earlier workers who reported losses caused by plant parasitic nematodes on different crops. Bhatti and Jain (1977) found that *Meloidogyne incognita* cause yield losses of okra, tomato, and brinjal at 90.9, 46.2 and 2.3%, respectively. Sharma and Baheti (1992) reported 46.0, 46.7, 47.8 and 55.4% losses on pea, okra, tomato and bottle gourd, caused by *M. incognita* and *M. javanica.* Nagesh & Reddy (2005) recorded 26 and 30% yield loss on carnation and Gerbera, respectively in commercial poly-house. The crop yield loss due to this tiny organism in various countries is enormous. In India, loss of Rs 21,068.73 million has been estimated due to plant parasitic nematodes. The overall average annual yield loss in major horticultural crops due to nematodes goes up to 60% under protected cultivation (Sharma *et al.,* 2009).

Chandel *et al*. (2010) conducted an experiment and found that avoidable losses due to nematode in greenhouse were estimated 11.31 per cent on tomato. Gautam *et al.* (2014) recorded 5 to 43% yield loss in vegetable crops due to plant parasitic nematodes. In Rajasthan, Baheti and Bhati (2017) also found avoidable yield losses caused by root-knot nematode, *M. incognita* on okra and observed these losses to the tune of 41.30-45.50 %, 37.50-41.52 % and 22.45-25.38 % in light, medium and heavy soil, respectively. Hema and Khanna (2018) recorded 35.2 and 37.4 per cent avoidable yield losses on tomato during 2016-2017, respectively in poly houses. Recently, Kumar *et al.* (2020) estimated 12% crop yield loss and Rs.110.46 million monetary losses in cucumber due to *Meloidogyne* spp. in India.

These studies exhibited that yield losses caused by *Meloidogyne* spp. on vegetables including cucumber, observed highly variable, might be due to difference in susceptibility of crop and it's variety, variation in climatic conditions (temperature and moisture etc.), initial inoculum of root-knot nematode during experimentation etc.

III. POPULATION FLUCTUATION:

The present work was carried out in poly-houses on cucumber for two years at two locations to find out variation in nematode population during crop period. Results showed that number of galls increased with the increase of crop time. Results revealed that minimum galls (2.60 galls/5g root) were found on cucumber at 15 days after sowing followed by 30 (6.10) and 45 (21.20) days of sowing. It was recorded highest at 120 days of sowing. (74.00 galls/5g roots) over rest of time interval of crop growth. Almost similar trends was observed with egg masses/5 g roots and final nematode population/100 cc soil on cucumber in poly-house. Eggs and larvae/egg mass gradually decreased with increase of crop period upto 120 days.

Results of present findings similar to Vincx (1989), Lucas (1992), Eapen (1993) and Cerevkova *et al.*, (2010), Ghonaimy *et al.* (2015), Surega and Ramakrishanan (2017) and Sen (2017). Vincx (1989) worked to find out the seasonal fluctuations of nematode community, based on the monthly samples. The mean density of the total 32 species were found in between 55 IJs/l0 cm2 (Feb., 1983) and 5610 IJs/10 cm2 (Jun., 1985) and an increase in reproductive activity appeared in spring and autumn. Lucas (1992) reported that population of root-knot nematodes, *Meloidogyne incognita, M. arenaria* and *M. hapla* fluctuated little in soil, but there was a trend toward reduced numbers at the end of the study, with higher numbers in winter than in summer of two years in kiwi orchard. Eapen (1993) found that ecological factors like rainfall and soil temperature mostly influencing the fluctuations in population of *Meloidogyne* spp. in a cardamom field for three years. Number of J_2 in soil was highest during March-April. Nematode population in roots increased rapidly during the post monsoon period, declined gradually during summer and was lowest in monsoon months. A study on the seasonal fluctuation of nematode population was conducted from 2005 to 2007 at different soil depth in a hop garden and found that seasonal fluctuation of the nematode population seemed to be related to temperature and rainfall. At 20 cm soil depth of each year, the largest nematode population was recorded in July and the smallest in October. At 40 cm soil depth, a decrease of nematode flow was observed from May to October (Cerevkova *et al.*, 2010).

Ghonaimy *et al.* (2015) conducted an experiment based on two cropping sequences and found that the population density of root-knot nematode fluctuated with respective plants in both two sequences after 2 and 4 months from planting each crop. Cucumber and common bean in the first sequence were found to be the best hosts for root knot nematode. The least number of nematodes were found on sesame. No galls or egg masses were found on onion.

Surega and Ramakrishanan (2017) find out the effect of seasonal changes on the population of plant parasitic nematodes and monitored at monthly intervals on turmeric grown under conventional and drip irrigation methods. The predominant genera *Meloidogyne incognita, Pratylenchus delattrei, Radopholus similis, Longidorus elongatus, Xiphinema elongatum, Hoplolaimus seinhorstii*, *Helicotylenchus multicinctus*, *Tylenchorhynchus martini* and *Rotylenchulus reniformis* recovered from rhizosphere. Among all, root-knot nematode population gradually started to build up right from the time of planting of turmeric and reached its peak around sixth month and towards crop maturity.

Sen (2017) carried out work in a Guava orchard and reported that the maximum population of nematodes were observed during monsoon with a population of 4169 IJS/250 gm soil in the month of July. During monsoon soil temperature (30.10^{0}C – 31.80^{0}C) and high soil moisture (20% - 26%) in the month of July were also observed. The minimum population (204 IJs/250 g soil) of nematode was observed during pre and post-monsoon with a wide range of low to high soil temperature and low soil moisture.

These studies clearly showed that population of plant parasitic nematodes greatly fluctuate and depends on crop season, initial inoculum level, ecological conditions (temperature, relative humidity, pH etc.), soil type, crop and it's variety, growth stage of crop etc.

IV. NEMATODE MANAGEMENT THROUGH HOT WATER TREATMENT:

Hot water treatment is easily adoptable, very effective and low cost physical method of nematode management. Looking to the importance of physical method of nematode management, 0.5,1.0, 1.5 litre of hot water was used in poly bags filled with nematode infested soil having an initial inoculum of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. After treatment, poly bags were kept for 15 days as such for maturation of soil and then sowing was made to find out the effect on nematode multiplication and crop growth parameters under poly house. Observations on number of galls/5g roots, egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield kg/plant were recorded.

Results revealed that application of hot water as soil treatment was found effective and significantly decrease the number of galls produced by *M. incognita* on cucumber. It has been observed that hot water at 1.5 litre /poly bag produced minimum 12.79 galls/5g roots on cucumber followed by 15.57 and 21.93 galls/5g roots with 1.0 and 0.5 litre of hot water, respectively under protected cultivation. These treatments significantly decreased galls over untreated check. Maximum 61.14 galls/5g roots were found in untreated check and it was observed significantly higher over rest of the treatments. Similar trend was observed with respect to egg masses/5 g roots, eggs and larvae/egg mass, final nematode population/100 cc soil on cucumber in poly-house.

Earlier worker also observed the effect of hot water treatment against root-knot nematode (Brcka *et al*., 2000). Brcka *et al.,* (2000) examined effects of hot water treatments to determine a temperature and time combination on population of the root-knot nematode on caladium tubers. In a preliminary experiment, tubers were immersed in a water bath at 50^0C for 30 min, 52^0C for 20 min, 54^0C for 10 min and a control (24^0C for 1 min). After treatment, tubers were planted in the greenhouse for evaluation of plant growth. Emergence and leaf growth were fastest in the treatment using 50^0C for 30 minutes. All tubers receiving a hot water treatment did not carry root-knot nematodes to sterile soil and produced more plant mass compare to control.

Results revealed that application of hot water significantly increase vine length of cucumber. Highest vine length (3.232 m) was obtained in 1.5 litre of hot water/ poly bag followed by 2.669 m (1.0 litre hot water/ poly bag) and 2.137 m (0.5 litre hot water/ poly bag) under protected cultivation in comparison to untreated check (1.246 meter vine length). All the treatments significantly increase vine length of cucumber over untreated check. Similar trend were noticed with vine weight (kg) and yield (kg/plant) of cucumber infested with *M. inconita* in poly-house.

The results of present findings are similar to that of Cabos *et al*. (2012) who observed effect of hot water through drenching for disinfesting potted dracaena from reniform nematodes, *Rotylenchulus reniformis*. Reniform nematodes were successfully eliminated in dracaena which treated at 50°C for 10 minutes or longer. No evidence of thermal damage was observed on plants drenched with hot water even at 52°C for 14 minutes. Continuous drenching for 15 minutes at 50°C is recommended to ensure effective penetration of water. Sellaperumal *et al*. (2015) applied hot-water with three temperatures (45, 50, 55^{o}C) and time (15, 30, 45 min) combinations to reduce the infection of root-knot nematode on tuberose bulbs. All the treatments improved plant growth and reduced nematode population. Hot water treatment at 50^{o}C for 45 minutes gave a reduction of 43, 36 and 57% in galls, egg masses and soil population of nematodes, respectively and enhance crop growth parameters.

These findings advocated that treatments of hot water is an effective, economical and environmentally safe means of reducing losses from nematodes in protected cultivation. Population of plant parasitic nematodes including *M. incognita* adversely affected by sudden change in temperature and their population bring down to a great level at higher temperatures.

With this option growers may reduce the cost of cultivation associated with the purchase of expensive chemicals, application requires limited resources that go into the production of a crop. Hot water treatment has gained further significance in integrated nematode management system.

V. NEMATODE MANAGEMENT THROUGH ORGANIC AMENDMENT:

The survival of plant parasitic nematodes depend on host plant, temperature, humidity, soil environment and change in any one from these factors influences the nematode survival directly as well as indirectly. Therefore, in the present investigation tea waste, tobacco churi, poultry manure, water hyacinth and lantana leaf powder were used at 20 and 40 g/plant tested for the management of root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation as soil application.

Results of pool analysis (2016 and 2017) revealed that number of galls per 5g roots significantly reduced with the organic amendment over untreated check. Among organic amendments , tobacco churi applied at 40g/plant was found to be the best and produced minimum galls (34.80 / 5g roots) followed by tea waste at 40g/plant (36.00 galls/ 5g roots) and poultry manure at 40g/plant (38.00 galls/5g roots) as compared to untreated check (73.70 galls per 5g roots) . Soil application of neem cake at 50 g/plant (33.20 galls per 5g roots) which was kept as standard check found to be the best and it was at par with tobacco churi 40g/plant. The similar trend was observed with respect to egg masses/5g roots, eggs and larvae/egg mass, final nematode population/100 cc soil.

The results obtained in present investigation are also in accordance with findings of Srivastava *et al*. (1971) who tested different oil-cakes against *M. javanica* on tomato and brinjal. They observed that neem cake was found most effective for the management of nematodes. Khan *et al*. (1979) recorded that the application of neem, groundnut, mahua and castor cakes significantly suppressed *M. incognita* in the okra. Thakur and Darekar (1995) reported that neem cake at 35 g/plant, karanj cake at 44 g/plant were found the most effective against root-knot nematode, *M incognita* on brinjal under pot and field trial conditions. Ramkrishanan *et al*. (1997) conducted a field experiment for the control of root-knot nematode on okra with various organics including neem and mustard cake as soil amendments. Maximum reduction in nematode reproduction factor was recorded in soil amended with neem cake. Goswami and Singh (1998) studied on efficacy of oil cakes (cotton, karanj, mahaua and mustard) against *M. incognita* infecting okra and observed significant reduction in the nematode population with karanj cake followed by mustard and mahua. A study was conducted by Nchore *et al.* (2011) in greenhouse as well as in field to determine the efficacy of cattle manure, goat manure, *Tithonia diversifolia* and agro-industrial wastes of tea [*Camellia sinensis* residue] pyrethrum, pymarc and vegetable waxy resins for the management of root-knot nematodes on *Solanum nigrum.* The results revealed suppression of RKN population and reproduction by the various amendments as compared to control in both field and greenhouse. Higher levels of tea waste and VWR application caused significant reductions in gall index, Rf and J2 populations. Mehta *et al*. (2015) evaluated the efficacy of neem (*Azadirachta indica*), aak (*Calotropis procera*) and water hyacinth (*Eichhornia crassipes*) leaf powder at 1, 2 and 4 g/plant against *H. zeae* on maize. Results revealed that maximum reduction in nematode reproduction was found with neem leaf powders at 4 g/plant followed by aak and water hyacinth leaf powders at 4 g/ plant.

The suppression of root-knot nematode with organic amendment under protected cultivation may be because of the several factors *i.e.* production of volatile fatty acids, phenols, ammonia, organic acid, amino acids etc. During decomposition of organic materials may be directly toxic to nematodes or the microbial metabolites produced during decomposition may also be toxic to nematodes or enhance activity of predators and parasites which may attack the nematodes and reduced their population.

Results exhibited that maximum 2.975 meter vine length of cucumber in protected cultivation was found with tobacco churi at 40 g/plant followed by 2.923 and 2.843 meter vine length observed with tea waste and poultry manure at 40 g/plant, respectively. Minimum vine length (1.390 m) was observed with untreated check. Among all the treatments, neem cake at 50 g per plant (3.039 meter) gives better response to increase in vine length of cucumber. The similar trend was exhibited with respect to vine weight and yield (kg/plant) of cucumber.

The results of present investigation are in accordance with the results of several previous workers who reported the effectiveness of organic amendments to enhance the crop growth parameters in nematode infested areas. Efficacy of karanj cake (*Pongamia glabra*) was reported by Singh (1965) to reduce root-knot nematode infection and enhance yield of tomato. Muhammad *et al*. (2001) reported that organic amendments of soil with neem cake, mustard cake, farm yard manure and poultry manure at 25 g/kg of soil significantly enhanced the growth of green gram. The most effective treatment was neem cake followed by mustard cake. Randhawa *et al*. (2002)

observed that soil amendment with neem cake significantly increased okra yield. Patel *et al.* (2003) reported that application of neem, castor, mahua, mustard, piludi and karanj cakes, farm yard and poultry manures, dry and fresh *Azolla*, press mud and urea significantly increased the plant growth of cotton. Baheti *et al.* (2019) tested neem, karanj and mustard oil-cakes for the management of root-knot nematode on okra. These cakes were applied at 2, 4 and 6 q/ha. An experimental result showed that neem cake at 6 q/ha was proved to be the most effective for the management of root-knot nematode, while karanj cake at 6 q/ha was found best to enhanced crop yield followed by neem cake and karanj cake over untreated check.

These findings support that application of organic amendments reduced the nematode population and enhanced plant growth in nematode prone areas. This might be possible due to the fact that organic amendments improve the physical properties of soil, increase the population of natural enemies of plant parasitic nematode and increase the activity of beneficial microbes in soil. However, different organic amendments showed different reaction may be due to variation in their nematicidal property, soil conditions, nematode species, initial nematode population, host crop and its variety etc.

VI. NEMATODE MANAGEMENT THROUGH BIO-AGENTS:

Biological management means the reduction of initial population of disease producing pathogen or parasite in its active or dominant state, by one or more organisms accomplished through manipulation (Baker and Cook, 1974). The earliest record of fungi as antagonists of Phyto-nematodes was reported by Duddington, 1954, Mankau, 1980 and Jatala, 1985. Biological control of plant parasitic nematodes by bacteria was first observed by Cobb in 1906 by *Pasteuria* sp. and later by Mankau, 1975 and Stirling, 1991.Therefore, in present investigation, efficacy of fungal bio-agents *(Paecilomyces lilacinus*, *Trichoderma viride* and *Trichoderma harzianum),* bacterial bio-agent *(Pseudomonas fluorescens)* and VAM (*Glomus fasciculatum)* were tested at 2.5 and 5.0 g/plant as soil application for the management of root-knot nematode, *M. incognita* on cucumber in poly-house during 2016 and 2017.

Results exhibited that all bio-agents significantly reduced galls over untreated check. Experimental findings revealed that number of galls per 5 g roots decreased on cucumber in protected cultivation significantly with the application of bio-agents. Among bio-agents, minimum number of galls per 5 g roots (33.10) were obtained when treated with *Pacilomyces lilacinus* at

5.0 g/plant followed by *Trichoderma harzianum* (37.10) and *Pseudomonas fluorescens* at 5.0 g/plant (38.80) over untreated check (76.70).Among treatments, maximum galls per 5g roots (47.80) were observed with *Glomus fasiculatum* at 2.5 g/plant and it was differed significantly with check. However, *Trichoderma viride* at 5 g /plant (30.20) was found the best among bio-agents which was kept as standard check. Almost similar trend was registered pertaining egg masses/5g roots, eggs and larvae/egg mass and final nematode population/100 cc soil.

Efficacy of bio-agents against plant parasitic nematodes including *M. incognita* was earlier reported by several workers. Mankau (1975) demonstrated biological control of root-knot nematode through *Bacillus penetrans* in glass house test. Jatala *et al.* (1979) reported the parasitization of eggs and females of *M. incognita* by *P. lilacinus* on potato. Mankau (1980) evaluated the fungal antagonist of nematodes and observed that fungi can be effectively be used as bio-control agents for nematodes and may be an alternative to chemicals.

Similarly, the efficacy of bio-agents was also reported by Zareen and Zaki (2001); Devi and Sharma (2002); Krishnaveni and Subramanian (2004). Zareen and Zaki (2001) evaluated the *P. lilacinus, T. Harzianum* and *T. flavus* as seed treatment and soil drenching in greenhouse on tomato. Seed treatment by *P. lilacinus* reduced gall formation, egg mass production, soil and root population as compared to control. Efficacy of *Trichoderma viride* and *T. harzianum* against root-knot nematode, *M. incognita* on tomato were studied by Devi and Sharma (2002). They observed improvement in plant growth and reduced nematode population as compared to untreated check. Krishnaveni and Subramanian (2004) tested the efficacy of seed and soil treatments with *Pseudomonas fluorescens* (10 g/seed and 2.5 kg/ha.), vesicular arbuscular mycorrhizal fungi (VAM, at 10 g/kg seed and 10 g/kg soil) and *Trichoderma viride* (at 5 g/kg seed and 2.5 kg/ha.) along with Carbofuran at 1 kg a.i./ha was also applied for comparison in the control of *M. incognita* infesting cucumber. Among the biological control treatments, *P. fluorescens* was found most effective against nematode population. Joshi *et al.* (2012) showed that *P. lilacinus* at 2 g/kg soil were found an effective treatment in reducing nematode reproduction factors as compared to other fungal agents on tomato.

Results revealed that soil treatment with bio-agents, significantly increased vine length of cucumber over untreated check. Results exhibited that among bio-agents, maximum vine length (2.969 m.) was recorded with *P. lilacinus* at 5.0 g/plant followed by *T. harzianum* (2.870 m.) and *P. fluorescens* (2.793 m.) at 5.0 g/plant. Vine length was recorded 3.128 m. in *T. viride* at 5 g/plant and was found at par with *P. lilacinus* at 5.0 g/plant. The similar trend was also observed with respect to vine weight and yield(kg/plant) on cucumber in poly house.

The results obtained in present investigation are also in accordance with findings of Santhi and Sivakumar (1995) who reported that various strains of *P. fluorescens* reduced the level of infestation of root-knot nematode *M. incognita* and enhanced the growth of tomato. Hanna *et al*. (1999) reported that *Bacillus thuringiensis* and *Pseudomonas fluorescens* showed most effective nematicidal activity against juveniles as well as adults of *M. incognita* and increased the growth of tomato. Rao *et al.* (2003) evaluated the efficacy of *V. chlamydosporium* and *Glomus fasciculatum* for the management of *M. incognita* on eggplant. They observed that these are significantly better to increase plant growth and reduced the nematode population. Sivakamasundari and Usharani (2013) studied on the efficacy of *P. fluorescens* and *G. fasciculatum* on the growth and yield of maize. Maximum germination percentage, vigour index, plant height, dry matter production and yield attributes were recorded with the treatment (*Pseudomonas fluorescens* + *Glomus fasciculatum*). Minimum growth and yield parameters were recorded in the treatment (*Glomus fasciculatum alone*).

Similarly, Hanawi (2014) conducted a greenhouse experiment to study the effect of *Paecilomyces lilacinus*, *Trichoderma harzianum*, *T. viride* with *G. Mosseae* and nematicide furfural against *Meloidogyne javanica* infecting tomato. Result revealed that *T. Harzianum* was found the most effective biocontrol agent to increasing shoot length and root length 16.2% and 26.1%, respectively. Ramezani and Ebrahimi (2014) conducted an experiment for biological management of reniform nematode on sunflower through bio-agents. This study was made to consider the effectiveness of commercial formulation of VAM fungus (*Glomus mosseae*), bacterial agent (*Pseudomonas fluorescens*) and antagonistic fungus (*Trichoderma viride*) against reniform nematode, *R. reniformis* on sunflower under greenhouse condition. Bhati *et al.* (2019) tested *Paecilomyces lilacinus, Pochonia chlamydosporia* and *Glomus fasiculatum* as seed treatment at 6 and 12 g/kg seed on bitter gourd. Results of experiment revealed that *Paecilomyces lilacinus* found to be effective followed by *Pochonia chlamydosporia* and *Glomus fasiculatum* at 12 g/kg seed to enhancing plant growth of bitter gourd and to reduce the infection of *M. incognita*.

The results of investigation clearly showed that soil application of bio-agents increased the yield of cucumber in nematode infested poly-house which may be due to reduction in nematodes population by micro-parasitism ,competition for food and space for nematode survival or release of some toxic metabolites *i.e.* serine, protease and chitinase which degrade the eggshell. Bio-agents also produced some nematotoxin such as paecilomycin, phomalactone, trichodermin, dermadin and trichoviridin etc. which may adversely affect the nematode activity. Biological control of nematodes is considered to encompass action of soil microorganisms and the soil micro fauna, which is mediated through mechanisms such as parasitism, predation, competition and antibiosis. Among the various kinds of organism's vesicular arbuscular mycorrhizae (VAM) is now also attracting greater attention. The endo-mycorrhizal fungi form a symbiotic relationship with their hosts and it is not restricted to nematode control only, it may be useful as "bio fertilizers" because of its ability to increase host nutrition particularly phosphate (Hall, 1987). Thus, bio-agents can be effectively employed to enhanced plant yield and reduced nematode population in agri-horticultural crops including cucumber in nematode infested poly-houses.

VII. NEMATODE MANAGEMENT THROUGH CHEMICALS:

Nematicides have tended to be broad-spectrum toxicants possessing high volatility or other properties promoting migration through the soil. Nematicides have been one of the important inputs which have allowed for "intensive agriculture (Michael Mckenry, 1994). The first nematicide carbon disulphide (CS_2) reported by Kuhn in 1871 against *Heterodera schachtii*, it caused serious nematode disease "beet tiredness" in sugarbeet.

In present investigation different chemicals *viz.*, Formalin at 10, 20 and 30 ml/plant, Metham Sodium and Sodium tetra thio-carbonate (STTC) at 2.5, 5.0 and 10 ml/plant were used for the management of root-knot nematode infecting cucumber in poly-house. Results revealed that application of formalin, metham sodium and Sodium tetra thio-carbonate as soil fumigant at all dose were found effective and significantly decrease galls produced by *M. incognita* on cucumber under protected cultivation. It was observed that minimum number of galls per 5 g roots (13.90) found in soil fumigated with formalin at 30 ml/plant followed by metham sodium at 10 ml/plant (18.50) and sodium tetra thio-carbonate at 10 ml/plant (20.90) as compared to untreated check (80.65). Among fumigants, formalin exhibited better response over metham sodium and STTC with respect to reducing egg mass contents. Among the treatments, phorate 2 g a.i./plant (14.10) also proved better but found at par with formalin 30 ml/plant. These treatments found significantly superior over rest of the treatments. Sodium tetra thio-carbonate at 2.5 ml/plant was found least effective over other treatments. The similar trends were also observed with respect to egg masses per 5g roots, eggs and larvae per egg mass and final nematode population/100cc soil on cucumber in poly-house.

The findings of present investigation also supported by Giannakou and Anastasiadis (2005) who conducted experiments with methyl bromide for management of root-knot nematodes (*Meloidogyne* spp.) on tomato and cucumber in commercial greenhouses. Methyl bromide was used as a reference treatment and was consistently superior to all the other treatments and combinations of other fumigants with contact nematicides. A significant reduction of nematode juveniles and root-galling index was observed in plots treated with either metham sodium or cadusafos or 1,3-dichloropropene and cadusafos. Nematode decrease was greater when these three chemicals were applied in the same plots. Sharma *et al.* (2007) studied Hi-Tech polyhouse cultivation of tomato, sweet pepper and cucumber. Crop management practices such as fumigation (formaldehyde 250 litre/ha) of polyhouse every year, removal/changing of top soil and supplement of pesticides (carbofuran 3G 1 kg a.i./ha) were regularly used against *M. incognita.* Results revealed that all the treatments reduced the nematode population and enhanced plant growth of sweet pepper, tomato and cucumber under protected cultivation. Oloo *et al.* (2009) reported that metham sodium and dozamet was found to be the most effective against nematodes under protected environment. Giriraj *et al.* (2018) recorded that soil fumigants (STTC and Metham Sodium) found effective against *M. incognita* on tomato in poly-house. Result showed that Metham Sodium at 40 ml/m^2 was observed as most effective fumigant followed by Metham Sodium at 30 ml and STTC 40 ml/m^2. Metham Sodium at 40 ml/m2 significantly reduced nematode reproduction and enhances plant growth over control.

Results showed that all the treatments found significantly better over untreated check with regards to enhance vine length of cucumber in poly house. Soil fumigation with formalin at 30 ml/plant showed maximum vine length (3.350 m.) followed by metham sodium (2.946 m.) and sodium tetra thio-carbonate(2.845 m.) at 10 ml/plant. It was observed 3.199 m. in phorate at 2 g a.i./plant. Sodium tetra thio-carbonate at 2.5 ml/plant (2.411 m.) was found least effective with regards to vine length over other chemicals. The similar trends were also observed in other plant growth parameters *i.e.* vine weight and yield of cucumber in poly house.

Sharma *et al.* (2009) recorded that continuous growing of crops in controlled environmental condition, the root-knot nematode (*Meloidogyne* spp.) has emerged as a major problem and caused enormous yield losses. The damage caused by root-knot nematode regularly increases if proper sanitation and control measures are not followed during the polyhouse cultivation of crops. After the banned of Methyl Bromide other fumigants like metham sodium and

Dazomet have been found quite effective when used under plastic mulch for single season. Non-fumigants, cadusaphos and oxamyl have also been used alone or in combination to protect 3-4 crops in protected cultivation. Gocher *et al.* (2018) also investigated on efficacy of three chemicals *viz.* Dimethoate, Triazophos & Chlorpyrifos at 0.5 and 1 ml/lit of water as seed soaking against *Meloidogyne incognita* on cucumber in polyhouse. Triazophos was found very effective followed by Chlorpyrifos and Dimethoate at 1 ml./lit water to improve plant growth characters and reducing nematode reproduction.

These studies revealed that fumigant nematicides are very volatile and quick effective against soil pest and pathogens including nematodes. There is a least residual problem, resurgence of nematode population and human hazards due to their application before sowing, but at the time of application we have to take proper safety measures due to their volatile nature. Chemical management of nematodes under protected cultivation is a need of the hour due to highly destructive nature, polyphagous behaviour and high fecundity rate of root-knot nematode, *Meloidogyne* spp. Nematicides may be used only when initial nematode population are high, crop is valuable and quick results are wanted. Cucumber is very valuable crop of poly-house growers so there is a need to use nematicides for the management of nematode in protected cultivation.

VIII. ECO-FRIENDLY NEMATODE MANAGEMENT:

Protected cultivation is a very important and profitable technique to increase farmer's income, but plant parasitic nematodes are very serious pest of protected cultivation. Among nematodes, root-knot nematode infestation has being very infectious in protected cultivation, justify the use of various measures for it's management. All the individual methods have their own advantage and disadvantages. With this view, in present investigation, physical method (Hot water at 1.0 lit./plant), organic amendments (Tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder at 20 g/plant) and bio-control agents (*Pacilomyces lilacinus* and *Trichoderma harzianum* at 2.5 g/plant) were used in combination for the management of root-knot nematode, *M. incognita* on cucumber under protected cultivation. A treated (Hot water at 1.0 lit./plant + Neem cake at 50 g/plant + *Trichoderma viride* at 5 g/plant) and untreated check was also maintained for comparison of the experimental findings. The experiment was conducted in poly house of farmer's field having an initial nematode population of 1350 and 1360 larvae/100 cc soil during 2016 & 17, respectively. Observations on number of galls/5g roots, number of egg masses/5g roots, number of eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield kg/plant were recorded.

Results revealed that all the treatments significantly reduced number of galls/5 g roots as compared to untreated check (Table-18). Among various combinations, minimum number of galls per 5 g roots (11.60) was recorded in Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (14.10) and Hot water + Tobacco churi + *T. harzianum* (17.80) in comparison to untreated check (77.30). These treatments were significantly differed from rest of the treatment combinations. Minimum galls (9.30) was obtained in combination with Hot water (1.0 litre/plant) + Neem cake (50 g/plant) + *Trichoderma viride* (5 g/plant) which was kept as standard check but it was found at par with Hot water + Tobacco churi + *P. lilacinus*. Hot water + lantana leaf powder + *T. harzianum* was found least effective among all the combinations but differed significantly over untreated check. The similar trend was noticed with regards to other nematode parameters such as egg masses/5g roots, eggs and larvae/egg mass and final nematode population/100 cc soil.

The results obtained in present investigation are also in the accordance with findings of Rao *et al*. (1997) who evaluated the effect of neem cake and *T. harzianum* either singly or in combination against *M. incognita* on tomato. Significant increase in plant growth and reduction in population of *M. incognita* were observed in tomato seedlings transplanted in neem cake amended soil incorporated with *T. harzianum*. It was also noticed that neem cake amendment encourages the activity of *T. harzianum*. Rangasamy *et al.* (2000) recorded that *Trichoderma viride* alone and in combination with either neem or castor cake was mostly parasitizing egg masses of the root-knot nematode, *M. incognita* on tomato. An experiment was conducted to find out the effectiveness of two bio-agents (*Pseudomonas fluorescens* and *Trichoderma viride)* and two botanicals (neem seed and tobacco waste dust) for the control of root-knot nematodes on tobacco. Results revealed that neem seed treatment has suppressed the RKN to the minimum level followed by tobacco waste and *P. fluorescens* (Motha *et al.*, 2010).

Results showed that all the treatments found significantly superior to increase vine length of cucumber under protected cultivation as compared to untreated check. Maximum vine length (3.467 m.) was observed with Hot water + Tobacco churi + *P. lilacinus* followed by Hot water + Tea waste + *P. lilacinus* (3.321 m) and Hot water + Tobacco churi + *T. harzianum* (3.225 m).

These treatments were found significantly better with regards to increase vine length. It was obtained 3.578 m in Hot water + Neem cake + *T. viride* as compared to untreated check (1.385 m). The similar trend was obtained with regards to other plant growth characters *i.e.* vine weight (kg) and yield (kg/plant).

Effects of bio-agents and neem cake were reported by Pandey *et al.* (2005) against M*eloidogyne incognita* on chickpea. The treatments comprised of neem cake, *Trichoderma harzianum, T. viride, Paecilomyces lilacinus, Aspergillus niger* and *Verticillum chlamydosporium*. The combined application of neem cake and bio-agents significantly increased shoot weight, root weight and chlorophyll content. Root and shoot length were highest in integrated application of bio-agents with neem cake. Sellaperumal *et al*. (2015) applied hot-water with three temperatures (45, 50, 55^{o}C) and time (15, 30, 45 min) combinations to reduce the infection of root-knot nematode on tuberose bulbs. All the treatments improved plant growth and reduced nematode population. Hot water treatment at 50^{o}C for 45 minutes gave a reduction of 43, 36 and 57% in galls, egg masses and soil population of nematodes, respectively and enhance crop growth parameters. Mehta *et al.* (2016) showed that among bio-agent and plant product combinations, *P. lilacinus* at 2% coupled with neem leaves powder at 4g/plant was found most effective followed by *T. harzianum* at 2% + neem leaves powder at 4g/plant and *P. lilacinus* at 2% + aak leaves powder at 4g/plant for the management of *H. zeae* and to enhanced plant growth of maize.

These findings showed that tretments of hot water, organic amendments and bio-agents with different combinations provide good protection against plant parasitic nematodes and provide good alternative as eco-friendly management of root-knot nematode, *M. incognita* in poly house. These may be specially adopted for organic production of cucumber under protected cultivation. Combined use of hot water, organic amendment and bio-agent might be helpful to reduce the cost of cultivation and improved the profit of poly house growers.

IX. INTEGRATED NEMATODE MANAGEMENT:-

Integrated nematode management refers to controlling the nematodes using two or more methods. Now a days looking to climate change, it is very difficult to control nematodes by any one method, so in present scenario integrated nematode management is very important. With this view, in present investigation, integration of hot water (1 litre/poly bag), organic amendment (tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder at 20 g/plant) and carbofuran (0.25 g a.i./plant and 0.50 g a.i./plant) have been tried for the management of root-knot nematode, *M. incognita* on cucumber in poly house. A standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) and untreated check were also maintained to compared experimental findings. Experimental trial was carried out in poly house at farmer's field having an initial nematode population of 1350 and 1360 larvae/100 cc soil (2016 &2017). Observations on galls/5 g roots, egg masses/5 g roots, eggs and larvae/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) and yield (kg/plant) was recorded.

Experimental results exhibited that all the integrated nematode management treatments significantly reduced number of galls/ 5 g roots as compared to untreated check. Among various combinations, minimum number of galls per 5 g roots (9.00) was recorded with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (10.80) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (13.00) in comparison to untreated check (70.10). These treatments found significantly better with regards to decrease galls on cucumber over check. On the whole, minimum galls per 5 g roots (7.80) were obtained with standard check (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) but it was found at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant. Almost similar trend was obtained pertaining to other nematode parameters *viz.* egg masses/5g roots, eggs and larvae/egg mass and final nematode population/100 cc soil.

Results of present findings are in accordance with the findings of earlier workers who reported that integration of different management options proved better over individual method of nematode management. Parvatha Reddy and Khan (1991) tested oil cakes (neem, castor, groundnut and karanj) at 1.0 t/ha as single and 0.5 t/ha with combined application of carbofuran (2 kg a.i./ha as single and 1.0 kg a.i./ha as combined application) for the management of root-knot nematode, *M. incognita* infecting okra. Results revealed that plots treated with karanj cake, neem cake + carbofuran, groundnut cake + carbofuran gave highest yield of okra. However, all the oil cakes in combination with carbofuran gave least root-knot index as compared to control followed by single application of neem cake (1 t/ha) and carboruan (2 kg a.i./ha). Jain and Gupta (1993) reported that summer ploughing with seed treatment (carbosufan 3 %) proved most effective for management of *M. javanica* and increasing okra yield over untreated check. At harvest, treated seeds had a significantly lower root-knot index and final soil population than untreated seeds.

Asawalam and Adesiyan (2001) tested the nematicidal potential of Carbofuran (Furadan) and *Azadirachta indica* (neem) leaf extract against root-knot nematode (*M. incognita*) on okra and found that *A. indica* and carbofuran significantly reduced root galls and increased mean fruit number and weight. Mishra *et al.* (2003) reported that seed treatment with bio-pesticides (neem seed powder, latex of *Calotropis procera* and Neemark), chemicals (dimethoate, triazophos, chlorpyriphos and carbofuran) and bio-agents (*Trichoderma viride*, *Aspergillus niger* and *Paecilomyces lilacinus*) found effective against root-knot nematode and increased plant growth and yield of chickpea. Soil treatment with carbofuran at 2 kg./ha was found equally effective as neem seed powder (50 kg/ha), but plant growth parameters were better under neem seed powder treatment. Das and Sinha (2005) found decrease in number of galls, egg masses per root system and final nematode population in soil was in the combine treatment of *P. lilacinus* at 4 g/ kg soil + carbosulfan 25 EC at 0.2 % + poultry manure at 2.5 t/ha + FYM at 2.5 t/ha over untreated check.

Haseeb and Kumar (2009) reported the effect of bio-agents (*P. fluorescens* and *T. viride* at 10 g/kg seed), neem seed powder at 10 g/kg seed and carbosulfan at 3.0% w/w as seed treatment alone and in combination against root-knot nematode, *M. incognita* on lentil. Highest improvement in grain yield and lowest root-knot index was observed with P. *fluorescens* + *T. viride* + neem seed powder + carbosulfan. Chandel *et al*. (2014) conducted experiment under protected cultivation and observed that soil fumigation with metham sodium alone and in combined application with neem cake (enriched with bio-agents *Paecilomyces lilacinus*, *Pseudomonas fluorescence*) found very effective against root- knot nematode infecting tomato, capsicum and carnation.

Experimental findings showed that vine length of cucumber increased significantly with the application of integrated treatments over untreated check. Results showed that maximum increase in the vine length was recorded with the application of Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant (3.406 m.) followed by Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (3.262 m.) and Hot water + Poultry manure + carbofuran at 0.5 g a.i./plant (3.126 m) over untreated check (1.386 m.). However, it was registered 3.550 m. with Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant and it was found at par with Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant. The similar trend was found with other parameters *i.e.* vine weight (kg) and yield (kg/plant) of cucumber in protected cultivation.

Study of Barman and Das (1996) showed that carbofuran 3 G at 3 % (w/w) and organic amendments (neem cake, mustard cake and poultry manure) each at 2 t/ha alone and combined application of seed dressing with organic amendments at 1 t/ha were found effective against root-knot nematode and improved plant growth and yield of green gram over untreated check. Effective results were found with poultry manure applied at 2 t/ha followed by combined application of seed dressing + neem cake at1 t/ha. A field experiment conducted by Patel and Patel (1998) on chickpea against root-knot nematode using seed treatment of carbosulfan 25 ST at 0.75% with soil application of organic amendments. Results revealed that seed treatment and organic amendments had no adverse effect on germination and significantly enhanced plant growth and reduced root-knot index as well as final population in soil. Begum and Sivakumar (2005) conducted an integrated study on carbofuran at 3 kg/ha (as soil application), *Pseudomonas fluorescens* (seed treatment) + neem cake (soil application) and *Trichoderma viride* (seed treatment) + neem cake (soil application) for the management of disease complex involving *Heterodera cajani* and *Macrophomina phaseolina* on green gram. Highest reduction in the nematode population was recorded with carbofuran at 3 kg/ha followed by combined application of *P. fluorescens* + neem cake and *T. viride* + neem cake.

Goswami *et al.* (2006) studied on the effect of fungal bio-agents along with mustard cake and furadan against root-knot nematode *Meloidogyne incognita* infecting tomato under greenhouse condition. Bio-agents *viz*., *Paecilomyces lilacinus* and *Trichoderma viride* alone or in combination with mustard cake or furadan boost up plant growth and exhibited least nematode reproduction as compared to untreated check. Yucel *et al.* (2007) carried out greenhouse experiments to found the effectiveness of a combination of soil solarization with low doses of metham-sodium (500, 750, 1000 and 1250 lha^{-1}) and dazomet (400 g ha^{-1}) against plant parasitic nematodes. Results showed that treatments reduced disease incidence and considered to be applicable for soil disinfestation. Results showed that, crop growth increased with all the treatments tested in both of the greenhouses. Mahalik and Sahoo (2019) evaluated the efficacy of oil cakes (neem and jatropha oil), bio control agents (*Purpureocillium lilacinum, Trichoderma viride* and *Pseudomonas flourescens*) and Carbofuran 3G. The experimental results showed that soil application of jatropha cake at 1.0 t/ha + seed treatment with *T. viride* and *P. fluorescens* (at 5g/kg seed) + soil application of *P. lilacinum* at 2.5kg/ha resulted maximum increase in plant growth with highest reduction in nematode population over control.

These studies advocates the use of integrated nematode management in high value crops in poly-houses. Integration of hot water as pre-sowing application bring down the nematode population quickly and economically, while addition of organic amendment helps to increase in activity of beneficial microbes. The production and release of nematicidal compounds by the organic amendment in soil was able to reduce the nematode population and ultimately improved plant growth of agro-horticultural crops. The main objective of integrated nematode management is to manage the population of nematodes below ETL level by keeping the safe environment for long time. The resistant against chemicals in nematodes and toxicity on plants by excessive use of agrochemicals can also be avoided with INM and the farmer's income can be increased by reducing cost of cultivation. Integration of different treatments when used at reduced dose as compare to their higher dose as sole application, effectively manage the root-knot nematode in poly house and enhance yield of cucumber in protected cultivation.

6. SUMMARY

Cucumber (*Cucumis sativus* L.) is a high nutritious and mineral-rich vegetable, which occupies a prominent place as a salad and vegetable. It is being used in many ways in the daily diet of humans and widely cultivated in India. The decrease of agricultural land and continuous increase of population, the demand of nutritious food is a matter of great concern to our country. Protected cultivation is a very effective tool to solve this problem because in this cultivation the productivity of crops is very high as compared to open field conditions. Looking to this attribute, protected cultivation units have been increased day by day in all parts of India. High value crops successfully grown in protected cultivation, specially vegetables (cucumber, tomato, *Capsicum* etc.) which are highly susceptible to the number of pests and pathogens including phyto-parasitic nematodes (specially root-knot nematode, *Meloidogyne* spp.). Hence to some extent the confidence of poly house growers gradually declines due to drastic damage caused by *Meloidogyne* spp. in protected cultivation. To fill this gap, experiments have been conducted during 2016 and 2017 to find out occurrence, distribution, estimation of avoidable losses and to manage root-knot nematode, *M. incognita* on cucumber in poly houses of farmer's field. Results of present investigation have been summarized below.

Survey was carried out to determine the occurrence and population status of root-knot nematode in poly-houses of different districts of Rajasthan (Udaipur, Chittorgarh, Rajsamand, Hanumangarh, Jaipur, Dausa, Nagaur and Jodhpur). During survey, one hundred fifty-eight samples were collected from forty poly-houses of Rajasthan. Results pertaining to survey revealed that occurrence of root-knot nematode, *Meloidogyne* spp. was recorded 100 % in all the poly-houses. Root-knot nematode infestation was recorded high from poly houses of Tana, Surajpole, Manda Gulfmroshan, Bikarni, Nandoli and Nohar locations whereas low infestation was observed in Badola farm, Krishna nursery, Kashmor and Piladar poly houses.

Avoidable losses caused by root-knot nematode, *M. incognita* on cucumber in poly-house estimated with the application of phorate at 2 kg a.i./ha over untreated control. Results revealed that application of chemical significantly reduced no. of galls/5 g roots, egg masses/5 g roots, eggs & larvae/egg mass and final nematode population 79.03, 81.10, 30.91 and 56.54 %, respectively. Avoidable yield losses were recorded to the tune of 66.84% on cucumber by *M. incognita* in poly-house situated on farmer's field.

Population fluctuation of root-knot nematode, *Meloidogyne incognita* was studied on cucumber in poly-houses. Population of root-knot nematode, *M. incognita* was monitored at fifteen days interval throughout the crop season up to 120 days on cucumber under protected cultivation. Results showed that number of galls increased with the increase of crop time. Results revealed that minimum galls (2.60 galls/5g root) on cucumber found at 15 days after sowing while highest at 120 days after sowing (74.00 galls/5g roots). Population of egg masses/5g roots and larvae/100 cc soil also showed similar trend as of galls/5g roots. However, egg mass contents found maximum at 30 days of sowing and minimum at 120 days after sowing of cucumber in poly-houses.

Hot water treatment was applied at 0.5, 1.0 and 1.5 litre per poly bag filled with nematode infested soil fifteen days prior to sowing. Results revealed that hot water treatment at 1.5 litre per poly bag was found the best followed by 1.0 litre and 0.5 litre/ poly bag with regards to reduced nematode population and to enhance cucumber yield in poly houses. Hot water at 1.5 litre / poly bag reduced galls/5 g roots (79.08%), egg masses/5g roots (80.55%), egg mass contents (15.87%) and final nematode population per 100 cc soil (63.93%). It enhanced 159.52 per cent vine length, 67.47 per cent vine weight and 181.53 per cent in yield over untreated check.

Organic amendments *viz.*, tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder were applied at 20 and 40 g/plant to manage *M. incognita* on cucumber in poly-house. Results showed that neem cake at 50 g/plant was found to be the best followed by tobacco churi at 40g/plant and tea waste at 40 g/plant with respect to reduced infection of *M. incognita.* Yield of cucumber significantly increased with the organic amendments over untreated check in root-knot nematode infested poly house. Among treatments, maximum yield (3.180 kg/plant) was obtained with the application of tobacco churi at 40 g/plant followed by tea waste (3.060 kg/plant) and poultry manure (2.890 kg/plant) at the rate 40 g per plant as compared to untreated check (1.215 kg/plant). Among all the treatments, the highest yield (3.390 kg/plant) was recorded with neem cake at 50 g/plant which was kept as standard check.

Bio-agents *i.e. Paecilomyces lilacinus*, *Trichoderma viride, Trichoderma harzianum, Pseudomonas fluorescens* and *Glomus fasciculatum* were applied as soil application at 2.5 and 5.0 g/plant against *Meloidogyne incognita* on cucumber under protected cultivation. Results exhibited that *T. viride* at 5 g/plant was found to be the best with regards to reduced infection of root-knot nematode, *M. incognita* and to increase plant growth parameters of cucumber in poly house followed by *P. lilacinus* and *T. harzianum* at 5 g/plant. Amongst different bio-agents, maximum yield was obtained with *T. viride* at 5 g/plant (3.161 kg/plant) followed by *P. lilacinus* (2.905 kg/plant) and *T. harzianum* at 5.0 g/plant (2.799 kg/plant) as compared to untreated check (1.131 kg/plant).

Keeping in mind about the high intensity and population of root-knot nematode on cucumber in poly-house, the chemical treatment trial was planned and conducted for effective management of nematode. Chemicals *viz*. Formalin at 10, 20 and 30 ml/plant, Metham Sodium at 2.5, 5.0 and 10 ml/plant, Sodium tetra thio-carbonate (STTC) at 2.5, 5.0 and 10 ml/plant and phorate at 2 g a.i./plant as standard check were tested against root-knot nematode infecting cucumber in poly-house. Results revealed that application of formalin, phorate, metham sodium and Sodium tetra thio-carbonate at all the doses used were found effective and significantly decreased nematode reproduction parameters of *M. incognita* on cucumber under protected cultivation. Maximum yield (3.657 kg/plant) was obtained with application of formalin 30 ml/plant followed by phorate at 2 g a.i./plant (3.482 kg/plant) and metham sodium (3.280 kg/plant) at 10.0 ml/plant as compared to untreated check (0.994 kg/plant).

To reduce the use of pesticides in poly-houses and to promote the crop production, an eco-friendly management trail was conducted with different combinations of physical method (Hot water treatment at 1.0 lit./polybag), organic amendment (Tea waste, tobacco churi, poultry manure, water hyacinth and lantana leaf powder at 20 g/plant) and bio-agents (*Paecilomyces lilacinus* and *Trichoderma harzianum* at 2.5 g/plant) were used as soil application against *M. incognita* on cucumber in poly-house with standard (Hot water at 1.0 lit./poly bag + Neem cake at 50 g/plant + *Trichoderma viride* at 5 g/plant) and untreated check. Results of pool analysis revealed that all the treatments significantly reduced nematode reproduction and enhanced plant growth parameters as compared to untreated check. Maximum yield was obtained with Hot water + Tobacco churi + *P. lilacinus* (3.865 kg/plant) followed by Hot water + Tea waste + *P. lilacinus* (3.690 kg/plant) and Hot water + Tobacco churi + *T. harzianum* (3.491 kg/plant) as compared to untreated check (0.983 kg/plant). However, highest yield (4.078 kg/plant) was obtained with Hot water + Neem cake + *T. viride* combination which was maintained as standard check.

An integrated nematode management trial was conducted for the management of *M. incognita* on cucumber in poly-house. In the present investigation different combinations of hot water at 1 litre per poly bag, organic amendment (tea waste, tobacco churi, poultry manure, water hyacinth powder and lantana leaf powder at 20 g/plant) and carbofuran (0.25 g a.i./plant and 0.50 g a.i./plant) were applied. Standard (Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant) and untreated checks were also maintained to compare experimental findings. Results exhibited that all the treatments significantly reduced nematode population parameters and plant growth characters over untreated check. Results revealed that among treatment combinations, Highest yield (4.171 kg/plant) was obtained with integration of Hot water at 1 litre + Neem cake 50 g/plant + phorate at 0.5 g a.i./plant followed by Hot water + Tobacco churi + carbofuran at 0.5 g a.i./plant (3.924 kg/plant) and Hot water + Tea waste + carbofuran at 0.5 g a.i./plant (3.781 kg/plant) as compared to untreated check (1.092).

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Distribution, Losses and Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Cucumber (*Cucumis sativus* L.) under Protected Cultivation

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ABSTRACT

Root-knot nematode, *Meloidogyne incognita* is polyphagous pest throughout the world and causes severe losses in cucumber under protected cultivation. Looking to its economic importance and severity, some experiments have been conducted for the management of this key pest in poly-houses. Attempts were made to find out the occurrence and population status, avoidable losses, seasonal fluctuations and to develop effective, economical and eco-friendly management strategies against root-knot nematode, *M. incognita* on cucumber under protected cultivation.

During survey, one hundred fifty-eight samples were collected from forty poly-houses of Rajasthan. Results revealed that occurrence of root-knot nematode, *Meloidogyne* spp. was recorded 100 % in poly houses. Root-knot nematode infestation was recorded high from poly houses of Tana, Surajpole, Manda Gulfmroshan, Bikarni, Nandoli and Nohar locations.

Results revealed that application of phorate at 2 kg a.i./ha avoided yield losses to the tune of 66.84% on cucumber caused by root-knot nematode, *M. incognita* in poly-house. Population fluctuation studies showed that nematode population increased with the increase of crop time. Results revealed that minimum galls on cucumber found at 15 days after sowing while highest at 120 days after sowing. Population of egg masses/5g roots and larvae/100 cc soil also showed similar trend as of galls/5g roots.

Results revealed that hot water at 1.5 litre per poly bag was found superior followed by 1.0 litre and 0.5 litre/ poly bag with regards to reduced nematode population and to enhance yield of cucumber in poly houses.

Organic amendments trial showed that neem cake at 50 g/plant was found to be superior followed by tobacco churi and tea waste at 40 g/plant with respect to reduced infection of *M. incognita* and to increase yield of cucumber under protected cultivation. Bio-agent trial exhibited that *T. viride* at 5 g/plant was found to be the superior with regards to reduced infection of root-knot nematode, *M. incognita* and to increase plant growth parameters of cucumber in poly house followed by *P. lilacinus* and *T. harzianum* at 5 g/plant.

Chemical treatment trial revealed that formalin at 30 ml/plant followed by phorate at 2 g a.i./plant and metham sodium at 10.0 ml/plant were found superior in decreasing nematode reproduction parameters of *M. incognita* and to enhance cucumber yield under protected cultivation.

Eco-friendly management trail revealed that Hot water 1 litre+ Neem cake 50 g /plant + *T. viride* 5 g/plant was found to be the superior to reduced infection of *M. incognita* and to enhance cucumber yield under protected cultivation followed by Hot water 1 litre + Tobacco churi 20 g/plant + *P. lilacinus* 2.5 g/plant and Hot water 1 litre + Tea waste 20 g/plant + *P. lilacinus* 2.5 g/plant combination.

An integrated nematode management trial was conducted for the management of *M. incognita* on cucumber in poly-house. Results exhibited that all the treatments significantly reduced nematode population parameters and plant growth characters over untreated check. Among treatment combinations, Highest yield was obtained with integration of Hot water at 1 litre + Neem cake at 50 g/plant + phorate at 0.5 g a.i./plant followed by Hot water at 1 litre + Tobacco churi at 20 g/plant + carbofuran at 0.5 g a.i./plant and Hot water at 1 litre + Tea waste at 20 g/plant + carbofuran at 0.5 g a.i./plant.

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संरक्षित खेती में जड़गाँठ सूत्रकृमि, *मेलॉइडोगाइनी इनकोग्निटा* का खीरा (*कुकुमिस सेटाइवस*) पर वितरण, हानि और प्रबन्धन

शक्ति सिंह भाटी* — **शोधकर्त्ता**

डॉ. बी. एल. बाहेती** — **मुख्य सलाहकार**

जड़गाँठ सूत्रकृमि, *मेलॉइडोगाइनी इनकोग्निटा* एक सर्वभक्षी विनाशकारी सूक्ष्म जीव है, जो लगभग पूरे विश्व मे पाया जाता हैं और संरक्षित खेती में खीरे की फसल पर बहुत अधिक क्षति पंहुचाता हैं। संरक्षित खेती में खीरे की फसल पर जड़गांठ सूत्रकृमियों के बढ़ते हुए प्रकोप से होने वाले आर्थिक नुकसान एवं गंभीरता को देखते हुए कुछ प्रयोग किये गये, जिससे कि पॉलीहाउस में जड़गाठ सूत्रकृमि द्वारा संक्रमित क्षेत्र, परिहार्य क्षति, सूत्रकृमि संख्या में ऋतुकालीन उतार–चढ़ाव का पता लगाया जा सके, साथ ही गर्म जल, कार्बनिक पदार्थों, जैवकारको, रसायनों तथा इनके समावेश से पर्यावरण अनुकूलित एवं समन्वित रूप से सुत्रकृमि प्रबंधन पर अध्ययन किया गया।

सर्वेक्षण के दौरान पाया गया कि उदयपुर, चित्तौड़गढ़, राजसमंद, हनुमानगढ़, जयपुर दौसा, नागौर एवं जोधपुर के 40 पॉलीहाउसों से लिये गये सभी 158 नमूने जड़गाँठ़ सुत्रकृमि द्वारा संक्रमित थे तथा सभी नमूनो में सूत्रकृमियों कि संख्या आर्थिक दहलीज स्तर से अधिक पायी गयी।

पॉलीहाउस में खीरे की फसल पर जड़गांठ सुत्रकृमि द्वारा परिहार्य क्षति का विश्लेषण करने पर पाया गया कि यह सुत्रकमि खीरे की फसल उपज में 66.84 प्रतिशत तक क्षति पँहुचाता हैं। ऋतुकालीन उतार–चढ़ाव के परीक्षण में पाया गया कि पॉलीहाउस में खीरे की फसल पर समय के साथ–साथ सूत्रकृमियों की संख्या भी लगातार बढ़ती रहती हैं।

पॉलीहाउस में खीरे की फसल में सूत्रकृमियों के प्रबन्धन हेतु विभिन्न प्रयोग किये गये। गर्म जल प्रयोग में, गर्म जल 1.5 ली./पॉलीबेग उत्तम पाया गया। विभिन्न कार्बनिक पदार्थों में से नीम खली 50 ग्राम के बाद तम्बाकू की चुरी और चाय अपशिष्ट 40 ग्राम प्रति पौधे की दर से तथा जैव कारको में *ट्राइकोडर्मा विरिडी* के बाद *पेसिलोमाइसिस लीलासीनस* और *ट्राइकोडर्मा हरजियानम* 5.0 ग्राम प्रति पोधे की दर से एवं ध्रुमण रसायनों में से फॉर्मेलिन 30 मिली. प्रति पौधे के बाद फोरेट 2 ग्राम सक्रिय तत्व प्रति पौधा और मेथाम सोडियम 10 मिली. प्रति पौधे की

दर से सूत्रकृमियों के संक्रमण को कम करने एवं खीरे की उपज को बढाने में कारगर पाये गये।

सुत्रकृमियों के पर्यावरण अनुकुलित प्रबन्धन के अन्तर्गत गर्म जल (1 लीटर/पॉलीबेग), नीम खली (50 ग्राम प्रति पौधा) एवं *ट्राइकोडर्मा विरिडी* (5 ग्राम प्रति पौधा) व गर्म जल (1 लीटर/पॉलीबेग), तम्बाकू चूरी (20 ग्राम प्रति पौधा) एवं *पेसिलोमाइसीस लिलासीनस* (2.5 ग्राम प्रति पौधा) का संयोजन प्रभावी सि़द्ध हुआ हैं। समन्वित प्रबन्धन के परिणाम दर्शाते हैं कि गर्म जल (1 लीटर/पॉलीबेग), नीम खली (50 ग्राम प्रति पौधा) और फोरेट (0.5 ग्राम सक्रिय तत्व प्रति पौधा) का संयोजन एवं गर्म जल (1 लीटर/पॉलीबेग), तम्बाकू चूरी (20 ग्राम प्रति पौधा) और कार्बोफ्यूरॉन (0.50 ग्राम सक्रिय तत्व प्रति पौधा) का संयोजन प्रयोग करने पर मूलग्रन्थी सूत्रकृमि का संक्रमण प्रभावी रूप से कम हुआ तथा पॉलीहाउस में खीरे की फसल की उपज में प्रभावी वृद्धि पायी गई।

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Appendix-I

Analysis of variance for seasonal fluctuation of *M. incognita* on cucumber at different time interval in poly-house

Source of variance	d.f.	M.S.S.							
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/100 cc soil	
		2016	2017	2016	2017	2016	2017	2016	2017
Treatment	7	3101.9	3158.1	2403.6	2336.5	51530.0	53024.4	412511.9	427286.2
Error	28	9.52	12.49	5.05	6.96	546.85	726.37	14077.6	13636.4

* Significant at 5 % level of probability

Appendix-II

Analysis of variance for effect of hot water treatment on root-knot nematode, *M. incognita* infecting cucumber in poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	3	3713.5	33.93.9	2263.1	1871.2	1913.3	2360.7	1842728.23	1790968.42	4.8	5.2	0.1	0.1	5.3	5.4
Error	18	7.46	5.44	4.15	4.88	234.89	129.95	4404.62	895.0	0.01	0.01	0.0	0.0	0.01	0.0

* Significant at 5 % level of probability

Appendix-III

Analysis of variance for effect of organic amendmentagainst root-knot nematode, *M. incognita* on cucumber in poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	11	536.6	586.6	546.5	446.9	1893.4	2436.3	581324.2	588386.8	0.9	1.0	0.1	0.1	1.6	1.7
Error	44	1.43	12.35	12.96	12.55	378.37	377.02	3181.66	3087.41	0.02	0.02	0.0	0.0	0.02	0.01

* Significant at 5 % level of probability

Appendix-IV

Analysis of variance forefficacy of bio-agents on root-knot nematode, *M. incognita* infecting cucumber in poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	11	678.8	687.1	367.1	438.0	1682.2	1964.6	636203.4	644372.9	1.1	1.1	0.1	0.1	1.6	1.7
Error	44	13.88	13.74	10.76	10.69	108.36	81.74	826.94	146.69	0.02	0.0	0.0	0.0	0.01	0.0

* Significant at 5 % level of probability

Appendix-V

Analysis of variance foreffect of chemicals as pre-sowing application against *M. Incognita* on cucumber under poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	10	1651.4	1760.9	1271.6	1426.9	3162.2	2763.1	539523.0	526870.8	1.3	1.5	0.1	0.1	2.7	2.6
Error	40	3.87	7.60	3.93	4.91	195.09	126.96	1787.2	2055.48	0.04	0.04	0.0	0.0	0.02	0.02

* Significant at 5 % level of probability

Appendix-VI

Analysis of variance for influence of eco-friendly management strategies against *M. incognita* infecting cucumber in poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	11	1464.79	1770.2	1127.9	1268.5	2388.3	2700.5	636379.6	583730.8	1.73	1.9	0.08	0.1	3.7	3.7
Error	44	3.9	3.21	2.6	4.15	59.6	98.07	2124.2	180.6	0.0	0.02	0.0	0.0	0.0	0.04

* Significant at 5 % level of probability

Appendix-VII

Analysis of variance foreffect of integrated nematode management on multiplication of *M. incognita* infecting cucumber in poly-house

Source of variance	d.f.	M.S.S.													
		Galls/5 g roots		Egg masses/ 5 g roots		Eggs and larvae/ egg mass		Final nematode population/ 100 cc soil		Vine length (m)		Vine weight (kg)		Yield (kg/plant)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Treatment	11	1254.63	1491.8	1065.1	1239.3	2308.0	2855.9	670767.1	696631.4	1.82	1.8	0.08	0.1	3.72	3.8
Error	44	2.6	1.70	2.3	1.05	175.8	23.11	2469.7	595.22	0.0	0.01	0.0	0.0	0.0	0.03

* Significant at 5 % level of probability

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