INTERACTION AND MANAGEMENT OF QUICK WILT OF GINGER CAUSED BY *Meloidogyne incognita* AND *Ralstonia solanacearum*

DAS, S., Ph.D (Ag.) THESIS, 2014, INTERACTION AND MANAGEMENT OF QUICK WILT OF GINGER CAUSED BY *Meloidogyne incognita* AND *Ralstonia solanacearum*.

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BHUBANESWAR, ODISHA

2014

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A

THESIS SUBMITTED TO

THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY IN AGRICULTURE (NEMATOLOGY)

BY

SIMLY DAS

DEPARTMENT OF NEMATOLOGY
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ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR, ODISHA
2014

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CERTIFICATE- I

This is to certify that the thesis entitled **"INTERACTION AND MANAGEMENT OF QUICK WILT OF GINGER CAUSED BY *Meloidogyne incognita* AND *Ralstonia solanacearum*",** submitted in the partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHYLOSOPHY IN AGRICULTURE (NEMATOLOGY)** to the Orissa University of Agriculture and Technology is an authentic record of the bonafide research work carried out by **Mrs. Simly Das** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that the evidence and help obtained by her from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE- II

This is to certify that the thesis entitled **"INTERACTION AND MANAGEMENT OF QUICK WILT OF GINGER CAUSED BY *Meloidogyne incognita* AND *Ralstonia solanacearum*",** submitted by **Mrs. Simly Das** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **DOCTOR OF PHYLOSOPHY IN AGRICULTURE (NEMATOLOGY)** has been approved by the Students' Advisory Committee and the external examiner.

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ACKNOWLEDGEMENT

Really in this beautiful world no creation is sole effort neither is this thesis. This thesis is the end of my journey in obtaining my Ph.D. I have not travelled in a vacuum in this journey. This thesis has been kept on track and been seen through to completion with the support and encouragement of numerous people from the boy who waters the pot to the person who binds it, everyone has a role. At the end of my thesis, it is a pleasant task to express my thanks to all those who contributed in many ways to the success of this study and made it an unforgettable experience for me.

I would like to start with the person who made the biggest difference in my life, my mentor, **Dr. P. K Swain**. *He has been there for last three and a half years, motivating and inspiring every bit of me towards new possibilities in life. He has been a living role model for me, taking up new challenges every day, tackling them with all his grit and determination and always thriving to come out victorious. It's his vigor and hunger to perform in adverse situation, which has inspired me to thrive for excellence and nothing less. During my initial days, I was apprehensive about my decision to join a less explored field, where things were new to me.* **Dr. Swain** *came to my rescue with his intelligent ideas, thought provoking discussions and comprehensive understanding to help me sail through the initial stumbling blocks. His attitude of living every moment as it comes, making serendipitous observation and converting them to new possibilities, correlating ideas and understanding the obvious has helped me come a long way and will always guide me in future. He made me realized what I had only heard, "When the going gets tough, the tough get going". I will never find words to tell what I owe to him, and if I start doing it, I would not know where to stop…thanks for everything Sir…to me, professionally; you are* **"Perfection Personified"**.

Special thanks go to my advisory committee members 1. **Dr. S. N. Mahapatra**, *Professor and Head, Department of Nematology for his* *constant motivation and support during the course of my thesis. He has always been there, more as a friend than a scientist and I have learnt extensively from him including how to raise new possibilities, how to regard an old question from a new perspective, how to approach a problem by systematic thinking, data-driven decision making and exploiting serendipity. 2.* **Dr. B. K. Mishra**, *Dean, College of Agriculture, 3.* **Dr. B. Behera**, *Former Professor and Head, Department of Plant Pathology, for their endless, important suggestions and remarks in this research program and for their time and effort in service on my doctoral committee despite their already heavy loads of responsibility.*

I feel greatly indebted and convey my profound sense of gratitude to the **Dr. N. K. Sahoo, Dr. S. Sahoo, Dr. D. K. Nayak, Dr. B. K. Das,** *Department of Nematology for their precious help, sincere cooperation, active support during my experiment for which I must thank all of them sincerely. I am greatful to* **Dr. Basudev Behera**, *Head of the Department, Agronomy for providing huge amount of planting materials for field experiment.*

I am grateful **Dr. B. K. Mishra**, *Head, Department of Plant Physiology,* **Dr. S. N. Pasupalak**, *Professor and Head, Department of Agro-Meteorology,* **Dr. A. K. Parida**, *Head, Department of Agricultural Statistics,* **Dr. S. K. Mohanty**, *Professor and Head, Department of Seed Science and Technology,* **Dr. S. K. Dash**, *Seed Technology research for giving me an opportunity to work with them and making the facilities available for carrying out research.*

Thanks are due to editors Annals of Plant Protection Sciences and Journal of Plant Protection and Environment for publishing some of my research outcomes in their esteemed journals.

I express my heart-felt gratitude to **Debasmita Rout** *for being with me as an elderly figure throughout was always by my side motivating me and giving me confidence that I can complete my Ph.D in time, her personal help and friendly nature has always made me feel at ease with her and I could always look back on her for any support during my course of Ph.D.*

*My special words of thanks should also go to **Mrs. Sujata Swain** for her continuous support, guidance, cooperation, encouragement and for facilitating all the requirements, going out of her way. She has taught me another aspect of life, that, "goodness can never be defied and good human beings can never be denied". Her constant guidance, cooperation, motivation and support have always kept me going ahead. I owe a lot of gratitude to her for always being there for me and I feel privileged to be associated with a person like her during my life.*

*My thanks to the **Mr B. S Bhujbal, Mrs B. P. Mohanty, Mr. P. Das, Mr. B. Mallick, Mr. A. K. Padhi and Mr. H. Sethi**, staff of Department of Nematology for their innumerable help. A special word of gratefulness to **Deepak** and **Kanhu** Bhaina who have gone out of way to help me with several laboratory and field work.*

*I express my heart-felt gratitude to **Shrabani Barik, Pradeep Nayak, Jayanta Mahalik** for their constant motivation and support during the course of my thesis. I enjoyed the personal discussion with them and the time I spent with them during festive seasons. My heartfelt thanks to my fellow mate **Swatilekha Mohanta** for always being there and bearing with me the good and bad times during my wonderful days of Ph.D.*

*During the course of my work, I had the pleasure of working with **Sarada, Subhrajyoti, Purnata, Chitta** their assistance during the presented work is gratefully acknowledged. My special gratitude to **Ipsita, Tushar** and **Satya** for being with me in thicks and thins of life, I find myself lucky to have friends like them in my life.*

*I thank the man behind the desk **Mr. Md Matlub Ali** who meticulously articulated the manuscript and plate into one piece, for this beautiful presentation I woe deep sense of gratitude for him.*

A special thanks to my family. Words cannot express how grateful I am to *my mother-in law, father-in-law, my mother, father and elders for all of the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far. Special thanks to my steadfast husband,* ***Sudipta*** *for his enduring love, for believing in me long after I'd lost belief in myself, and for sharing my wish to reach the goal of completing this task, but caring enough to love me even if I never achieved it. I wish to express my deep sense of gratitude to my brothers and sisters, sister-in-law and their families for their co-operation who are directly or indirectly involved assisting throughout my research work as well as for their valuable motivation and support. Special thanks to my lil angels of my family* ***Mamun, Rikun, Gulgul*** *and* ***Shreya*** *who helped me a lot when I was stressed. They were the only entertainment I had during my work.*

*Above all, I owe it all to Almighty God for granting me the wisdom, health and strength to undertake this research task and enabling me to its completion……….****Sairam***

Bhubaneswar

Date: ***(SIMLY DAS)***

TITLE OF THE THESIS	**:**	**Interaction and Management of Quick Wilt of Ginger caused by *Meloidogyne incognita* and *Ralstonia solanacearum***
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DEGREE FOR WHICH THE THESIS IS SUBMITTED	**:**	Doctor of Philosophy (Agriculture), **Nematology**
YEAR OF SUBMISSION	**:**	2014

ABSTRACT

Ginger is a most important spice crop of India constrained by several diseases resulting in severe yield losses. Quick wilt complex of ginger very often resulted in total crop failure in several parts of the state of Odisha.

Meloidogyne incognita and *Ralstonia solanacearum* were isolated and characterized from ginger plants exhibiting such symptoms from three geographical locations of the state.

The role of *M. incognita* and *R. solanacearum* in the quick wilt disease complex was established through inoculation study. Synergistic interaction in growth, yield and physiological parameters were recorded under concomitant (N+B) inoculation of both the pathogens as well as prior inoculation of *M. incognita to R. solanacearum* (N→B) by 10 days. The incubation period of *R. solanacearum* wilt symptoms was reduced by 5 days in concomitant inoculation and 10 days in sequential inoculation, when *M. incognita* was inoculated 10 days prior to *R. solanacearum.*

M. incognita alone induced polynucleated giant cells inside the vascular parenchyma which served as metabolic sinks to sequester nutrient demand of the developing nematode accompanied by disruption of vascular tissues, hypertrophied phloem and cortical cells, hyperplastic pericycle cells leading to typical gall formation in the roots of ginger. In the combined infection, the giant cells formed by *M. incognita* were extensively colonized by bacterial inclusion, including formation of extensive cavities followed by quick disintegration and degeneration.

The yield loss by both *M. incognita* and *R. solanacearum* in a naturally infested field was estimated to be 24.57 per cent.

Soil application of sesame oil cake @ 1.5 t/ha 21 days before sowing + soil drenching with phosphonic acid 300 ppm @ 0.6 kg/ha was the best cost effective integrated disease management module for quick wilt complex.

CONTENTS

LIST OF TABLES

LIST OF FIGURE

ABBREVIATIONS USED

cm	-	Centimeter
CRD	-	Complete randomized block design
˚C	-	Degree centigrade
cfu	-	Colony forming unit
DAP		Days after planting
dia	-	Diameter
e.g.	-	for example
et al.	-	and co-workers
etc.	-	and so on
Fig.	-	Figure
g	-	Gram
i.e	-	that is
lb	-	Pound
m	-	Meter
mg	-	Milligram
ml	-	Milliliter
nm	-	nanometer
µg	-	micro gram
pH	-	Potential hydrogen
RBD	-	Randomised block design
RCC	-	Reinforced concrete cement
kg	-	kilogram
sec.	-	Second
sp	-	Species (singular)
Spp	-	Species (Plural)
t		Ton
Viz	-	Namely
%	-	Per cent

INTRODUCTION

Ginger (*Zingiber officinale* Rosc. Zingiberaceae), is a high value oriented important commercial spice crop of India. It is extensively cultivated in tropical and sub tropical countries of the world like Brazil, China, Japan, India, Indonesia and West Indies. It is believed to have originated in South East Asia, probably in India (Burkill, 1966, Purseglove *et al.*, 1981). India is the largest grower of ginger and also the producer of dry ginger in the world, contributing about 30 per cent of the world's production (Verghese, 2014). The rhizome or modified underground stem of ginger is used worldwide as a spice for flavouring a multitude of foods and food products, alcoholic and non alcoholic beverages, confectionary and prickles as well as in pharmaceutical preparations and traditional medicines (Lawrence, 1984; Selvan *et al.*, 2002).

The total area under ginger cultivation in India is 1,36,000 hectares, total production is 6,83,000 MT with productivity of 5 MT/ ha (Tiwari *et al.*, 2013). The important ginger growing states in India are Kerala, Meghalaya, Odisha, West Bengal, Mizoram, Andhra Pradesh, Himachal Pradesh and Madhya Pradesh.

Majority of ginger growers in India face wide range of problems like year to year price fluctuation in national and international markets, non availability of fertile land, low quality planting materials and increasing prevalence of pests and diseases. The production and productivity of this crop is constrained due to several biotic and abiotic stresses. Among, the biotic stresses the most important are fungi, bacteria and nematodes. Major diseases of ginger are soft rot (*Pythium, Rhizoctonia*), slow wilt (*Fusarium*), quick wilt (*Ralstonia solanacearum*), nematode (*Meloidogyne incognita, Pratylenchus* spp.*, Radopholus similis*). Root knot nematode, *Meloidogyne incognita* produce brown, water soaked areas on rhizomes of ginger (Huang, 1966). The visible symptoms of nematode infested field are stunting, chlorosis and necrosis of leaves, incipient wilting of lower leaves, resulting in a poor tillering.

Bacterial wilt caused by *R. solanacearum* is also one of the important and devastating diseases of ginger. This disease was for the first time reported from Mauritius (Orian, 1953). Subsequently, it was reported from Hawaii (Ishii and Aragaki, 1963), Malaya (Jamil, 1964) and Australia (Hayward *et al.*, 1967). Although the disease occurred in India quite early, Mathew *et al.* (1979) reported it from Kerala. Supriadi (2000) reported that bacterial wilt causes losses up to 75 billiion rupees per year. Initially water soaked spots appear on the collar region of the pseudostem of ginger plants. There is yellowing on margins of the lower most leaves which gradually progress upwards, later on the leaves become flaccid with intense yellow colour and droop exhibiting typical wilt symptoms. Vascular tissues of pseuodostem exhibit dark streaks and the rhizomes on pressing ooze out milky bacterial exudates (Dohroo, 1982)

Soil is a complex ecosystem that supports a wide variety of life forms including plants and animals. Under normal growing conditions, rhizosphere biotic and abiotic factors are constantly subjected to interrelationship in various degrees maintaining equilibrium or balance. Under specific conditions a significant alterations in this balance may lead to an interaction between various factors causing diseases of complex etiology. It would be rather unrealistic to view nematode plant interactions as if they occurred in isolation from the other biotic components of the environment. The germ theory of disease and the need to justify disease based on specific etiology has caused many scientists to overlook the complexities of disease with multiple pathogens. Given the complexity of the typical environment in which nematodes parasitize plants, one should not be surprised that nematode parasitism and pathogenesis of plant are often greatly affected by other organisms in the environment and conversely. Akiew *et al.*, 1991 elucidated the role of root knot nematodes on the development and severity of bacterial wilt. Initially nematodes were thought to cause wounds for bacterial invasion (Hayward, 1991). Nematodes play much more roles than simple wounding agent in the diseases of complex etiology.

Meloidogyne incognita is considered as one of the most important pathogen facilitating infection to *Ralstonia solanacearum* and resulting in increased severity of wilt (Johnson and Powell, 1969; Jatala *et al.*, 1975; Davide, 1972). Ginger wilt or wilt complex often result in 100 per cent crop failure in many ginger growing states in India (Thomas, 1941; Sharma *et al.*, 1978; Mathew *et al.*, 1979; Dohroo, 1991; Dake, 1995). It is a serious disease complex all over the country. Continuous monocropping of ginger in the same field and use of infected planting materials often resulted in total crop failure. The intricacies of association and nature of interrelationship between *M. incognita* and *R. solanacearum* in ginger are yet to be investigated. Therefore, all efforts made in this direction to combat the disease complex in the line of specific etiology were futile. Also the growing concern about the harmful effects of chemicals has necessitated concerted efforts to develop suitable non toxic and eco friendly alternative methods for the management of this disease.

In view of the above limitations, it was imperative to investigate this disease complex in ginger with following objectives.

- Isolation, multiplication and characterisation of *M. incognita* and *R. solanacearum.*
- Interaction of *M. incognita* and *R. solanacearum* in the development of quick wilt complex.
- Studies on the physiological, biochemical and histopathological changes in ginger inoculated with *M. incognita* and *R. solanacearum.*
- Estimation of avoidable yield loss caused by this disease complex under field condition.
- Develop ecologically sound and economically viable management strategies through integrated approaches.

REVIEW OF LITERATURE

Ginger is a valuable spice crop grown throughout the tropics and sub tropics. India is a major producer and exporter of this crop. There are several biotic constraints limiting the successful production of this important spice crop. Rhizome rot (*Pythium, Rhizoctonia*), soft rot (*Fusarium*), quick wilt (*Ralstonia solanacearum*) and root knot nematode, *Meloidogyne incognita* parasitize this crop and cause diseases resulting in crop losses. Very often these pathogens form disease complex on combined infection resulting in total crop failure. The following reviews are the present status of pathogens associated with quick wilt of ginger, their interaction, yield loss and management.

2.1. *MELOIDOGYNE INCOGNITA*

Routaray *et al.* (1987) reported several nematodes *viz*., *Helicotylenchus abunaamai, Hoplolaimus columbus, Hoplolaimus indicus, Macroposthonia ornata, Meloidogyne incognita, Rotylenchulus reniformis* and *Xiphinema insigne* in ginger and turmeric in Phulbani and Koraput districts of Odisha. However *Meloidogyne incognita* was most frequent (50%) with a mean density of 0-160.

Kaur and Sharma (1988) reported the occurrence and pathogenicity of *M. arenaria* on ginger and have reported reduction in various growth parameters.

Large number of nematodes in the soil and root samples from 36 localities of Himachal Pradesh, with frequent and high densities of *M. incognita* and *P. coffeae* involved in ginger yield decline and other diseases were reported by Kaur *et al.* (1989).

Ferraz (1994) presented a review on the biology and morphology of *M. incognita*, *Radopholus similis*, *Scutellonema bradys* and *P. coffeae* in Brazil on sweet potato, beet root, ginger and yam.

Ramana and Eapen (1995) reported several plant parasitic nematodes on major spices *viz.*, black pepper (*Piper nigrum*), cardamom (*Elettaria cardamomum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and tree spices. In ginger and turmeric *Meloidogyne* sp, *Radopholus similis* and *Pratylenchus* spp. were the major nematode pests of economic importance.

Sheela *et al.* (1995) reported *M. incognita*, *Radopholus similis*, *Rotylenchulus reniformis*, *Helicotylenchus multicinctus*, *Pratylenchus* sp., *Tylenchorhynchus* spp. *Hoplolaimus indicus*, Criconemoides sp. and *Xiphinema* sp. in the rhizosphere of ginger, *Zingiber officinale* in Kerala. Out of these nematodes *Meloidogyne incognita* and *Radopholus similis* were the major nematode species and the frequency of *M. incognita* was maximum.

Khan and Makhnotra (1998) reported *M. incognita* to be the widely distributed species of nematode in ginger in Himachal Pradesh along with few other species.

Srivastava *et al.* (1998) surveyed disease occurrence in ginger growing areas in Sikkim. Thirty nine micro organisms were found associated with ginger including two nematode species (*M. incognita* and *Pratylenchus coffeae*) and one bacterium (*R. solanacearum*).

Vadhera *et al.* (1998) conducted a study on a genera of plant parasitic nematodes associated with ginger in Madhya Pradesh and observed that *M. incognita* was predominant with 63% absolute frequency of occurrence in the state.

Koshy *et al.* (2005) reported the species of plant parasitic nematodes infesting spices, condiments and medicinal plants. *Meloidogyne sp.* and *Pratylenchus coffeae* were the important species associated with ginger.

Singh and Gupta (2011) for the time first observed the occurrence of *M. javanica* on ginger with heavy infestation and *M. incognita* on coriander from Jammu and Kashmir.

2.2. *RALSTONIA SOLANACEARUM*

Das and Chattopadhyay (1955) reported a new disease in brinjal caused by *P. solanacearum* var. *astiaticium* during May to October which was highly destructive to the crop in the years of heavy rainfall. The other collateral hosts like potato, tomato and tobacco were reported to be invaded by the same bacterium that incited wilt in brinjal. Multiplication of the bacterium was greater in the susceptible cv. ‘Marglobe’ than in ‘Saturn’.

Digat and Escudie (1967) reported that *P. solanacearum* was responsible for the wilt of tomato, *Capsicum*, brinjal and potato.

Zehr (1970) isolated *P. solanacearum* in Philippines from *Musa textilis* and banana plants suffering from vascular wilts. The isolate was found to be highly virulent to tomato, pepper and brinjal.

Zehr (1971) studied the pathogenesis influenced by the interaction of two virulent strains of *P. solanacearum* in inoculated tobacco plants. Inoculation of tobacco plants near the shoot tip with a mixture of two isolates of *P. solanacearum*, virulent to tomato but differing in virulence to tobacco, exhibited a less severe wilt compared to the same number of virulent bacterial cells inoculated alone. When older plant tissues were inoculated with the mixture, disease severity was not reduced. Plant inoculated with the less virulent isolates near the shoot tip with a mixture of two isolates of *P. solanacearum*, virulent to tomato but differing in virulence to tobacco, exhibited a less severe wilt compared to the same number of virulent bacterial cells inoculated with the mixtures, disease severity was not reduced. Plant inoculated with less virulent isolates near the shoot tip and with the more virulent one in the lower stem, reduction in disease severity was exhibited but this was not evident when the position of the isolates was reversed.

Granada and Sequeira (1975 a) reported that the isolate S-123 of *P. solanacearum* was highly pathogenic to cultivable tobacco varieties. This isolate multiplied rapidly in tobacco leaves until the bacterial population reached 2 × 10^7 cells/cm^2 of leaf disc and induced hypersensitive response (HR) by the leaves. On production of the HR, the pathogen population declined. A comparison of physiological characteristics of the isolates capable or incapable to induce HR did not reveal any specific features that could be correlated with the resistance of the crop.

Granada and Sequeira (1975 b) observed that all the local and resistant cultivars of tobacco from USA were apparently susceptible under field conditions to Colombian isolates of *P. solanacearum*. The susceptibility of these cultivars were found to be related to the strains obtained from the tropical or subtropical countries where the same type of cultivars were grown successfully for many years. They differed in physiological properties mainly on utilization of different carbohydrates, other organic compounds as carbon sources and production of different types of enzymes.

Rao *et al.* (1975) tested the reaction of 23 wilt resistant tomato varieties and breeding lines to *P. solanacearum* in India. Only one line CRA-66 selection-A from Hawai was found to be resistant. All other lines including the newly released 'Venus' and 'Saturn' cultivars from North Carolina were susceptible.

Sonoda and Augustine (1978) reported higher degree of resistance of *P. solanacearum* of the tomato lines PI-126408, PI -1212441, PI-263722, PI-365930, Hawaii -7981, Hawaii-7997 and CRA-66. 'Venus' and 'Saturn' were highly tolerant in 4 or 5 plantings. Several other accessions were observed to have intermediate levels of tolerance to bacterial wilt differing with the time of planting. It was also concluded that tomato lines with intermediate levels of tolerance to bacterial wilt can safely be transplanted in infected soil earlier in the autumn.

Hayward and Moffett (1978) reported *P. solanacearum* as the causal agent of leaf spot in the cultivar “Northern-Belle” of *Capsicum annum*.

Gopimony and George (1979) tested 36 varieties of egg plant (including two wild ones) in naturally infected soils by *P. solanacearum* and screened out 12 disease free varieties. Only the variety Insanum (a wild variety) of *Solanum melongena* was found to be resistant when tested by dipping seedlings in fresh bacterial ooze solution just before transplanting.

Mochizuki and Yamakawa (1979) studied the resistance of selected egg plant cultivars and related wild *Solanum* spcies to bacterial wilt (*P. solanacearum*). Among the varieties tested, denagrass multiple purple (India), aubergine (USA) and the wild *Solanum* species like *S. nigrum* and *S. sisimbrifolium* exhibited higher degree of resistance than Taiwan Naga, one of the highly resistant variety grown in Japan. The wild *Solanum toxicarium* exhibited the highest degree of resistance to *P. solanacearum*.

Waller and Manser (1980) isolated *P. solanacearum* from a bacterial wilt of exotic *Capsicum* cultivar, “Asgrow-Long-Green”.

Sohi *et al.* (1981) studied the effect of crop rotation on bacterial wilt of tomato and egg plant. In the field, the sequence of cowpea-maize-cabbage and okra-cowpea-maize suppressed *P. solanacearum* infection in tomato whereas the sequences, maize and ragi-egg plant (resistant cultivar pusa purple cluster)-bean (*Phaseolus vulgaris*), suppressed the bacterium on egg plant.

Moffett *et al.* (1981) reported that *P. solanacearum* was transmitted from contaminated seeds to the cotyledons of *Capsicum* at 60, 73 and 92% RH, whereas, it was 92% in case of the cotyledons of tomato seedlings. Subsequent epiphytotic colonization in the leaves of *Capsicum* occurred at 73 and 92% RH.

Sitaramaiah *et al.* (1981) screened 22 brinjal cultivars against bacterial wilt through sick-plot techniques. The cultivars like Pusa Purple Round, Vijay hybrid, Banaras giant green, and Pusa Purple cluster exhibited persistently higher degree of resistance against *P. solanacearum*.

Devi *et.al* (1982) reported the population threshold of *P. solanacearum* at the onset of first wilt symptom in tomato. In pot experiments, the symptoms developed through an increase in initial count of 3.6×10^3 cells/g to 1.07×10^7 cells/g in sterilized soil and from 3.6×10^4 cells/g to 2.52×10^7 cells/g in non-sterilized soils.

In Kerala, bacterial wilt of ginger caused by *P. solanacearum* biotype III was reported by Dake *et al.* (1988) along with its symptomatology, epidemiology, cultural and chemical control of these soil borne pathogen.

From the rotten ginger rhizomes collected from Korean farms and markets 15 bacterial isolates of *Pseudomonas* were isolated out of which 11were identified as *P. solanacearum* and rest as *P. marginalis* that caused bacterial rhizome rot of ginger (Choi and Han, 1990).

Dake (1995) reviewed the diseases of *Zingiber officinale* in India that included *Pythium aphanidermatum* soft rot, *F. oxysporum*; *Pseudomonas* (*Ralstonia*) *solanacearum* bacterial wilt along with constraints and disease management strategies.

Zhang *et al.* (1997) isolated two bacteria from ginger plants in which one showed wilt symptom caused by *P. solanacearum* (*R. solanacearum*) and the other caused streak leaf blight by *Xanthomonas zingibericola*.

Sharma and Rana (1999) observed 80% of 310 *Zingiber officinale* fields in H.P. to be affected by bacterial wilt caused by *R. solanacearum*.

Supriadi (2000) considered bacterial wilt disease caused by *R. solanacearum* to be a serious threat to medicinal plant cultivation in Indonesia. Bacterial wilt of ginger was thought to cause loss up to 75 billion rupiahs per year. Strategies for the management of diseases included selection of disease free soil, disease free planting materials, resistant cultivars, control of nematodes, soil treatment using heat, chemicals and biological substances as well as quarantine measures.

Nath *et.al* (2001) reported on the bacterial wilt of ginger exhibiting wilting and yellowing symptoms by *R. solanacearum with l*oss of leaf turgidity followed by leaf rolling and wilting. The diseased leaves became orange yellow at the margins with a band of green on either side of the midrib. Under microscope the stem and rhizome revealed the presence of bacteria identified as *R. solanacearum*.

Based on the symptoms of disease, morphological cultural, biochemical characteristics and pathogenicity test of the pathogen causing bacterial wilt in castor, rapeseed, ginger and spinach was identified as *R. solanacearum* (Bora and Das, 2002).

Characterization of bacterial wilt pathogen *R. solanacearum* isolated from ginger for biovar, pathogencity, infectivity, titre and intrinsic antibiotic resistance was carried out resulting in fluidal colonies with spiral pink centre on 2, 3, 5 triphenyl tetrazolium chloride, amended medium.All the isolates were resistant to tetracycline, polymyxin B sulfate and chloramphenicol. (Kumar and Sharma, 2004).

An overview of the current information on the global situation of bacterial wilt (*R. solanacearum*) through review of the recent literature and over 100 additional reports submitted at the 3rd International Bacterial Wilt Symposium, South Africa, 2002 was made. A more detailed impression of the current status on major crops (such as banana, potato, tomato and ginger) in some areas (including North America, S.A., Europe, Asia & Africa), a questionaire was distributed to 56 experts in 25 countries and the opinions obtained were reported. Currently used diagnostic methods and their role in surveying pathogen distribution and preventing further spread were also discussed (Elphinstone, 2005).

Sambasivam and Girija (2005) studied on the host range of *R. solanacearum* infecting ginger. Strains of these pathogens were collected from ginger growing tracts of three different districts of Kerala, cross inoculated on tomato and aubergine which induced wilt symptoms. In another study, chilli isolate produced wilt symptom on ginger. Later, the pathogenic bacteria were also screened for resistance against various antibiotics such as ampicillin, carbenicillin, chloramphenicol, gentamicin, kamamycin, nalidixic acid, rifampicin, streptomycin sulfate, tetracycline at various concentration and based on their sensitivity pattern, antibiotic markers were developed for each isolates.

The biochemical characterisation of 15 isolates of *R. solanacearum* from ginger in three different districts of Kerala revealed that all isolates were homogeneous in their reaction. The isolates on triphenyl tetrazolium chloride (TZC) medium appeared as small creamy white colonies with pink centre and exhibited positive reaction for solubility in KOH, nitrate reduction, production of catalase and oxidase enzymes and fermentation of glucose. Also all isolates produced ammonia from arginine and oxidized lactose, maltose, cellobiose, mannitol and sorbitol but failed to oxidize dulcitol and they were classified under biovar III A (Sambasivam and Girija, 2006).

All the isolates of *R. solanacearum* from different ginger producing areas of Kerala showed a positive reaction for solubility in KOH, nitrate reduction, production of catalase and oxidase, production of ammonia from arginine and fermentation of glucose. They oxidised lactose, maltose, cellobiose, mannitol and sorbitol but failed to oxidize dulcitol (Sambasivam and Girija, 2007a).

The isolates of *R. solanacearum* infecting ginger were screened against various antibiotics such as amplicillin, carbenicillin, choramphenicol, gentamicin, kanamycin, nalidixic acid, rifampicin, streptoxycin sulphate and tetracycline. The isolates were resistant to ampicillin and rifampicin at 100 mg/ml concentration and sensitive to chloromphenicol and kanamycin at 150 and 50 mg/ml concentration. (Sambasivam and Girija, 2007b).

Twelve out of fourteen ginger species belonging to Zingibearaceae and Costaceae family were found to be susceptible to bacterial wilt pathogen *R. solanacearum* (race 4) by several methods of inoculation (Paret *et al.*, 2008) in Hawai.

Gonzalez *et al.* (2009) investigated on *R. solanacearum*, the causal agent of bacterial wilt of many crop plants in the tropical and sub tropical countries, its pathogenicity mechanisms as well as the molecular ones for the natural and induced resistance.

Mohumad and Kamaruzaman (2010) reported *R. solanacarum* (race 3 biovar 2), the bacterial wilt causal agents of many plant species like potatoes, eggplant, tomatoes, ginger etc to be transmitted by contaminated soil, equipments, water and insects or by transplantation of infected seeds or seedlings.

Hayward and Pegg (2013) reported severe bacterial wilt disease occurring on ginger in Queensland, caused by a strain of *Ralstonia solanacearum* identified as *R. squeirae.* Several DNA based diagnosis revealed the similarity of Queensland strain to that of one causing bacterial wilt of ginger in China.

Naranjo and Martin (2013) reported on bacterial wilt caused by *R. solanacearum* as a devastative plant disease that affects several crops of worldwide economic importance. They also recommended a combination of techniques based on different biological principles to increase reliability of diagnosis.

Incidence of bacterial wilt caused by *R. solanacearum* was widespread in some economically important crop *viz.*, brinjal tomato, potato, chilli, marigold, ginger, banana, jute, tobacco etc. in diverse location of West Bengal (Mondal *et al.*, 2014).

2.3. INTERACTION BETWEEN *M. INCOGNITA* AND *R.SOLANACEARUM*

Lucas *et al*. (1955) studied the relationship between infection by root knot nematode, *M. incognita acrita* and severity of Granville wilt caused by *P. solanacearum* in a moderately wilt resistant tobacco variety. Plants grown in soil infested with both the pathogens exhibited early wilt symptom to a greater extent than plants grown in soil infested with *P. solanacearum*. The role of nematodes appeared to mainly predispose the host to the invasion by wound parasite like bacteria.

Stewart and Schindler (1956) reported the incidence of bacterial wilt in carnation caused by some ectoparasitic and endoparasitic nematodes. Root knot nematodes like *Meloidogyne hapla, M. javanica, M. incognita M. acrita* and ectoparasitic nematode *Helicotylenchus nannus* increased the rate of wilting in the presence of bacteria. Both endo and ectoparasitic nematodes were found to play active role in the bacteria-nematode disease complex of carnation.

Libman and Leach (1962) concluded that some nematodes play important role in the incidence of southern bacterial wilt of tomato caused by *P. solanacearum*. They determined the role of nematode by using nemagon on plants infected with unidentified nematodes. In green house experiments, *Helicotylenchus nannus* and *P. solanacearum* alone and in combinations were found to induce 42 per cent wilt, whereas, bacterial infection caused 17 per cent wilt. These results supported the conclusion that certain ecto-parasitic nematodes were capable of increasing infection and that some infection could take place through uninjured roots.

Libaman *et al.* (1964) highlighted the role of some plant parasitic nematodes in the infection of tomatoes by *P. solanacearum*. The nematodes, *Meloidogyne hapla* and *Helicotylenchus nannus* increased the severity of wilt symptoms. *Rotylenchus* sp. had no significant effect whereas; artificial wounding of roots in the presence of bacterium resulted in severe wilt symptoms than with injury caused by any of the nematode species. Of course some infection could occur in uninjured roots probably at the points of origin of secondary roots.

Johnson and Powell (1969) studied the influence of root-knot nematode on development of bacterial wilt in flue cured tobacco. In bacterial wilt susceptible tobacco plants, the presence of *M. incognita* greatly increased the incidence of wilt. Plants inoculated with nematodes, three and four weeks prior to bacterial inoculation developed wilt symptom to a greater extent than plants inoculated with nematodes and bacteria simultaneously.

Nirula and Paharia (1970) observed that *M. incognita* helped in transmitting the brown rot disease in potato caused by *P. solanacearum*. The data on nematicidal trial indicated that with the control of root-knot nematodes, brown rot disease decreased considerably.

Fukudome and Sakasegawa (1972) reported that simultaneous inoculation of the root-knot nematode, *M incognita* and *P. solanacearum* hastened the disease occurrence and advanced the progress of Granville wilt of tobacco compared to bacterial inoculation alone or bacteria with artificial wounding. When bacteria were inoculated three weeks earlier than nematodes, the disease was more severe than when the interval was reduced to one or two weeks. The disease became very severe as the number of nematodes increased with constant inoculums of bacterium. Infection occurred only when simultaneous inoculation of nematodes with 10^4 numbers of bacterial cells was used.

Jenkins (1972) studied the interaction of *P. solanacearum* and *M. incognita* on bacterial wilt against susceptible cultivars of tomato. Tomato cultivar "Manapal" was moderately susceptible to *P. solanacearum* in the presence of *M. inocgnita*. There was no wilting in the resistant cultivars "Venus" and "Saturn" either with or without the presence of *M. incognita*.

El-Goorani *et al.* (1974) observed for the first time that the interrelation between *Meloidogyne javanica* and *Pseudomonas marginata* greatly increased the severity and incidence of *Gladiolus* scab caused by *P. marginata*.

Jatala *et al.* (1975) studied the interrelationship of *M. incognita acrita* and *P. solanacearum* on potatoes. In pot experiment, the potato cultivar, BR-73-40 (*Solanum phoreja* × *S. tuberosum tuberosum*) resistant to *Pseudomonas* and the cultivar Renacimiento (*S. tuberosum andigena*) susceptible to this pathogen were inoculated with *P. solanacearum* (20 ml/pot of 1×10^9 or 2.4×10^7 cells/ml) and/or *M. incognita acrita* (2000 larvae/pot). Following inoculation with nematode and bacterium (at the highest inoculum level) all Renacimiento died within 42 days and 80% of BR-73-40 in 56 days. when inoculated with the nematode plus the bacterium at the lower inoculum level, all Renacimiento and 60% BR-73-40 died in 53 days. No wilt symptom was observed from inoculation with the nematodes alone.

Jatala and Martin (1977) reported the interactions of *M. incognita acrita* and *P. solanacearum* on field grown potato crop. In field experiments resistance of potato crop against *P. solanacearum* was broken by the addition of *M. incognita acrita*.

Reddy *et al.* (1979) studied the effect of root-knot nematode on the susceptibility of 'Pusa purple cluster' brinjal variety which was highly resistant to *P. solanacearum*. The wilted plants were found to be infected with *P. solanacearum* and the root-knot nematode *M. incognita*. In a pot culture experiment, the seedlings of brinjal variety "Pusa purple cluster" were inoculated with the nematode/bacterium either alone or in different combinations, *viz.*, nematode and bacterium simultaneously, nematode followed by bacterium and bacterium followed by nematode. More number of plants wilted (80%) when nematode and bacterium were inoculated simultaneously than nematode followed by bacterium (50%) and bacterium followed by nematode (40%). None of the plants wilted either in control, or in treatments with nematode or bacterium alone. This clearly indicateed that theroot-knot nematode broke bacterial wilt resistance in "Pusa purple cluster" variety of brinjal.

Wisnuwardana (1979) reported wilt in tomatoes in severe forms when *Meloidogyne* sp. and *P. solanacearum* were inoculated together but not with the bacterium alone.

Sallen *et al.* (1980) studied the interrelationship of *M. incognita* and *P. solanacearum* on tomato. In pot experiments severe wilt was observed in combined inoculation in comparison to inoculation by either of the two. The presence of the bacterium in nematode infested soil had no effect on galling. Dual inoculation caused severe reduction in plant height, shoot and root fresh and dry weights. Wilt severity increased as bacterial population increased in mechanically injured plants or when the soil was previously infested with nematode. Disease incidence decreased as the time between bacterial inoculation and root injury (nematode or mechanical) increased.

Napiere (1980) reported the varying inoculums levels of bacteria and nematodes with relation to the severity of tomato wilt. Seedlings of tomato cultivar "Yellow plum" inoculated with *P. solanacearum* (0, 2.9×10^2, 2.9×10^3 or 2.9×10^6 cells / ml) and *M incognita* (0, 50, 250 or 500 eggs/plant) developed wilt symptoms earlier than the seedlings inoculated with bacterium alone. An increase in the number of *M. incognita* egg/inoculums caused increased seedling mortality. Similar results were obtained with seedlings of

CV 2029 grown in soil naturally infested with *M. incognita* and *P. solanacearum*.

Sitaramaiah and Sinha (1984b) observed greater pathogenic effects of *P. solanacearum* (biotype-3) and *M. incognita* together on brinjal in comparison to the independent effects of these pathogens. Severe wilt symptoms developed in plants inoculated with the nematode, two and three weeks prior to bacterial inoculation. A minimum of 10 egg masses/plant enhanced wilt development 6 days after bacterial inoculation. Increasing nematode inoculums levels to 50, 100 or 150 egg masses/plant also hastened wilt development. The higher nematode population (100 and 150 egg / plant) significantly reduced the plant growth. Bacterial inoculation alone on the root zone did not affect the growth parameters.

The combined pathogenic effects of *M. incognita* and *P. solanacearum* on a resistant brinjal cultivar (Pusa purple cluster) provided synergistic effect towards the development of wilt symptoms and influenced different plant growth parameters such as shoot length, shoot weight, root length and root weight. Production of 2-8 per cent wilt in plants occurred at 1000 larvae +47 percent transmittance and the other at 2000 larvae +85 per cent transmittance (bacterial suspension) level of inoculums. Population of nematode present inside the soil after the harvesting of plants increased at different levels of initial nematode inoculums with three different levels of bacterial inoculums (Swain *et. al*, 1987)

The individual and interactive effects of *M. incognita* with *Pythium aphanidermatum* and *R. solanacearum* in ginger was demonstrated by Ramana *et. al* (1998). *M. incognita* caused 29.6 to 33.35% yield loss at Pi = 0.2 to 2.0 / 100 cc soil. However, the nematode, *M. incognita* had no role in bacterial wilt.

Ateka *et al.* (2001) investigated interaction between *M. incognita* and *R. solanacearum*, concluded that the severity of disease was more in presence of root knot nematode. Fifteen varieties were tested for resistance out of which Keniya, Dhamana was found resistance to both.

The synergistic interaction between root knot nematode (*Meloidogyne* spp.) and *R. solanacearum* on a variety of hosts is widely recognized. Root infection by nematodes has a positive correlation with bacterial wilt as the wounds created by the nematodes on the root system provide points of pathogen entry (Agrios, 2005).

Rhizome rot-wilt complex is a serious disease caused by a complex of pathogens, inducing considerable yield losses. A survey was conducted to study the symptoms and severity of the disease by Debnath *et al.* (2009) in the Terai region of West Bengal and reported two types of symptoms. One was the quick wilt type symptom and the other was slow wilt and yellowing type symptom. Slow wilt and the yellowing type symptom were more common than quick wilt type symptom. These symptoms were attributed to *Pythium* and *Fusarium.* Quick wilt symptom was attributed to *Ralstonia solanacearum*. However, nematodes were observed in both the type of symptoms.

Interaction between root knot nematode, *Meloidogyne incognita* alone and in combination with *Ralstonia solanacearum* were evaluated on the growth of potato plants cv. Diamant and Spunta, nematode reproduction and bacteria under greenhouse conditions. Results showed that potato cv. Spunta was highly susceptible to bacterial wilt disease than cv. Diamant. The possible combinations of *M. incognita* and *R. solanacearum* revealed that potato plants inoculated with *M. incognita* 10 days prior to bacterial pathogen's inoculation showed higher bacterial wilt disease rating than those inoculated with both pathogens simultaneously with values of 3.95 and 3.45, respectively. The higher nematode galling index was noted on potato plants cv. Diamant than cv. Spunta with values of 2.32 and 1.92, respectively. Results also showed that plants receiving nematodes with bacteria added at the same time, the highest injury of nematode accompanied by the highest rate of build-up that recorded to be 30.83 and 22.15 for potato cv. Diamant and Spunta, followed by the combination with *R. solanacearum* 10 days after nematode inoculation that was recorded to be 26.78 and 20.35 for the same potato cultivars respectively. Moreover, there was a significant reduction in both shoot and root fresh weights of the two tested cultivars infected with either pathogen alone or together. (Bekhiet *et. al*, 2010)

Siddiqui *et al.* (2014) studied the effect of interaction of *M. incognita* and with *R. solanacearum* in sequential and simultaneous inoculation on potato. *M. incognita* alone caused less reduction in plant growth than *R. solanacearum* alone. Combined inoculation of both pathogen resulted in greater reduction in plant growth. *M. incognita* inoculation prior to *R. solanacearum* resulted in greater reduction in plant growth than *R. solanacearum* inoculated prior to *M. incognita*. Inoculation of *R. solanacearum* with *M. incognita* had adverse effect on galling and nematode multiplication. Wilting index was 3 when *R. solanacearum* was inoculated alone when both the pathogen were inoculated wilting or soft rot indices was 5.

2.3.1 Physiology:

Phaseolus vulgaris inoculated with 0, 1000, 5000 or 10,000 J_2 of *Meloidogyne incognita* showed significant increase in dark respiration, percentage root nitrogen, calcium, copper and iron content as well as decrease in leaf area, dry weight, number of flowers, total carbon, hydrogen, manganese, potassium and zinc content of shoot and root, leaf chlorophyll content and photosynthetic rate (Melakeberhan *et al*. 1985).

The effect of a single generation of *M. incognita* on the growth of potted French bean plants inoculated at three, eleven and thirteen days old plants before primary leaf expansion (BPLE), at the appearance of trifoliate leaves (TRIF) and at the flower bud (BDS) stages respectively, with 0, 2000, 4000 or 8000 second-stage juvenile was investigated. The photosynthetic rate of the plants inoculated at the TRIF and BDS stages decreased significantly with increasing inoculums level. Chlorophyll content, plant dry weight and the numbers of buds, flowers, pods and seeds were significantly lower in infected plants than in the controls. The leaf area was significantly smaller only when nematode infection occurred at the BPLE stage (Melakeberhan *et al*., 1986).

Greenhouse and field microplot tests were conducted to evaluate the effects of *M. incognita* and *M. javanica* on plant water relations and growth performance of NC 2326 flue-cured tobacco. In the greenhouse, afternoon leaf water potential values at 8-11 weeks after transplanting were lower by as much as 0.22 MPa in plants infected with either nematode than in the control plants. From 11 to 22 weeks, leaf water potential values were similar in all treatments. Over the course of the 22-week experiment, all infected plants exhibited similar evapotranspiration patterns, and plants in these treatments used 87-88% of the water utilized by non infected plants. Biomass production from nematode-infected plants, however, was only about 50% of the biomass of control plants (Rahi *et al*., 1988).

Chlorophyll content of leaves was reduced in green gram plants inoculated with *Meloidogyne incognita* (Mohanty *et al*., 1997).

Wang *et al.* (1997) reported on plant dark respiration to double CO_2 concentration and found that at higher temp (30-35^{0}C) elevated CO_2 concentration positively stimulated dark respiration.

Ramakrishnan and Rajendran (1998) undertook a study on the effect of individual and concomitant inoculation of *M. incognita* (race 3) and *R. reniformis* at 10, 100 and 1000 nematode/pot on the growth and physiology of papaya. *M. incognita* caused a reduction in total chlorophyll, chlorophyll 'a' and 'b' with increased, leaf temperature accompanied with high rate of evaporation and lowered photosynthesis at an initial inoculation density of 100 J_2/kg soil. Changes induced by *M. incognita* in physiology were greater than the responses to inoculation of *R. reniformis* or concomitant inoculation of both nematodes.

Ramakrishnan and Rajendran (1999) studied the effect of physiological function, leaf chlorophyll and plant nutrients of papaya at different inoculum level (10,100 and 1000) of *M. incognita* and *R. reinformis* alone and in combination. There was greatest reduction in chlorophyll 'a', 'b' and total chlorophyll content, increase in leaf temperature, evaporation rate and diffusion resistance; decrease in photosynthesis; accumulation of N, P, K, Ca and Mg in the roots at an initial inoculum density of 1000 J_2 of *M. incognita* / kg of soil.

Photosynthesis and plant growth at elevated levels of CO_2 indicated suppression of photosynthesis by CO_2 enrichment along with decrease in leaf N and Rubisco contents (Makino and Mae, 1999).

Chlorophyll a, b, a: b, carotenoid, CHO, sugar protein and polyphenol content were estimated and their association with rhizome yield were compared with 10 cultivars of ginger. Higher rhizome yield were associated with greater chlorophyll a and CHO (r = 0.52 & 0.6 resp.) in the leaf. Polyphenols showed a +ve significant correlation with chlorophyll b and carotenoids (Rai *et al.*, 1999).

The inhibition of photosynthesis and the diurnal variation of photosynthetic efficiency of ginger were measured using L1-6200 portable photosynthesis system and PEAMK II plant efficiency analyser. Photo inhibition phenomena were observed under high light stress during midday and marked diurnal variations. The extent of photo inhibition reduced as growth phase progressed and PFD decreased. Apparent quantum yield (AQY) and photochemical efficiency of PSII (Fv/Fm) increased and the degree of photo inhibition declined markedly after shading and greater shading resulted in reduced photo inhibition, but photosynthetic rate declined (Zhang *et. al*, 2000).

The interactive effect of concomitant infection of *M. incognita* (10 J_2 / pot) and *R. solanacearum* (10^8 cfu/ml) on the gas exchange in potato plants under glass house condition at Shimla in potato was studied by Singh *et al.* (2000). Inoculation of nematode alone, bacteria alone and in nematode then bacteria after two weeks was done. Gas exchange when measured with the help of LICOR portable photosynthetic system (LI 6400) highest rate of photosynthesis (µmol CO_2 m^{-2} s^{-1}) was observed in control plants (22.09) followed by nematode alone (20.39) or bacteria alone (20.37) with minimum photosynthetic rate with concomitant infection of bacteria and nematode (17.06) and with similar trend in case of transpiration rate (µ molH_2O m^{-2} s^{-1}). Reduced rate of transpiration observed in combined treatment (11.87) as compared with either bacteria (12.05) or nematode (12.81) alone.

Vasil'eva *et.al* (2000) conducted a study to examine the effects of furostanol glycosides on photosynthetic pigments (carotenoids and chlorophyll 'a' and 'b') involved in the photosynthetic activity of tomato plant cells under stress due to *M. incognita*. There was significant increase (24.2%) in total content of photosynthetic pigments as soon as 2 h after invasion of *M. incognita* in tomato and there was significant increase in the ratio of sum of chlorophyll 'a' and 'b' to the total content of carotenoids from 3.7 to 4.2. Furostanol glycosides modified the photosynthetic pigments and stabilized the photosynthetic apparatus.

Ai-XiZhen *et. al* (2000) reported that on sunny days, the photochemical efficiency of PS II (Fv/Fm) and apparent quantum yield (AQY) of ginger leaves declined gradually in morning and increased continuously after 12 h. Superoxide dismutase (SOD) activity increased gradually before 14.00 h followed by a subsequent decrease. In 60% shade during seedling stage, Fv/Fm and AQY of ginger leaves increased with SOD activity and Pn decreased. Pn, AQY and Fv/Fm in ginger treated with DDTC decreased with or without shade.

Soil water stress decreased the light saturation point and the rate and diurnal changes of photosynthesis and enhanced photosynthesis midday depression of ginger. Also under high temperature and light conditions, soil water stress decreased the superoxide dismutase, peroxidase and catalase activities (Xu and Zheng, 2000).

There is change in the leaf nutrient status, total chlorophyll content and photosynthetic efficiency with banana due to *M. incognita* alone and in association with *Pasteuria penetrans*. Gall index, number of egg masses and nematode population in soil recorded a significant reduction in *M. incognita* infestation and reduced total chlorophyll and photosynthetic efficiency upto 7.2 & 13% respectively. (Devrajan *et.al,* 2003).

Guo *et.al* (2005) reported several physiological changes and chemical indexes in ginger under *M. incognita* infection. Mostly changes occurred during first and second stage of infection and little or no change in later stage. Physiological and chemical changes occurred mostly in the leaves followed by roots and least in rhizomes.

Significant reduction in growth parameters, bulk density of pigeon pea stem, oil content of linseed, chlorophyll content of leaf and water absorption capacity of roots of both the plants caused by *M. incognita* and *R. reniformis* were recorded by Anver and Suhail in 2007.

Physiological changes induced by *M. javanica* in mung bean were studied and there was decreased chlorophyll and carotenoid contents in nematode-infected plants (Ahmed *et. al*, 2009).

You *et al.* (2011) studied on the effect of nematode infection on photosynthesis, chlorophyll fluorescence parameters and physiological indices related to cucumber leaves resistant and susceptible to *M. incognita*. Results revealed that nematodes infected plant induced significant decrease of leaf chlorophyll content in resistant sour cucumber than in susceptible Beijingjietou and also decrease of chlorophyll content with nitrogen content reduction in sour cucumber than Beijingjietou. Net photosynthetic rate (Pn), stomatal conductance (GS) in two varieties of leaves after nematode infection, intercellular CO_2 concentration (Ci) of leaves decreased in sour cucumber than Beijingjietou. Stomatal conductance (GS) reduction in response to relative water content (RWC) declining in sour cucumber leaves was more sensitive than the other. There was lower reduction of actual photochemical efficiency (Phi PS II) and photochemical quenching (qp) in nematode infected plants and significant higher increase in non-photo chemical quenching in sour cucumber.

Strajnar *et. al* (2012) reported that root galls had a major influence on the hydraulic conductivity of the root system, which was significantly reduced and low leaf water potential of infested plants coincided with decreased stomatal conductivity, transpiration and photosynthesis due to effect of *M. ethiopica.*

The inoculation of 1000 J_2 of *M. incognita* per 500 g soil and above were found to cause significant reductions in N, P, K uptake in the plant and total chlorophyll content in the leaves of chilli (Joshi and Kaul, 2012).

Meloidogyne incognita hampered the rate of photosynthesis and also reduced the chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll content of mentha plants (Thakur, 2014)

2.3.2. Histopathology

Except the aerial shoot system all other parts of the plant, the roots, rhizomes and scale leaves of ginger were infected by *Meloidogyne* sp. The initial target of the nematodes was near xylem pole. Hyperplasia of parenchymatous cells was common in infected roots and rhizomes. However, galling was conspicuous on adventitious roots. The infection induced formation of giant cells and the active division of the cells surrounding the infected area. The giant cell exhibited akaryotic division of nuclei and thickened cell walls which showed fine irregular wall projection (Shah and Raju, 1977)

Second stage larvae of *M. incognita* penetrated in the endodermis and entered the stele inducing multinucleated giant cells which were solely confined to the stele and not found in the cortex of banana roots (Sudha and Prabhoo, 1983).

Histopathological examination was done on roots of soybean infected with *M. incognita* and *Rhizobium sp.* Nematode infection resulted in the formation of giant cells from the parenchymatous cells in the xylem and phloem. Giant cells were observed to be multinucleated and thick-walled, and occasionally formed near tissues infected with bacteroids (Molina and Nelson, 1983)

Sitaramaiah and Sinha (1984) in histological studies of brinjal roots with *M. javanica* 2 or 3 weeks before *P. solanacearum* (biotype-3) inoculation, observed extensive cavities, broken cortical and endodermal cells. The nematode inoculated roots contained pronounced hyperplastic and hypertrophic growths with dense cytoplasm and enlarged nuclei. The cellular changes resulted in syncytia formation. They further reported the predisposition of nematode infested roots to bacterial invasion and colonization.

Lanjewar and Shukla (1988) studied the transverse sections of fresh galls of roots of ginger showing *Meloidogyne incognita* entering the cortex and stelar region forming giant cells.

Out of selected commercial cultivars of tomato screened for resistance against *M.incognita*, moderate resistance and susceptibility were subjected to histopathological observations. The cultivars with moderate resistance manifested higher concentrations of total insoluble polysaccharides, nucleic acids and total proteins as compared to susceptible cultivars. There was increase in overall size of the cells in epidermal and cortical layers of the infected roots as compared to their healthy one (Gopinatha *et al.*, 2004).

Volvas *et al.* (2005) demonstrated feeding sites of root-knot nematodes (*Meloidogyne* spp.) serving as strong metabolic sinks to which photosynthates were mobilized. The histopathological modifications in the nematode induced feeding sites in chickpea cv. UC 27 were qualitatively and quantitatively compared using 5 isolates of *M. artiellia* and one isolate of *M. arenaria, M. incognita* and *M. javanica*. All isolates showed root gall thickening more than *M. artiellia*. The member of nuclei per giant cell was significantly smaller, nuclei and nucleoli diameter were greater, in giant cells induced by *M. artiellia* than the other isolates.

M. incognita induced variable number of distinct multinucleated giant cells in the central cylinder of black gram roots as early as 4 days of inoculation. The nuclei of giant cells were amoeboid and dense without the association of the fungus in comparison to the fungal invaded giant cells where the nuclei were small, rounded with little cytoplasm and few cell organelles (Mahapatra and Swain, 2006).

There was marked difference in the histopathology of roots of resistant and susceptible rice varieties infected by *M. graminicola.* The larval migration in cortex and their establishment in stele occurred in two days in susceptible variety and 4 to 12 days in the resistant variety (Senthilkumar *et al.,* 2007).

Merajul *et al.* (2010) studied the histopathology of *Glycine maximum* roots (L. Merrill) infected by *M. incongita*. The J_2 entered the root in the apical meristem or elongation zone and induced giant cells in the zone of vascular strands and exhibited abnormalities in their shape and structure as well as affected the xylem and phloem. Giant cells were dense with granular cytoplasm and large nuclei and nucleoli accompanied by hypertrophy and hyperplasia of giant cells.

Samad *et al.* (2012a) studied on the histological changes of apricot roots infected with *M. incognita*. The root epidermis were broken, numerous mature females sections and egg masses lying alongside the cortex and endodermis were observed. The giant cells were with dense cytoplasm than the healthy ones.

Samad *et al.* (2012 b) reported histopathological studies of guava (*Psidium guajava* L.) var. Safeda roots infected with *M. incognita*. They reported extensive damage of the cortex and alterations of vascular bundles. Cell hypertrophy and hyperplasia were also observed with dense cytoplasm.

Singh and Hisamuddin (2013) studied the histopathological response of *Lens culinaris* roots infected by *M. incognita*. The J_2 entered the roots inter and intracellularly causing hypertrophy and hyperplasia in the root tissue. The vascular tissues were disturbed and abnormatites in xylem and phloem favored transport water, minerals and metabolites towards the giant cells.

2.4. YIELD LOSS

Evaluation on the yield loss in mungbean due to *M. incognita* was conducted in nematode sick plots following paired plot techniques consisting of treated (carbofuran@ 3 kg *a.i*/ha) and untreated control. Significant reduction in root-knot index and grain yield (50-60.71%) including yield loss recorded 33.33% in one year and 37.77% in other year was reported by Mohanty and Mahapatra, 1994.

Ray *et al.* (1995) reported severe yield losses in ginger due to root knot nematode. Soil application of carbofuran @ 3kg *a.i*/ha, 3 weeks after planting, decreased yield loss due to *M. incognita* to an extent of 26.30%.

Sheela *et al.* (1995) estimated an avoidable yield loss due to *M. incognita* in ginger to the tune of 43% at an initial population level of 166 larvae per 250g soil sample.

Bai *et al.* (1995) reported avoidable yield loss in turmeric under field condition to the tune of 45.3% by *M. incognita* in five districts of Kerala.

Makhnotra and Khan (1998) reported carbofuran @ 1kg ai/ha treated pots to increases yield by 20% and decrease nematode population at harvest in ginger.

The avoidable yield loss in banana cv. Poovan due to *M. incognita* was 30.9 % using carbofuran 3G @ 4kg *a.i*/ha. and significant reduction in plant height, pseudostem girth, number of leaves and leaf area was observed by Jonathan and Rajendran (2000).

Ploeg and Phillips (2001) estimated 65 % yield loss in melon cv. Durango by *M. incognita* in Southern California at high nematode densities.

Hazarika *et al.* (2006) estimated yield loss in jute due to combined infestation of *M. incognita* and *R. solanacearum* and result revealed that alone *M. incognita* and *R. solanacearum* caused loss up to 18.3% and 26.1% respectively and in combination a loss of 35.6%.

Haidar *et al.* (2009) reported on avoidable yield losses due to infestation of *M. incognita* and other plant parasitic nematodes on field pea to the tune of 18.32 %.

Anita and Selvaraj (2011) studied the biology and yield loss in carrot due to *M. hapla* and reported that the avoidable yield loss in carrot due to *M. hapla* was 35.95 % and combined application of *P. fluorescence* @ 1kg/ha along with *P. lilacinus* @ 25 kg/ha and carbofuran 3G @ 0.25 kg *a.i*/ha at the time of sowing enhanced the yield and reduced the soil nematode population by 66.19%.

Surveys were conducted in Aligarh and Hathras districts of Uttar Pradesh by Khan and Anwer in 2011 to determine frequency of occurance and disease incidence of *Meloidogyne graminicola*. Sagandh 5 and Pusa 1121 were found highly susceptible to the nematode and exhibiting 16 to 41% yield loss.

Field studies were conducted to determine yield loss of cowpea (cv. ART98-12) due to natural infestation by *M. incognita* using Carbofuran 3G at 2kg *a.i*/ha and untreated as check. The yield of cowpea was found to be higher with the application of carbofuran 3G @ 2kg *a.i*/ha. The percentage increase over control was 39.0 and 33.0% in the years 2008 and 2009, respectively. A significant reduction in the yield of cowpea in untreated plots was mainly attributed to direct damage of the root system by the feeding of root-knot nematode, *M. incognita*. The root knot nematode population in carbofuran treated plots was significantly lower than in check. (Adegbite,2011).

2.5. MANAGEMENT

2.5.1. *Pseudomonas fluorescens*

Anith *et al.* (2000) used *P. fluorescens* strain EM 85 along with solarization which decreased the incidence of bacterial wilt caused by *R. solanacearum* in ginger to 7.42 per cent and increased yield up to 29.42 t/ha compared to 19.51 t/ha in control.

Anita and Rajendran (2002) conducted experiment in nursery plots using *P. fluorescens* as soil application @ 10 to 20 g/m^2/plot at the time of planting in tomato (cv. PKM-1) and aubergine (cv CO.2). Results indicated significant increase in seedling growth and reduced *M. incognita* infestation.

Study on the efficacy of five fungal and bacterial antagonists (*P. fluorescens* and *B. subtilis*) medicinal plants and chemicals (Streptocycline 200 ppm and 0.25% Blitox) were assessed against *R. solanacearum* causing bacterial wilt of ginger helped in suppressing the growth of pathogen (Devanath *et al.*, 2002).

The management of root knot nematode in brinjal using *P. fluorescens* and its compatibility with carbofuran was studied. This resulted in reduced number of root knot index with application of *P. fluorescens* (10 g and 20 g/m^2) alone and in combination with carbofuran (1.5 g *a.i*/m^2). Bacterium alone at higher dose (20 g/m^2) and its combination with carbofuran at lower dose (10 g/m^2) caused significant root knot index reduction of 38.4 and 31% respectively (Mahapatra and Mohanty, 2002).

Senthilkumar and Ramakrishnan (2004) studied the efficacy of *P. fluorescens, T viride* and carbofuran 3G alone and in combination for management of *M. incognita* in okra cv. Co3 under green house condition which resulted in significant increase in plant growth in treatment of *P. fluorescens* (2.5 kg/ha) alone and in combination with carbofuran 3G.

Senthilkumar and Rajendran (2004) undertook the management of a disease complex by *M. incognita* and *Fusarium moniliforme* on grape vines using commercial formulation of biological control agent *viz*., *P. fluorescens* and *T. viride* (100 g/vine) alone and in combination at half dosage, along with FYM and carbofuran (20 and 60 g/vine respectively) which resulted in significant reduction in final soil nematode population (56.9%) , wilt incidence and least root gall index (1.8). However, least wilt disease incidence was observed in FYM (20 kg) + *P. fluorescens* (100 g/ vine).

Shanthi and Sivakumar (2005) evaluated the efficacy of *P. fluorescens* strain Pf-1 against *M. incognita* in tomato along with carbofuran and untreated control. *P. fluorescens* resulted in increase in shoot length, shoot weight, root length, root weight and decrease in root knot population (49.4%) with increase tomato yield.

Senthamarai *et al.* (2006) in a pot culture experiment under glass house condition using *P. fluorescens* @ 2.5 kg/ha against *M. incognita* in *Coleus forskohilii* reported increase in plant growth and decrease in root knot nematode population both in soil and root.

The compatibility of *Trichoderma harzianum* and *Pseudomonas fluorescens* against *M. incognita* and *R. solanacearum* complex on brinjal was studied by Barua and Bora (2009). There was highest reduction of both the pathogen due to combined application of both the treatments. *P. fluorescens* proved to be more promising in suppressing the population of *R. solanacearum*.

Kumar and Jain (2010) evaluated some fungal and bacterial antagonists as seed treatment against *M. incognita* infecting okra with *T. viride, T. harzianum* and *P. fluorescens* each @ 10 g/kg seed along with carbosulfan 25 (DS) @ 3% *a.i* (w/w) as treated check. The growth parameters of okra were better with reduction in *M. incognita* population in all the treatments compared to inoculated control.

Kumar *et al.* (2010) studied on the efficacy of pesticides, organic cakes and bioagents as seed dressing against *M. incognita* infecting cowpea. The seed treatment with *P. fluorescens* @ 10 g/kg and *T. viride* @ 4g/kg, neem seed kernel powder @ 10% (w/w), Jatropha seed kernel powder @ 10% (w/w), carbosulfan 25 (DS) @ 3% w/w and cartap hydrochloride 50 (SP) @ 1.5%

(w/w) before sowing resulted in high growth parameters. *M. incognita* population was reduced in all treatment as compared to control.

Maketon *et al.* (2010) studied on the control of bacterial wilt disease by *R. solanacearum* in ginger. Seventy eight bacterial isolates and two commercially available micro organisms were evaluated against this wilt disease out of which two bacteria, *B. subtilis* K1 and *P. fluorescens* PS12 and fungus *T. harzianum* AP-001 provided best result in controlling this disease. Post harvest treatment dipped in the bacterial combination at 5×10^6 cfu/ml resulted in better control than *T. harzianum* for protection from bacterial rot.

Kumar *et al.* (2011) conducted management of *M. incognita* Race-1 and *Rotylenchulus reniformis* by seed treatment with *P. fluorescence* @ 10 g/kg, *T. viride* @ 4 g/kg, neem seed and jatropha seed powder each @ 10% (w/w), cartap hydrochloride 50 (SP) @ 1.5% (w/w) and carbosulfan 25 (DS) @ 3% (w/w). Soil application of carbofuran 3G @ 2 kg *a.i*/ha was included as treated check. Observations resulted in better growth parameters of cowpea and decline population level of both the nematodes in all treatments compared to inoculated control.

Dutta *et al.* (2011) used *P. fluorescens* as an eco-friendly, bio agent for the management of *M. incognita* and leaf spot disease of okra. There was maximum value of growth parameters like root length, shoot length, fresh root weight, fresh shoot weight and number of leaves in *P. fluorescens* treated plots @ 1 kg/20 kg of seed with minimum root knot index.

Kavitha *et al.* (2011) studied on the efficacy of the biocontrol agent *P. fluorescens* for the management of *M. incognita* in tomato. Pft 20 @ 2.5 kg/ha when applied in soil significantly reduced the nematode infestation in all the bacterized plants both in soil and roots with least number of adult females, number of egg masses, number of eggs/egg mass and gall index with increased plant growth.

Rao *et al.* (2012) conducted experiment for management of disease complex caused by *M. incognita* and *R. solanacearum* in bell pepper using combined formulation of *P. fluorescens* and *P. lilacinus.* 10 g of this formulation as seed treatment (1 kg), 5 g for treating 1 kg of substrate (coco peat) and 5 kg for the enrichment of vermicompost (500 kg) applied in field reduced the population of *M. incognita* and disease incidence with significant increase in yield.

Kumar *et al.* (2012) reported in pot culture experiment to evaluate different fungal and bacterial anatogonists *viz., Trichoderma harzianum, T. viride, Pochonia chlamydosporia*, *Paecilomyces lilacinus* and *Pseudomonas fluorescens* at 20 g/kg seed as seed coating to reduce *M. incognita* population infecting okra as compared to untreated control.

Dwivedi and Kulkarni (2012) reported *P. fluorescens* (20 g/kg seed) as seed treatment for reduction in the population of *M. incognita* infecting mungbean.

Singh (2013) conducted field experiment to develop an eco-friendly field application method for controlling root knot disease of eggplant. Treatments *viz.,* neem cake (1.5 t/ha), *P. fluorescens* (10 kg/ha) and *T. harzianum* (10 kg/ha) as soil application and seed treatment 10 g/kg seed alone and in combination significantly reduced the incidence of root knot disease in eggplant, reduction in number of galls (81%) and reproductive factor (Pf/Pi < 0.5) of the nematode with increase in yield upto 70%.

Efficacy of *T. harzianum*, *P. fluorescens,* and *Bacillus subtilis* against rhizome disease of ginger as well as nematode population was determined. Combined application of all the bioagents resulted a minimum disease incidence on rhizomes (8.64%) as well as tillers (12.5%). Minimum *M. incognita* population was observed in combined treatment of *T. harzianum* + *P. fluorescens* + *B. subtilis* (21-66/200 cc of soil). (Dohroo and Gupta, 2014).

2.5.2. Phosphorous Acid

Margarey *et al.* (1990) studied on control of *Plasmopara viticola* the cause of downy mildew of grapevines by application of phosphonic (phosphorus) acid (as FOLi-R-FOS 200) at 600 ml/lit. It showed effective post but not pre infection control of *P. viticola* in grapes in greenhouse.

Holderness (1990) reported the efficacy of partially pH neutralized phosphorous acid as injection to cocoa trees to give similar or better control of *P. palmivora* than with metalaxyl /copper oxide pod sprays. Injection reduced canker incidence up to 90% at some sites. Two foliar spray of phosphorous acid showed little effect on yield or pod rot incidence at rates up to 24 g *a.i*/tree.

McGregor and Franz (2002) conducted field experiment for control of root rot in raspberries caused by *Phytopthora* sp. in Australia (1997). Several fungicides were tested for their efficacy against *Phytopthora* sp. control. Phosphorous acid at 2 l/ha as Foli-R-phos in autumn and spring Phosphonate (phosphorous acid) salts showed a positive effect for control of root rot.

Various bactericides were screened for efficacy in protecting geranium plants (*Pelargonium hortorum*) from *Ralstonia solanacearum* infection. Many of these bactericides were found to slow the disease progress; however, they were not able to protect the plants from infection and subsequent death. Potassium salts of phosphorous acid were found to be effective in protecting geranium plants from infection when applied as a drench. The active portion of the potassium salts was found to be phosphorous acid (H_3PO_3). Phosphorous acid was found to inhibit in vitro growth of *R. solanacearum*. It is thought to be protecting plants from infection by acting as a bacteriostatic compound in the soil. The plants, however, are not protected from above ground infection on wounded surfaces. Phosphorous acid drenches were shown to protect geranium plants from infection by either race 1 or 3 of *R. solanacearum*. Other phosphorous-containing products commonly used in the industry, such as phosphorus pentoxide (P_2O_5) and phosphoric acid (H_3PO_4), were not able to protect plants from bacterial wilt infection (Norman *et al.*, 2006)

Wen *et al.* (2009) evaluated phosphorus acid salts (PASs) alone or in combination with other products for managing bacterial spot of tomato in greenhouse and field experiments. Field treatment data showed that disease control with PAS combined with standard copper-bactericide, DAS alternated with a standard copper bactericide and PAS every week of ASM was similar to that obtained using the standard copper bactericide.

Babadoost *et al.* (2010) reported spray application of phosphorous acid (Pro Phyt 4.2f at 2.84 lit/ha) to reduce yield loss from more than 30% to less than 10% in cucurbit fields caused by *P. capsici.*

Industrial grade PAS (95%) and potassium hydroxide (95-98%) dissolved sequentially in water 1:2 ratio and the final solution (pH 6.0-6.2) at 300 ppm drenched @30 ml/plant reduced bacterial wilt of tomato by 38%. (Lin and Wang, 2011).

Phosphorous acid is being investigated as a fungicide for the management of a needle disease caused by *Phytophthora pluvialis* in *Pinus radiata* in New Zealand. However, little is known about the penetration characteristics of this fungicide into *Pinus radiata* foliage. This study was undertaken to determine: i) the penetration characteristics of a commercial phosphorous acid formulation, applied at 3 kg/ha and 12 kg/ha in 100 L water, into *Pinus radiata* foliage and, ii) the effect of four commercially available adjuvants on phosphorous acid uptake into *Pinus radiata* foliage. Efficacy of phosphorous acid was demonstrated in vitro with two *Phytophthora* species, *Phytophthora kernoviae* and *P. pluvialis.* (Rolanda *et al*., 2014)

2.5.3. Carbosulfan:

Sharma and Sharma (1995) used nematicides *viz*., carbosulfan, phosphamidon and triazophos 1000 ppm as root dip treatment in tomato for the management of *M. incognita* and *M. javanica* and obtained higher yield in all the treatments. Among soil treatments 2.0 kg *a.i*/ha dose of carbofuran and phorate resulted in highest yield and reduction in root knot galling indices over control.

Monocrotophos 35 EC followed by carbosulfan 25 EC and triazophos 40 EC (each at 0.05 and 0.1%) were found effective in controlling *M. incognita* through seed soaking of chickpea. Also soil application of carbofuran @ 2 kg *a.i*/ha was better in improving plant growth parameters and reducing nematode population. (Pareek *et al.,* 1998).

Vadhera *et al.,* (1999) reported seed dressing in okra with carbosulfan, benfuracarb and triazophos to reduce gall index by *M. incognita* and increase yield. Maximum yield was recorded in carbosulfan at 3% and seed soaking with all these chemicals reduced the number of galls and egg masses out of which carbosulfan reduced the invasion of *M. incognita* larvae.

Vats *et al.* (2000) conducted experiments to evaluate the efficacy of seed dressing chemicals *viz.*, carbosulfan (Posse ST) or benfuracarb (Oncol 40 ST) at 3 or 6% *a.i* w/w. Fresh shoot weight was significantly higher in 3% carbosulfan and benfuracarb. Lowest number of galls/plant, egg masses/root and eggs/egg masses were obtained at higher concentration of carbosulfan and benfuracarb.

Karbasayya and Rahman (2001a) studied on the efficacy of carbosulfan 25 ST and Achook @ 3% (w/w) as seed dressing and 1% multineem, 1% Neemazal F and 0.1% monocrotophos 36 SL as seed soaking for the management of *M. incognita* on black gram. All the seed treatment were effective in reducing gall, egg mass and soil nematode population and improving the growth characteristics and yield of black gram.

Karbasayya and Rahman (2001b) determined the effect of deep ploughing and seed treatment with 3% carbosulfan 25 ST (w/w), 0.1% carbosulfan 25 EC and 0.1% monocrotophos 36 SL on *M. incognita* infesting black gram. The interaction between ploughing and seed treatment was at par with the interaction between no ploughing and seed treatments. Ploughing with seed treatment improved the growth characteristics and reduced the soil nematode population.

Sharma and Majumdar (2003) conducted an experiment to determine the efficacy of seed soaking, alone or in combination with foliar spray against root knot nematode of chickpea. The treatments comprised 500 and 1000 ppm of carbosulfan seed treatment (soaking); 1000 ppm carbosulfan foliar spray; *Rhizobium* alone; 2.0 kg carbofuran/ha furrow application and untreated control. The lowest root knot index (11.3) and highest grain yield (17.5 q/ha) were recorded in carbofuran followed by 500 ppm carbosulfan seed soaking + 1000 ppm carbosulfan foliar spray treatments. The result indicated that 500 ppm of carbosulfan as seed soaking was effective in increasing root nodulation, grain yield and reducing root knot disease incidence.

Ravishankar and Singh (2005) studied on the effect of carbosulfan (25 STD) and neem seed kernel powder (NSKP) as corm dressing on the growth of gladiolus infested with *M. incog*nita. Carbosulfan (25 STD; 3% w/w) reduced *M. incognita* infestation. Both carbosulfan (3% w/w) and NSKP at 10% (w/w) resulted in increased plant growth and reduced number of galls as compared to lower concentration of carbosulfan (1.5%) and NSKP (50%).

Soil treatment with Furadan at 0.3g *a.i*/m^2 and seedling root dip with 0.05% marshal. (Carbosulfan) at 0.05% for 20-30 minutes resulted in 15-31% reduction in root gall index in transplanted seedling and 34-49 % reduction in *M. incognita* field in (Sharma and Kashyap, 2005).

Shevale *et al.* (2006) conducted a study to manage root-knot nematode (*Meloidogyne incognita*) infesting mung bean (cv. Vaibhav) using carbosulfan. Treatments comprising of seed dressing with carbosulfan 25 DS at 1.5% w/w (T1), seed dressing with carbosulfan 25 DS at 3.0% w/w (T2), seed soaking in carbosulfan 25 EC at 0.1% (T3), seed soaking in carbosulfan 25 EC at 0.2% for

4 hour (T4), and an untreated control (T5). Maximum reduction (45.83%) in nematode population was recorded in T2, which was at par with T4 and T1. Minimum gall index was recorded in T2, followed by T4. T1 and T2 were at par with each other in terms of yield. Cost:benefit ratio was positively highest in T1 followed by T4 compared to the rest of the treatments. It is concluded that T1 and T4 were the most economical treatments for the management of root-knot nematode infesting mung beans.

Das (2008) used carbosulfan at 1% seed treatment followed by soil application of granular carbofuran @ 1.0 kg/ha in pea infected by *M. incognita* which resulted in effective and economic management of nematodes and increase in pea yield.

Assessment were made to test the efficacy of nematicides, seed treatment with carbosulfan 25 SD 5% *a.i* (w/w), acephate (75 SP) 5% *a.i* (w/w), soil application of carbofuran 3G @ 2kg *a.i*/ha, phorate @ 2kg *a.i*/ha, benfurocarb 3G @ 2kg *a.i*/ha, slurry application of naemin with FYM 25 kg/ha for management of *M. incognita* in okra. Nematicides which are seed dresser and granular formulations were found to be cost effective and easy to apply whenever they were compared with Naemin. Granular application of carbofuran and phorate, both at 2 kg *a.i.*/ha were quite effective in reducing root-knot disease and nematode population densities and in increasing fruit yield of okra. Next promising chemicals were seed dressing with carbosulfan and acephate both at 5% a.i. and application of "Naemin" at 25 kg/ha. (Bhosle *et. al*, 2012).

Gowda *et al.* (2013) evaluated emulsifiable concentration of carbosulfan 25 EC as seed soaking for management of root knot nematode, *M. incognita* in infected tuberose bulbs. Soaking of tuberose bulb @ 500, 1000 and 2000 μg/ml of carbosulfan 25 EC for 2-4 h reduced the hatching of *M. incognita* eggs significantly.

Venkatesan and Patel (2013) investigated on the efficacy of organic amendments, nematicides and biological control agent (BCA's) in controlling root knot nematode in bitter gourd. Seed treatment with carbosulfan @ 0.75% (Marshal 25 DS at 30 g/kg seed) and soil application of carbofuran (Furadan 3G at 66.66 kg/ha) at 2 kg/ha and cartap hydrochloride (Padan 4G at 50 kg/ha) @ 2 kg/ha, different organic amendments such as mustard cake and jatropha cake each at 2 t/ha, vermicompost and poultry manure each at 3 t/ha, BCAs *T. harzianum* and *P. lilacinus* each at 10 kg/ha were applied for control of root knot nematode *M. incognita* in bitter gourd. Carbofuran treatment recorded a longest vine length which was at par with carbosulfan and poultry manure. Significantly lowest soil nematode population was recorded in carbofuran (313 / 100 g soil) which was at par with mustard cake followed by poultry manure and jatropha cake.

2.5.4. Neem Oil Cake

Khan (1969) observed the suppressed population of *M. incognita* along with few other nematodes around the roots of egg plants when soil was amended with oil cakes of margosa, mahua, peanut and castor.

Siddiqui *et al.* (1976) observed the reduction in nematode population and yield of certain vegetables being influenced by amendments of oilcakes like neem, groundnut mustard, castor and mahua against several plant parasitic nematodes in a field experiment.

Singh *et al.* (1985) in an experiment on effectiveness of sawdust, urea, cow dung, leaf mold, castor, mustard and neem cakes against the development of *M. incognita* in tomato indicated that mixture of sawdust with different oil cakes promoted the growth of plant reducing the infestation of root knot nematode. The adverse effect of saw dust on plant growth was mitigated by combined application of saw dust with different organic nitrogen sources. The mechanism behind the control was presumed to be the liberation of total free phenols due to decomposition.

Goswami and Vijayalakshmi (1987) studied the effects of period of decomposition of oilseed cakes in soil on the juveniles of *M. incognita.* The toxicity of exudates in the soil amended with neem cake (*Azadirachta indica*) and undi cake (*Colophyllum inophyllum*) to *M. incognita* increased up to 3 weeks of decomposition and then decreased by sixth week when it was almost negligible. Undi cake was more toxic at 4th and 5th week in comparison to that found in neem cake.

Significant reduction in number of galls, egg masses and nematode population against *M. incognita* were observed on *Vigna radiata* by application of poultry manure, mustard cake, neem cake @ 1-2 t/ha (Borah and Phukan, 1992).

Devappa *et al.* (1997) used carbofuran @ 2 kg *a.i*/ha, neem cake @ 2.5 t/ha and *P. penetrans* at 924 g of inoculum either singly or in combination for management of *M. incognita* infecting sunflower. Significant increase in plant growth parameters and reduction in nematode population in soil and root galling were recorded in combined application of carbofuran, neem cake and *P. penetrans* treatment.

Amending the soil with different oil cakes were found to be effective in reducing the *M. incognita* population in soil as well as root gall formation in ginger and highest yield with maximum reduction of nematode population was recorded in neem cake treated plots. (Vadhera *et al.*, 1998).

Patel *et al.* (1999) included several organic amendments *viz.*, pressmud, neem cake, castor cake, mustard cake, poultry manure, farmyard manure and celrich for management of *M. incognita* and *M. javanica* in bottle gourd. Out of these organic amendments maximum root knot nematode reduction was recorded in neem cake (56.7%) followed by rest other over control. Except for the celrich treatment, fruit yield was significantly higher (104-141%) in all treatments over the control.

Soil application of neem cake @ 1 t/ha in a 1.8×1.2 m^2 plot against *M. incognita* and *M. javanica* in chickpea resulted in significant improvement in plant growth parameters, increased grain (166%) and fodder yield (118.9%) with reduction in root knot index (44.1%) and final nematode population 36.8% (Patel and Patel, 1999).

Neem cake @ 2% w/w and carbofuran @ 2 kg *a.i*/ha were effective in reducing *M. incognita* population as well as increase in growth parameters of Japanese mint (*Mentha arvensis*) cv. Shivalik (Singh and Kumar, 2000).

Seed soaking with neem products like neem seed kernel, neem seed cake, neem seed coat and Achook @ 20% w/w was found to be effective in reducing the nematode population of *M. incognita, R. reniformis, Tylenchorhynchus mashhoodi, Hoplolaimus indicus* and increase in grain yield of cowpea (Mojumder and Mishra, 2000).

Chakrabarti and Mishra (2001) used neem based integrated management with seed treatment of different neem products and soil application of systemic nematicides. Neem seed powder @ 10% w/w along with carbofuran @ 1kg *a.i*/ha were found to be most effective against *M. incognita*. Crude neem products *viz.*, neem cake and neem seed powder were more effective than commercial neem based formulations.

Organic amendments, namely sawdust, poultry manure, mustard cake and neem cake were applied at 100 g per furrow or 16.6 g per spot were applied to manage root-knot nematode, *Meloidogyne incognita,* infesting French bean. Poultry manure applied as spot application was effective in increasing plant growth characters whereas neem cake, as spot application, was effective in reducing gall, egg masses and soil population of *M. incognita*. Spot application of all the organic amendments was comparatively better than furrow application in reducing nematode population and increasing yield (Ahmed and Choudhury, 2004).

The combined application of neem cake and biological control agents significantly increased shoot and root weight, chlorophyll content and reduced gall index in chickpea cv. H 208 by *M. incognita* (Pandey *et al.*, 2005).

Yadav *et al.* (2005) studied the effect of different oil cakes *viz*., neem, mustard, mahua, castor and karanj as seed soaking @ 10, 15 and 20% (w/v) aqueous extract. The result revealed that all oil cakes increased plant growth and reduced nematode reproduction of *M. incognita* in gram. Higher concentration of aqueous extract of neem cake increased maximum plant growth parameters with reduction in nematode reproduction.

Neem cake both spot and general application, carbofuran 3G alone and in combination with neem cake was most effective in reducing J_2 population of *M. incognita* in tomato after 30 and 60 days of transplanting. Neem cake spot application exhibited highest increases in shoot and root lengths over control (Bhat *et al.*, 2005).

Yadav *et al.* (2006) conducted pot experiment to determine the efficacy of oil cakes *viz.*, neem, karanj, mustard, castor and mahua @ 10, 15 and 20 q/ha for management of *M. incognita* on chick pea. When applied 20 days before sowing treatments resulted in increased plant growth characters and suppressed nematode reproduction, number of galls and egg masses per plant, soil population over untreated control. Among the treatments neem and karanj cakes were most effective and superior to other treatments in improving plant growth parameters and suppressing population of *M. incognita* in chickpea.

The effects of nematicides and organic amendments in control of *M. incognita* in nursery tea with treatments comprising of untreated control, phorate @ 3 g/seedling, carbofuran @ 3 g/seedling, neem cake @ 10 g/seedling, mustard cake at 10 g/seedling alone and in combination with half dose were superior to the untreated control with higher growth parameters and reduced number of galls, egg masses and eggs/egg mass. Neem cake @ 10 g/seedling was best in reducing nematode population. (Kalita and Bora, 2006)

Efficacy of organic amendments *viz.*, neem cake, vermicompost, neem seed kernel, saw dust and carbofuran 3G against *M. incognita* in brinjal under field condition applied alone and in combination resulted in significant effects on plant growth parameters and yield of brinjal with corresponding decrease in nematode population. Neem cake + carbofuran 3G showed superior over control with respect to growth parameters, yield and decrease in nematode multiplication. (Saikia *et al.*, 2007)

Singh *et al.*, (2009) used neem gold and neem seed kernel extract (NSKE) @ 100 ml/kg seed v/w against *M. incognita* on green gram. The result indicated better root length as compared to other treatments. Neem gold exhibited best performance provided 4.25 and 3.64 g/plant of fresh shoot and root weight followed by 2.65 and 2.36 g/plant of dry shoot and root weight with reduction in root galls (85.4%), egg mass (63.9%) and also highest reduction in *Meloidogyne* sp. (42.1%) in neem gold followed by NSKE.

Sharma and Trivedi (2009) studied the efficacy of neem products like powdered neem leaf, neem bark, nimboli, kitguard, neem tonic and neem oil against *M. incognita* on mung which resulted in reduction of nematode population and disease incidence.

Haseeb and Kumar (2012) undertook a field experiment to determine the effect of oil cakes *viz*., neem castor and jatropha each @ 30 g/pot as spot treatment applied 10 days prior to sowing and carbofuran as treated check @ 10 g/pot against *M. incognita* on bottle gourd. Improvement in percentage seed germination, fruit yield 33.0 and 22.9% respectively and lowest root knot index is 3.3 was observed in neem cake treated plants followed by jatropha and castor cake.

Rajvanshi and Bishnoi (2012) used neem cake (5 q/ha) as 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 treated check (Carbofuran @ 1.5 kg *a.i*/ha) and untreated check to control *M. incognita* in cowpea. All these treatments exhibited significantly higher grain yield and reduced root knot population over check. Maximum grain yield was recorded in carbofuran followed by carbosulfan, NSKP, neem cake and reduced root knot population over control. Carbosulfan treatment grain yield was at par with NSKP followed by neem cake with reduced nematode count.

Khan *et al.* (2012) evaluated different dose of Achook (1500 ppm *Azadirachtin* EC) against *M. incognita* infecting okra. Soil drenching with Achook and Achook A-1 (containing sesame oil) at higher dosage (≥10 lit/ha) showed reduced root galling, greater suppression of final soil nematode (J_2) population and increased shoot height of okra.

Rajvanshi (2012) used treatments *viz.*, Neem cake (10 q/ha), Vermi compost (10 q/ha,), Poultry manure (10 q/ha), *Trichoderma viride* (6-8 g/kg seed), Neem cake + vermi compost, Neem cake + Poultry manure, Neem cake + *Trichoderma viride* + Poultry manure + vermi compost, Vermi compost + *T. viride* along with treated check (Carbofuran 3G @ 2.0 kg ai/ha) and untreated check. All treatments were significantly higher as compared to untreated check. It was found that the treated check (carbofuran 3G) was very effective in the management of root-knot nematode followed by Neem cake + *Trichoderma viride* + Poultry manure + Vermi compost, Neem cake + Vermi compost, Neem cake + Poultry manure, Neem cake as compared to untreated check resulted in highest nematode population. It was found that the fruit yield was higher in carbofuran which was at par of Neem cake + Trichoderma viride + Poultry manure + vermi compost as compared to untreated check.

Somasekhara *et al.* (2013) conducted experiments on the management of root knot nematode on cucurbits using organic amendments which have nematicidal effect *viz.*, neem cake, castor cake and jatropa cake applied 15 days before sowing @ 30 g/plant. Neem cake performed well with less number of galls and minimum nematode population compared to control in bitter gourd. Neem cake treated fields showed higher B: C (1: 2.48). Soil application of neem cake @ 30 g/plant when applied reduced *M. incognita* incidence and also increased yield.

Neem cake (1.5 t/ ha), *P. fluorescens* (10 kg/ha) and *T. harzianum* (10 kg/ha) as both soil application and seed treatment (10 g/kg seed) alone and in combination were tested against *M. incognita* infecting egg plant. Neem cake, *P. fluorescens and T. harzianum* alone and in combinations significantly reduced root knot disease of egg plant. Significantly higher fresh and dry weight of shoot, reduced number of galls (by 81%) and low reproductive factor (Pf / Pi < 0.5) were recorded in neem cake + *P. fluorescens* + *T. harzianum* treated plants as compared to other treatments (Singh, 2013).

Chedekal (2013) investigated the bio-efficacy of leaf extracts *viz.*, *Calotropsis procera, Azadirachta indica*, *Clerodendrum inerme* and *Lantana camara* on egg hatching and juvenile mortality of *M. incognita* and observed that maximum mortality of J_2 were observed in leaf extracts of *A. indica* (90.17%) and least in *C. procera* (60.33%).

2.5.5. Streptocycline

Chemical control with antibiotics and fungicides were evaluated for the control of *R. solanacearum* in ginger at different concentrations. Out of the six antibiotics tested as seed protectant, terramycin [oxytetracycline] at 500 ppm was the most effective in terms of per cent plant mortality (11.11%), and yield (175 q/ha) followed by streptocycline. Good results were obtained at high concentration (500 ppm) (Ray *et al.*, 2005).

Pythium rot cum *Ralstonia* wilt complex of ginger is very serious in different areas of Karnataka. Pre-sowing of rhizome with 0.05% streptocycline + 0.2% copper oxy-chloride for 20 minutes and post sowing soil drench with 0.2% bleaching powder and (TS) 0.1% Metalaxyl MZ thrice at 20 days intervals from disease inception found very effective in reducing the disease to the maximum extent (PDI-2.79) compared to PDI of 51.63% in control. The same treatment showed the highest rhizome yield (172.75 q/ha) compared to 58.75 q/ha in control. The treatment recorded low C : B ratio (1:11.72) compared to (1:30.52). (Kumar and Suryanarayana, 2011).

Streptocycline showed significant result against *R. solanacearum* causing rhizome wilt of ginger with highest inhibition (2.59 cm) at 500 ppm followed by k-cycline and plantomycin. Rhizomes treated with streptocycline @t 0.5 g/l + copper oxychloride @ 2 g/l + soil application of carbofuran + drenching with metalaxyl MZ 1 g/l and drenching the streptocycline at 0.5 g/l of water twice at 20 days interval recorded very less incidence of disease (20.7%) with maximum yield 224.0 q/ha (Raghu *et al.*, 2013).

2.5.6. Sesame oil cake

Trivedi *et al.* (1978) observed that application of oilcakes of peanut, sesame (*Sesamum indicum*), mustard (*Brassica campestris*) and taramira (*Eruca sativa*) at the rate of 2.5, 5.0, 7.5, and 10.0 per cent of the soil in pots infested 15 days before transplanting / seedling with *M. incognita* respectively, promoted the growth of test plants effectively when amended with oil cakes at 2.5 or 5.0 per cent level.

Bhatnagar *et al.* (1978) in a pot experiment observed different degrees of control *M. incognita* when the soil was treated with 50/70 ml of water soluble extracts of oil cakes like groundnut, sesamum, mustard and taramira inoculated with 3000 root knot larvae per pot of okra seedlings. Groundnut cake proved to be the best at higher dosage in controlling root knot nematode with the root knot index of 1.0 and 0.52 number of galls per gram of roots compared with 5.0 and 54.36 in control respectively.

Singh *et al.* (1979) observed that the oil cake extracts of mustard, taramira, sesamum and cotton prepared either by soaking or boiling 100 gram cake per pound of water suppressed hatching of *M. incognita* differentially. It was 99.92 and 99.38 per cent with mustard and cotton boil extracts; 57.06 and 67.25 per cent in taramira and sesamum soaked extracts respectively.

Tomato seedlings were given root-dip treatments of water extracts of oilseed cakes of *Arachis hypogaea*, *Azadirachta indica*, *Sesamum indicum, Brassica rapa* and *Madhuca indica* and then exposed to *Meloidogyne incognita* (1000 juveniles/pot). After 45 days there was a significant reduction in nematode in all treatments with a marked increase in plant growth (Vijayalakshmi and Goswami, 1987).

Aldicarb, carbofuran and phorate all @ 3.75, 6.25 and 8.75 kg *a.i.*/ha and the oil cakes of neem, castor, gingelly (Sesame) and coconut @ 100 or 200 kg N/ha were effective in suppressing the effect of *M. incognita* and improving the yield of betel vine in pot experiments (Murthy and Rao, 1992).

Sesame oil seed cake was used at the rates of 0, 10 and 15 g/pot, to study its effect on reproduction and development of the root-knot nematode on squash plant. There was significant reduction in nematode galls and egg-masses with improved plant growth (Youssef and El-Nagdi, 2004).

In a pot experiment, oil cakes of cotton, flax, olive, sesame and soybean were mixed with soil at the rate of 5, 10, 15, 20 or 50 g/kg soil and carbofuran as standard were compared against *M. incognita* infecting tomato. The highest reduction in galls was noted in plants treated with sesame cake (Radwan *et al.,* 2009).

A pot experiment was conducted to evaluate the influence of certain oil-seed cakes *i.e.* fennel, sesame, anise or plant dry seed powder of red pepper as soil amendments in comparison with oxamyl or urea on controlling *M. incognita* infecting eggplant seedlings. The highest values of percentage reduction in number of galls (64.2%), females (58.5%) and egg masses (55.7%) on eggplant roots were achieved by sesame oil cake application, followed by anise oil cake (El-Sherif *et al*., 2010).

2.5.7. Integrated Management

Mohanty *et al.* (1992) reported management of root knot nematode, *M. incognita* infecting ginger. Neem cake @ 2.5 t before planting; carbofuran @ 1 kg before planting; neem cake @ 1 t/ha before planting + carbofuran @ 1 kg at 45 days after planting; carbofuran @ 1 kg before planting + neem cake @ 1 t at 45 DAP; carbofuran @ 1 kg at 45 DAP or neem cake @ 1 t at 45 DAP were applied to ginger in field for control of *M. incognita*. Final root knot index was lowest in treatments with neem cake followed by carbofuran.

Sheela *et al.* (1995) studied on various treatments in an integrated management trial and observed that neem cake @ 2.5 t/ha at planting +

carbofuran 1 kg *a.i*/ha at 45 DAP was effective in reducing population of *M. incognita* in soil, root and root knot index and increase in yield of ginger.

Pre planting application of neem cake (1 t/ha) followed by post planting application of carbofuran (1 kg *a.i*/ha) 45 DAP gave best result in terms of suppression of *M. incognita*, disease intensity and increased in yield of ginger (Mohanty *et al.*, 1995).

Seed treatment (carbofuran 3G @ 3% w/w) and organic amendments (neem cake, poultry manure, mustard oil cake @ 2 t/ha) alone and in combined application of seed dressing followed by organic amendments at 1 t/ha each, were effective in improving plant growth characters, yield and reduced number of galls, egg masses and final nematode population on green gram. (Barman and Das,1996).

Dipping disease- free banana suckers in 0.2% Bavistin for 45 minutes was found to be effective against the wilt complex disease caused by *F. oxysporum*, *R. solanacearum* and *M. incognita* (Roy *et al.*, 1998).

Important diseases of ginger which included rhizome rot (*Pythium* and *Fusarium*), bacterial rot (*R. solanacearum*), root knot nematode (*M. incognita*) and their management was reviewed. (Mathur, 2000)

Nehra and Trivedi (2004) conducted combined effect of arbuscular mycorrhizal fungi *Glomus fasciculatum* (G.F) and *G. mosseae*, neem leaf (@ 2.5 g/pot) and nimim (@3 g/pot) on root-knot nematode, *M. incognita* infecting ginger. There was significant reduction in disease incidence and increased in plant growth characters after 150 days of treatment when applied in combination. In second trial, combination of GF (@100 spores per pot), oilcakes (neem and mustard @ 2.5 or 5 g/pot) & FYM @ 2.5 or 5 g/pot were taken. Among the treatments, GF + neem cake and GF + oilcake (neem + mustard) were found highly effective in reducing the root-knot population with a consequent increase in the growth of ginger plant.

Das and Sinha (2005) studied the efficacy of integrated pest management in controlling *M. incognita* infesting okra. Treatments included inoculation of *Paecilomyces lilacinus* and FYM, poultry manure and carbosulfan, alone or in different combinations. *P. lilacinus* + carbosulfan, FYM and poultry manure resulted in tallest plants (123.6 cm), highest mean root length (24.7 cm), fresh and dry weight of shoot and root, crop yield (3.7 kg/plot), lowest mean number of galls (83.5), egg masses (23.6) and nematode population (200).

Hazarika and Bora (2007) tested nematicidal compounds *viz.*, carbofuran, neem cake and mustard oil cake and the bacterial compound *viz.*, streptocycline etc. against the *M. incognita* and *R. solanacearum* disease complex in jute. Combination of these treatments showed better results as compared to individual treatments. Lowest wilt incidence observed in individual effect of neem cake and carbofuran with bleaching powder.

Hussain and Bora (2008) investigated on the integrated management of *M. incognita* and *R. solanacearum* complex in brinjal. Integration of summer ploughing, half recommended dose each of carbofuran 3G, neem cake, streptocycline and full dose of *T. harzianum* were found to be superior against this disease complex in brinjal under field condition. The treatment effectively improved all the plant growth parameters and yield of the crop with corresponding decrease in the nematode reproductive rate. The treatment also produced minimum final bacterial population in the soil along with less per cent wilt incidence (PWI).

Bio-control agents (*P. fluorescens* and *T. viride* @ 10 g/kg seed), neem seed powder @ 10 g/kg seed and carbosulfan @ 3.0% w/w as seed treatment alone and in combination @ half, 1/3rd and 1/4th dose, applied in combination of 2, 3 and 4 additives respectively against *M. incognita* on lentil resulted in significant improvement in grain yield and reduction in root knot index. 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 (Haseeb and Kumar, 2009).

Integrated management of root-knot nematode, *M. incognita* infesting okra with 13 treatments resulted in reducing root knot nematode population, number of galls and gall index and increase length, fresh and dry weight of root, shoot and yield of okra over untreated control. Carbofuran 3G @ 2kg *a.i*/ha as soil application was found to be more effective in reducing root knot nematode population (59.49%), number of root galls (69.57%) and gall index (39.33%) and increasing the length of root (64.28%) and shoot (71.37%), fresh weight of root (93.41) and shoot (83.67%), dry weight of root (103.13%) and shoot (87.58%) and the fruit yield of okra (32.94%) in micro plots (Shendge *et al.*, 2010).

Munawar *et al.* (2011) reported *Paecilomyces lilacinus* and carbosulfan at optimum dose alone reduces *M. incognita* and *Rotylenchulus reniformis* population either singly or concomitantly and increased plant growth. However, integration of these components in various treatments was better in reducing the population of both the nematode species and increased plant growth than when used alone. The best combination of these components with regard to reduction in gall number and population of either of the nematode species and increase in plant growth of infected plants (singly or concomitantly) was 2.0 g *P. lilacinus* combined with 1.0 g *a.i* carbosulfan.

Bandyopadhyay and Bhattacharya (2012) evaluated physical, chemical and biological methods in the field for three ginger growing seasons to manage rhizome rot disease of ginger caused by a complex of fungal (*Pythium, Fusarium and Rhizoctonia*), bacterial (*Ralstonia solanacearum*) and root knot nematode complex. Hot water treatment, fungicide treatment with mancozeb, a biocontrol agent *T. harzianum*, and soil application of neem cake individually and in combinations resulted in the lowest disease incidence (27.14%) and highest rhizome yield (6.46 kg/plot).

Singh and Mahanta (2013) studied the effect of carbosulfan, *Glomus fasciculatum*, *Trichoderma harzianum* and vermicompost alone and combination for management of *M. incognita* on green gram. The results were found to be significantly different from control in respect of increasing growth parameters including significant reduction of final nematode population in soil. Maximum growth parameters *viz*.; plant height, fresh and dry weight of shoot and root were recorded in the treatment with combination of all the control agents (*T. harzianum* @ 2.5 kg/ha + *G. fasciculatum* @ 300 spores/ m^2 + carbosulfan ST @ 1.5% w/w+vermicompost 1.5 t/ha) followed by the treatment with integration of *T. harzianum* and *G. fasciculatum*. Maximum reduction in nematode population and maximum yield were obtained in the treatment, with integration of all the control options.

MATERIALS AND METHODS

Several field and laboratory experiments were conducted in the Department of Nematology, Plant Physiology, Seed Science and Technology and Agricultural Meteorology, Orissa University of Agriculture and Technology, Bhubaneswar during the year 2011-2013 for the investigation on interaction between *Meloidogyne incognita* and *Ralstonia solanacearum* causing quick wilt complex and management in ginger. Various materials used and methods followed for carrying out the present investigation are described hereunder.

3.1. OBJECTS OF INVESTIGATION

Meloidogyne incognita and *Ralstonia solanacearum* inciting rapid wilt in ginger were selected for investigation.

3.2. COLLECTION, ISOLATION AND MULTIPLICATION OF *M. INCOGNITA*

3.2.1. Isolation and Multiplication:

In a small plastic cup coarse sand was filled to which few brinjal seeds were sown. At 4-5 leaf stage one seedling was kept and the rest were thinned out. Single egg mass from the infected ginger plant was surface sterilized in several changes of sterile distilled water and carefully inoculated around the root zone of brinjal seedling. Three to four weeks after inoculation, sand along with brinjal plant was transferred to a big circular RCC tank containing sterilized soil and few brinjal seedlings. Further, after a period of 3-4 weeks, few plants were uprooted to isolate egg masses for extraction of nematodes and use in different experiments. Also the soil of the pot was collected to isolate second stage juveniles for different experiments. Intermittently, healthy brinjal seedlings were transplanted in the culture pots for further sub-culturing and multiplication of nematodes monoxenically.

3.3. CHARACTERIZATION OF *M. INCOGNITA*

Second stage juveniles collected from single egg mass culture were fixed in 4% formalin and processed through Seinhorst I and II solution, mounted on glass slides with glycerol and sealed with zut. Twenty such processed specimens were examined under microscope for morphological as well as morphometrical characters pertaining to measurements using the D-Mans formula.

Adult females from monoxenically cultured pots in brinjal roots were isolated after staining in sodium hypochlorite (NaOCl) acid fuchsin solution (Byrd *et.al*, 1983). Ten such females were taken in a glass slide and the posterior portion of the females were cut, internal contents removed and trimmed. Trimmed sections were mounted on a drop of glycerol and sealed with zut. Such sections were studied under compound research microscope using oil immersion objectives for observation of posterior cuticular pattern and correct identification on the basis of perineal pattern for identification of *Meloidogyne* species.

3.4. COLLECTION, ISOLATION AND PURE CULTURE OF *R. SOLANACEARUM*

3.4.1. Cleaning and Sterilization of Glassware:

Standard procedure for cleaning and sterilizing glasswares and media were followed (Riker and Riker, 1936). All the glasswares were cleaned with chromic acid followed by thorough washing with tap water and subsequent rinsing with distilled water and drying in hot air oven.

3.4.2. Sterilization by Flame:

Scalpels, inoculating needles, glass rods, platinum wire loops etc. were sterilized by dipping them in 70% alcohol followed by flaming over the spirit lamp.

3.4.3. Sterilization in hot air oven:

Glasswares were sterilized in hot air oven at 160^0C for 2 hours.

3.4.4. Sterilization of soil:

Soil mixtures were sterilized in autoclave at 15 lb pressure for 30 minutes at 121.6^0C twice in alternate days.

3.4.5. Preparation of Media:

Pseudomonas specialized media from Hi media was melted in a 250 ml conical flask containing distilled water. The flask was plugged with non absorbant cotton and sterilized in an autoclave at 15 lb pressure for 20 minutes. The media was then cooled. Subsequently, sterilized media was poured in test tubes and petriplates under aseptic condition and kept in BOD incubator for isolation of pathogen and further study**.**

3.4.6. Isolation and Multiplication in Pure Culture:

Infected ginger plants with rhizomes and roots exhibiting wilting symptoms were collected from three different locations of Odisha *viz*., Pottangi (Isolate 1), Phulbani (Isolate 2) and Central Farm OUAT, Bhubaneswar (Isolate 3). The infected rhizomes (Fig 1) were processed in laboratory for further investigation. They were washed under running tap water to remove the sand and soil. The rhizomes were surface sterilized in 70% alcohol. A small piece of surface sterilized rhizome was carefully transferred onto *Pseudomonas* specialized media petriplates and slants under asceptic condition. The plates and slants were then placed in BOD incubator at 30^0C for 24-48 hòurs to allow the growth of pathogen in the medium. Further, morphologically uniform bacterial colonies were isolated and pure cultured on nutrient agar petriplates (Fig 2), conical flasks as nutrient broth. At periodic interval the bacteria was sub cultured to prevent dehydration as well as virulence.

3.5. CHARACTERIZATION OF *R. SOLANACEARUM*

Morphologically distinct colonies of similar types from the three isolates were put into the standard protocol of Gram staining technique for observation of its morphological characters. Different biochemical tests, various sugar utilization and antibiogram and enzymatic activities shown by the isolates were compared with Beqrgey's manual of determinative bacteriology, 9th edn. 1994; PIB win (Bryant, 2004) version 2.0 and ABIS online.

3.5.1. Colony Characteristics of the Bacterial Isolates:

Fresh cultures of the three bacterial isolates grown in nutrient broth were taken. Freshly grown broth cultures of the isolates were streaked onto *Pseudomonas* specialized media for the development of colony. After 24 hours of incubation the growth pattern, colony size, appearance and colouration was observed. These characters were used for obtaining primary information about their identity.

3.5.2. Grams Reaction of the Bacterial Isolates:

Bacterial suspension of three isolates (Bhubaneswar, Pottangi and Phulbani) from nutrient agar solution was diluted in sterile distilled water. Thin smear of the three isolates were made on a clean glass slide with the help of a sterilized loop. The smears were air dried followed by heat fixing by quickly passing it over a spirit lamp. The slides were stained in crystal violet for 30 seconds and then washed in water. Slides were then stained in 0.5% iodine as moderant followed by destaining in ethyl alcohol and counter stained in safranine (Gram, 1884 and Cruickshank 1968). Finally, photographs were taken to represent the reaction type.

3.6. BIOCHEMICAL CHARACTERISATION OF THE BACTERIAL ISOLATES

3.6.1. Test on Triple Sugar Iron Agar:

All the three isolates were taken in Triple sugar iron (TSI) agar. The isolates were screened on this medium to test their ability to utilize glucose, sucrose and lactose as well as their capability to produce acid, gas and H_2S. The fermentation of glucose, sucrose and lactose was indicated by production of acid which changed the colour of the slant and butt from orange red to yellow. Production of H_2S was observed as the blackening of the medium while elevation or presence of air bubbles in the butt was considered a positive test for production of gas.

3.6.2. Mannitol Motility Test:

The capacity of the isolates to utilize mannitol, reduce nitrate indicating the presence of the enzyme nitrate reductase and their motility were studied using mannitol. The fermentation of mannitol was indicated by the production of acid which changed the colour of the butt from red to yellow. Presence of air bubbles was taken as a positive indication of nitrate utilization. Diffused growth along the stabbed line was considered positive test for motility while growth only on the stabbed line indicated a negative test for motility.

3.6.3. Indole Production Test:

The isolates were inoculated and grown on peptone water broth to test their ability to produce indole from tryptophan by the action of the enzyme tryptophanase. After incubation, 0.2 ml of Kovac's indole reagent was added to the broth culture slowly along the side wall of the test tube. Appearance of a pink ring at the top of the culture was considered as a positive test for indole production by the isolates.

3.6.4. Urease Test:

Test for the presence of the enzyme urease in the isolates which split urea into ammonia and carbon dioxide was studied using Christensen's urea agar medium. Colour change of the slant from yellow to pink was considered as positive result while no change in colour was taken as negative for urease production by the isolates.

3.6.5. Citrate Utilisation Test:

The capability of the isolates to utilize citrate as the sole source of carbon and energy was studied on Simmons citrate agar medium. Colour change of the slant from green to royal blue was considered as positive result while no change in colour was taken as negative.

3.6.6. Methyl Red Test:

The isolates were tested on MR-VP broth medium to detect their ability to produce sufficient acidic products by fermentation of glucose present in the medium. After incubation, about 5 drops of 0.04% methyl red solution was added to 2.5ml of broth culture. Positive reaction was indicated by the colour change of the medium to bright red while yellow or no colour change of the medium indicated a negative result.

3.6.7. Voges – Proskauer Test:

The isolates were tested on MR-VP broth medium to detect their ability to produce nuitral products like autoin (i.e. acetyl methyl carbines) during metabolism of glucose present in the medium. After incubation, 0.6ml of 5% α-naphthol selection was added followed by 0.2ml of 40% KOH to about 1 ml of broth culture. The solution was allowed to stand for 30 minutes. A change in colour of the medium to wine red was taken as positive reaction while copper colour indicated a negative result.

3.6.8. Catalase Test:

Presence of the enzyme catalase in the isolates was studied in this test. Effervescence production from the bacterial culture on addition of 1-2 drops of 3% hydrogen peroxide (H_2O_2) was considered positive result (Schaad, 1980).

3.6.9. Oxidase Test :

Presence of the enzyme cytochrome-c-oxidase in the isolates was studied in this test. Development of purple or blue colour within 10-30 seconds of rubbing the bacterial culture on oxidase discs (coated with a dye, 1%. N-nitro-metheyl paraphenyl diamine hydrochloride) was taken as positive result while no colour change or delayed positive reaction was considered as negative.

3.6.10. Test on Motility:

The motile nature and dehydrogenase activity of the isolates was detected by treating with 1% triphenyl tetrazo..lium chloride solution in the medium. Pink coloured diffused growth along the stabbed line was considered positive test for motility, while pink colour or no colour on the stabbed line indicated a negative test for motility. The pink colour also indicated a positive test for dehydrogenase activity.

3.6.11. Nitrate Reduction Test:

Nitrate broth was used to determine the ability of the bacterial isolates to reduce nitrate (NO_3) to nitrite (NO_2) to which nitrate reductase was added. Simultaneously the ability of the isolates to denitrify nitrate and nitrite ultimately producing ammonia and molecular nitrogen was also tested. For this, after incubation, 1ml each of sulphanilic acid (in 30% acetic acid) and α-napthylamine solution (in 30% acetic acid) were added to the broth culture.

Development of red colour was a positive result for nitrate reduction. In case of no change in colour, a pinch of powered zinc was added to the broth. Development of red colour in this step indicated a negative result while no change in colour after the addition of the Zn powder, indicated a positive result for denitrification with the formation of ammonia or molecular nitrogen.

3.6.12. Sugar Utilization Test:

The test for utilization of different carbon sources was performed on oxidation – fermentation medium. Disc diffusion method to study both the oxidation and fermentative modes of metabolic degradation of various sugars and sugar alcohols by the isolates was used. The oxidative utilization of sugar was studied in a plate while the fermentative utilization of the sugars was studied in the tube by oil over laying method. Yellow colouration of the medium around the sugar discs was considered as positive test while negative test was indicated by no colour change of the medium.

3.6.13. Amino acid Decarboxylation Test:

The three amino acids tested in the decarboxylase media were ariginine, lysine and ornithine. Each decarboxylase enzyme produced by an organism was specific to the amino acid on which it acted. Therefore, test for the ability of isolates to produce arginine decarboxylase, lysine decarboxylase and ornithine decarboxylase using three different but very similar media was conducted.

3.6.14. Antibiogram study:

The antibiogram patterns of the isolates were studied following the disc diffusion methods of Bauer *et al.* (1966). Ten selective antibiotic discs *viz*., erythromycin, gentamycin, amikacin, streptomycin, ampicillin, cefatoxime, co-triamanzole, ciprofloxacin and olfoxacin from Hi media, Mumbai were used in the study depending on their use and mode of action. Freshly grown bacterial culture from nutrient broth was sweeped onto pre sterilized Muller Hilton Agar No. 2 (MHA) plates containing casein acid hydrolysate 17.5 g, agar agar 17 g, beef extract 2 g and starch soluble 1.5 g in 1000 ml DW at a pH of 7.5 ± 0.2. The selected antibiotic discs were placed aseptically on the MHA plates. The plates were then incubated at 30^0C for 24 hours in a BOD incubator. The zone of inhibition was measured with the help of a scale and was further categorized as sensitive or resistant.

3.7. INTERACTION STUDY

The experiment was conducted in the pots containing 9 kg steam sterilized soil in net house to study the inter-relationship between *M. incognita* and *R. solanacearum*.

3.7.1. Preparation and Sterilization of Soil Mixture:

Well pulverized sandy loam soil from the Central Experimental Farm, OUAT, Bhubaneswar was mixed with sand and FYM in the ratio of 2:1:1. The soil was then steam sterilized twice within a gap of 24 hours in an autoclave at

15 lb (121.6^{0}C) for 20 minutes. The mixture was aerated under shade on a cemented floor for 2-3 days. Earthern pots of 12" diameter were surface sterilized with 4% formal dehyde solution followed by air drying. Sterilized soil mixture was filled up to the brim of each pot, weighing 9 kg of soil mixture.

3.7.2. Planting of Ginger:

To the 12" diameter pots (24 nos.) each containing 9 kg steam sterilized soil, sand and compost mixture, ginger rhizomes of susceptible cultivar Suprabha were planted. The pots were mulched (Fig 3) and watered regularly.

3.7.3. Inoculation of *M. incognita*:

Egg masses from galled roots of culture pots were collected and placed on tissue paper wire gauge assembly on petridishes containing distilled water just touching the surface of the wire gauge for 24 hours. Freshly hatched second stage juveniles (J_2) of *M. incognita* in distilled water were used for inoculation. The estimation of second stage juveniles was done by counting replicated aliquots of the suspension. Inoculation of 2nd stage juveniles was carried out @ 1000 J_2/kg soil into the pots around the rhizosphere of ginger plant 40 days after planting by removing the soil, pouring the required nematode suspension and replacing again with the soil.

3.7.4. Inoculation of *Ralstonia solanacearum*:

Pure culture of *R. solanacearum* was raised on nutrient broth. Seven days old broth culture was serial diluted and the optical densities (OD) were recorded, followed by plating on nutrient agar for development of colony. Counting of bacterial colony was done and serial dilution of *R. solanacearum* with optical density of 1.08 was considered the inoculums level with a colony count of 4 x 10^6 cfu/ml. To each pot containing 9 kg of steam sterilized soil, 9 ml of *R. solanacearum* culture with 1.08 OD was inoculated around root zone by carefully removing soil and replacing after inoculation.

3.7.5. Treatment Assignment and Experimental Design:

A total of six treatments (Fig 4) with four replication were arranged in a completely randomized design which was repeated for two seasons. The treatments were:

T_1 - Check

T_2 - *M. incognita* alone @ 1000J_2/kg soil (N) at 40 DAP

T_3 - *R. solancearum* alone @ 4 x 10^6 cfu/ml/kg soil (B) at 40 DAP

T_4 - *M. incognita* + *R. solanacearum* simultaneously (N+B) at 40 DAP

T_5 - *M. incognita* at 40 DAP + *R. solanacearum* 50 DAP (N→B)

T_6 - *R. solanacearum* 40 DAP + *M. incognita* 50 DAP (B→N)

3.8. HISTOPATHOLOGY

Histopathological studies of healthy and infected ginger roots were carried out to determine the cellular changes brought about by invasion of *M. incognita* and *R. solanacearum* alone and in combination.

3.8.1. Killing and Fixation:

Healthy and infected galled roots and healthy roots of ginger collected from pots at 75 DAP were washed thoroughly in tap water to remove the debrises and sand particles, cut into 1-2 cm long pieces. The roots were immersed in FAA fixative prepared by mixing 91.1 ml of 50 % ethanol, 2.4 ml of glacial acetic acid and 6.5 ml of 37 % formal dehyde (Johansen, 1940). The root piece were kept in the fixative for 48 hour.

3.8.2. Dehydration:

The fixed root materials were washed in distilled water before dehydration. The materials were dehydrated through graded series of tertiary butyl alcohol (TBA) followed by three changes in 100% TBA after washing in 50 % ethyl alcohol to remove the traces of unbound water from the root tissues (Table 1). In the last solution enough safranin was added to give a red tinge in order to stain the roots for easy orientation during embedding and sectioning.

Table.1: Tertiary butyl alcohol dehydration schedule

Step	% Alcohol	Time	Quantity (ml) needed for 100 ml solution			
			DW	95% Ethyl Alcohol	Absolute Ethyl Alcohol	TBA
1	50	2 h	50	40	0	10
2	70	Overnight	30	50	0	20
3	85	2 h	15	50	0	35
4	95	2 h	5	45	0	50
5	100	3 h	0	0	25	75
***6**	100	3 h	0	0	0	100
7	100	3 h	0	0	0	100
8	100	Overnight	0	0	0	100

3.8.3. Infiltration:

After dehydration, paraffin was impregnated into the root tissue. The root pieces were transferred to a specimen tube containing mixture of 100% paraffin oil and TBA in a ratio of 1:1. These were kept at least for 2 hours in this mixture. Another specimen tube was filled 3/4th with melted paraffin wax and allowed to solidify. The root pieces were transferred on solidified parawax and then filled with 1/4th volume of TBA and 3/4th paraffin oil mixture and placed in an incubator at 60^{o}C for 2 hours during which root materials slowly sank to the bottom of the specimen tube. The mixture thereafter was poured off and the roots were replaced with pure melted wax, twice at one hour interval inside the oven at 60^{o}C for embedding.

3.8.4. Embedding:

The inner surfaces of the embedding discs were first coated with thin layer of glycerin and afterwards melted paraffin was poured into the bottom of the disc inside the oven. As the wax started solidifying on the bottom of the disc, the root pieces from the specimen tube were transferred carefully after thorough shaking on the solidifying surface. The root materials were arranged orderly into bundles with the help of heated forceps and needles. More melted wax was added when the wax around the root solidified in the disc. The embedding discs were immediately transferred to a container filled with chilled water for solidification of wax. After solidification the blocks floated on water which were collected, dried and cut into smaller pieces according to the position of the root tissue.

3.8.5. Sectioning:

The small blocks of wax having root tissues were trimmed to remove extra wax. The wax blocks were mounted on the wooden blocks and then fixed in semi automatic spencer rotary microtome. Transverse and longitudinal sections of 12 μ thick were cut in the form of ribbons.

3.8.6. Mounting of Ribbons:

The ribbons were floated on a hot water bath to stretch and collected on clean glass slides coated with a solution of egg albumin and glycerin (1:1). These slides were then kept in an incubator at 40 ^{0}C for 6-8 hours.

3.8.7. Staining:

The sections were stained in safranin and counter stained in malachite green after removing paraffin wax (Table 2). Few drop of DPX mount were applied to the stained slides and rectangular cover glasses were placed on the slides. Prepared slides were left at room temperature and then transferred to incubator at 60 ^{0}C overnight. The slides were examined under the light microscope and necessary photographs were taken through magnified image projection system (MIPS).

Table.2: Safranin and fast green schedule

Step	Solution	Time
1	Xylene	15 min
2	Xylene	15 min
3	Absolute ethanol + Xylene	5 min
4	Absolute ethanol	5 min
5	90% ethanol	5 min
6	70% ethanol	5 min
7	50% ethanol	5 min
8	30% ethanol	5 min
9	1% Aqueous safranin	3 h
10	30% ethanol	5 min
11	50% ethanol	5 min
12	75% ethanol	5 min
13	95% ethanol	5 min
14	0.5% malachite green in 95% ethanol	5-30 sec
15	Absolute ethanol	1 min
16	Absolute ethanol + Xylene	5 min
17	Xylene	5 min

3.9. ESTIMATION OF AVOIDABLE YIELD LOSS

Estimation of yield loss in ginger susceptible variety Suprabha was carried out in a field naturally infested with *M. incognita* (1000 J_2 per kg soil) and *R. solanacearum* (4×10^6 cfu). The field was thoroughly ploughed, laddered and divided into two strips. Each strip comprised of twelve raised beds each measuring 4m x 1m x 0.15m. One strip of 12 beds was treated with carbofuran 3G @ 1.5 kg *a.i*/ha as broadcast and rhizome soaked in streptocycline 0.02% @ 2 g/10 lit of water for 30 minutes followed by shade drying. The other strip was left as such. The treated and untreated plots (Fig 5) were arranged using paired plot technique with twelve replications. The experimental plots were enriched with required dose of manures and fertilizers. Treated and treated rhizomes of susceptible ginger cultivar Suprabha were sown with a spacing of 25cm x 20cm at a depth of 5cm. Before soil treatment the initial nematode population of soil was estimated. All the recommended cultivation practices in vogue for the crop were followed during the study. Observations on number of plant germinated and yield / plot after harvest were recorded for calculation of avoidable yield loss by the quick wilt pathogens.

$$\text{Percentage of yield loss } = \frac{\text{Yield in treated} - \text{Yield in untreated}}{\text{Yield in treated}} \times 100$$

3.10. INTEGRATED MANAGEMENT OF QUICK WILT COMPLEX

Both pot and field experiments were conducted to evaluate the various eco friendly and bio rational management strategies for management of quick wilt complex of ginger.

3.10.1.Pot Culture Trial:

A pot culture experiment (Fig 6) was carried out in the net house of Department of Nematology having 12 treatments each with 3 replications for the management of quick wilt disease complex of ginger. Thirty six pots having steam sterilized soil @ 9 kg/pot were chosen in twelve rows each having three plots to which second stage juveniles of *M. incognita* @ 1000 J_2/kg soil and 4×10^6 cfu/ml/kg soil of *R. solanacearum* were inoculated followed by application of different treatments. This pot culture experiment was conducted during the first season.

3.10.1.2. Treatment Assignment and Experimental Design:

The various treatments tested for their efficacy against quick wilt complex of ginger are:

T_1 - Untreated check

T_2 - Seed soaking in Carbosulfan 25 EC 0.5% for 30 minutes.

T_3 - Seed soaking in Streptocycline 0.02% for 30 minutes.

T_4 - Soil drenching with Phosphonic acid 300 ppm @ 0.6 kg/ ha twice *i.e* one at 45 DAP and second at 75 DAP

T_5 - Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed.

T_6 - Soil application of Neem cake @ 1.5 t/ha at 21 days before sowing.

T_7 - Soil application of Sesame cake @ 1.5 t/ha at 21 days before sowing

T_8 - Seed soaking in Carbosulfan 0.5% + Streptocycline 0.02% for 30 minutes.

T_9 - Seed soaking in Carbosulfan 0.5% + Phosphonic acid 300 ppm

T_{10} - Seed soaking in Carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed

T_{11} - Soil application of Sesame cake @ 1.5 t/ha + Phosphonic acid 300 ppm

T_{12} - Soil application of Neem cake @ 1.5 t/ha + Phosphonic acid 300 ppm

3.10.2. Field trial:

A field having infestation of *M. incognita* and *R. solanacearum* was selected in the Department of Nematology, College of Agriculture, OUAT, Bhubaneswar. The field was ploughed after a light irrigation, ploughs and labeled. Composite soil samples were taken for determining the number of *M. incognita* juveniles per 250 cc soil. The beds were applied with FYM @ 5 t/ha.

Basal dosages of fertilizers @ 100 kg P and 50 kg K/ha were applied in the beds at the time of planting. First top dressing was carried out at 45 DAS @ 62.5 kg N and 50 kg K and 2nd top dressing was carried out at 90 DAS @ 62.5 kg N. The field was divided into thirty six raised beds in three blocks each having twelve beds. Each bed measured 4 × 1 m^2 with a height of 0.15 m.

3.10.2.1. Planting of Ginger:

Healthy ginger rhizomes (var. Suprabha) weighing 15-20 g with atleast two buds were planted in the beds with a spacing of 25 × 20 cm at 5 cm depth during May followed by mulching (Fig 7) and irrigation.

3.10.2.2. Treatment Assignment and Experimental Design:

The various treatments tested for their efficacy against quick wilt complex of ginger were further applied in field to find out effective management modules. Thus the experiment with 12 treatments as in pot culture trial was conducted for two years in a randomized block design having 3 replications.

3.11. PARAMETERS OF INVESTIGATION

Various trials conducted to study the interaction and management of quick wilt complex of ginger undertook several parameters of observation described here as under.

3.11.1. Characterization of *M. incognita*:

Second stage juveniles of *M. incognita* from cultured pot were obtained by modified Baermann funnel technique. Several such juveniles were killed and fixed followed by processing in Seinhorst I and II solution to prepare permanent slides for microscopic observations. Infected roots of brinjal in cultured pot were stained in NaOCl and acid fuchsin followed by dissection of roots to extract few adult females. The females were utilized for preparation of posterior cuticular pattern by using an oculist scalpel, mounted on slides for further microscopic observations.

3.11.2. Characterization of *R. solanacearum*:

For characterization of the three isolates of *R. solanacearum*, initially gram staining was done followed by testing done on the basis of the following tests through several parameters *viz*., Triple sugar iron agar, Production of indole, urease test, methyl red, voges – proskauer, citrate utilization test, catalase, oxidase, motility test, nitrate reduction test, amino acid decarboxylation tests and sugar utilization test. Further, the isolates were tested for their sensitivity to ten antibiotics.

3.11.3. Interaction

3.11.3.1. Plant Growth:

Observations on plant growth *viz*., plant height (cm), number of tillers and dry weight of shoots (g) were recorded towards end of the experiment.

3.11.3.2. Root Knot Index and Wilting:

The infectivity of plants to nematode invasion was measured by recording root knot index in 1-5 scale (Table 3).

The incidence of wilting in various treatments was recorded from time to time.

Table.3: Root knot index (1 to 5 scale)

Scale	Number of galls / egg mass	Reaction
1	No galls / no egg mass	Highly Resistant (HR)
2	0-10 galls with egg mass	Resistant (R)
3	11-30 galls with egg mass	Moderately Resistant (MR)
4	31-100 galls with egg mass	Susceptible (S)
5	>100 galls with egg mass	Highly susceptible (HS)

3.11.3.3. Physiological Parameters:

3.11.3.3.1. Leaf Water Potential (Ψ) was recorded in a Dew point potentiometer by placing the leaves in the leaf basement container.

3.11.3.3.2. Relative Water Content (RWC) and Relative Water Deficit (RWD) was estimated by recording the fresh weight (FW), then the leaves were soaked in water for 2 h to record the turgid weight (TW) and then dried in hot air oven at 80˚C for 48 h to measure the dry weight (DW). Finally the relative water content and relative water deficit of leaves in per cent were estimated by using the standard formula.

$$\mathrm{RWC} = \frac{\mathrm{FW} - \mathrm{DW}}{\mathrm{TW} - \mathrm{DW}} \times 100$$

$$\mathrm{RWD} = 100 - \mathrm{RWC}$$

3.11.3.3.3. Estimation of Chlorophyll: 0.1g of mid portion of leaf was immersed in 10 ml of 80% acetone in test tubes, sealed and kept in dark for 24 hours for extraction of chlorophyll. The chlorophyll extracts were filtered through Whatman No. 1 filter paper. The OD of chlorophyll extract in a spectrophotometer at 645 nm and 663 nm using 80% acetone as blank was recorded. Estimation of chlorophyll a, chlorophyll b and total chlorophyll was made by using the formula given by Mac Lachlan and Zalik (1963).

$$\mathrm{Chl\ a} = \{(12.7 \times \mathrm{OD\ @\ 663}) - (2.69 \times \mathrm{OD\ @\ 645})\} \times \frac{\mathrm{v}}{1000 \times \mathrm{w}}$$

$$\mathrm{Chl\ b} = \{(22.9 \times \mathrm{OD\ @\ 645}) - (4.68 \times \mathrm{OD\ @\ 663})\} \times \frac{\mathrm{v}}{1000 \times \mathrm{w}}$$

$$\mathrm{Total\ Chl} = \{(20.2 \times \mathrm{OD\ @\ 645}) + (8.02 \times \mathrm{OD\ @\ 663})\} \times \frac{\mathrm{v}}{1000 \times \mathrm{w}}$$

where, v = 10 ml

w = 0.1 g

3.11.3.3.4. Dark Respiration, Photosynthesis, Stomatal Conductance and Fluorescence: A potable photosynthesis system LI 6400 was used for recording fluorescence, 5^{th} leaf from top of plant was taken to which black colour cloth was covered for 24 hours and next day fluorescence was recorded in different wavelength *viz.*, 0, 150, 300, 500, 800, 1200 nm. Similarly, the above instrument recorded photosynthesis, stomatal conductance, Phi PS II, Phi CO_2, including dark respiration.

3.11.4. Estimation of Avoidable Yield Loss

Observations pertaining to number of plants germinated were recorded four weeks after planting and yield (kg) after harvest.

3.11.5. Integrated Management

3.11.5.1. Pot Culture Trial:

Observations on different growth parameters *viz*., plant height (cm), number of tillers, dry weight of shoot (g) and yield along with chlorophyll (μg/g fw) were recorded following standard protocols and instrumentation.

3.11.5.2. Field Trial:

Data were recorded on different growth parameters *viz.*, number of tillers, plant height (cm), dry weight of shoot (g), yield (kg), % wilted plants, % of germination at 30 DAS, root knot index (1-5 scale), soil population (250 g soil) and root population (5 g root). Further, shoot dry weights were recorded after harvesting followed by sun drying for 1 week and hot air oven drying for 48 hours at 80^0C.

Soil population was estimated after extraction of nematode from soil by Cobb's sedimentation and decantation technique.

For estimation of root population, 0.5 g of root samples were stained in sodium hypochlorite – acid fuchsin followed by pressing between two slides to observe the different developmental stages under binocular stereoscope.

3.12. ANALYSIS OF DATA

Prior to analysis, data were properly arranged, tabulated and transformed to different scales as may be applicable to the nature of data. Analysis pertaining to pathogenicity, yield loss and integrated management of *M. incognita* and *R. solanacearum* infecting ginger were carried out by following CRD pooled analysis, paired 't' test and randomized block design (RBD) pooled analysis through standard statistical procedures (Snedecor and Cochran, 1968). Further, the significance of the means of treatments was tested by calculation of SEM, CD or Duncan's Multiple Range Test (DMRT) as per the suitability of the appropriate experimental designs along with the number of treatments.

RESULTS

4.1. IDENTIFICATION AND CHARACTERIZATION OF *M. INCOGNITA*

Permanent slides of root knot nematode larvae were prepared from the population of single egg mass culture grown monoxenically in the pots. Few perineal patterns of adult females were cut to examine the cuticular patterns for identification.

4.1.1. Second Stage Larvae:

Results of the present investigation on second stage juveniles revealed a head cap which were anteriorly flattened and rounded posteriorly. Stylet knobs were posteriorly rounded and clearly set off from shaft or extension. The conus and shaft gradually widened towards the base. Dorsal esophageal gland orifice was located 3 µm from the base of stylet. Hemizonid was anterior to the excretory pore. Length of larvae (L) ranged between 320 and 430 µm. Tail length varied between 40-60 µm, tail notched with rounded tail tip. Hyaline portion of tail tip measured 8-15 µm.

4.1.2. Perineal Pattern of Adult Female:

The posterior cuticular pattern (Fig 8a, 8b) appeared somewhat squarish with a high dorsal arch flattened at the tip. The ventral arch appeared low. Both the dorsal or ventral arch was composed of closely spaced wavy striae. Interior portion of the arch above the anus was marked by numerous zig zag and broken striae forming a whorl. Lateral lines were absent, but along the lateral lines, dorsal and ventral striae forked. Few short transverse striae extended from inner side towards the vulva.

4.2. CHARACTERIZATION OF *R. SOLANACEARUM*

The three isolates of ginger from RRTS Pottangi, Phulbani and Bhubaneswar exhibiting quick wilt symptom were isolated, sub cultured, subjected to various biochemical, antibiotic and pathogenicity tests followed by matching and comparing with Bergys manual of determining bacteria and two soft ware's *viz.*, PIB win (Bryant, 2004) and ABIS online software for determining the bacteria.

4.3. COLONY CHARACTERIZATION

The isolates were cultured on nutrient agar media. There was no variation in the appearance, fluidity and colour of the colonies of the three isolates of ginger. All the three isolates from the infected ginger rhizomes produced fluidal and irregular colonies (Fig 9) with pink or light red centers on *Pseudomonas* specialized media at 30^{o}C after 24-48 hours of incubation. The above characteristic fluidal colonies by different isolates were suggestive for its identity as *R. solanacearum*. For further confirmation, various tests like grams reaction, biochemical, antibiotic and pathogenicity tests were conducted.

4.4. GRAM STAINING:

Bacterial smear after air drying and staining with crystal violet for 30 seconds stained bluish purple colour. However, after washing in water followed by iodine staining (0.5%), a complex with crystal violet was formed which upon treatment with alcohol destained the bacterial colonies. Counter staining with safranin resulted in pink colour by all the isolates having rod shaped bacterium occurring in chains or in clusters (Fig 10) indicating gram negative reaction (Table 4)

4.5. BIOCHEMICAL CHARACTERIZATION OF *R. SOLANACEARUM*

In a Hi Assorted Biochemical Identification Test Kit, all the three isolates were compared along with a control. The kit was tested for reaction of the isolates to maltose (MA), lactose (LA), adonitol (AD), arabinose (AR), glucose (G), H_2S, nitrate reductase (NR), phenylalanine deamination (PA), urease (UR), ornithine (OR), lysine (LY), citrate (CT). The tests resulted in a positive reaction of the isolates to lysine, ornithine, urease, H_2S, maltose, arabinose and glucose. The responses of the isolates to lactose, adonitol, nitrate reductase, phenylalanine deamination and citrate were negative (Fig 11). (Table 5)

All the three isolates exhibited a positive reaction to methyl red, voges and proskeur (Fig 12). The test for amino acid decarboxylation resulted in a positive reaction to lysine, ornithine and arginine. The colour changed from mustard yellow to light or dark purple (Fig 13).

When the isolates were tested for citrate utilization, the reaction of the isolates to triple sugar iron was positive with black colour, ciman citrate positive with blue colour and manitol positive with yellow colour having diffusion motile. (Fig 14)

Table 4: Biochemical identification of bacterial isolates of ginger

PARAMETERS	ISOLATE 1	ISOLATE 2	ISOLATE 3
Gram Staining	-	-	-
Citrate	-	-	-
Lysine	+	+	+
Ornithine	+	+	+
Urease	+	+	+
Phenyl Alanine Deamination	-	-	-
Nitrate Reductase	-	-	-
H_2S	+	+	+
Indole	+	+	+
Motility	+	+	+
Methyl Red	+	+	+
Voges and Proskeur	+	+	+
Triple Sugar Iron (TSI)	Yellow, Black	Yellow, Black	Yellow, Black
Ciman Citrate	Blue +	Blue +	Blue +
Manitol	Yellow + Diffusion (Motile)	Yellow + Diffusion (Motile)	Yellow + Diffusion (Motile)

4.6. SUGAR UTILIZATION TEST

Sugar utilization test of three isolates using sugar disc resulted in a positive reaction to arabinose, maltose, glucose, dextrose, sorbitol, dulcitol, mannose, trehalose, inositol, rhamnose and mellibiose. On the contrary, the isolates tested negative to insulin, raffinose, sucrose, adonitol and lactose (Fig 15) (Table 5).

Table 5: Sugar utilization test by bacterial isolates of ginger

SUGARS	ISOLATE 1	ISOLATE 2	ISOLATE 3
Dextrose	+	+	+
Sorbitol	+	+	+
Dulcitol	+	+	+
Mannose	+	+	+
Arabinose	+	+	+
Insulin	-	-	-
Maltose	+	+	+
Raffinose	-	-	-
Trehalose	+	+	+
Inositol	+	+	+
Rhamnose	+	+	+
Mellibiose	+	+	+
Sucrose	-	-	-
Glucose	+	+	+
Adonitol	-	-	-
Lactose	-	-	-

4.7. ANTIBIOTIC SENSITIVITY TEST

The three isolates reacted to various antibiotics differently. All the three isolates indicated resistant reaction to erythromycin, gentamycin, amikacin, streptomycin and ampicillin/ sulbactam with no zone of inhibition in the petriplates containing antibiotic discs (Fig 16).However, these isolates were sensitive to antibiotics like cefatoxime, cefatrioxone/ tazobactam, co-trimanazole, ciprofloxacin and ofloxacin indicating different inhibition zone among and within the antibiotics (Table 6). The isolates were sensitive to antibiotics in the order of ciprofloxacin > ofloxacin > co-trimanazole > cefatrioxone > cefatoxime. The clearance zone observed around the antibiotic disc indicated the sensitivity of organism towards the specific drop. The growth around the disc indicated the resistance pattern.

Table 6: Sensitivity of antibiotics to bacterial isolates of ginger

Antibiotics	Isolate 1	Isolate 2	Isolate 3
Erythromycin (E)	NZ (Resistance)	NZ (Resistance)	NZ (Resistance)
Gentamycin (GEN^{30})	NZ (Resistance)	NZ (Resistance)	NZ (Resistance)
Amikacin (AK^{30})	NZ (Resistance)	NZ (Resistance)	NZ (Resistance)
Streptomycin (S^{25})	NZ (Resistance)	NZ (Resistance)	NZ (Resistance)
Ampicillin/Sulbactam ($A/S^{10/10}$)	NZ (Resistance)	NZ (Resistance)	NZ (Resistance)
Cefatoxime (CTX^{30})	18 mm	16 mm	16 mm
Cefatrioxone/Tazobactam ($CIT^{30/10}$)	18 mm	20 mm	18 mm
Co-Trimanazole (COT^{25})	26 mm	24 mm	24 mm
Ciprofloxacin (CIP^{30})	32 mm	30 mm	32 mm
Ofloxacin (OF^{2})	32 mm	30 mm	30 mm

NZ – No Zone of Inhibition

4.8. INTERACTION STUDY

The interaction trial was conducted in 12" diameter earthen pots containing 9 kg steam sterilized soil with ginger plants and inoculated with *M. incognita* @ 1000 J_2/kg soil alone, *R. solanacearum* @ 4×10^6 cfu/ml/kg soil alone, concomitant as well as sequential inoculation of both the pathogen 10 days after the initial pathogen along with a check. The experiment was conducted consecutively for two seasons. Data pertaining to various growth, physiological, biochemical and nematode parameters were recorded from time to time suitably transformed and analyzed using appropriate experimental design.

4.8.1. EFFECT OF INDIVIDUAL AND COMBINED INOCULATION OF *M. INCOGNITA* AND *R. SOLANACEARUM* ON THE INCIDENCE OF QUICK WILT, PLANT GROWTH AND YIELD

Results of individual, concomitant and sequential inoculation of *M. incognita* and *R. solanacearum* infecting ginger is presented in Table 7**.** Depending on the type of inoculums of pathogens *i.e.* individual, concomitant and sequential, data pertaining to various parameters exhibited different degrees of trend.

4.8.1.1. Incidence of Wilting:

During the course of experimentation, mostly plants inoculated with *M. incognita* (N) exhibited reduction in growth and vigour (Fig 17) followed by chlorosis of leaves and transient wilting during hottest part of the day which recovered during cool hours in contrast to healthy plants exhibiting green foliage without chlorosis and wilting (Fig 18). *M. incognita* infected plants exhibited numerous beaded galls on roots which were often encircled and thickened (Fig 19**)**. The number of tillers of such infected plants was less as compared to check. In the plants inoculated with *R. solanacearum* (B) deep water soaked spots initially appeared at the collar region which progressed both upward and downward. Mild drooping and curling of the margins of lower leaves were the typical and conspicuous symptoms of bacterial invasion. Such plants also exhibited symptoms of irregular black necrotic lesions on the leaf margins with the symptoms of wilting (Fig 20). The symptoms of wilting in *R. solanacearum* inoculated plants appeared 29th day and 25th day after inoculation during first season (S I) and second season (S II) respectively. On simultaneous (N+B) inoculation of *M. incognita* and *R. solanacearum,* wilting commenced 22nd days after inoculation in both the seasons. Prior inoculation of *M. incognita* 10 days to *R. solanacearum* (N→B), resulted in quick wilting symptoms (Fig 21) by 17th day after inoculation of *R. solanacearum* during both the seasons. Similarly, prior inoculation of *R. solanacearum* 10 days to *M. incognita* (B→N) induced wilting in plants 33 days in Season I and 30 days after inoculation of *M. incognita* in season II.

Pooled mean of incidence of wilting in different treatments over the seasons indicated a similar trend to that of first season (S I) and second season (S II). *R. solanacearum* (B) inoculated plants exhibited wilting on 27th days after inoculation. Simultaneous (N+B) inoculated plants exhibited wilting on

22nd days, prior inoculation of *M. incognita* to *R. solanacearum* (N→B) by 17th day and prior inoculation of *R. solanacearum* to *M. incognita* (B→N) on 32nd day.

4.8.1.2. Number of Tillers:

Data on number of tillers/plant exhibited a declining trend in different treatments as compared to check. The highest number of tillers, 17.25 and 18.00 were recorded in check during season I and season II respectively. Lowest number of tillers (10.25) with 40.58 per cent decrease in season I and 10.00 with 44.44 per cent decrease in season II were recorded in treatment inoculated with prior inoculation of *M. incognita* to *R. solanacearum* by 10 days (N→B). Statistical analysis of data indicated significant difference in the number of tillers among various treatments in season I as well as in season II. Significant reduction in the number of tillers over check was recorded in *M. incognita* + *R. solanacearum* (N+B), *M. incognita* prior inoculated to *R. solanacearum* (N→B) by 10 days and *R. solanacearum* prior inoculated to *M. incognita* (B→N) by 10 days with 20.29, 40.58 and 24.63 per cent reduction over check respectively in season I. However, significant reduction in number of tillers/plant over check was observed in *M. incognita* (N), *R. solanacearum* (B), *M. incognita* + *R. solanacearum* (N+B), *M. incognita* prior inoculated to *R. solanacearum* (N→B) by 10 days and *R. solanacearum* prior inoculated to

M. incognita (B→N) with 22.22, 33.33, 38.88, 44.44 and 22.22 per cent decrease.

Pooled analysis of data exhibited significant decrease in number of tillers/plant (Fig 22) over check among season (S), treatments (T) as well as interaction of seasons with treatments (S × T). All the treatments indicated a significant decline over check with the highest (42.29 per cent) in *M .incognita* followed by *R. solanacearum* (N→B) by 10 days which was significantly different from rest others followed by simultaneous inoculation (N+B) of both the pathogens with 36.23 per cent decline. The reduction in number of tillers/plant irrespective of the treatments was significantly higher in season II. Similarly, simultaneous inoculation of *M. incognita + R. solanacearum* (N+B) and *M. incognita* prior inoculated to *R. solanacearum* (N→B) exhibited significantly lower number of tillers which were at par with each other during season I and season II.

4.8.1.3. Plant Height:

Height of the plants exhibited a declining trend over check in different treatments, during both the seasons. Reduction of plant height was found to be statistically significant for each season. The plant height was more in check (114.75 and 115.00 cm) for season I and II respectively. *M. incognita* inoculated plants (N) recorded 111 cm with 3.27 per cent decrease in season I and 109.00 cm with 5.22 per cent decrease in season II. Treatment with *R. solanacearum* alone (B) recorded 111.50 cm for both season with a decrease of 2.83 and 3.04 per cent in season I and II respectively. In simultaneous inoculation of both (N+B), there was a corresponding significant decrease in plant height which recorded 101.50 and 106.00 cm with 11.55 and 7.82 per cent decrease over check in season I and II. Prior inoculation of *M. incognita* followed by *R. solanacearum* after 10 days (N→B) also caused significant reduction in plant height recording 101.75 and 102.00 cm with 11.33 and 11.30 per cent decrease respectively in season I and II. Prior inoculation of *R. solanacearum* followed by *M. incognita* after 10 days (B→N) recorded 107.00 and 103.00 cm in season I and II with corresponding decrease of 9.40 and 7.62 per cent.

Pooled analysis of data over both the seasons resulted in significant differences in plant height in various treatments (Fig 23, 24). Treatments with *M. incognita* alone (N) recorded mean plant height of 110.00 cm with 4.25 per cent decrease which was significantly less than check (114.88 cm). *R. solanacearum* (B) inoculated plants recorded 111.50 cm with 2.93 per cent decrease but was at par with the check. Plant height recorded in simultaneous inoculation of both the pathogens (N+B) recorded 9.68 per cent decrease over check. The plant height in treatment in which *M. incognita* was inoculated 10 days prior to *R. solanacearum* (N→B) was lowest (101.88 cm) with 11.32 per cent decrease over check. *R. solanacearum* preceding the inoculation of *M. incognita* (B→N) by 10 days also recorded significantly less plant height (105.00 cm) with 9.40 per cent decrease over check.

4.8.1.4. Dry Weight of Shoot:

Different treatments of *M. incognita* or *R. solanacearum* alone and their combinations indicated a reduction in dry weight of shoot over check. The reduction in dry weight of shoot was found to be statistically significant during season I and II. The highest shoot dry weight of 65.33 g for season I and 71.25 g for season II were recorded in check. Treatments inoculated with *M. incognita* alone (N) recorded 62.33 g and 68.50 g of dry weight of shoot with 64.60 and 70.50 per cent decrease over check respectively for season I and II. However, the dry shoot weight recorded in *M. incognita* inoculated plants alone was at par with check in both the seasons. *R. solanacearum* (B) inoculated plants recorded 64.60 g with 1.12 per cent decline for season I and 70.50 g with 1.05 decline for season II which were at par with check. In simultaneous inoculation of both the pathogens (N+B) there was a further decrease in dry weight of shoot which recorded as 51.98 g with 20.43 per cent decrease and 58.00 g with 18.59 per cent decrease in season I and II respectively. This treatment was significantly different from rest other treatments. Similarly, prior inoculation of *M. incognita* followed by bacteria (N→B) after 10 days also caused significant reduction in shoot dry weight which recorded 46.25 g with 29.21 per cent decrease and 52.25 g with 26.67 per cent decrease respectively over check in season I and II. Further, prior inoculation of *R. solanacearum* followed by *M. incognita* (B→N) after 10 days recorded 60.35 g and 66.25 g with 7.62 per cent and 7.02 per cent decline over check. This treatment was significantly different from all other treatments.

Pooled mean dry weight of shoot in all the treatments showed a declining trend over check (Fig 25). Statistical analysis of data indicated significant difference in treatments over both the seasons. Highest dry weight of shoot (68.29 g) was recorded in check and the lowest (49.25 g) in the treatment prior inoculated with *M. incognita* by 10 days to *R. solanacearum* (N→B) with 27.88 per cent decline over check followed by simultaneous inoculation (N+B) of both the pathogens (54.99 g) with 19.47 per cent decline. The dry weight of shoot (67.55 g) recorded in *R. solanacearum* (B) alone inoculated plants was at par with the check. However, *R. solanacearum* prior inoculated to *M. incognita* (B→N) also resulted significant decline over check. Similarly, individual inoculation of *M. incognita* (N) recorded significant decline (4.20 per cent) over check. Further, the seasonal difference in shoot weight over the various treatments was found to be statistically significant. The mean dry weight of shoot irrespective of treatments recorded in season I was significantly less than season II.

4.8.1.5. Rhizome Yield:

Data on rhizome yield/pot in different treatments indicated a declining trend over check. Rhizome yield recorded for different treatments exhibited significant differences among themselves in both the seasons. The highest rhizome yield of 0.44 and 0.55 kg/pot were recorded in season I and II respectively. When *M. incognita* (N) was inoculated alone, 0.29 kg and 0.31 kg rhizome yield were recorded with 34.10 per cent and 43.64 per cent decrease over check in season I and season II respectively which was significantly different from respective checks. Inoculation with *R. solanacearum* (B) alone resulted significant decline in rhizome yield over check for both seasons. *R. solanacearum* inoculated plants recorded yield of 0.31 kg with 29.55 per cent yield decline in season I and 0.28 kg with 49.10 per cent yield decline in season II. However, the rhizome yield recorded in the above treatment was at par with *M. incognita* (N) inoculated plants as well as plants inoculated with simultaneous inoculation (N+B) in season I and *M. incognita* (N) alone inoculated plants in season II. In simultaneous inoculation (N+B), the rhizome yield (0.23 kg for season I and 0.21 kg for season II) recorded a significant decrease over check. The decrease in rhizome yield in this treatment was 47.73 and 61.82 per cent respectively for season I and II. However, this treatment was at par with *M. incognita* prior inoculated to *R. solanacearum* (N→B) as well as *R. solanacearum* prior inoculated to *M. incognita* (B→N) in season I and *M. incognita* prior inoculated to *R. solanacearum* (N→B) in season II. Prior inoculation of *M. incognita* 10 days to *R. solanacearum* (N→B) recorded 0.19 kg and 0.18 kg of rhizome yield with 56.82 per cent and 67.27 per cent decrease over check in season I and II respectively. This treatment was at par with *R. solanacearum* followed by *M. incognita* by 10 days (B→N), *R. solanacearum* alone (B) and *M. incognita* alone (N) in season I and with simultaneous inoculation (N+B). Prior inoculation of *R. solanacearum* followed by *M. incognita* (B→N) recorded 0.26 kg and 0.28 kg rhizome yield with 40.90 per cent and 49.10 per cent decrease over check.

Table 7: Individual and combined inoculation of *M. incognita* and *R. solanacearum* on the incidence of quick wilt, plant growth and yield.

Treatments	Incidence of Wilting [DAP]			No. of Tillers			Plant Height (cm)		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
Check	0.0	0.0	0.0	17.25	18.00	17.25	114.75	115.00	114.88
N	0.0	0.0	0.0	16.75 (2.90)	14.00 (22.22)	14.00 (18.84)	111.00 (3.27)	109.00 (5.22)	110.00 (4.25)
B	29.0	25.0	27.0	16.00 (7.25)	12.00 (33.33)	12.00 (30.44)	111.50 (2.83)	111.50 (3.04)	111.50 (2.93)
N+B	22.0	22.0	22.0	13.75 (20.29)	11.00 (38.88)	11.00 (36.23)	101.50 (11.55)	106.00 (7.82)	103.75 (9.68)
N→B	17.0	17.0	17.0	10.25 (40.58)	10.00 (44.44)	10.00 (42.29)	101.75 (11.33)	102.00 (11.30)	101.88 (11.32)
B→N	33.0	30.0	31.5	13.00 (24.63)	14.00 (22.22)	14.00 (18.85)	107.00 (6.75)	103.00 (10.43)	105.00 (9.40)
CD(0.05) S	-	-	-	-	-	0.75	-	-	NS
T	-	-	-	1.75	2.04	1.3	3	4.58	4.85
S*T	-	-	-	-	-	1.84	-	-	NS

**** DAP – Days after planting***
***** Figures in the parentheses indicate per cent decrease over check.***

Table 7: (contd.) Individual and combined inoculation of *M. incognita* and *R. solanacearum* on the incidence of quick wilt, plant growth and yield.

Treatments	Dry weight of shoot (g)			Rhizome Yield (kg)			Root Knot Index (1-5 scale)		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
Check	65.33	71.25	68.29	0.44	0.55	0.495	1	1	1
N	62.33 (4.60)	68.50 (3.86)	65.42 (4.20)	0.29 (34.10)	0.31 (43.64)	0.300 (39.39)	5	5	5
B	64.60 (1.12)	70.50 (1.05)	67.55 (1.09)	0.31 (29.55)	0.28 (49.10)	0.295 (40.40)	-	-	-
N+B	51.98 (20.43)	58.00 (18.59)	54.99 (19.47)	0.23 (91.30)	0.21 (61.82)	0.220 (55.55)	3	3.5	3.25
N→B	46.25 (29.21)	52.25 (26.67)	49.25 (27.88)	0.19 (56.82)	0.18 (67.27)	0.185 (62.63)	4	4	4
B→N	60.35 (7.62)	66.25 (7.02)	63.30 (7.31)	0.26 (40.90)	0.28 (49.10)	0.270 (45.45)	3	3	3
CD(0.05) S	-	-	1.17	-	-	NS	-	-	NS
T	3.09	2.89	2.03	0.13	0.03	0.02	0.8	0.75	0.77
S*T	-	-	NS	-	-	0.03	-	-	NS

**** DAP – Days after planting***

***** Figures in the parentheses indicate per cent decrease over check.***

Pooled analysis of data exhibited significant differences in the rhizome yield of various treatments (Fig 26). *M. incognita* (N) inoculated plants recorded 0.30 kg of rhizome yield with 39.39 per cent decrease over check. *R. solanacearum* (B) inoculated plants recorded 0.29 kg and 40.40 per cent significant decrease over check but at par with *M. incognita* (N) inoculated plants. *M. incognita* and *R. solanacearum* (N+B), *M. incognita* followed by *R. solanacearum* (N→B) and *R. solanacearum* followed by *M. incognita* (B→N) recorded 0.22, 0.19 and 0.27 kg of rhizome yield with 55.55, 62.63 and 45.45 per cent decrease over check. These treatments were significantly different from each other and rest other treatments including check.

4.8.1.6. Root Knot Index:

The data on root knot indices recorded in various treatments exhibited significant differences in season I and II. The root knot indices in treatment with *M. incognita* alone were 5 for season I and II. When *M. incognita* and *R. solanacearum* were inoculated concomitantly (N+B) there was also further decline in root knot indices over the individual inoculation of *M. incognita*. The root knot indices in the above treatments were 3.0 and 3.5 respectively for season I and season II. Again the root knot indices in *M. incognita* preceding the inoculation of *R. solanacearum* (N→B) were 4.0 for both the seasons which were significantly different from the individual effect of *M. incognita* alone, as well as the concomitant effect of either pathogen. However, root knot index recorded in the concomitant (N+B) inoculation of both the pathogen in season

II was at par with prior inoculation of *M. incognita* by 10 days to *R. solanacearum* (N→B). Root knot indices recorded in treatment with *R. solanacearum* prior inoculated to *M. incognita* (B→N) was lowest (3.0) in both the seasons. The root knot indices recorded for this treatment were significantly different from concomitant as well as sequential inoculation in which *M. incognita* was pre inoculated to *R. solanacearum* (N→B).

Pooled analysis of data also indicated significant differences in root knot indices (Fig 27). The lowest root knot index (3.0) was recorded in treatment where *R. solanacearum* was pre inoculated to *M. incognita* (B→N). This treatment was significantly less than *M. incognita* + *R. solanacearum* (N+B) as well as *M. incognita* followed by *R. solanacearum* (N→B). However, the root knot index (3.25) recorded for *M. incognita* followed by *R. solanacearum* (N→B) was at par with simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B). The later treatment recorded significantly lower root knot index as compared with *M. incognita* (N) alone.

4.8.2. PHYSIOLOGICAL CHANGES

Since a cascade of physiological and biochemical changes as a result of host parasitic interaction manifest in the expression of different symptoms, the changes in the above parameters induced by *M. incognita* and *R. solanacearum* in ginger were recorded (Table 8).

4.8.2.1. Leaf Water Potential:

Data on leaf water potential (Ψ) indicated significant differences in the various treatments viz., *M. incognita* alone (N), *R. solanacearum* (B) alone and their combination in season I and season II. In check plants leaf water potential was -1.79 Ψ and -2.34 Ψ during season I and season II respectively. Treatment with *M. incognita* alone (N) recorded -1.64 Ψ and -2.70 Ψ with 8.38 per cent increase and 15.38 per cent decrease over check. *R. solanacearum* (B) inoculated (B) plants recorded -1.64 Ψ with 5.58 per cent increase in season I and -2.59 Ψ with 10.69 decrease over check in season II which was significantly different from check and at par with *M. incognita* inoculation alone during both the seasons. In simultaneous inoculation of both the pathogens (N+B), there was a corresponding significant decrease of 7.26 and 20.08 per cent which recorded -1.92 Ψ and -2.81 Ψ during season I and season II respectively. This treatment was significantly different from rest other treatments during both the seasons except *M. incognita* preceding the inoculation of *R. solanacearum* (N→B) in season II. Similarly prior inoculation of *M. incognita* followed by *R. solanacearum* (N→B) caused significant reduction of 15.64 and 20.51 per cent with -2.07 Ψ and -2.82 Ψ respectively for season I and season II. This treatment recorded highest reduction in leaf water potential over check which was significantly different from rest other treatments during both the seasons. Prior inoculation of *R. solanacearum* followed by *M. incognita* (B→N) recorded -2.10 Ψ and -2.68 Ψ with a corresponding significant decline of 17.31 and 14.52 per cent in season I and II.

Pooled analysis of data over the seasons indicated significant differences among treatments (Fig 28), seasons of investigation and the interaction of treatments with the seasons. Individually *M. incognita* (N) and *R. solanacearum* (B) inoculated plants exhibited significant decrease in leaf water potential over check. *M. incognita* inoculated plants recorded -2.17 Ψ with 5.08 per cent decline and *R. solanacearum* inoculated plants recorded -2.14 Ψ with 3.63 per cent decline over check. However, these two treatments although significantly different from rest other treatments, were at par with each other. The combined inoculation of both the pathogens either simultaneously or sequentially also resulted in further significant decline of leaf water potential. Among these the lowest leaf water potential of -2.45 Ψ with 18.4 per cent decline was recorded in *M. incognita* followed by *R. solanacearum* (N→B) inoculated plant. However, this treatment was at par with the simultaneous inoculation treatment of *M. incognita* and *R. solanacearum* (N+B) with -2.37 Ψ and 14.53 per cent decline including *R. solanacearum* followed by *M. incognita* (B→N) with -2.39 Ψ and 15.74 decline over check. The leaf water potential of season II irrespective of the treatments was significantly lower than season I. The interaction of treatments with season was found to be significant except treatment inoculated with *M. incognita* alone during first season.

4.8.2.2. Relative Water Content (RWC):

Relative water content exhibited significant differences among the treatments in season I and season II. In *M. incognita* (N) inoculated plants, relative water content was 97.23 per cent with a decline of 0.08 per cent and 90.20 per cent with an increase of 3.40 per cent in season I and II respectively. However, this treatment was at par with checks of corresponding seasons. *R. solanacearum* (B) inoculated plants in season I recorded 96.15 per cent relative water content with a decrease of 1.18 per cent and 82.27 with a decline of 5.69 per cent in season II over check which was significant. Simultaneous (N+B) inoculation also recorded 95.83 per cent relative water content with 1.52 per cent decrease over check in season I. This treatment was at par with check in season II. *M. incognita* followed by *R. solanacearum* (N→B) recorded 95.50 per cent relative water content with 1.85 per cent decrease over check in season I. This treatment was also at par with *R. solanacearum* followed by *M. incognita* (B→N) which in turn recorded 95.93 per cent RWC with 1.42 per cent decline over check. In season II relative water content in *M. incognita* followed by *R. solanacearum* (N→B) and *R. solanacearum* followed by *M. incognita* (B→N) were at par. However, *M. incognita* followed by *R. solanacearum* recorded 88.80 per cent RWC with 1.79 per cent increase over check in season II.

Table 8: Physiological and biochemical changes in ginger as influenced by individual, concomitant and sequential inoculation of *M. incognita* and *R. solanacearum*.

Treatments	LWP (ψ)			RWC %			RWD %		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
Check	-1.79	-2.34	-2.07	97.30	87.23	92.27	2.69	12.77	7.73
N	-1.64 (8.38)	-2.70 (-15.38)	-2.17 (-5.08)	97.23 (-0.08)	90.20 (3.40)	93.71 (1.57)	2.78 (2.85)	9.80 (-23.25)	6.29 (-18.63)
B	-1.69 (5.58)	-2.59 (-10.68)	-2.14 (-3.63)	96.15 (-1.18)	82.27 (-5.69)	89.21 (-3.31)	3.85 (42.70)	10.74 (-15.92)	7.29 (-5.69)
N+B	-1.92 (-7.26)	-2.81 (-20.08)	-2.37 (-14.53)	95.83 (-1.52)	86.80 (-0.49)	91.31 (-1.03)	4.18 (54.74)	13.20 (3.38)	8.68 (12.28)
N→B	-2.07 (-15.64)	-2.82 (-20.51)	-2.45 (-18.4)	95.50 (-1.85)	88.80 (1.79)	92.15 (-0.13)	4.50 (66.79)	11.20 (-12.3)	7.85 (1.55)
B→N	-2.10 (-17.31)	-2.68 (-14.52)	-2.39 (-15.74)	95.93 (-1.42)	87.13 (-0.11)	91.53 (-0.80)	4.08 (51.04)	12.87 (0.78)	8.47 (9.57)
CD(0.05) S	–	–	0.04	–	–	–	–	–	–
T	0.08	0.11	0.07	0.461	1.853	–	–	–	–
S*T	–	–	0.09	–	–	0.921	–	–	0.921

Figure in the parentheses indicated per cent increase or decrease (-) over check.

Pooled analysis of data indicated significant differences only the interaction between treatments with the seasons. The treatment (Fig 29) and season effects were found to be not significant.

4.8.2.3. Relative Water Deficit (RWD):

Relative water deficit exhibited an increasing trend over check in all the treatments in season I. In season II relative water deficit increased over check in simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) as well as in *M. incognita* followed by *R. solanacearum* (N→B) inoculated plants. The relative water deficit varied between 2.69 to 4.50 and 9.80 to 12.87 per cent for season I and season II respectively. However relative water deficit recorded for both the seasons in different treatments was not significant.

Pooled analysis of data (Fig 30) also indicated relative water deficit to be not significant for different treatments over seasons as well as for seasons over treatments. The interaction of treatments with seasons was found to be statistically significant. Relative water deficit was more pronounced in *R. solanacearum* alone (B), *M. incognita* and *R. solanacearum* (N+B), *M. incognita* followed by *R. solanacearum* (N→B) and *R. solanacearum* followed by *M. incognita* (B→N) with 3.85, 4.18, 4.50 and 4.08 respectively in season I. However, in season II *M. incognita* and *R. solanacearum* (N+B) recorded significantly higher relative water deficit of 13.20 per cent over check.

4.8.2.4. Chlorophyll a:

Chlorophyll a exhibited a declining trend over check in different treatments during season I and season II. The decrease in chlorophyll a was progressive over check in the order of *M. incognita* (N), *R. solanacearum* (B), *R. solanacearum* followed by *M. incognita* (B→N), *M. incognita* and *R. solanacearum* (N+B) and *M. incognita* followed by *R. solanacearum* (N→B). Statistical analysis of data revealed significant differences among the various treatments during season I and season II. In season I, individual inoculation of *M. incognita* (N) resulted in significant decline over check with 1.498 μg/g fw with 2.60 per cent decline followed by *R. solanacearum* having 1.497 μg/g fw with 2.67 per cent decline which were at par with each other. Simultaneous inoculation of both *M. incognita* and *R. solanacearum* (N + B) resulted in 1.282 μg/g fw with 16.64 per cent decline which was at par with *R. solanacearum* followed by *M. incognita* (B→N) with 1.475 μg/g fw and 4.09 per cent decline over check. Sequential inoculation of *M. incognita* followed by *R. solanacearum* (N→B) recorded lowest chlorophyll a of 1.225 μg/g fw with 20.35 per cent decline over check which was significantly different from rest other treatments. In season II although the treatments were significantly different from themselves, sequential inoculation of *M. incognita* followed by *R. solanacearum* (N→B) only recorded significantly lower chlorophyll a (0.868 μg/g fw) with 28.91 per cent decline over check. The rest other treatments were at par with check.

Pooled analysis of data over the seasons resulted in not significant differences among the treatments (Fig 31) and interaction of treatment with seasons of investigation. However, significantly less chlorophyll a irrespective of treatments were recorded in season I.

4.8.2.5. Chlorophyll b:

Chlorophyll b as recorded in season I and II revealed significant differences among the treatments. In season I all the treatments recorded reduced chlorophyll b over check except *R. solanacearum* (B) alone where the chlorophyll b (0.593 μg/g fw) was more. However, it was at par with check. Significant reduction of chlorophyll b over check was recorded in simultaneous (N+B) inoculation, *M. incognita* followed by *R. solanacearum* (N→B) as well as in *R. solanacearum* followed by *M. incognita* (B→N) with 0.517, 0.432 and 0.504 μg/g fw respectively. The lowest chlorophyll b (0.432 μg/g fw) with highest decline (24.74 per cent) over check was recorded in *M. incognita* preceding to *R. solanacearum* (N→B) by 10 days which was also significantly different from all other treatments. In season II reduction in chlorophyll b over check was recorded in simultaneous inoculation of *M. incognita* and *R. solanacearum* (N + B), *M. incognita* followed by *R. solanacearum* (N→B) and *R. solanacearum* followed by *M. incognita* (B→N) with 3.76, 15.83 and 15.07 per cent decline.

Table 8: (contd.) Physiological and biochemical changes in ginger as influenced by individual, concomitant and sequential inoculation of *M. incognita* and *R. solanacearum*.

Treatments	Chlorophyll a (µg/g fw)			Chlorophyll b (µg/g fw)			Total Chlorophyll (µg/g fw)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
Check	1.538	1.221	1.38	0.574	0.398	0.486	2.112	1.62	1.866
N	1.498 (-2.60)	1.187 (-2.78)	1.343 (-2.89)	0.548 (-4.53)	0.399 (0.25)	0.474 (-2.46)	2.046 (-3.13)	1.585 (-2.16)	1.816 (-2.73)
B	1.497 (-2.67)	1.163 (-4.75)	1.330 (-3.62)	0.593 (3.31)	0.406 (2.01)	0.499 (2.88)	2.09 (-1.04)	1.569 (-3.15)	1.829 (-1.93)
N+B	1.282 (-16.64)	1.04 (14.82)	1.161 (-15.87)	0.517 (-9.93)	0.383 (-3.76)	0.450 (-7.41)	1.799 (-14.82)	1.423 (-12.16)	1.611 (-13.66)
N→B	1.225 (-20.35)	0.868 (-28.91)	1.046 (-23.91)	0.432 (-24.74)	0.335 (-15.83)	0.384 (-21.19)	1.657 (-21.54)	1.204 (-25.67)	1.431 (-0.23)
B→N	1.475 (-4.09)	1.132 (-7.29)	1.304 (-5.79)	0.504 (-12.19)	0.338 (-15.07)	0.421 (-13.37)	1.979 (-6.30)	1.47 (-9.26)	1.725 (-7.55)
CD (0.05) S	–	–	0.117	–	–	0.035	–	–	0.127
T	0.118	0.227	NS	0.037	0.056	–	0.132	0.243	–
S*T	–	–	–	–	–	–	–	–	–

Figure in the parentheses indicated per cent increase or decrease (-) over check.

The decrease in chlorophyll b was significantly different from check in *M. incognita* followed by *R. solanacearum* (N→B) and *R. solanacearum* followed by *M. incognita* (B→N). However, these two treatments were at par with each other. Treatment with *M. incognita* alone (N) and *R. solanacearum* alone (B) recorded increased chlorophyll b over check. However, they were at par.

Pooled analysis of data (Fig 32) was found to be not significant among the various treatments over seasons (S) and the interaction of seasons with treatments (S × T). However, the season effect was found to be significant where less chlorophyll b was recorded in season I.

9.8.2.6. Total chlorophyll:

Total chlorophyll in season I and season II exhibited a decreasing trend over check in all the treatments and were found to be significantly different. Although there were increase in total chlorophyll content over check, treatments with *M. incognita* (N), *R. solanacearum* (B), in season I and II including *M. incognita* and *R. solanacearum* (N+B) recorded total chlorophyll at par with the respective checks. Significant reduction in chlorophyll content was recorded in treatment with *M. incognita* and *R. solanacearum* (N+B), *R. solanacearum* followed by *M. incognita* (B→N) in season I and *M. incognita* followed by *R. solanacearum* (N→B) in season I and II. The total chlorophyll content of 1.657 μg/g fw with 21.54 percent decrease and 1.204 μg/g fw with 25.76 per cent decline in *M. incognita* followed by

R. solanacearum (N→B) over check was the highest reduction for season I and season II respectively.

The effect of various treatments on total chlorophyll (Fig 33) content in pooled analysis although indicated a decreasing trend over check, they were not significant. Significant decrease in total chlorophyll content was recorded in season I.

4.8.2.7. Stomatal Conductance:

Stomatal conductance (Fig 34) recorded in different treatments were significantly different among them. The lowest stomatal conductance (0.0072 µmol H_2O m^{-2} s^{-1}) was recorded in treatment receiving the individual inoculation of *R. solanacearum* (B) with 64.71 per cent decline over check which was significantly different from all the treatments. The highest stomata conductance (0.0243 µmol H_2Om^{-2} s^{-1}) was observed in treatment having simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) with 19.12 per cent increase over check. Stomata conductance in *M. incognita* (N) inoculated plants was 0.0228 µmol H_2O m^{-2} s^{-1} with 11.76 per cent increase over check. However, the above two treatments were found to be at par. Treatments inoculated with *M. incognita* preceding *R. solanacearum* (N→B) and *R. solanacearum* preceding *M. incognita* (B→N) recorded 0.0164 and 0.0144 µmol H_2O m^{-2} s^{-1} with a corresponding decrease of 19.62 and 29.41 per cent were at par with each other but significantly different from check as well as rest other treatments.

4.8.2.8. Fv/Fm:

The fluorescence (Fig 35) of ginger leaves measured as a ratio of variable fluorescence to maximum fluorescence (Fv/Fm) indicated a decrease over check. Maximum fluorescence (0.8602) was recorded in check. The decrease in fluorescence activities was found to be statistically significant among the various treatments. Fv/Fm in individual inoculation of *M. incognita* (N) and *R. solanacearum* (B) were 0.7897 with 2.05 per cent decrease and 0.7933 with 1.6 per cent decrease over check respectively which were significantly different from each other. Simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) also resulted in significant reduction over check which recorded 0.7982 with 0.99 per cent decrease. However, Fv/Fm in *M. incognita* followed by *R. solanacearum* (N→B) inoculated plants (0.7881 with 2.25 percent decrease) was significantly less than all other plants. Fv/Fm in treatments with *R. solanacearum* followed by *M. incognita* (B→N) exhibited significantly higher ratio of 0.7992 with 0.86 per cent decrease over check.

4.8.2.9. Phi PS II:

Significant difference among the treatments was recorded in Phi PS II (Fig 36). *M. incognita* inoculated plants exhibited value of 0.1537 which was 2.05 per cent increase over check and significantly different from rest other treatments. The rest other treatments exhibited a declining trend in Phi PS II. Phi PS II in *R. solanacearum* was 0.0947 with 37.00 per cent decline over check which significantly less than all other treatments. Simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) recorded a value of 0.1372. Prior inoculation of *M. incognita* followed by *R. solanacearum* (N→B) recorded Phi PS II 0.1244 with 21.06 per cent decline and prior inoculation of *R. solanacearum* followed by *M. incognita* (B→N) exhibited 0.1018 with 32.40 per cent decline over check. All the above combined treatments were significantly different from each other as well as check.

4.8.2.10. Phi CO_2:

Significant differences in Phi CO_2 (Fig 37) were observed among treatments with individual and combined inoculation. The highest Phi CO_2 was recorded for simultaneous (N+B) inoculation of both the pathogen which recorded -0.0323 µmol m^{-2} s^{-1} with 17.39 per cent increase over check. This treatment was followed by *M. incognita* alone (N) and *M. incognita* preceding the inoculation of *R. solanacearum* (N→B) by 10 days which recorded -0.0365 µmol m^{-2} s^{-1} with 6.64 per cent and -0.0382 µmol m^{-2} s^{-1} with 2.30 per cent increase over check respectively. However, the above treatments were also significantly different from each other as well as others. Rest other treatments exhibited a declining trend over check. *R. solanacearum* (B) inoculated plants recorded -0.0419 µmol m^{-2} s^{-1} with 7.16 per cent decline over check. When *R. solanacearum* was prior inoculated to *M. incognita* (B→N) Phi CO_2 was -0.0410 µmol m^{-2} s^{-1} with 4.85 per cent decrease over check.

Table 8: (contd.) Physiological and biochemical changes in ginger as influenced by individual, concomitant and sequential inoculation of *M. incognita* and *R. solanacearum*.

Treatments	Stomatal Conductance (S 1) μ mol H_2O m^{-2} s^{-1}	Fv/Fm	Phi PS II	Phi CO_2 μmol m^{-2} s^{-1}	Pn μ mol CO_2 m^{-2} s^{-1}	Dark Respiration μ mol m^{-2} s^{-1}
Check	0.0204	0.8062	0.1506	-0.0391	3.8469	-0.356
N	0.0228 (11.76)	0.7897 (-2.05)	0.1537 (2.05)	-0.0365 (6.64)	3.6755 (-4.45)	-0.251 (29.49)
B	0.0072 (-64.71)	0.7933 (-1.60)	0.0947 (-37.12)	-0.0419 (-7.16)	0.6322 (-83.56)	-0.328 (7.86)
N+B	0.0243 (19.12)	0.7982 (-0.99)	0.1372 (-8.89)	-0.0323 (17.39)	3.8103 (-17.33)	-0.173 (51.4)
N→B	0.0164 (-19.62)	0.7881 (-2.25)	0.1244 (-21.06)	-0.0382 (2.3)	2.9095 (-32.22)	-0.107 (69.9)
B→N	0.0144 (-29.41)	0.7992 (-0.86)	0.1018 (-32.40)	-0.0410 (-4.85)	0.6108 (-84.12)	-0.275 (22.75)
CD (0.05)	**0.0041**	**0.005**	**0.0011**	**-0.002**	**2.434**	**-0.0189**

Figure in the parentheses indicated per cent increase or decrease (-) over check

4.8.2.11. Net Photosynthesis Rate (Pn):

Net photosynthesis rate (Fig 38) indicated a declining trend over check among the treatments. The decrease in photosynthesis rate over check was found to be statistically significant. Although there was a decrease in photosynthesis rate in all the treatments over check, the treatments *M. incognita* alone (N), simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) and *M. incognita* followed by *R. solanacearum* (N→B) recording 3.6755 µmol CO_2 $m^{-2}s^{-1}$ with 4.45 per cent decrease, 3.8103 µmol CO_2 $m^{-2}s^{-1}$ with 17.33 per cent decrease and 2.9095 µmol CO_2 $m^{-2}s^{-1}$ with 32.22 per cent decrease were at par with each other as well as check. Net photosynthesis rate of 0.6322 µmol CO_2 m^{-2} s^{-1} with 83.56 per cent decrease as well as 0.6108 µmol CO_2 $m^{-2}s^{-1}$ with 84.12 per cent decline over check respectively in *R. solanacearum* (B) alone and *R. solanacearum* followed by *M. incognita* (B→N) were significantly different from the check. However, the above two treatments were at par with each other.

4.8.2.12. Dark Respiration:

Dark respiration recorded for various treatments (Fig 39) exhibited significant difference among them. All the individual as well as combined inoculated treatments exhibited increased respiration over check. Inoculation with *M. incognita* alone (N) and *R. solanacearum* (B) recorded respiration rate of -0.251 µmol m^{-2} s^{-1} with 29.49 per cent increase and -0.328 µmol m^{-2} s^{-1} with 7.86 per cent decrease over check which were significantly different from check as well as among themselves. Simultaneous inoculation of *M. incognita* and *R. solanacearum* (N+B) recorded -0.173 µmol m^{-2} s^{-1} with 51.40 per cent increase which was significantly different from all the treatments. *M. incognita* preceding the inoculation of *R. solanacearum* (N→B) recorded - 0.107 µmol m^{-2} s^{-1} with 69.9 per cent increase over check. However, prior inoculation of *R. solanacearum* followed by *M. incognita* (B→N) recorded -0.275 µmol m^{-2} s^{-1} with 22.75 per cent decline over check. These two treatments were significantly different from each other as well as all other treatments including check.

4.9. HISTOPATHOLOGY

Roots of ginger inoculated with *M. incognita* alone and *M. incognita* and *R. solanacearum* together along with healthy roots were used for histopathological study. Such roots were killed and fixed in F.A.A, dehydrated in tertiary butyl alcohol (TBA) series, infiltrated and embedded in paraffin wax. The paraffin blocks containing tissues were trimmed and 12 µm thin sections were cut and collected on glass slides which were further dehydrated in xylol series, stained in safranin and counter stained in malachite green. Permanent slides were made by DPX mountant. The slides were observed under research microscope to examine the histopathological changes in the roots and photographs were taken by using a magnified image projection system (MIPS) attached to the research microscope.

4.9.1. Transverse Sections of Healthy Roots:

Tissue organization in healthy root sections was intact and not malformed and disrupted as compared to roots infected with *M. incognita* alone or *M. incognita* and *R. solanacearum* together. Healthy root section (Fig 40) comprised of a thin walled, single layer compact and barrel shaped cells representing the outer layer of epidermis. The cortex, just below the epidermis was large, multilayered loose parenchymatous cells with lot of intercellular spaces. The endodermis was represented by single layer barrel shaped cells. The passage cells representing few thin walled endodermal cells did not stain. Passage cells were the site of symplastic water and nutrient flow. The cells of casparian strip were deeply stained and characterized by thickenings on their radial walls by deposition of suberin. The casparian strip was impervious to water and nutrient flow. Beyond the endodermis, the pericycle was represented by a single layer of parenchymatous cells. Vascular bundles were 6-7 in numbers, polyarchic, radially arranged, xylem and phloem bundles were alternate to each other. Xylems were exarch and vessels rounded. Loosely arranged parenchymatous cells present between xylem and phloem bundles represented the conjuctive tissue. Pith which representing the central axis was large and prominent.

4.9.2. Transverse and Longitudinal Sections of Infected Roots:

Initially second stage pre parasitic juveniles penetrated and migrated into the root by intercellular migration without the sign of broken or necrotic cells of the cortex. The second stage juveniles remained inside the apoplast of cortex and penetrated its head deep inside the symplast of the vascular tissue and started feeding. After initiation of feeding the second stage juveniles become sedentary. It modified the host function by reprogramming the root cells into polynucleated hypertrophied transfer cells called giant cells (Fig 41) to serve as a metabolic sink for the developing nematode. These multinucleated giant cells were initiated in the xylem parenchymatous cells opposite to the protoxylem poles. Polynucleated giant cells numbering 5-7 were formed inside the xylem parenchyma. Multiple infection sites (Fig 42) by several second stage juveniles with giant cell were also observed. The giant cells expanded its volume by several fold, even more than ten times of normal cells. In early stages, giant cell nuclei were distributed in the peripheral cytoplasm indicating the loss of spindle polarity along with several rounds of mitosis without cytokinesis. Repeated mitosis shortened the cell cycle. The cytoplasm of giant cells (GC) was dense, granular and became a factory of cytoplasmic activities to meet the nutrient demand of the developing nematode, as a positive feedback mechanism. The nuclei and nucleoli of giant cells were hypertrophied and prominent (Fig 43). The cells of undifferentiated phloem around the nematode head were severely hypertrophied. Concurrent with giant cell formation, cortical cells underwent hypertrophy and pericycle cells hyperplasia to induce typical root gall symptoms. Giant cell walls were thickened along with wall ingrowths (Fig 43). Gradually cytoplasm of the giant cells aggregated along their thickened cell wall and consequently the vascular tissues became disrupted and disorganized. Wall separating the giant cells indicated the presence of plasmodesmata for symplastic nutrient flow. Later on with the aging of plants, giant cells were devoid of cytoplasm, giant cell nuclei became globular, conical, elongated, and lobed and vacuoles were more prominent (Fig 44). Finally the giant cells were shrunken and cytoplasm extracted with little ground cytoplasm. Longitudinal section of *M. incognita* infected root clearly depicted disorganization of vascular tissue along with giant cell and hypertrophied phloem and cortical cells (Fig 45).

Transverse section of ginger roots combine inoculated with *M. incognita* and *R. solanacearum* exhibited broken endodermal and cortical cells along with extensive cavities (Fig 46). The giant cells were heavily colonized by rod shaped bacterial inclusions which stained pink colour (Fig 47). Hypertrophic and hyperplastic growth of cortex and pericycle respectively was observed. However, these giant cells degenerated rapidly as compared to giant cells induced by *M. incognita* alone.

4.10. ESTIMATION OF AVOIDABLE YIELD LOSS

The experiments was carried out using paired plot technique, consisting of two treatments *viz.*, untreated and treated with soil application of Carbofuran 3 G @ 1.5 kg *a.i/*ha + rhizome treated with streptocycline @ 2 g/10 litre of water. Each treatment was replicated 12 times in 4 × 1 × 0.15 m raised beds. Observations on the number of plants germinated and yield/plot after harvest were recorded. Data were subjected to paired ‘t’ test for significance.

Perusal of data (Table 9) indicated that the total number of plant stand after germination to be 56 in treated plots as against 46 in untreated plots (Fig 48) causing a loss of 17.85 per cent in germination. Paired 't' test indicated significant differences between the treated and untreated plots. The plant stand and crop vigour in treated plots (Fig 49a) was more as compared to untreated (Fig 49b) plots. The yield of ginger after harvest was 3.63 kg/plot in treated and 2.71 kg/plot in untreated plots. The application of carbofuran @ 1.5 kg a.i/ha + streptocycline @ 2g/10 liter of water recorded higher yield than check (Fig 50). Statistical analysis of data revealed significant differences. The avoidable yield loss caused by both *M. incognita* and *R. solanacearum* in ginger was estimated to be 24.57 per cent.

Table 9: Estimation of avoidable yield loss in quick wilt complex caused by *M. incognita* and *R. solanacearum*

Treatment	Number of plants germinated / plot	Germination loss (%)	Yield (kg/plot)	Yield loss (%)
Treated	56	-	3.63	-
Untreated	46	17.85	2.71	24.57
t (P = 0.05)	2.57*	-	8.29*	-

**** Significant at P=0.05***

4.11. INTEGRATED MANAGEMENT (POT CULTURE TRIAL)

A pot culture experiment in 12" dia earthen pots containing 9 kg steam sterilized soil was carried out in the net house condition inoculated with 1000 J_2/ kg soil of *M. incognita* and 4×10^6 cfu/ml of *R. solanacearum.* The various treatments as described under materials and methods were applied to replicated pots followed by observations at different stages of crop growth. (Table 10)

4.11.1. Plant Height:

Perusal of data indicated increase in the plant height (Fig 51) in different management modules as compared to check (T_1). Height of plant ranged between 100.33 cm to 109.33 cm with coefficient of variation of 0.002. Soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan (0.5%) + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded plant height greater than the mean. Statistical analysis of data indicated significant differences among the treatments. Treatments *viz*., seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly greater plant height as compared to other treatments which were at par with each other.

4.11.2.Number of Tillers:

Data indicated on number of tillers (Fig 52) in different management modules exhibited increase over check (T_1). Number of tillers ranged between

11 and 17 with coefficient of variation of 0.008. Seed soaking in carbosulfan @ 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more number of tillers than the general mean. Statistical analysis of data indicated significant differences among the treatments. Treatments *viz.*, seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded highest number of tillers as compared to other treatments which were at par with each other.

4.11.3. Dry Weight of Shoot:

Dry weight of shoot (Fig 53) recorded in different management modules exhibited an increasing trend over check (T_1). It ranged between 53.00 g to 81.03 g with coefficient of variation of 0.003. Seed soaking in carbosulfan @ 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), soil application of neem cake @ 1.5 t/ha (T_6), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid

300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded dry weight of shoot more than the mean. Statistical analysis of data indicated significant difference among the treatments. Seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded highest dry weight of shoot as compared to other treatments in which seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) were at par with each other and soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) was significantly different from both the above treatments.

4.11.4.Chlorophyll a:

Perusal of data indicated increase in the chlorophyll a (Fig 54) in different management modules as compared to check (T_1). Chlorophyll a ranged between 1.19 to 1.66 µg/g fw with coefficient of variation of 0.012. Soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan

Table 10: Efficacy of Integrated Management Modules on Quick Wilt Complex of Ginger (Pot Trial)

Treatments	Plant height (cm)	No. of Tillers	Dry weight of shoot (g)	Chl a (µg/g fw)	Chl b (µg/g fw)	Total Chl (µg/g fw)	Yield (kg)
T_1	100.33^{e}	11.00^{e}	53.00^{f}	1.19^{b}	0.38^{c}	1.60^{c}	0.30^{b}
T_2	102.67^{cde}	14.33^{bcd}	66.80^{cd}	1.42^{ab}	0.50^{bc}	1.91^{abc}	0.40^{b}
T_3	100.67^{de}	12.00^{de}	57.03^{e}	1.25^{ab}	0.39^{bc}	1.64^{abc}	0.33^{b}
T_4	104.00^{bcde}	14.33^{bcd}	66.83^{cd}	1.46^{ab}	0.52^{bc}	1.92^{abc}	0.43^{b}
T_5	101.00^{de}	12.67^{cde}	57.67^{e}	1.31^{ab}	0.41^{bc}	1.78^{abc}	0.36^{b}
T_6	102.67^{cde}	14.00^{bcd}	66.27^{cd}	1.42^{ab}	0.49^{bc}	1.90^{abc}	0.40^{b}
T_7	102.33^{cde}	14.00^{bcd}	64.00^{d}	1.39^{ab}	0.47^{bc}	1.90^{abc}	0.38^{b}
T_8	104.33^{bcd}	14.67^{abc}	67.33^{cd}	1.50^{ab}	0.54^{bc}	2.00^{abc}	0.43^{b}
T_9	105.67^{abc}	15.33^{ab}	69.23^{bc}	1.52^{ab}	0.54^{bc}	2.06^{abc}	0.45^{b}
T_{10}	106.67^{ab}	16.00^{ab}	71.90^{b}	1.54^{ab}	0.57^{b}	2.13^{abc}	0.48^{b}
T_{11}	109.33^{a}	17.00^{a}	81.03^{a}	1.66^{a}	0.78^{a}	2.42^{a}	2.30^{a}
T_{12}	107.33^{ab}	16.33^{ab}	73.17^{b}	1.56^{ab}	0.76^{a}	2.28^{ab}	2.27^{a}
SEM	1.174	0.745	1.340	0.125	0.057	0.165	0.129
CV	0.002	0.008	0.003	0.012	0.076	0.013	0.083
Mean	103.920	14.310	66.190	1.430	0.530	1.960	0.710

***Letters common in the figures are not statistically significant**

0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan (0.5%) + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more chlorophyll a than the mean. Statistical analysis of data indicated significant difference among the treatments. Treatments *viz*., seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly higher chlorophyll a as compared to other treatments which were at par with each other.

4.11.5.Chlorophyll b:

Chlorophyll b (Fig 55) in different management modules increased over check (T_1). Data ranged between 0.38 to 0.78 µg/g fw with coefficient of variation of 0.076. Soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan (0.5%) + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more chlorophyll b than the mean. Statistical analysis of data indicated significant differences among the treatments. Treatments with soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly higher chlorophyll b as compared to other treatments which were at par with each other.

4.11.6. Total Chlorophyll:

Perusal of data indicated increase in the total chlorophyll (Fig 56) in different management modules as compared to check (T_1). Data ranged between 1.6 to 2.42 µg/g fw with coefficient of variation of 0.013. Seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more total chlorophyll than the mean. Statistical analysis of data indicated significant differences among the treatments. Treatments with soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded highest total chlorophyll content as compared to other treatments which were at par with each other, but significantly different from rest others.

4.11.7. Rhizome Yield:

Perusal of data indicated increase in the rhizome yield (Fig 57) of different management modules as compared to check (T_1). Data ranged between 0.30 to 2.30 kg with coefficient of variation of 0.083. Soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more rhizome yield than the mean. Statistical analysis of data indicated significant difference among the treatments. Treatments *viz*., soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly higher rhizome yield as compared to other treatments which were at par with each other.

4.12. INTERGRATED MANAGEMENT (FIELD TRIAL)

A replicated field experiment was carried out for management of quick wilt disease complex of ginger consecutively for two years during 2011-2013 in naturally infested field having the initial soil population of >1000 J_2/kg soil of *M. incognita* and 4×10^6 cfu/ml/kg soil of *R. solanacearum*. Altogether twelve eco friendly and bio rational modules comprising of single or various combinations of measures along with an untreated check were used. Various growth, yield and nematode parameters recorded during the course of investigation or after the termination of the experiment through destructive sampling were transformed to appropriate scales and analyzed using suitable experimental design and presented in Table 11.

4.11.1.Number of Tillers:

Perusal of data indicated increase in the number of tillers in all the management modules over check (T_1) during both the seasons. It ranged between 10.83 to 18.73 in season I and 10.97 to 19.07 in season II with coefficient of variation of 5.05 and 4.26 in season I and II respectively. Seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded number of tillers more than the mean for respective years. Statistical analysis of data indicated significant difference among the treatments in both the seasons. Treatments *viz*., seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly more number of tillers as compared to other treatments which were at par with each other in both the seasons except seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9) in season II. Pooled analysis of data also indicated a similar trend of increase over check in the number of tillers (Fig 58) in different management modules. Lowest number of tillers (10.9) was recorded in check and highest number of tillers (18.82) was recorded in treatment applied with neem cake 1.5 ton/ha + phosphonic acid 300 ppm (T_{12}). Treatments *viz*., seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more number of tillers as compared to general mean. Seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly more number of tillers as compared to other treatments and were at par with each other.

4.11.2.Plant Height:

Plant height (cm) as recorded in different management modules during both the seasons was more as compared to check (T_1). Height of plant ranged between 67 cm to 88.3 cm in season I and 54.87 cm to 71.17 cm in season II with coefficient of variation of 1.60 and 2.46 in season I and II respectively. Seed soaking in carbosulfan 25 EC 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid

300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded height of the plant greater than the mean for respective seasons. Statistical analysis of data indicated significant difference among the treatments in both the seasons. Soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) in season I and soil application of sesame cake + phosphonic acid 300 ppm (T_{11}) in season II recorded significantly greater plant height over check and rest other treatments. Pooled analysis of data indicated a similar trend in the plant height (Fig 59) with an increase over check in different management modules. Lowest plant height (60.93 cm) was recorded in check and highest plant height (18.82 cm) was recorded in treatment applied with sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}). Treatments *viz.*, seed soaking in carbosulfan 25 EC 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded mean plant height greater than the general mean. Seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha +

phosphonic acid 300 ppm (T_{12}) recorded significantly greater height of plant as compared to other treatments and were at par with each other.

4.11.3.Dry Weight of Shoot:

Dry weight of shoot in different management modules during both the seasons increased as compared to check (T_1). It ranged between 26.40 g to 57.60 g in season I and 25.00 g to 54.90 g in season II with coefficient of variation of 3.01 and 3.74 respectively. Seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more dry weight of shoot than the mean for season I and season II. Statistical analysis of data indicated significant differences among the treatments in both the seasons. Soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) recorded significantly more dry weight of shoot as compared to other treatments followed by soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of neem cake @ 1.5 ton/ha + phosphonic acid 300 ppm (T_{12}) in both the seasons. Pooled analysis of data indicated a similar trend in the dry weight of shoot (Fig 60) with an increase over check in different treatments. Lowest dry weight of shoot (25.70 g) was recorded in check and highest dry weight of shoot (56.25 g) in treatment applied with sesame cake @ 1.5 t/ha + phosphonic acid 300ppm

Table 11: Effects of Integrated Management Modules on Quick Wilt Complex of Ginger. (Field trial)

Treatments	No. of tillers			Plant Height (cm)			Dry wt. of shoot (g)		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
T_{1}	10.83^{c}	10.97^{f}	10.90^{e}	67.00^{d}	54.87^{f}	60.93^{d}	26.40^{g}	25.00^{g}	25.70^{i}
T_{2}	14.43^{b}	14.33^{cde}	14.38^{d}	79.57^{c}	65.73^{c}	72.65^{abc}	36.20^{d}	35.67^{d}	35.93^{de}
T_{3}	11.67^{c}	11.63^{f}	11.65^{e}	67.00^{d}	61.60^{e}	64.30^{d}	27.57^{g}	27.05^{g}	27.31^{h}
T_{4}	14.57^{b}	14.63^{cd}	14.60^{d}	81.50^{bc}	67.53^{b}	74.52^{ab}	37.37^{d}	36.65^{d}	37.01^{d}
T_{5}	14.30^{b}	13.33^{e}	13.82^{d}	67.73^{d}	62.97^{de}	65.35^{cd}	31.43^{f}	31.10^{f}	31.27^{g}
T_{6}	14.33^{b}	14.30^{cde}	14.32^{d}	70.37^{d}	64.20^{cd}	67.28^{bcd}	35.67^{de}	34.67^{de}	35.17^{e}
T_{7}	14.30^{b}	14.10^{de}	14.20^{d}	68.13^{d}	63.83^{d}	65.98^{cd}	33.80^{e}	32.40^{ef}	33.10^{f}
T_{8}	15.43^{b}	15.40^{c}	15.42^{c}	81.83^{bc}	67.73^{b}	74.78^{ab}	43.87^{c}	43.30^{c}	43.58^{c}
T_{9}	17.40^{a}	17.30^{b}	17.35^{b}	83.07^{bc}	67.83^{b}	75.45^{a}	45.23^{c}	44.75^{c}	44.99^{c}
T_{10}	18.30^{a}	18.73^{a}	18.52^{a}	83.80^{b}	68.73^{b}	76.27^{a}	48.43^{b}	47.70^{b}	48.07^{b}
T_{11}	18.73^{a}	19.07^{a}	18.90^{a}	88.30^{a}	71.17^{a}	79.73^{a}	57.60^{a}	54.90^{a}	56.25^{a}
T_{12}	18.63^{a}	19.00^{a}	18.82^{a}	85.77^{ab}	69.20^{b}	77.48^{a}	49.47^{b}	49.40^{b}	49.43^{b}
SEM	0.44	0.37	0.28	1.30	0.60	2.46	0.68	0.83	0.51
CV	5.05	4.26	4.37	2.92	1.60	2.46	3.01	3.74	3.18
Mean	15.24	15.23	15.24	77.01	65.45	71.23	39.42	38.55	38.98

**** Letters common in the figures are statistically not significant***

(T_{11}). Treatments *viz.*, seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded dry weight of shoot greater than general mean. Soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) recorded significantly more dry weight of shoot as compared to others followed by soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) and seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}). However, the shoot dry weight in seed soaking with carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) were at par with each other but significantly different from soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}).

4.11.4. Percentage of Wilted Plants:

Perusal of data indicated decrease in the percentage of wilted plants in various management modules during both the seasons as compared to check (T_1). Wilted plants ranged between 7.5 to 45 per cent in season I and 11.5 to 59.07 per cent in season II with coefficient of variation of 16.44 and 5.94 in season I and II respectively. Soil drenching with phosphonic acid at 300 ppm(T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed

Table 11: (contd.) Effects of integrated management modules on quick wilt complex of ginger (Field Trial)

Treatments	% wilted plants*			% of germination at 30 DAS*		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
T_1	45.00 (42.13[a])	59.07 (50.23[a)])	52.03 (46.18[a])	12.89 (21.04[f])	14.45 (22.27[e])	13.67 (21.66[h])
T_2	15.00 (22.59[d])	35.50 (36.57[d])	25.25 (29.58[bcd])	14.66 (22.53[f])	17.66 (24.87[d])	16.16 (23.70[g])
T_3	35.00 (36.25[b])	51.10 (45.63[b])	43.05 (40.94[a])	18.22 (25.26[de])	19.33 (26.08[d])	18.77 (25.67[f])
T_4	10.50 (18.66[e])	31.10 (33.88[e])	20.80 (26.1[cd])	15.55 (23.22[ef])	18.33 (25.35[d])	16.94 (24.29[fg])
T_5	25.00 (29.97[c])	39.93 (39.19[c])	32.47 (34.58[b])	26.66 (31.08[ab])	26.00 (30.65[ab])	26.33 (30.87[bc])
T_6	20.00 (26.55[c])	37.73 (37.9[d])	28.87 (32.22[bc])	24.89 (29.90[ab])	25.66 (30.43[ab])	25.27 (30.16[bcd])
T_7	21.00 (27.27[c])	39.53 (38.57[cd])	30.27 (33.11[b])	23.55 (29.01[bc])	23.66 (29.10[bc])	23.61 (29.06[de])
T_8	10.00 (18.34[e])	31.07 (33.87[e])	20.53 (26.1[cd])	21.33 (27.48[cd])	22.00 (27.97[c])	21.67 (27.72[e])
T_9	9.00 (17.44[e])	24.33 (29.53[f])	16.67 (23.49[de])	27.99 (31.91[a])	26.00 (30.66[ab])	27.00 (31.29[abc])
T_{10}	8.50 (16.92[e])	14.20 (22.13[g])	11.35 (19.52[e])	25.33 (30.21[ab])	24.00 (31.30[a])	24.67 (29.77[cd])
T_{11}	7.50 (15.89[e])	11.50 (19.82[h])	9.50 (17.85[e])	28.44 (32.21[a])	27.00 (31.30[a])	27.72 (31.75[ab])
T_{12}	8.50 (16.95[e])	12.40 (20.61[gh])	10.45 (18.78[e])	28.44 (32.22[a])	27.66 (31.70[a])	28.05 (31.96[a])
SEM	1.70	1.11	3.19	1.17	0.82	0.73
CV	16.44	5.94	6.17	9.07	6.24	4.43
Mean	17.92	32.29	25.10	22.33	22.65	22.49

Figures in the parentheses indicated angular transformed values.
Letters common in the figures are statistically not significant.

soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less percentage of wilted plants than the mean for respective seasons. Statistical analysis of data indicated significant differences among the treatments in both the seasons. Treatments *viz.*, seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly less percentage of wilted plants as compared to other treatments which were at par with each other for season I where as in season II soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly less percentage of wilted plants than others, but at par with each other. However, the later treatment (T_{12}) was also at par with seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) Pooled analysis of data indicated a decline trend in the percentage of wilted plants (Fig 61) over check in different management modules. Lowest percentage of wilted plants (9.50 per cent) was recorded in soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and highest percentage of wilted plants (52.03

per cent) was recorded in check. Treatment *viz.,* soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan (0.5%) + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less percentage wilted plants than the general mean. Seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significantly less percentage of wilted plants as compared to other treatments which were at par with each other.

4.11.5.Percentage of Germination 30 DAS:

Perusal of data indicated increase in the percentage of germination 30 DAS among different management modules during both the seasons as compared to check (T_1). Germination percentage at 30 DAS ranged between 12.89 to 28.44 in season I and 14.45 to 27.66 in season II with coefficient of variation of 9.07 and 6.24. Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed (T_5), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake @ 1.5 t/ha (T_7), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% +

Pseudomonas fluorescens @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more germination percentage than the mean for respective years. Statistical analysis of data indicated significant differences among the treatments in both the seasons. Treatments *viz.*, seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded higher percentage of germination as compared to other treatments and were at par with each other for both the season I and II. Combined analysis of data indicated a similar trend of increase in the percentage of germination (Fig 62) over check in different management modules. Lowest percentage of germination (13.67 per cent) was recorded in check and highest percentage of germination (28.05 per cent) was recorded in treatment applied with neem cake 1.5 t/ha + phosphonic acid 300 ppm (T_{12}). Seed treatment with *Pseudomonas fluorescens* @ 10g/kg seed (T_5), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake @ 1.5 t/ha (T_7), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more percentage of germination than the mean. Treatments those exhibited significant differences among themselves with regard to percentage of germination over the seasons were seed soaking in carbosulfan (0.5%) + drenching with phosphonic acid 300 ppm (T_9), soil application of sesame cake + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}). However the above treatments were at par with each other.

4.11.6. Population of *M. incognita* in Soil:

Perusal of data indicated decrease in population of nematodes in soil of various management modules during both the seasons as compared to check (T_1). It ranged between 1569 to 3561 in season I and 1870 to 4245 in season II with coefficient of variation of 2.26 and 0.59 respectively. Seed soaking in carbosulfan 25 EC @ 0.5% (T_2), seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed (T_5), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake @ 1.5 t/ha at 15 days before sowing (T_7), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) in both the seasons and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less nematode population in soil than the mean for corresponding seasons. Statistical analysis of data indicated significant difference among the treatments in both the seasons. Significant reduction in the population of *M. incognita* in soil was recorded in all the management modules except in the module comprising of seed soaking in streptocycline 0.02% (T_3). Pooled analysis of data indicated a similar trend in the reduction of *M. incognita* population (Fig 63) over check in different management modules. Lowest population (1590) of *M. incognita* in soil was recorded in treatment with seed soaking in carbosulfan 0.5% (T_2) and highest population (3903) in check. Treatment *viz*., seed soaking in carbosulfan 25 EC @ 0.5% (T_2), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake @ 1.5 t/ha (T_7), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less population of *M. incognita* in soil than the mean. Population of *M. incognita* in seed soaking with carbosulfan 0.5% (T_2) and seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8) were lowest which were at par followed by soil application of sesame oil cake @ 1.5 t/ha (T_7), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}).

4.11.6. Population of *M. incognita* in Root:

Perusal of data indicated decrease in the population of *M. incognita* in root among various management modules during both the seasons as compared to check (T_1). Population in root ranged between 3857 to 7950 in season I and

3086 to 6360 in season II with coefficient of variation of 0.42 and 0.48 respectively. Seed soaking in carbosulfan 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed (T_5), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of sesame cake @ 1.5 ton/ha + phosphonic acid 300 ppm (T_{11}) recorded less population in root than the mean for respective years. Statistical analysis of data indicated significant difference among the treatments in both the seasons. Treatments *viz*., seed soaking carbosulfan 0.5 % (T_2), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9) and seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) recorded significantly lower population in root as compared to others but at par with each other. Pooled analysis of data indicated a similar trend in the population decline (Fig 64) in root over check in different management modules. Lowest nematode population in root (3472) was recorded in treatment with seed soaking in carbosulfan 0.5% + soil drenching with phosphonic acid 300 ppm (T_9) and highest nematode population in root (7155) was recorded in check. Seed soaking in carbosulfan 0.5% (T_2), soil drenching with phosphonic acid at 300 ppm (T_4), seed treatment with *Pseudomonas fluorescens* @ 10g/kg seed (T_5),

Table 11: (contd) Effects of integrated management modules on quick wilt complex of ginger (Field trial)

Treatments	Soil population**			Root population**		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean
T_1	3561 (3.546^{a})	4245 (3.628^{a})	3903 (3.587^{a})	7950 (3.9^{a})	6360 (3.803^{a})	7155 (3.852^{a})
T_2	1450 (3.149^{f})	1729 (3.237^{h})	1590 (3.194^{f})	3996 (3.601^{g})	3197 (3.504^{g})	3596.5 (3.553^{gh})
T_3	2975 (3.463^{ab})	3547 (3.549^{b})	3261 (3.506^{b})	6289 (3.799^{b})	5031 (3.701^{b})	5660 (3.750^{b})
T_4	2562 (3.405^{bc})	3054 (3.485^{c})	2808 (3.445^{c})	4569 (3.650^{de})	3655 (3.562^{de})	4112 (3.611^{e})
T_5	2025 (3.305^{cde})	2414 (3.383^{e})	2220 (3.344^{d})	4300 (3.633^{ef})	3440 (3.536^{ef})	3870 (3.585^{f})
T_6	1897 (3.277^{def})	2261 (3.343^{f})	2079 (3.315^{d})	5152 (3.712^{c})	4122 (3.615^{c})	4637 (3.663^{c})
T_7	1775 (3.243^{def})	2116 (3.325^{f})	1946 (3.284^{de})	4850 (3.685^{cd})	3880 (3.588^{cd})	4365 (3.637^{d})
T_8	1569 (3.195^{ef})	1870 (3.271^{g})	1720 (3.233^{ef})	4045 (3.607^{fg})	3236 (3.510^{fg})	3640.5 (3.558^{g})
T_9	2240 (3.350^{bcd})	2670 (3.426^{d})	2455 (3.388^{c})	3857 (3.586^{g})	3086 (3.489^{g})	3471.5 (3.538^{h})
T_{10}	1820 (3.257^{def})	2169 (3.336^{f})	1995 (3.296^{de})	3865 (3.587^{g})	3092 (3.490^{g})	3478.5 (3.539^{h})
T_{11}	1800 (3.251^{def})	2146 (3.331^{f})	1973 (3.291^{de})	4759 (3.677^{d})	3807 (3.579^{d})	4283 (3.628^{de})
T_{12}	1850 (3.267^{def})	2205 (3.343^{f})	2028 (3.305^{d})	4810 (3.682^{cd})	3848 (3.585^{cd})	4329 (3.634^{d})
SEM	(0.04)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
CV	(2.26)	(0.59)	(1.46)	(0.42)	(0.48)	(0.39)
Mean	(3.31)	(3.39)	(3.35)	(3.68)	(3.58)	(3.63)

Letters common in the figures are statistically not significant.
***** Figures in the parenthesis indicate log transformed values.***

seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + soil drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) recorded root population less than the general mean. Management modules comprising of seed soaking in carosulfan 0.5% (T_2), seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) recorded significantly less population of *M. incognita* in root as compared to others but at par with each other.

4.11.7. Root Knot Index:

Perusal of data indicated decrease in the root knot index in different management modules during both the seasons as compared to check (T_1). Root knot index ranged between 1.33 to 4.67 in season I and 1.33 to 5 in season II with coefficient of variation of 26.76 and 22.23 respectively. Seed soaking in carbosulfan 0.5% (T_2), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake (1.5 t/ha) at 21 days before sowing (T_7), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less root

Table 11: (contd) Effects of integrated management modules on quick wilt complex of ginger (Field trial)

Treatment	Root knot index			Yield (kg)			
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled Mean	B : C
T_1	4.67^{a}	5.00^{a}	4.83^{a}	0.81^{i}	0.77^{h}	0.79^{g}	1.004 :1
T_2	1.33^{c}	2.00^{bc}	1.67^{de}	1.30^{ef}	2.23^{de}	1.77^{de}	2.24 : 1
T_3	4.00^{a}	4.67^{a}	4.33^{a}	0.97^{hi}	1.63^{g}	1.30^{fg}	1.63 : 1
T_4	3.00^{b}	3.00^{b}	3.00^{bc}	1.43^{e}	2.28^{de}	1.86^{cd}	2.33 : 1
T_5	3.00^{b}	3.00^{b}	3.00^{b}	1.00^{h}	1.80^{fg}	1.40^{ef}	1.74 : 1
T_6	2.00^{bc}	2.67^{b}	2.33^{bcd}	1.23^{fg}	2.00^{ef}	1.62^{def}	1.88 : 1
T_7	2.00^{bc}	2.00^{bc}	2.00^{cde}	1.07^{gh}	2.00^{ef}	1.53^{def}	1.75 : 1
T_8	1.33^{c}	2.00^{bc}	1.67^{de}	1.47^{e}	2.30^{cde}	1.88^{cd}	2.35 : 1
T_9	1.33^{c}	1.33^{c}	1.33^{e}	1.87^{d}	2.53^{cd}	2.20^{bc}	2.74 : 1
T_{10}	1.33^{c}	1.33^{c}	1.33^{e}	2.07^{c}	2.60^{bc}	2.33^{b}	2.88 : 1
T_{11}	1.33^{c}	1.33^{c}	1.33^{e}	2.50^{a}	3.10^{a}	2.80^{a}	3.16 : 1
T_{12}	1.33^{c}	2.00^{bc}	1.67^{de}	2.30^{b}	2.87^{ab}	2.58^{ab}	2.99 : 1
SEM	0.34	0.32	0.22	0.06	0.10	0.13	
CV	26.76	22.23	23.09	6.76	7.78	7.50	
Mean	2.22	2.53	2.38	1.50	2.18	1.84	

Letters common in the figures are statistically not significant.

knot index than the general mean for resprctive seasons. Statistical analysis of data indicated significant difference among the treatments in both the seasons. Treatments *viz.,* seed carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded lowest root knot index as compared to other treatments which were at par with each other for season I and II and significantly different from others. Pooled analysis of data indicated a similar trend in the root knot index (Fig 65) with a decrease over check in different management modules. Lowest root knot index (1.33) was recorded in seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) and soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and highest number (18.82) were recorded in check. Treatments with seed soaking in carbosulfan 0.5% (T_2), soil application of neem cake @ 1.5 t/ha (T_6), soil application of sesame cake @ 1.5 t/ha (T_7), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded less root knot indices than the mean. Treatments which exhibited significant reduction in root knot index over others were seed soaking in carbosulfan 0.5% + drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}).

4.11.8. Rhizome Yield:

Perusal of data indicated increase in the yield (kg/4m^2) in different management modules during both the seasons as compared to check (T_1). Yield ranged between 0.81 kg to 2.5 kg in season I and 0.77 kg to 3.1 kg in season II with coefficient of variation of 6.76 and 7.78 respectively. Seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded more yield than the mean yield for season I. Similarly soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan (0.5%) + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded yield more than the mean yield for season II. Statistical analysis of data indicated significant increase in the rhizome yield over check among the treatments in both the seasons. Treatments *viz*., seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded higher yield as compared to other treatments which in turn were significantly different from each other for season I. However, in season II soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) which recorded highest rhizome yield of 2.80 kg was at par with soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) with 2.58 kg which again was at par with seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}) with the yield of 2.33 kg/4 m^2. Pooled analysis of data also indicated a similar trend in the yield (Fig 66) with an increase over check in different management modules. Lowest yield (0.79 kg) was recorded in check and highest yield (2.8 kg) was recorded in treatment applied with sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}). Treatments *viz*., soil drenching with phosphonic acid at 300 ppm (T_4), seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded rhizome yield greater than the mean yield. Although increase in yield over check was recorded in all the treatments, seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm ($T_{9,}$ Fig 67), seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescens* @ 10 g/kg seed ($T_{10,}$ Fig 68), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}, Fig 69) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm ($T_{12,}$ Fig 70) recorded significantly greater yield as compared to other treatments.

4.11.9. Benefit Cost Ratio (B : C)

Data on B : C ratio ranged from 1.004 : 1 to 3.16 : 1. Highest B: C ratio (3.16 : 1) was recorded in soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and lowest (1.004 : 1) in check (T_1). Treatments *viz*., seed soaking in carbosulfan 0.5% + *Pseudomonas fluorescence* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded higher B : C ratio from rest other treatments including check (T_1).

DISCUSSION

Ginger is an important cash crop cultivated almost all the tracts of tropics and sub tropics. The modified underground stem is used directly for a variety of purposes, starting from culinary to carminative, spices as well as in wide range of pharmaceutical products. India occupies a unique position in the world as regards to production, consumption and export of dry ginger. This most important spice crop is very often constrained by the invasion of several biotic stresses resulting in decline production and productivity. Important biotic stresses that contribute to the decline production in ginger are soft rot, slow wilt, quick wilt and nematodes. The quick wilt disease caused by *R. solanacearum* is often associated with many nematode species among which root knot nematodes, *Meloidogyne* spp. are frequent. Since quick wilt disease occurs in wide scale in the ginger growing areas causing huge losses to ginger, the present study was undertaken to establish the association of *R. solanacearum* and *M. incognita* in forming a disease complex along with investigation pertaining to their isolation, characterization, estimation of avoidable yield loss and management through eco friendly, bio rational and sustainable measures.

5.1. CHARACTERIZATION OF *M. INCOGNITA*

Ginger plants exhibiting quick wilt symptoms and root galling from different locations on examination exhibited heavy infection of root knot nematode, *Meloidogyne* spp. Single egg mass progeny of the nematode species was raised monoxenically in pots containing brinjal plants. The base population served as the inoculums for experimental purposes as well as identification. Observations pertaining to larval morphology and measurements including perineal pattern of adult female were examined and compared with already identified species. On examination, second stage juveniles exhibited an anteriorly flattened head cap which was rounded posteriorly. Stylet knobs were clearly set off from the stylet extension. The conus as well as the shaft were widened towards their base. The dorsal esophageal gland opening was located 3 μ away from base of stylet. Hemizonid was anterior to excretory pore. Larvae length ranged between 320 and 730 μm. Tail length ranged between 40 and 60 μ with a notched tail. Hyaline tail of tip measured 8-15μ. Further, examination of the posterior cuticular pattern of adult females revealed somewhat squarish shape with high dorsal arch almost flattened at the tip. However the ventral arch was low as compared to dorsal arch. Striae of both dorsal and ventral arch were wavy and closely spaced. Numerous zig zag broken straie formed a whorl above the anus. Although lateral lines were absent, the striae were forked at the point of lateral lines. Occasionally few transverse straie extended from inner sides towards the vulva. The observations pertaining to larval morphology and measurements including perineal pattern of adult females matched to that of *M. incognita*. The observation of present findings is in agreement with the findings of Eisenback *et al*, 1981; Hunt and Handoo, 2009. Hence, the test nematode species was identified as *M. incognita*.

5.2. CHARACTERIZATION OF *R. SOLANACEARUM*

Three isolates of ginger from Pottangi, Phulbani and Bhubaneswar exhibiting typical quick wilt symptoms were isolated from rhizomes and pure cultured in *Pseudomonas* specialized media at 30^{0}C after 24-48 hours of incubation. All the isolates exhibited no variation as regards to the appearance of colonies, fluidity and colour. The colonies were fluidal, irregular with a pink or light red centre. These colonies characterized the bacterium as *R. solanacearum*. The result of the present investigation with regard to colony characterization of bacterium identified as *R. solanacearum* is in conformity with the findings of Kumar and Sharma, 2004; Sambasivam and Girija, 2006. However, the media used by the above workers was TZC agar in contrast to *Pseudomonas* specialized media used in the present investigation.

5.3. GRAM STAINING

On further exposing the test isolates to grams reaction through a process of air drying of bacterial smear and staining with crystal violet, all the isolates stained bluish purple colour. After washing and iodine staining the bacterial isolates formed a complex which was destained with alcohol. Counter staining with safranin and observation under oil immersion objective exhibited rod shaped bacterium in clusters having pink colour which suggested a gram negative reaction. The result of the present study is in corroboration with the findings of Cruickshank, 1968.

5.4. BIOCHEMICAL CHARACTERIZATION

The isolates were tested in a high assorted biochemical identification kit which resulted positive reaction to lysine, ornithine, urease, hydrogen sulphide, maltose, arabinose, glucose, methyl red - voges and proskeur. The amino acid decarboxylation test resulted positive reaction to lysine, ornithine and arginine with a colour change from mustard yellow to purple. The reaction of above isolates to triple sugar iron was positive with black colour, ciman citrate positive with blue colour and manitol positive with yellow colour having diffusion motility. All the isolates exhibited negative reactions to phenyl alanine deamination, nitrate reductase and citrate. Sugar utilization test was positive to arabinose, maltose, glucose, dextrose, sorbital, dulcitol, mannose, trehalose, ionsitol, rhamnose and mellibiose. However, it was negative to insulin, raffinose, sucrose, adonitol and lactose. Sambasivam and Girija 2006, 2007) conducted biochemical characterization of ginger isolates from Kerala similar to the present study. However, the isolates of ginger in the present study tested negative to citrate and lactose, positive to dulcitol as against the reverse by the above workers. The isolates of the present investigation reacted positive to lysine, ornithine, urease, H_2S, indole, motility, MR-VP, TSI, ciman citrate, manose, trehalose, inositol, rhamnose and mellibiose. Thus the above tests for bacterial isolates were new in addition to the exhisting tests of bacteria.

5.5. ANTIBIOTIC SENSITIVITY TEST

All the three isolates of ginger were resistant to erythromycin, gentamycin, amikacin, streptomycin and ampicillin/sulbactam and no inhibition zone was exhibited by them. The isolates were sensitive to antibiotics in different degrees in the order of ciprofloxacin > ofloxacin > co-trimanazole > cefatrioxone > cefatoxime. Sambasivam and Girija (2005, 2007) tested several antibiotics to ginger isolates for their reactions similar to the present study. There were only three antibiotics *viz.*; gentamycin, streptomycin and ampicillin common to all the investigations which tested resistance to the isolates. The antibiotics cefatoxime, cefatrioxone/tazobactam, co-trimanazole, ciprofloxacin and ofloxacin sensitive to all the isolates exhibiting different zone of inhibition in present study were not tested by the above workers. Bora and Das, 2002 also characterized *R. solanacearum* isolates from several crop plants including ginger on the basis of morphological, cultural and biochemical characteristics in corroboration to the present study.

The results of various biochemical and antibiotic tests were further compared with Bergey's manual and P1B win version (2.0) soft ware's (Bryant, 2004) confirming their identity as *R. solanacearum*.

5.6. INTERACTION STUDY

Quick wilt of ginger, a devastating disease causing serious threat to sustainable ginger cultivation. The association of *R. solanacearum* and *M. incog*nita in this disease was found to be frequent. In view of the above facts, the present investigation was undertaken to study the interaction between *M. incognita* and *R. solanacearum* in the quick wilt complex. Individual, concomitant and sequential inoculation studies of both the pathogens were undertaken.

5.6.1. Quick Wilt, Plant Growth and Yield:

Individual pathogens inoculated to ginger plants exhibited varying degrees of results. Plants inoculated with *M. incognita* alone exhibited reduction in growth and vigour followed by yellowing of leaves and transient wilting during hottest part of the day. Such plants exhibited numerous beaded galls on roots which were often encircled and thickened. Lopez *et al.,* 2004 reported symptoms of root knot nematode, *Meloidogyne* spp. on ginger rhizomes exhibiting light brown watery necrotic areas in outer rhizomes often in surface folds. Koshy *et al.,* 2005 reported galling and rotting of fibrous root and underground rhizomes along with stunting poor tillering chlorotic of leaves with marginal necrosis similar to the present study. Although Routaray *et al.* (1987); Kaur and Sharma (1988); Ferraz (1994); Ramana and Eapen (1995); Sheela *et al.,* 1995; Khan and Makhnotra (1998) reported root knot nematode *Meloidogyne* sp. along with other plant parasitic nematode species, there were no mention on symptoms by *M. incognita*.

In plants inoculated with *R. solanacearum,* deep water soaked spots appearing at the collar region progressed both upward and downward direction, mild drooping and curling of margins of leaves were more conspicuous. Plants exhibited irregular black necrotic lesions on leaf margin and wilted. The mean wilting over both the seasons was 27 days from the date of inoculation of *R. solanacearum.* Symptoms of wilting, yellowing, leaf rolling, stunting as reported in the present study is in conformity with the work of Nath *et al.* (2001); Sambasivam and Girija (2005); Naranjo and Martin (2013). Simultaneous inoculation with both the pathogens exhibited wilting at 22nd days of inoculation where as prior inoculation of *M. incognita* to *R. solanacearum* exhibited wilting on 17th day and prior inoculation of *R. solanacearum* exhibited wilting on 32nd day. The results of present investigation revealed the reduction in the period of incubation of *R. solanacearum* when *M. incognita* was inoculated simultaneously as well as prior to *R. solanacearum*. The period of incubation was reduced by 5 days in simultaneous inoculation and further by 10 days in prior inoculation with *M. incognita*. The early incidence of wilting symptoms in above two treatments was synergistic. Lucas *et al.* (1955); Libman and Leach (1962); Reddy *et al.* (1979); Sitaramaiah and Sinha (1984); Swain *et al.* (1987); Siddiqui *et al.* (2014) have reported earlier appearance of wilting symptoms in several crops by *R. solanacearum* inoculated simultaneously or following *M. incognita* inoculation which is in conformity with the present study. Although Debnath *et al.* (2009) reported the association of nematodes in quick wilt symptoms of ginger caused by *R. solanacearum* there was no mention about the associated nematodes as well as the increase or decrease in the incidence of wilting in contrast to the present study. However, the present study explicitly attributed the role of nematodes in reducing the incubation period of *R. solanacearum* to induce earlier wilting symptoms. Results of interaction trial on various growth parameters exhibited reduction in the number of tillers, plant height, dry weight of shoot including rhizome yield in both the seasons as well as in pooled means of different treatments. The reduction in number of tillers and rhizome yield over check irrespective of the seasons was less in *M. incognita* inoculated plants as compared to *R. solanacearum* inoculated plants. In contrast, the reduction in height of plant and dry weight of shoot over check was more in *M. incognita* inoculated plants than *R. solanacearum* inoculated plants. Concomitant inoculation of both the pathogens also resulted significant decrease in all the growth parameters over check. The effect of concomitant inoculation of both the pathogen was more than the individual effects as regards to number of tillers and rhizome yield. However, concomitant inoculation of both the pathogen has resulted in synergistic reduction in growth parameters *viz;* plant height and dry weight of shoot. *M. incognita* preceding the inoculation of *R. solanacearum* by 10 days also induced similar synergistic reduction in plant height and dry weight of shoot. *R. solanacearum* preceding the inoculation of *M. incognita* by 10 days exhibited less reduction in number of tillers and more reduction in plant height, dry weight of shoot and rhizome yield as compared to *R. solanacearum* alone. The different individual, concomitant and sequential inoculation of both *M. incognita* and *R. solanacearum* resulted significant reduction in growth parameters as compared to check excepting root knot index where infectivity of nematodes in plant root increased over check depending on the inoculums of *M. incognita* alone or *M. incognita* and *R. solanacearum* together. The damaging effect of *M. incognita* followed by *R. solanacearum* was more as compared to *R. solanacearum* followed by *M. incognita* with regards to growth, yield and infectivity of nematodes in ginger. The effect of *M. incognita* and *R. solanacearum* on wilt and reduction in growth and yield parameters of several crop plant species was studied and by Fukudome and Sakasegawa, 1972; Sallen *et al.,* 1980; Sitaramaiah and Sinha, 1984; Swain *et al.*, 1987; Ateka *et al.,* 2001 and Siddiqui *et al.*, 2014. Greater pathogenic and synergistic effect of *M. incognita* and *R. solanacearum* as observed in the present investigation is in conformity with the work of Hazarika *et al.* (2006) and Bekhiet *et al*., 2010. Root knot index as recorded in present investigation was more in plants prior inoculated with *M. incognita* to *R. solanacearum* as compared to *R. solanacearum* prior inoculated to *M. incognita*. The decrease in root knot index in the above treatment was due to extensive colonization of vascular tissues by *R. solanacearum* making it unfavorable for invasion, development and formation of galls by *M. incognita*. The result of present investigation is in corroboration with the findings of Siddiqui *et al*., 2014 who have reported adverse effect of *R. solanacearum* on root galling by *M. incognita* in potato. However, Sallen *et al.*, 1980 have reported no effect of *R. solanacearum* on root galling of tomato by *M. incognita* a contradiction to the present study.

5.6.2. Physiological Changes:

Since root knot nematode, *M. incognita* and *R. solanacearum* are biotrophic heterotrophic parasites, their infection induce a cascade of physiological and biochemical changes leading to formation of visible symptoms of wilting and root galling. It was necessary to investigate the various physiological and biochemical changes of different parameters *viz*., leaf water potential, relative water content, relative water deficit, chlorophyll a, chlorophyll b and total chlorophyll, stomatal conductance, fluorescence, Phi PS II, Phi CO_2, net photosynthesis rate and dark respiration, brought about by them.

M. incognita inoculated plants over the seasons indicated a decline in leaf water potential, relative water deficit, chlorophyll a, chlorophyll b and total chlorophyll, fluorescence (Fv/Fm) and net photosynthesis rate (Pn). However, there was an increase in relative water content, stomatal conductance, Phi PS II, Phi CO_2 and dark respiration. Similarly, *R. solanacearum* inoculums decreased leaf water potential, relative water content, relative water deficit, chlorophyll a, chlorophyll b and total chlorophyll, stomatal conductance, fluorescence, Phi PS II, Phi CO_2, net photosynthesis rate. Dark respiration and chlorophyll b increased as compared to check. The decrease in above parameters in *R. solanacearum* infected plants was more as compared to *M. incognita* infected plants. In simultaneous as well as sequential inoculation of both the pathogens, a further decline was recorded in various physiological and biochemical parameters *viz*., leaf water potential, relative water content, chlorophyll a, chlorophyll b and total chlorophyll, fluorescence, Phi PS II and net photosynthesis rate over check. On the contrary stomatal conductance, Phi CO_2 and relative water deficit in plants inoculated with *M. incognita* and *R. solanacearum* together, relative water deficit, Phi CO_2 and dark respiration in *M. incognita* followed by *R. solanacearum* and relative water deficit and dark respiration in *R. solanacearum* followed by *M. incognita* exhibited an increasing trend. The increase or decrease in various physiological and biochemical parameters were found to be statistically significant among different treatments. Such increase or decrease in above parameters were more pronounced in simultaneous inoculation of both pathogen as well as *M. incognita* prior inoculated to *R. solanacearum* by 10 days. However, the physiological and biochemical effect of *M. incognita* followed by *R. solanacearum* was significantly different from simultaneous inoculation of both the pathogens. Synergistic decrease in leaf water potential, chlorophyll a, chlorophyll b, total chlorophyll and increase in dark respiration was encountered in simultaneous inoculation of both the pathogen. Similarly prior inoculation of *M. incognita* by 10 days to *R. solanacearum* induced synergistic decrease in leaf water potential, chlorophyll a, chlorophyll b, Phi CO_2 and increase in dark respiration. However, *R. solanacearum* followed by *M. incognita* resulted in similar decrease in leaf water potential, chlorophyll b, total chlorophyll and increase in dark respiration. The effects of *M. incognita* on induced physiological and biochemical changes in crop plants have been carried out by various workers. Reduced leaf water potential as reported by

Rahi *et al.*, 1988; Xu and Zheng, 2000 is in conformity with the present findings as regards to induce physiological and biochemical changes by *M. incognita* alone. However Strajnar *et al.* (2012) have reported reduced leaf water potential along with decreased stomatal conductance and photosynthesis in line with the present study. Since leaf water potential had a bearing on hydraulic conductivity of the root system, it resulted in reduced water supply including reduced photosynthesis. The relative water content in the present study indicated a declining trend over check in all the individual, concomitant and sequentially inoculated treatments. Anver and Suhail (2007) reported significant reduction in water absorption and chlorophyll content of pigeon pea plants infected by *M. incognita*. Further, You *et al.* (2011) reported reduced water content, chlorophyll, stomatal conductance, Phi PS II and net photosynthsis rate as observed in the present study in *M. incognita* infected plants. Relative water content is directly related to stomatal conductance in terms of transpiration loss from the surface of the leaves. Thus reduced water content resulted in decreased stomatal conductance as a severe biotic stress induced by *M. incognita* due to impeded water flow through xylem vessels from the root to the leaf periphery. The phenomenal decrease in Phi PS II of *M. incognita*, *R. solanacearum* as well as concomitant and sequential inoculation of both the pathogens is in conformity with the findings of the above workers as well as Ai-Xi Zhen *et al.* (2000). The decrease in Phi PS II as observed in the present study is related to photo system II in which a molecule of water is broken down to release an electron to pass downstream to photo system I. Since a molecule of water is involved in this process, water stress attributes to closure of photo system II and transfer of electrons. Melakeberhan *et al.* (1986); Ramakrishnan and Rajendran (1998, 1999); Deverajan *et al.* (2003) and Thakur (2014) have reported reduced chlorophyll and photosynthesis in *M. incognita* infected plants in agreement with the present study. However, Mohanty *et al.*, 1997; Joshi and Kaul (2012) have also reported reduction in chlorophyll content of plants infected by *M. incognita* which is in agreement with the present investigation. A decline in fluorescence (Fv/Fm) was also recorded in the present study by all the individual and combined treatments. Fluorescence is a measure of plant stress; it can be used as a proxy of plant stress because extreme temperature, light and water availability can reduce the normal metabolism in plants. This phenomenon is due to an imbalance between absorption of light energy by chlorophyll and use of light energy in the photosynthesis. Ai-Xi Zhen *et al.* (2000), have reported decrease fluorescence in ginger plants treated with DDTC similar to the biotic stress induced by *M. incognita* in the present study. Dark respiration in the present study however increased in all the treatments over check in contrast to all other physiological parameters investigated. Maximum reduction (69.90 per cent) in dark respiration was observed in treatment prior inoculated with *M. incognita* to *R. solanacearum* by 10 days followed by simultaneous inoculation of both the pathogens. Photosynthesis and respiration are two ongoing processes in the plant which undergo simultaneously side by side. Both the processes share some of the enzymes and each influence the activity of the other. Photosynthesis is an anabolic process, where as respiration is a catabolic or destructive process. Respiration takes place in both light and dark. In the present study only dark respiration was recorded leaving aside photorespiration. Dark respiration in plants includes various pathways of oxidation of sugars namely glycolysis, pentose phosphate pathways and tri carboxylic acid (TCA) cycle. It also further oxidizes NADH and $FADH_2$ by transfer of electrons in the mitochondrial electron transfer pathway. Since, *M. incognita* and *R. solanacearum* alone or in different combination are responsible for inducing biotic stress resulting in reduced photosynthesis, the photosynthates thus formed underwent the catabolic activity of dark respiration thereby increasing the rate of respiration. The result of present study is in confirmation with the findings of Melakaberhan *et al.* (1985) and Wang *et al.* (1997). Singh *et al.,* 2000 have also reported reduced rate of photosynthesis and transpiration in *M. incognita*, *R. solanacearum* and concomitant inoculation of both the pathogens as compared with check, the maximum being in concomitant inoculation of both.

Photosynthesis and respiration are a co-ordinated process controlled by several biotic and abiotic factors. In the present study, reduced photosynthesis in all the treatments over check was due to increased stomatal resistance to the diffusion of CO_2 into leaf through mesophyll cells. Increased stomatal resistance in present study was preceded to leaf water stress as measured in terms of decrease leaf water potential caused by decrease absorption of water. The changes in the above parameters are attributed to physical and physiological stress induced by *M. incognita*, *R. solanacearum* and their nature of infection in ginger plant.

5.7. HISTOPATHOLOGY

M. incognita and *R. solanacearum* are two important obligate parasites of ginger causing huge losses through physical, physiological and biochemical changes. Since both the pathogens are intricately associated in quick wilt disease complex of ginger, investigation pertaining to histopathological changes of healthy roots and roots inoculated with *M. incognita* alone and in combination of *M. incognita* and *R. solanacearum* together were carried out. Healthy root sections of ginger clearly exhibited distinct epidermis; multilayered cortex followed by single layer endodermis and pericycle along with alternate xylem and phloem bundles each with 8 numbers. The space between vascular bundles was filled with parenchymatous conjunctive tissues along with a distinct pith. In the nematode infected tissue there were no disruption of the epidermal, cortical and pericycle cells. The movement of the second stage juvenile was by intercellular migration through the epidermis and cortex. After reaching the cortex the second stage juveniles inserted its feeding apparatus into the symplast of xylem parenchymatous cell opposite to protoxylem pole and started feeding. The posterior part of body remained parallel to the longitudinal axis of the plant inside the apoplast. The second stage juveniles soon after feeding induced multinucleated giant cells numbering 5-7 in the vascular parenchymatous tissue. Multiple giant cell formation sites were also encountered in the present study. Hypertrophied giant cell along with multinucleated nuclei and nucleoli were also encountered in the present study. Concurrent with the induction of multinucleated transfer cells inside the vascular parenchymatous cells the adjoining cortical cells undifferentiated phloem was hypertrophied and pericycle cells were hyperplastic giving rise to typical root gall symptoms. Giant cell wall was thickened and uneven due to deposition of polysaccharides along with wall ingrowths. Giant cell cytoplasm was initially dense but later on with the aging of plant, cytoplasm was gradually withdrawn and the giant cell nuclei became lobed and shrunken with little ground cytoplasm. Shah and Raju (1977); Lanjewar and Shukla (1988) have reported the initial site of invasion of *Meloidogyne* sp. near xylem pole, hypertrophy of cortical cells, galling on roots, formation of giant cells by akaryotic division with thicker walls and wall projection in ginger, similar to the present study. However, their study did not reflect on the number of giant cells and nature and behavior of giant cell nuclei and nucleoli and hypertrophied condition of phloem cells adjoining the giant cells as observed in the present study. Merajul *et al.* (2010) reported giant cell formation by *M. incognita* vascular strands exhibiting abnormalities in the shape and size of xylem and phloem cells as reported in this study. Sudha and Prabhoo (1983), Molina and Nelson (1983), Gopinatha *et al.* (2004), Volvas *et al.* (2005), Mahapatra and Swain (2006), Samad *et al.* (2012a, 2012b) and Hisamuddin (2013) reported entry of *Meloidogyne* sp. and formation of giant cells in the stellar region of different plant species similar to the present investigation. However, the intracellular migration as reported by Singh and Hisamuddin

(2013) in the root cells of *Lens culinaris* infected by *M. incognita* is a contradiction to the present study.

In the present study, transverse sections of ginger roots inoculated with *M. incognita* and *R. solanacearum* indicated broken endodermal and cortical cells as well as extensive cavities in contrast to transverse sections of *M. incognita* infected root alone. Further, such giant cells were colonized by extensive bacterial inclusion. Although hypertrophic and hyperplastic growth of cortex and pericycle was observed, the giant cell degradation in combined inoculation was quick as compared to inoculation with *M. incognita*. The results of present study is in corroboration with the findings of Sitaramaiah and Sinha (1984) who have reported broken endodermal and cortical cells, extensive cavities, colonization of hypertrophied giant cells by *R. solanacearum* in brinjal root inoculated with *M. javanica*.

5.8. AVOIDABLE YIELD LOSS

Ginger, a commercial spice crop, is very often invaded by multitude of pathogens causing serious losses in yield as well as yield attributing characters. However, the present study basically confined the investigation on estimation of avoidable yield loss in the quick wilt disease complex caused by *M. incognita* and *R. solanacearum*. Determining the obvious effects of both *M. incognita* and *R. solanacearum* on ginger plants under field condition is an important component of management options to combat this disease complex. Estimation of yield losses in ginger to the combined infection of *M. incognita* and *R. solanacearum* has so far not being carried out. However, there are few reports on yield loss estimation in ginger due to infestation of root knot nematode, *M. incognita*. Ray *et al.* (1995) reported 26.30 per cent in contrast to 43.00 per cent by Sheela *et al.* (1995). Bai *et al.* (1995); Makhnotra and Khan (1998); Jonathan and Rajendran (2000); Ploeg and Phillips (2001); Haidar *et al.* (2009); Anita and Selvaraj (2011), Khan and Anwer, 2011 and Adegbite, 2011 have reported yield loss induced by *Meloidogyne* sp. in various crop with wide range of variation. However, in the present study no separate estimate of yield loss in ginger for either *M. incognita* or *R. solanacearum* was done. The yield loss estimates was carried out for combined infection of both the pathogens under natural field condition in a replicated paired plot technique comprising of a treated (carbofuran 3G @ 1.5 kg *a.i*/ha as broadcast and rhizome soaked in streptocycline @ 2 g/10 lit of water for 30 minutes) and a check (Untreated). Since quick wilt pathogens very often reduce the emergence of seedlings from the soil, percentage germination was taken as a parameter of investigation in addition to the yield in kg/plot to estimate the avoidable yield loss. Soil application of carbofuran 3G @ 1.5 kg *a.i*/ha + rhizome soaked in streptocycline @ 2 g/10 lit of water for 30 minutes enhanced number of germinated plants in treated plots. The reduction in percentage of germination was 17.85 per cent. Although various above workers have estimated the loss in ginger rhizome yield in their study caused by *M. incognita* invasion, there are no reports about percentage loss in plant or germination loss as observed in the present study for both *M. incognita* and *R. solanacearum*. Further, this percentage loss in germination has a direct bearing on plant stand which can be used as yardstick for yield estimation. Subsequently, the rhizome yield of ginger as recorded in the present study also indicated increase in treated plots in comparison to untreated ones. Thus, an estimate of 24.57 per cent avoidable yield loss was recorded due to combined infection of *M. incognita* and *R. solanacearum* in naturally infested soil. Hazarika *et al.* (2006) have reported 35.60 per cent avoidable yield loss in jute fibre to the combined infection of *M. incognita* and *R. solanacearum*. The difference in yield loss estimate by the above workers are attributed to the difference in plant species, biovar of *R. solanacearum* and race of *M. incognita* and initial inoculum density in the field. Although in the present study *M. incognita*, race 2 along with specified initial inoculums density was used; such information was not mentioned by the above workers. However, 17.85 per cent and 24.57 per cent estimates are the first record of germination and yield loss estimates respectively in ginger to the combined infection of *M. incognita* and *R. solanacearum.*

5.9. INTEGRATED MANAGEMENT

Quick wilt complex of ginger is an emerging disease posing a great threat to the successful cultivation and production of ginger. The spread of this disease is through planting materials and soil. Efforts were made in the past to reduce or prevent this disease with suitable intervention of different management strategies and tactics by targeting individual pathogens. Also effective blending of different strategies was made through integrated approach to reduce the disease caused by *M. incognita* and *R. solanacearum* alone below damaging threshold level. However, in the present study, 12 individual and combined management modules were tested in pot as well field condition against *M. incognita* and *R. solanacearum* together causing quick wilt complex of ginger.

5.9.1. Pot Culture Trial:

Perusal of data under pot culture condition indicated increase in the parameters of plant height, number of tillers, dry weight of shoot, chlorophyll a, chlorophyll b, total chlorophyll including rhizome yield in all the treatments over check. Among the individual modules, seed soaking in streptocycline 0.02% (T_3) and seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seed (T_5) resulted in significant increase of dry weight of shoot over check. Ray *et al.,* 2005 have reported less mortality and enhanced yield of ginger plants infected with *R. solanacearum* by streptocycline treatment similar to the present study. Application of *P. fluorescens* resulting in enhanced growth and yield including reduction in the disease incidence caused by either *M. incognita* or *R. solanacearum* similar to the present investigation was reported by Anita and Rajendran, 2002; Shanthi and Sivakumar, 2005; Senthamarai *et al.,* 2006; Maketon *et al.,* 2010; Kumar *et al.,*, 2011; Dutta *et al.,* 2011; Kavitha *et al.,* 2011 and Kumar *et al.,* 2012. Soil drenching with phosphonic acid 300 ppm (T_4), soil application of neem cake @ 1.5 t/ha (T_6) and soil application of sesame cake @ 1.5 t/ha (T_7) resulted in significant increase in number of tillers and dry weight of shoot. Maragrey *et al.,* 1990; Holderness, 1990; McGregor and Franz, 2002 and Babadoost *et al.,* 2010 have reported reduction in the incidence of several fungal and bacterial diseases by application of phosphorous acid. Enhanced growth and yield by application of neem cake as observed in the present study is in conformity with the works of Singh *et al.,* 1985; Borah and Phukan, 1992; Vadhera *et al.,* 1998; Patel *et al.,* 1999; Ahmed and Choudhury, 2004; Yadav *et al.,* 2005; Sharma and Trivedi, 2009; Haseeb and Kumar, 2012; Rajvanshi, 2012 and Somasekhara *et al.,* 2013. Similarly, reduction in the population of *M. incognita* including increased yield by application of sesame oil cake as observed in the present study was also reported by Trivedi *et al.,*1978; Vijayalakshmi and Goswami, 1987; Youssef and El-Nagdi, 2004; Radwan *et al.,* 2009 and El. Sherif *et al.,* 2010. Further, combined application of different management modules resulted in significant increase of different growth, physiological and yield parameters. Significant increase in plant height, number of tillers and dry weight of shoot was observed in seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + phosphonic acid 300 ppm (T_9) and seed soaking in carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed (T_{10}). However soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) were very effective in significant increase in plant height, number of tillers, dry weight of shoot, chlorophyll a, chlorophyll b, total chlorophyll including rhizome yield. Reduction in the population of *M. incognita* and improved plant growth as observed in the present study by carbosulfan application is in conformity with Pareek *et al*., 1998; Vadhera *et al*., 1999; Vats *et al*., 2000;

Karbasayya and Rahman, 2001a; Sharma and Majumdar, 2003; Ravishankar and Singh, 2005; Sharma and Kashyap, 2005; Shevale *et al*., 2006and Gowda *et al*., 2013. Carbosulfan (0.5%) in combination with streptocycline (0.02)/phosphonic acid 300 ppm/*P. fluorescens* as well as sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm and neem cake @ 1.5 t/ha + phosphonic a 300 ppm were effective in improving the growth and yield of ginger. The effectiveness of the later two treatments are attributed to the nutrient elements present in both the oil cakes including phosphonic acid resulting in improved growth and yield as compared to other treatments.

5.9.2. Field Trial:

The results of the field trial revealed a general increase in plant growth, yield and decrease in disease incidence over check. Significant increase in percentage germination, plant growth, yield and decrease in disease incidence including population of *M. incognita* in both soil and root was observed among the various management modules during season I and II as well as in the pooled mean. Among the individual management modules, modules comprising of seed soaking in carbosulfan 25 EC 0.5% (T_2) and soil drenching with phosphonic acid 300 ppm (T_4) resulted in significant increase in growth, yield and decrease in nematode parameters as compared to others. The above two treatments recorded higher B: C ratio as compared to check as well as other individual management modules. The results of the present study is in corroboration with the findings of first season pot culture trial with regards to improved growth and yield in the above two treatments. Seed treatment with *P.*

fluorescens @ 10 g/ kg seed (T_5), soil application of neem cake @ 1.5 t/ha (T_6) and soil application of sesame cake @ 1.5 t/ha (T_7) also exhibited similar trend to that of the above two treatments except plant height which was found to be not significant. The enhancement of growth and yield parameters including decrease in disease incidence as observed in the present study is in conformity with the works of several workers already cited in the pot culture experiment.

Combined application of seed soaking in carbosulfan 0.5% + streptocycline 0.02% (T_8), seed soaking in carbosulfan 0.5% + soil drenching with phosphonic acid 300 ppm (T_9), seed soaking in carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) also resulted in significant increase in plant growth, percentage germination as well as decrease in disease incidence including reduction in the population of nematode in both soil and root. All the above integrated management modules recorded higher B: C ratio than the check as well as individual management modules. Integrated management of *M. incognita*/*R. solanacearum* and *M. incognita* + *R. solanacearum* using a combination of carbofuran + streptocycline was carried out by Hazarika and Bora, 2007; Husain and Bora, 2008 and Raghu *et al.*, 2013. Although carbosulfan was a component in the management modules of the present study along with streptocycline, results of present findings are in conformity with the above workers in which carbofuran was a component instead of carbosulfan. Hence, the similarity in results is due to similar mode of action by carbofuran and carbosulfan both belonging to dithio carbamate group of nematicides. The efficacy of combined application of carbosulfan 0.5% + phosphonic acid 300 ppm in the present study is in extension to the work carried out by Patel and Patel, 1999; Das and Sinha, 2005; Norman *et al.*, 2006 and Munawar *et al.*, 2011. Management modules comprising of seed soaking in carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significant increase in plant growth, percentage germination, yield including decrease in percentage wilting, root knot index and population of nematode in both soil and root which were significantly different as compared to rest other treatments and were at par with each other. However, soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) with B: C ratio 3.16: 1, soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) with B: C ratio 2.99: 1 and seed soaking in carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed (T_{10}) with B: C ratio 2.88: 1 were highly effective in the management of quick wilt complex. Use of carbosulfan and *P. fluorescens* for mangement of *M. incognita*/ *R. solanacearum* or *M. incognita* + *R. solanacearum* was reported by Anith *et al.*,2000; Devanath *et al.*, 2002; Mahapatra and Mohanty, 2002; Barua and Bora, 2009; Haseeb and Kumar, 2009 is in agreement with the present study. The efficacy of this management module is attributed to active nematicidal components of carbosulfan as well as to induce systematic resistance, production of siderophores, hydrogen cyanide (HCN), phytohormones, phytoalexins, lignifications and PR proteins by *P. fluorescens* harmful to both *M. incognita* and *R. solanacearum.* Integrated management of *M. incognita* alone or combined with *R. solanacearum* by use of neem cake with various combinations was carried out by Singh and Kumar, 2000; Chakrabarti and Mishra, 2001; Bhat *et al.,* 2005; Kalita and Bora, 2006; Bandyopadhyay and Bhattacharya, 2012. The efficacy of neem cake in the management of *M. incognita*, *R. solanacearum* and both together in various crop plants similar to the present study is due to its wide biocidal properties including its property to improve the soil texture and structure. Marked increase in the plant growth, yield and significant reduction in population of *M. incognita* as recorded in the present study by application of sesame oil cake was also reported by Bhatnagar *et al.*, 1978; Vijayalakshmi and Goswami, 1987; Murthy and Rao, 1992. Sesamum oil cake contains a mixture of unsaponifiable and unsaturated materials in high concentrations like linolenic, linoleic, palmitic, stearic and oleic acid including aldehydes and ketons possessing nematostatic and nematicidal properties which resulted in low population of nematodes including higher plant growth and yield. In the present study, soil drenching with phosphonic acid 300 ppm was found to be very effective in reducing the quick wilt complex either applied alone or in combination with neem cake or sesame oil cake. Management of several fungal and bacterial diseases by application of phosphonic acid was reported by Norman *et al.,* 2006; Wen *et al.,* 2009; Lin and Wang, 2011 and Rolanda *et al.,* 2014. Phosphonic acid (H_3PO_3) is a white crystalline solid which dissociates to phosphonate ($H_2PO_3^{--}$

) ions in aqueous solution having fungicidal and bactericidal properties mostly used as an anti microbial product in many countries of the world. Thus, combined application of phosphonic acid with neem cake or with sesame cake was more effective in the present study. Integrated management module comprising of soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}) and soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) are solely the original and new contributions to the management of quick wilt disease complex of ginger. Hence, soil application of sesame cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{11}), soil application of neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) and seed soaking in carbosulfan 0.5% + *P. fluorescens* @ 10 g/kg seed (T_{10}) are most effective, bio rational, environmentally sound and economically viable integrated management modules in the decreasing order for management of devastating quick wilt disease complex.

SUMMARY AND CONCLUSION

The present investigation was undertaken during 2011-2013 in the department of Nematology, Plant Physiology, Seed technology and Agrometereology to carry out the interaction and management of quick wilt of ginger caused by *Meloidogyne incognita* and *Ralstonia solanacearum*. The study included isolation and characterization of pathogens of quick wilt, interaction between root knot nematode *M. incognita* and *R. solanacearum*, physiological and biochemical response of ginger to the infection of *M. incognita* and *R. solanacearum* in the development of disease complex, histopathological changes of ginger to *M. incognita* and combined inocula of both *M. incognita* and *R. solanacearum*, estimation of avoidable yield loss and development of cost effective, eco friendly disease management modules which are summarized hereunder.

The isolates of bacteria and nematodes collected from three geographical locations *viz*., Bhubaneswar, Pottangi and Phulbani were cultured and multiplied on suitable substrates and subjected to their identification and characterization. The bacterial isolates with gram negative reactions and other biochemical and antibiotics tests were confirmed as *R. solanacearum*. The isolated nematode on the basis of larval morphology, measurements and perineal pattern of adult females was diagnosed as *M. incognita*.

M. incognita alone induced reduction in growth and vigour, chlorosis and numerous beaded galls on roots of ginger. *R. solanacearum* inoculated plants exhibited deep water soaked spots on collar region which progressed both upward and downward, drooping and curling of margins of lower leaves followed by wilting at 27 days after inoculation. The simultaneous inoculation of both the pathogen (N+B) and *M. incognita* followed by *R. solanacearum* (N→B) exhibited wilting at 22 days and 17 days after inoculation.

Significant reduction in plant growth and yield including nematode infectivity was observed by individual and combined inoculation studies of both the pathogens. However, synergistic reduction in plant height, dry weight of shoot and rhizome yield was recorded in treatments having *M. incognita* and *R.solanacearum* combined together (N+B) and *M. incognita* followed by *R.solanacearum* (N→B) which also exhibited synergistic reduction in root knot index.

M. incognita and *R. solanacearum* alone, together and sequential inoculation studies significantly reduced various physiological and biochemical characteristics *viz*., leaf water potential, chlorophyll, stomatal conductance, fluorescence, Phi PSII, Phi CO_2 and photosynthesis including increase in physiological parameters which were more prominent in *M. incognita* + *R. solanacearum* combined inoculums (N+B) and *M. incognita* inoculated prior to *R. solanacearum* (N→B) by 10 days.

Second stage larvae of *M. incognita* induced variable number of multinucleated giant cells in the central cylinder of ginger root along with hypertrophied cortical, phloem and hyperplastic pericycle cells resulting in gall formation. The giant cell nuclei and nucleoli were enlarged with dense cytoplasm. However, in the combined infection of *M. incognita* and *R. solanacearum* extensive damage of cortical cells, giant cell colonization by bacterial inclusion, formation of cavities including rapid degeneration of giant cells were observed.

The avoidable loss in rhizome yield induced by *M. incognita* and *R. solanacearum* together in a naturally infested field was 24.57 per cent.

Soaking of ginger rhizomes in 0.5% carbosulfan (T_2) for 30 minutes resulted significant increase in all the growth and yield parameters, decrease in percentage germination at 30 DAS, percentage wilted plant, soil and root population including root knot index over check followed by soil drenching with phosphonic acid at 300 ppm applied @ 0.6 kg/ha (T_4). Among the combined management modules, seed soaking in carbosulfan 25 EC 0.5% for 30 minutes + seed treatment with *P. fluorescence* @ 10 g/kg seed (T_{10}), soil application of sesame cake @ 1.5 t/ha at 21 days before sowing + phosphonic acid 300 ppm (T_{11}) and neem cake @ 1.5 t/ha + phosphonic acid 300 ppm (T_{12}) recorded significant increase in percentage germination, plant growth and yield, decrease in percentage of wilting, population of nematodes in soil and root as well as root knot index which were at par with each other. Out of these three modules, sesame cake @ 1.5 t/ha at 21 days before sowing + soil drenching with phosphonic acid 300 ppm (T_{11}) was the most economic, environmentally sound, bio rational management module with a high cost benefit ratio of 3.16:1.

Conclusions:

- Isolation of *M. incognita* and *R. solanacearum* from infected ginger plants of three geographical locations of the sate exhibiting quick wilt symptoms was carried out and their characterization was done through standard protocol confirming the identity.
- Simultaneous inoculation of *M. incognita* @ 1000 J_2/kg soil + *R. solanacearum* @ 4×10^6 cfu/ml/kg soil (N+B) and *M. incognita* @ 1000 J_2/kg soil followed *R. solanacearum* @ 4×10^6 cfu/ml/kg soil (N→B) synergistically reduced plant height, dry weight of shoot and rhizome yield including reduction in infectivity as well as population of *M. incognita*.
- Presence of *M. incognita* in simultaneous inoculation (N+B) and *M. incognita* preceding the inoculation of *R. solanacearum* by 10 days reduced the incubation period of wilting by 5 and 10 days respectively
- *M. incognita* and *R. solanacearum* together synergistically reduced various physiological and biochemical process and increased dark respiration of ginger plant.

- Nematode infection in ginger caused disorganisation of vascular tissues, formation of giant cells for colonisation of *R. solanacearum* including gall formation and extensive cavities and degradation confirming the role of both the pathogens in the quick wilt complex.
- *M. incognita* played significant role not only by predisposing ginger roots to invasion by *R. solanacearum* but modified the host substrate to the advantage of bacterium.
- *M. incognita* and *R. solanacearum* combinely caused a yield reduction to the tune of 24.57 per cent.
- Soil application of sesame oil cake @ 1.5 t/ha + soil drenching of phosphonic acid 300 ppm (T_{11}) was the best integrated diseased management module to combat quick wilt disease complex.

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Appendix I

Weather Data

Climate Bhubaneswar historical weather **(2011)**
Data reported by the weather station: **429710 (VEBS)**
Latitude: **20.25** | Longitude: **85.83** | Altitude: **45**
Weather Bhubaneswar

Average climatic values and annual totals

To calculate annual averages, we analyzed data of 360 days (98.63% of year).

If in the average or annual total of some data is missing information of 10 or more days, this is not displayed.

The total rainfall value 0 (zero) may indicate that there has been no such measurement and / or the weather station does not broadcast.

Data	Valor	Computed days
Annual average temperature:	**26.8°C**	360
Annual average maximum temperature:	**33.1°C**	360
Annual average minimum temperature:	**22.1°C**	360
Annual average humidity:	**75.4%**	360
Annual total precipitation:	**1661.67 mm**	356
Annual average visibility:	**2.4 Km**	360
Annual average wind speed:	**9.5 km/h**	360

To calculate the average temperature used **2863** measurements.
To calculate the average wind speed used **2863** measurements.

Total occurrences

Number of days with extraordinary phenomena.

Total days with rain:	**104**
Total days with snow:	**0**
Total days with thunderstorm:	**72**
Total days with fog:	**25**
Total days with tornado or funnel cloud:	**0**
Total days with hail:	**0**

Days of extreme historical values in 2011

The highest temperature recorded was **42.6°C** on May 11.
The lowest temperature recorded was **9.9°C** on January 12.
The maximum wind speed recorded was **92.4 km/h** on May 16.

Interpretation

T-Mean temperature (°C)
TM-Maximum temperature (°C)
Tm-Minimum temperature (°C)
SLP-Mean sea level pressure (hPa)
H-Mean humidity (%)
PP-Precipitation amount (mm)
VV-Mean visibility (Km)
V-Mean wind speed (Km/h)
VM-Maximum sustained wind speed (Km/h)
VG-Maximum wind gust (Km/h)
RA-Indicator for occurrence of: Rain or Drizzle
SN-Indicator for occurrence of: Snow or Ice Pellets
TS-Indicator for occurrence of: Thunder
FG-Indicator for occurrence of: Fog

January(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	22.3	30.4	14.6	1009.5	73	0	1.6	4.1	13	-				
2	20	25.2	16	1012.6	72	0	1.3	8.9	16.5	-				O
3	18.7	25.1	14.7	1014.1	61	0	1.6	9.1	18.3	-				
4	16.9	23.5	13	1013.8	65	0	1.6	6.7	11.1	-				
5	17	24.8	10.8	1012.9	62	0	1.9	6.1	9.4	-				
6	16.1	25.7	11.2	1014.1	70	0	1.8	6.9	13	-				
7	17.4	25.4	10.4	1013.3	63	0	1.8	7.6	13	-				
8	19.2	25.5	11.9	1011.5	59	0	1.9	8.3	16.5	-				
9	19.8	28	13.1	1011.1	64	0	2.1	6.3	11.1	-				
10	19.3	28.4	13.9	1011.1	63	0	1.6	5.4	9.4	-				
11	18	27.2	11.1	1012	58	0	1.6	5.4	7.6	-				
12	18.3	28.5	9.9	1011.4	56	0	2.1	4.6	7.6	-				
13	19.6	28.6	11.8	1012.5	62	0	1.9	5.4	7.6	-				
14	19.9	28.6	12.8	1012.9	71	0	1.8	4.1	5.4	-				
15	21.8	32	13.5	1013.2	72	0	1.8	9.3	14.8	-				O
16	22.3	31.8	13.8	1010.4	67	0	2.6	9.3	18.3	-				
17	20.8	29.6	14	1011.9	52	0	2.9	5.9	9.4	-				
18	19	29.7	12	1011.7	65	0	2.3	6.7	14.8	-				
19	22.7	31.2	15	1010.6	73	0	2.3	7.8	18.3	-				
20	21.9	28	18	1013.2	77	0	1.9	6.7	16.5	-				
21	20.7	27.8	15.9	1013.7	65	0	1.9	7.8	16.5	-				
22	21.2	29.2	14.8	1014.8	74	0	1.4	3.1	7.6	-				
23	22.1	31.1	15.2	1015.8	68	0	1.8	3.3	9.4	-				O
24	22.5	32.6	14.6	1015	66	0	1.9	5.6	11.1	-				O
25	24.6	33	15.8	1014.9	63	0	1.9	3.9	7.6	-				O
26	24.2	32	19.6	1016.1	73	0	1.3	4.8	9.4	-				O
27	24.3	33.4	18.8	1015.7	71	0	1.6	8.3	22.2	-				O
28	22.7	29.7	18.4	1015.2	74	0	1.6	7.4	11.1	-				O
29	23.7	30.6	18.6	1013.8	77	0	1.4	7.2	16.5	-				
30	24.1	31.8	20	1013.9	76	0	1.1	7.2	11.1	-				O
31	25	31.7	20.4	1014	75	0	1.4	4.6	9.4	-				O
Monthly means and totals:														
	20.8	29	14.6	1013.1	67.3	0	1.8	6.4	12.4		0	0	0	10

February(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	23.8	30.3	19.5	1014.8	65	0	1.4	7.6	18.3	-				
2	23.3	30	17.8	1014.7	71	0	1.4	5.7	11.1	-				O
3	22.6	29.8	17.2	1014.7	64	0	1.6	6.7	11.1	-				
4	22.7	31.3	16.1	1013.4	61	0	1.6	4.6	14.8	-				
5	23.1	30.6	16	1012.6	64	0	1.6	3.9	9.4	-				
6	23.8	31.6	17.1	1012.4	64	0	1.4	5.6	13	-				O
7	24.7	34.1	16	1010.5	62	0	1.4	6.5	11.1	-				O
8	24.9	35.2	15.7	1008	57	0	2.6	6.1	9.4	-				
9	24.8	34.6	15.9	1008.3	53	0	2.1	8.1	20.6	-				
10	24.6	33.6	17.5	1011.2	58	0	1.8	6.7	13	-				
11	25.7	34	18.3	1011.6	64	0	2.1	7	14.8	-				O
12	26.3	34.9	20.6	1010.5	65	0	1.8	8	18.3	-				O
13	26.1	36	20	1009.1	58	0	2.1	4.8	11.1	-				O
14	26.5	37	18	1008.8	58	0	2.3	8.9	18.3	-				O
15	27.5	37.5	19	1009.8	49	0	3.1	11.3	18.3	-				
16	24.9	34.1	20.4	1010.5	72	0	2.3	11.9	27.8	-				O
17	26.3	34.4	19.6	1010.5	72	0	2.4	8	18.3	-				
18	25.4	31	22.4	1011.4	79	0	1.8	10.2	14.8	-				
19	25	32.1	21.4	1013.3	81	37.08	2.3	12.6	20.6	-	o			
20	23.1	28.7	19.6	1013.8	87	0.51	1.9	12	16.5	-	o		o	
21	21.3	25.3	19.2	1014.4	89	11.94	1.1	7.6	11.1	-	o			
22	23.4	29.2	17	1014	67	0	1.4	4.8	7.6	-				O
23	23.2	30.5	16.8	1014.4	64	0	1.8	4.8	7.6	-				
24	23.8	31.2	17.3	1012.3	64	0	1.6	7.4	11.1	-				
25	25	32.6	18.1	1009.9	67	0	2.6	6.3	16.5	-				
26	25.3	32.4	19.8	1011.3	72	0	1.6	4.6	16.5	-				
27	27.1	33	19.4	1013.3	57	0	2.6	5.7	11.1	-				
28	24.8	32.6	19.4	1013.9	56	0	2.4	10.2	20.6	-				
Monthly means and totals:														
	24.6	32.4	18.4	1011.9	65.7	49.53	1.9	7.4	14.7		3	0	1	9

March(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	24.8	32.7	17.7	1012.3	57	0	2.6	5	9.4	-				
2	25.7	34	18.2	1011.2	59	0	1.9	6.7	16.5	-				
3	27.1	36.1	19.8	1010.8	65	0	2.3	8.1	18.3	-				
4	27.9	37.3	19.7	1009.6	56	0	2.9	11.1	18.3	-				
5	28.3	37.9	20.7	1009.9	58	0	2.7	10	16.5	-				
6	29.1	38.6	21.3	1011.2	55	0	3.1	6.9	14.8	-				
7	28.3	36.6	22.2	1011.3	61	0	1.9	7.8	16.5	-				O
8	28.9	37.7	22.6	1009.4	54	0	2.6	7.8	14.8	-				O
9	28.1	38	19.3	1009.6	62	0	1.8	11.1	25.9	-				
10	29	37.8	24	1010.1	60	0	2.6	16.7	29.4	-				
11	27.7	35.3	21.8	1009.9	66	0	3.1	13.7	25.9	-				
12	27.6	35.1	22.4	1010.6	69	0	2.7	11.7	18.3	-				
13	27.8	36.4	22.5	1010.2	70	0	3.1	8.5	14.8	-				
14	28.8	36.6	22.9	1009.3	70	0	2.9	10	-	-				
15	26.5	35.8	21.8	1009.5	63	0	2.6	14.1	37	-	o		o	
16	26.1	33.7	19.1	1008.8	57	0	2.7	7	9.4	-				
17	27.1	35	19.2	1009.2	66	0	3.2	13	22.2	-				
18	27.7	34.7	22.5	1007	70	0	3.1	23.3	29.4	-				
19	28.8	36.1	23.7	1005.5	74	0	2.6	22.4	25.9	-				
20	28.9	36.1	24.8	1005.6	75	0	2.7	24.1	33.5	-				
21	28.7	35.5	25	1006.8	76	0	2.7	27	37	-				
22	29.3	36.8	25.4	1007.8	75	0	2.6	18.5	25.9	-				
23	29.2	36.2	25.4	1008.8	73	0	2.7	18.5	25.9	-				
24	28.6	35.7	24	1009.5	69	0	3.1	15.9	25.9	-				
25	27.2	32.5	22.3	1009.8	74	0	2.3	11.5	18.3	-				
26	28.8	36	23	1009.5	67	0	2.7	14.4	27.8	-				o
27	29.7	38	23.8	1008.5	70	0	2.9	15.7	27.8	-				
28	29.6	37.1	24.9	1008.1	73	0	2.7	18.3	25.9	-				
29	29.7	36.3	25	1008.4	71	0	2.7	24.8	29.4	-				
30	29.8	35.7	26	1007.1	75	0	3.5	29.8	37	-				
31	29.9	37.2	25.6	1007.7	74	0	2.7	15	25.9	-				
Monthly means and totals:														
	28.2	36.1	22.5	1009.1	66.6	0	2.7	14.5	23.5		1	0	1	3

April(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.7	36	25.5	1008.4	75	0	2.7	18.7	29.4	-				
2	29.3	35.2	25.1	1008.4	76	0	1.9	18.9	27.8	-				
3	29.8	35.7	25.2	1008.1	76	0	1.9	23.2	27.8	-				
4	28.9	35	25	1008.5	73	0	2.6	19.1	27.8	-	o			
5	25.1	32.7	21.9	1011.6	80	3.05	2.6	9.4	20.6	-			o	
6	28.8	36.4	21	1010.9	64	0	2.7	9.3	24.1	-				
7	30	37.6	24.2	1010.5	68	0	2.6	14.8	22.2	-				
8	30.4	39.1	24	1010.1	56	0	2.7	16.1	25.9	-				
9	30.5	37.7	24.9	1011.3	61	0	2.7	8	11.1	-				
10	29.7	37.2	23.1	1011.9	65	0	1.9	9.8	16.5	-	o			
11	30.3	38	24.5	1010.1	66	0	2.7	11.9	20.6	-				
12	30.4	38.9	24.2	1009.4	64	0	3.1	13	22.2	-				
13	30.5	38.5	25	1009.4	68	0	2.9	15.9	25.9	-				
14	29.2	36.1	24	1008.2	64	0	2.6	17.2	25.9	-				
15	29.9	39.6	24.7	1007.5	72	6.1	2.7	13	22.2	-				
16	30.4	37.6	25.8	1008.7	71	0	3.1	16.9	29.4	-				
17	30.7	38	26.1	1008.2	75	0	2.7	14.1	25.9	-			o	
18	31.6	39.7	26.4	1005.5	71	0	2.7	22	25.9	-				
19	28.2	34.5	24.8	1007.4	79	3.05	2.4	18	44.3	-	o		o	
20	30.9	38.5	23.4	1007.2	60	0	3.1	12	25.9	-				
21	29.6	37.1	25.2	1008.4	73	1.02	2.7	13.9	25.9	-	o		o	
22	27.4	32.6	20.8	1008.4	77	0	2.7	9.3	16.5	-	o			
23	30.3	38.2	23.5	1006.7	60	0	3.5	15.2	31.3	-				
24	29.3	37.1	24.8	1007.5	65	0	3.1	15.6	29.4	-	o			
25	29.3	35.6	23.1	1007.9	69	0	3.5	12	22.2	-				
26	28.5	35.2	22.1	1008.4	66	0.25	3.2	9.3	20.6	-				
27	27.7	35.6	23.8	1006.2	78	0	2.6	7.6	14.8	-	o		o	
28	28.8	35.7	22	1004.2	67	0	3.2	8.9	25.9	-				
29	28.1	38	22.6	1004.9	75	13.97	2.7	11.7	18.3	-	o		o	
30	29.9	36.6	21.2	1006.4	73	0	3.2	13.5	24.1	-				
Monthly means and totals:														
	29.4	36.8	23.9	1008.3	69.6	27.44	2.8	13.9	24.3		8	0	6	0

May(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.6	37.6	25	1006.2	70	0.51	3.1	14.1	27.8	-	o		o	
2	30.8	38.4	22.6	1004.1	73	0	3.1	13.7	29.4	-				
3	31.8	38.6	26.4	1003.2	72	0	3.1	20.9	27.8	-				
4	31.4	37.8	24.8	1004.1	76	-	2.3	22	33.5	-	o		o	
5	30.1	37.6	23.5	1004.7	67	2.03	3.1	18.3	27.8	-	o		o	
6	28.8	33.6	22.6	1004.5	74	11.94	2.7	10.9	18.3	-				
7	29.1	36.4	25.8	1002.8	77	0	1.9	5.7	11.1	-				
8	30.1	35.6	25.2	1002.5	74	9.91	2.7	12	16.5	-				
9	31.8	39.6	24.6	1001.9	67	0	3.2	14.8	22.2	-				
10	33.1	40.6	27.6	1001.2	70	0	2.6	19.6	29.4	-				o
11	33.9	42.6	28.5	1001.1	63	0	2.1	13.7	24.1	-				
12	33.7	42.2	28.6	1002.4	58	0	2.1	10.6	25.9	-				
13	33	40.3	27.9	1002.5	70	0	2.6	14.6	25.9	-				
14	31.7	37.6	28.8	1003.8	79	0	1.9	12	20.6	-				
15	32.4	39.1	28.4	1006	70	0	2.7	18	25.9	-				
16	30.9	37	28.4	1008.3	78	0	2.9	18.5	92.4	-				
17	31.9	38.2	27.4	1006.6	72	0	3.1	23.5	29.4	-				
18	32.1	38.1	28.6	1004.5	70	0	2.7	27.8	33.5	-				
19	29.8	39	23	1003.9	76	77.98	2.6	25.4	38.9	-	o		o	
20	26.2	29.8	22	1002.2	85	-	2.7	16.5	24.1	-	o		o	
21	29.1	34.8	24	1000.6	83	0	2.7	24.1	35.2	-				
22	31.4	37.2	27.6	1002.4	83	0	2.6	18.7	25.9	-				
23	31.5	36.8	28.3	1003	81	2.03	2.4	15.6	22.2	-	o			
24	30.7	37.3	26	1002.5	73	0	2.1	16.7	22.2	-			o	o
25	31.7	37.2	25.8	1002.2	81	0	2.1	19.8	24.1	-				
26	30.1	37.7	25	1003.4	76	7.11	2.6	12.2	16.5	-			o	
27	30.4	35.9	24	1003.1	73	0	3.1	9.1	16.5	-				
28	31.3	36.4	27.4	1001.8	78	0	2.7	7.6	14.4	-			o	
29	30.5	38.2	27	1002	74	2.03	2.1	9.1	14.8	-			o	
30	31.5	36.9	26.4	1001.2	76	0	1.9	9.4	14.8	-				
31	32.7	38	28.6	1000.3	73	0	2.3	18.5	27.8	-			o	
Monthly means and totals:														
	31.1	37.6	26.1	1003.2	73.9	113.54	2.6	15.9	26.4		6	0	10	2

June(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	31.8	38	26.4	1001.4	72	0	2.6	12	18.3	-				
2	31.9	37.4	27.3	1003.6	72	0	3.1	14.8	25.9	-				
3	31.4	37.6	27	1003.6	74	0	2.6	13	20.6	-			o	
4	29.8	38.2	25.4	1002.3	81	26.92	3.1	9.6	14.8	-	o		o	
5	29	34.7	24.5	1002.6	87	0	2.6	5.4	9.4	-	o		o	
6	31.2	36.6	26.8	1002.7	78	0	2.1	7.6	22.2	-				
7	30.6	36.6	26.6	1001.8	76	0	2.1	8.3	14.8	-				
8	31.2	36	25.8	1000.8	74	0	1.9	10.6	16.5	-				
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	29.7	36.2	23.8	997.8	79	8.89	3.1	9.8	20.6	-	o		o	
15	25.2	27.3	23.6	997.1	99	23.11	1.9	15	18.3	-	o		o	
16	26.1	28.1	23.9	995.8	98	67.06	2.3	13.3	18.3	-	o			
17	26.2	27.7	24.8	995	97	17.02	2.3	15	24.1	-	o			
18	27.3	32.1	24.2	994.3	92	12.95	2.6	17	25.9	-	o		o	
19	29.5	33.3	24.8	994.8	83	18.03	3.1	17.2	25.9	-	o			
20	29.3	34.7	26.2	997.4	86	0.51	2.6	8.3	25.9	-	o		o	
21	28.9	35.8	25.2	999	86	5.08	2.1	8.5	22.2	-	o		o	
22	29.2	35.3	25	999.1	85	13.97	2.6	11.9	33.5	-	o			
23	29.2	35.8	26.4	999	86	1.02	2.7	11.7	14.8	-	o		o	
24	29.8	35.8	25.9	998.2	84	22.1	3.1	10	14.8	-	o		o	
25	28.2	33.4	25	997.4	91	14.99	2.1	10.7	14.8	-	o		o	
26	28.2	32.2	25.8	997.9	87	7.87	3.2	10	22.2	-	o			
27	28.8	33	26.3	998.1	86	2.03	3.2	9.4	18.3	-	o			
28	29.4	34.1	26.7	998.6	86	0	2.6	8.1	18.3	-	o			
29	29.4	34.6	26.3	1000.6	87	1.02	2.6	10.2	14.8	-			o	
30	29.2	35.5	26	1001.7	87	0.51	2.4	7.6	14.8	-	o		o	
Monthly means and totals:														
	29.2	34.4	25.6	999.2	84.5	243.08	2.6	11	19.6		18	0	13	0

July(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.3	35	26	1001.6	90	34.04	1.9	7.4	14.8	-			o	o
2	29.4	34.4	25.7	1000.8	83	14.99	1.9	10.2	18.3	-				
3	29.3	33.7	25.7	1001.9	82	0	2.7	9.6	14.8	-				
4	26.9	30.2	24	1003.1	91	5.08	2.1	6.1	11.1	-	o			
5	27.9	32	25.6	1002.1	84	3.05	2.6	6.7	14.8	-	o			
6	27.2	30.9	25	1001.9	90	1.02	2.6	10.9	18.3	-	o			
7	25.8	28.2	23.5	1004.7	98	67.06	2.6	12.8	20.6	-	o			
8	28.4	31.6	25	1005.7	88	6.1	3.1	16.1	22.2	-				
9	29.6	35.4	26.8	1003.6	85	0	2.6	11.1	16.5	-	o		o	
10	30.8	35.4	26.7	1001.5	79	0.76	3.2	11.5	24.1	-				
11	29.8	34.2	26.4	999.1	81	0	2.9	10.7	16.5	-	o			
12	27.8	33.4	25	997.6	92	9.91	2.3	6.9	13	-	o		o	
13	28.1	31.5	25.6	997.1	95	19.05	2.3	5.6	13	-	o			
14	28.9	32.4	25.3	997.3	88	25.91	3.1	11.5	18.3	-				
15	29.4	33.7	26.6	997.6	87	0	2.7	11.1	14.8	-			o	
16	27.8	32.6	26	997.8	95	0.25	2.1	6.3	11.1	-	o		o	
17	26.7	28.7	25	998.2	99	105.92	2.1	8	11.1	-	o		o	
18	28.4	33.3	26.4	998.7	94	8.89	2.6	13.3	18.3	-	o		o	
19	28.1	32.2	26	998.2	95	3.05	1.9	12	18.3	-	o		o	
20	27.7	32.4	25	996.7	94	17.02	2.4	14.1	18.3	-	o		o	
21	25.8	27.9	24.6	996.8	99	38.1	1.9	13.3	18.3	-	o			
22	26.5	31.1	23.4	998.7	87	7.11	3.1	10.6	22.2	-	o		o	
23	27.5	32.3	24.4	1000.5	89	0	3.1	8.3	14.8	-	o			
24	28.7	33.5	24.4	1001.9	84	8.89	2.9	5.6	7.6	-				
25	27.4	32.9	25.6	1004.9	93	0	2.4	4.6	9.4	-	o		o	
26	28.8	32.6	25.4	1005.6	83	21.08	3.1	8.5	18.3	-				
27	29.5	33.7	26	1003.9	81	0	3.2	11.1	18.3	-				
28	29.9	34.7	26.6	1002.2	82	0	3.1	9.4	16.5	-			o	
29	30	34.9	26.7	1001.6	81	0	3.2	8.5	14.8	-				
30	30.2	34.6	26.8	999.9	80	0	3.5	8.5	16.5	-				
31	30.8	36	26.7	998.6	79	0	3.5	7.8	16.5	-				
Monthly means and totals:														
	28.5	32.8	25.5	1000.6	88	397.28	2.7	9.6	16.2		17	0	12	1

August(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	28.2	35.8	25.2	998.3	88	46.99	2.6	8.1	22.2	-	o		o	
2	28	34.5	24.2	998.6	92	36.07	2.6	8.5	14.8	-	o		o	
3	27.2	30.7	25.5	999.4	97	5.08	2.3	9.1	16.5	-	o		o	
4	28.6	32	26.1	999.6	93	0.51	2.7	11.3	18.3	-	o		o	
5	28.6	32.2	26.4	999.1	93	16	2.3	10.7	20.6	-	o		o	
6	27.4	31.7	26	998	97	71.12	1.9	12	22.2	-	o		o	
7	28.2	31.6	25.4	997.6	95	4.06	2.4	8.1	14.8	-	o		o	
8	28.8	31.6	26.3	999.1	92	-	2.3	17	24.1	-	o		o	
9	27.8	32.1	26.8	1001.4	94	0	1.9	17.6	33.5	-			o	
10	27.6	32.7	26	1001.9	94	11.94	2.6	13	25.9	-	o		o	
11	26.6	31.2	25	1000.5	97	18.03	2.3	12.2	16.5	-	o			
12	26.5	29.4	24.2	997.1	97	18.03	2.3	17	22.2	-	o			
13	28.2	33	25	999.1	89	1.02	3.7	15.6	25.9	-				
14	29.4	33.7	26.8	1004.8	85	0	3.2	19.3	35.2	-				
15	29.6	34.1	26.7	1005.7	85	0	2.7	13.5	22.2	-				
16	29.3	34.4	25.9	1004.5	85	0	2.7	12	22.2	-				
17	27.7	33.2	24.8	1003.8	87	19.05	3.1	7	14.8	-	o			
18	27	31.1	24.6	1003.5	93	-	2.7	4.6	14.8	-	o			
19	26.2	28.9	25.2	1004.1	97	0.51	1.9	5.4	9.4	-	o		o	
20	28.1	32.2	25	1005.1	87	19.05	2.7	8.5	14.8	-				
21	28.5	33.6	25	1005.1	87	1.02	3.4	6.5	11.1	-	o			
22	29	32.7	25.8	1005.4	85	0.76	3.1	11.5	22.2	-				
23	27.6	34.6	25.2	1004.4	90	0	2.6	9.3	14.8	-	o		o	
24	27.3	31.6	24.3	1002.8	93	21.08	2.3	5.9	18.3	-	o		o	
25	27.1	30.6	25.3	1002.3	95	10.92	1.9	5.6	9.4	-	o			
26	26.5	32.1	25.2	1001.3	97	4.06	2.3	5	18.3	-	o		o	
27	27.6	31.4	24.9	1000	93	85.09	2.9	3.3	9.4	-	o			
28	27.2	31.4	24.8	999.6	95	13.97	2.3	5.6	18.3	-	o		o	
29	26.6	30.2	25.4	1000.6	98	9.91	1.9	5.7	14.8	-	o		o	
30	27.8	30.5	25.6	1000.3	93	42.93	2.3	10.2	14.8	-	o			
31	26.4	29	25.2	1000.3	97	7.11	2.3	6.1	11.1	-	o			
Monthly means and totals:														
	27.8	32.1	25.4	1001.4	92.3	464.31	2.5	9.8	18.5		24	0	16	0

September(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	26.5	28.3	24.2	999.7	97	53.09	1.9	18.7	33.5	-	o			
2	27	30	24.3	1000.6	95	35.05	2.4	12.2	18.3	-	o		o	
3	26.2	29.1	25.2	1002.2	98	4.06	2.4	4.8	9.4	-	o		o	
4	26.3	30.3	24.7	1002.3	98	36.07	2.6	7.2	11.1	-	o		o	
5	26.3	28.6	24.7	1000.5	98	21.08	2.6	8.7	14.8	-	o			
6	26.8	31	24.8	999.9	95	9.91	2.1	13.1	27.8	-	o			
7	26.3	31.7	24.6	999.7	97	18.03	2.4	8.7	20.6	-	o		o	
8	26.7	29.6	24.4	999.8	94	24.89	2.3	13	22.2	-	o			
9	26.6	30.2	24.1	1002.3	94	4.06	3.1	8.5	20.6	-	o			
10	28.7	33.6	24.8	1003.5	85	0.25	3.1	7.6	16.5	-				
11	27.8	32.8	26	1002.7	92	0	2.6	2.8	7.6	-			o	
12	28.7	33.5	24.8	1002.6	88	4.06	1.9	5.7	14.8	-				
13	28.9	33.1	25.6	1002.1	85	0	2.6	5	14.8	-	o		o	
14	27.3	28.8	25.1	1001.8	96	12.95	1.9	5.4	9.4	-	o			
15	27.2	30.9	23.7	1002.2	96	7.87	2.7	5.2	9.4	-	o		o	
16	28.6	33.1	25.5	1002.9	93	10.92	2.3	12.6	18.3	-	o			
17	28.7	32.6	25.8	1001.5	87	1.02	2.7	11.1	14.8	-	o		o	
18	27.1	31	25	1003.1	92	0.51	3.1	10.2	22.2	-	o			
19	27.5	31.3	24.2	1004	88	8.89	3.1	9.6	14.8	-				
20	27	33.4	24.7	1002.9	90	0	2.7	9.8	18.3	-	o		o	
21	25.2	26.8	22.5	1000.9	99	67.06	1.9	14.1	18.3	-	o			
22	25.2	27.4	23.9	1000	95	16	1.9	20.4	33.5	-	o			
23	28.1	31.3	24.4	1001.1	87	2.03	3.1	14.3	24.1	-				
24	28	33.1	24.8	1003.9	85	0	2.7	9.3	22.2	-	o		o	
25	29.7	34.4	25	1005.4	83	0.76	2.6	10.4	18.3	-				
26	29.4	34	26.5	1005.9	83	0	2.7	8	11.1	-	o			
27	28.9	33.6	25.4	1005.3	78	0	3.2	7.4	14.8	-				
28	29	34.5	24.6	1005.4	76	0	2.6	7.2	11.1	-				
29	28.8	34.2	24.8	1005.3	77	0	3.1	8.3	14.8	-				
30	28.7	34	24.4	1005.5	79	0	2.7	5.2	11.1	-				
Monthly means and totals:														
	27.6	31.5	24.7	1002.5	90	338.56	2.6	9.5	17.3		20	0	10	0

October (2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	28.2	34	24.2	1005.3	75	0	3.1	7.8	11.1	-				
2	28.1	34.6	23.5	1005.7	73	0	3.1	6.3	9.4	-				
3	28.7	34.5	24.3	1005.7	72	0	2.7	5	9.4	-				
4	28.2	34.8	23.6	1006.5	73	0	2.7	5.7	11.1	-				
5	28.8	34.7	24.2	1008.6	79	0	2.7	5.7	13	-				
6	27.6	33.4	25.1	1009.4	89	23.11	2.3	3.9	7.6	-				
7	27.7	33.4	25.1	1009.2	85	0	2.7	4.8	11.1	-				
8	27	32.8	24.6	1009.2	88	0	3.5	4.8	9.4	-	o			
9	27.9	32.7	24.8	1010	86	0	3.1	5.6	13	-				
10	28.4	33.4	24.6	1010.6	84	0	3.5	4.3	13	-				
11	29.1	34.4	24.7	1010.9	80	0	2.7	5.9	11.1	-	o			
12	28.7	34.6	25.2	1009.7	81	0	2.7	6.3	14.8	-			o	
13	28.8	35.6	25	1008.4	83	0	2.3	5	7.6	-	o		o	
14	28.1	34.8	24.1	1007.4	82	0	2.3	4.8	7.6	-				
15	28.9	34.6	23	1007.3	77	0	1.9	3	5.4	-				
16	28.5	34.2	23.4	1007.7	78	0	1.9	4.1	7.6	-				
17	26.4	33.9	22.6	1008.6	75	0	2.3	4.1	5.4	-				
18	27.2	32.4	22.8	1006.8	79	0	1.9	7.6	13	-				
19	28.1	33.3	24	1006.4	79	0	3.1	5.7	11.1	-				
20	26.6	33.6	24	1008.2	87	4.06	2.6	4.6	22.2	-	o		o	
21	26.6	31	24	1008.8	89	0	3.1	4.3	14.8	-	o			
22	26.6	32.1	23.8	1009.6	85	0	2.7	5.7	13	-	o			
23	27.1	32.2	22.3	1010.8	81	0.76	2.7	4.8	11.1	-				
24	27.3	32.8	23.3	1011	76	0	1.9	4.8	11.1	-				
25	26.9	32.9	22.6	1010.9	77	0	1.9	5.2	11.1	-				
26	26.9	33	23.3	1011.6	74	0	1.6	4.8	9.4	-				
27	26.1	33.5	21.5	1012	67	0	2.6	3.7	7.6	-				
28	25.3	33.2	19	1012.2	67	0	2.3	4.3	9.4	-				
29	24.9	32.4	18.8	1011.5	65	0	2.3	6.9	11.1	-				
30	24.8	33	18.1	1010.7	62	0	2.9	3.7	7.6	-				
31	25.2	32.6	18.3	1011.5	65	0	2.3	3.9	7.6	-				
Monthly means and totals:														
	27.4	33.5	23.2	1009.1	77.8	27.93	2.6	5.1	10.6		6	0	3	0

November(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	25.8	32.4	19.8	1011.8	67	0	1.9	4.8	9.4	-				
2	25.7	32.9	20.5	1011.1	66	0	1.9	5.6	11.1	-				
3	24.9	33.2	18.7	1010.5	65	0	1.9	4.6	7.6	-				
4	24.7	33.2	18.2	1011.8	63	0	2.6	5.7	7.6	-				
5	25.2	33.7	18.8	1011.9	64	0	2.6	4.4	9.4	-				
6	26	34.8	18.5	1011.3	61	0	2.6	5.7	11.1	-				
7	25.1	34.3	18.5	1011.4	61	0	2.7	6.3	11.1	-				
8	23.7	32	18.2	1011.6	64	0	2.1	5.6	9.4	-				
9	24.2	32.5	18	1011.6	68	0	2.3	5.9	11.1	-				
10	25.1	32.9	18	1011.6	68	0	2.3	3.3	9.4	-				
11	25.4	34	19.5	1011.2	67	0	2.6	4.1	9.4	-				
12	25.9	33.5	19.7	1011.8	73	0	2.7	7.2	14.8	-				
13	25.6	32.7	20.5	1012.6	75	0	2.6	3.3	11.1	-				
14	25.7	32.6	21.1	1013.4	75	0	2.6	3.9	11.1	-				
15	25.7	31.6	20.9	1013.4	74	0	2.3	4.6	9.4	-				
16	24.6	31.8	20.4	1013	70	0	1.9	4.6	7.6	-				
17	23.9	32.3	16.9	1013	60	0	2.7	4.8	7.6	-				
18	24.4	34	17	1012.2	54	0	2.6	6.5	11.1	-				
19	24.9	33.3	17.9	1012.5	61	0	2.6	4.3	7.6	-				
20	24.7	31.5	18.3	1014.3	68	0	1.9	5	9.4	-				
21	24.4	30.5	19.7	1014.8	66	0	2.1	4.1	9.4	-				
22	23.9	30.5	18	1014.1	62	0	2.6	5.9	9.4	-				
23	24.3	30.5	18.4	1014.1	69	0	1.9	5.9	11.1	-				
24	24.4	31.6	19.5	1014.3	72	0	2.3	5.6	9.4	-				
25	25.6	31.5	18.5	1013.3	55	0	2.7	6.3	13	-				
26	25.4	32.3	18.6	1012.8	62	0	2.6	6.3	11.1	-				
27	25.1	32	19.3	1012.2	67	0	2.6	4.6	9.4	-				
28	24.8	30.8	20.3	1010.9	73	0	1.9	3.7	9.4	-				
29	24.4	32.1	18.9	1010.7	74	0	2.1	2	5.4	-				
30	23.9	30	17.9	1011	72	0	1.9	3.7	7.6	-				
Monthly means and totals:														
	24.9	32.4	18.9	1012.3	66.5	0	2.3	4.9	9.7		0	0	0	0

December(2011)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	24	30.6	18.6	1011.5	68	0	1.9	5.7	9.4	-				
2	23.9	30	18.9	1010	67	0	1.4	3.9	5.4	-				
3	23.1	29.6	18.5	1009.1	71	0	1.4	3.9	7.6	-				
4	23.1	31	16.9	1010.5	65	0	1.9	1.9	5.4	-				
5	23.8	32.7	16.5	1011.5	65	0	1.9	3.9	9.4	-				
6	23.7	32.6	17.3	1011.9	62	0	2.3	3.3	7.6	-				
7	23.4	31.2	16.8	1013	66	0	1.9	3.1	5.4	-				
8	22.8	29.9	17.1	1013	69	0	1.9	3.9	9.4	-				
9	22.8	30.8	16.8	1012.9	69	0	1.9	4.6	5.4	-				
10	23.7	31.6	17.4	1012	69	0	1.6	4.4	7.6	-				
11	23.8	31.9	17.5	1012.9	71	0	1.8	4.3	11.1	-				
12	23.3	30.6	18.1	1014.1	71	0	2.3	3.7	7.6	-				
13	23.3	29.9	18.5	1014.5	74	0	1.9	5.6	9.4	-				
14	22.6	28.5	18.9	1015.1	69	0	1.8	7.4	11.1	-				
15	21.2	28.4	17	1015.1	68	0	1.4	6.5	11.1	-				
16	21.3	28.1	16.2	1015.3	68	0	1.8	6.7	14.8	-				
17	21.1	27.7	15.8	1015.3	69	0	1.4	6.5	11.1	-				
18	20.4	28.5	16	1016	59	0	1.6	7.4	11.1	-				
19	19.5	27.6	13.5	1015.2	63	0	1.3	5.4	11.1	-				
20	19.4	27.4	13.8	1014.5	63	0	1.4	5.9	11.1	-				
21	20.2	28.5	13.5	1014.6	54	0	1.9	7.6	16.5	-				
22	19.5	28.4	12.8	1014.4	51	0	1.8	5.2	9.4	-				
23	20.2	28.6	13.1	1012.8	47	0	2.4	5.9	11.1	-				
24	19.1	26.4	13.1	1012.9	56	0	1.8	4.1	11.1	-				
25	18.8	26.8	13.2	1013.1	54	0	1.9	6.5	9.4	-				
26	19.3	27.4	11.7	1013	55	0	1.9	7	14.8	-				
27	20.7	24.4	15	1013.1	56	0	1.9	8.3	14.8	-				
28	22.3	25.9	19.8	1014	63	0	1.9	11.5	18.3	-				
29	23.8	27.2	20.4	1014.7	74	0	1.9	10.9	16.5	-	o			
30	25.4	29.8	21.4	1015.2	57	0	2.1	8	11.1	-				
31	25	31.2	21	1015.7	60	0	1.9	6.9	11.1	-				
Monthly means and totals:														
	22.1	29.1	16.6	1013.4	63.6	0	1.8	5.8	10.5		1	0	0	0

Climate Bhubaneswar historical weather (2012)

Average climatic values and annual totals

To calculate annual averages, we analyzed data of 366 days (100% of year).

If in the average or annual total of some data is missing information of 10 or more days, this is not displayed.

The total rainfall value 0 (zero) may indicate that there has been no such measurement and / or the weather station does not broadcast.

Data	Valor	Computed days
Annual average temperature:	**27.3°C**	366
Annual average maximum temperature:	**33.7°C**	366
Annual average minimum temperature:	**22.3°C**	366
Annual average humidity:	**76.1%**	366
Annual total precipitation:	**1734.74 mm**	359
Annual average visibility:	**2.6 Km**	366
Annual average wind speed:	**10.4 km/h**	366

To calculate the average temperature used **2934** measurements.
To calculate the average wind speed used **2934** measurements.

Total occurrences

Number of days with extraordinary phenomena.

Total days with rain:	**109**
Total days with snow:	**0**
Total days with thunderstorm:	**59**
Total days with fog:	**21**
Total days with tornado or funnel cloud:	**0**
Total days with hail:	**0**

Days of extreme historical values in 2012

The highest temperature recorded was **46.7°C** on June 5.
The lowest temperature recorded was **9.3°C** on January 15.
The maximum wind speed recorded was **40.7 km/h** on April 9.

January(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	24.6	31.8	17.3	1014.1	58	0	1.9	4.6	11.1	-				
2	24	30.8	20	1013.6	65	0	1.9	8	14.8	-				
3	24.4	30.6	19	1012.5	80	4.06	1.8	6.5	14.8	-	o			o
4	23.2	27.8	21.4	1013.4	87	0	1	7	11.1	-				o
5	25.3	31.6	21.1	1014.2	80	0	1.6	7.8	14.8	-				o
6	25.9	32.7	22.5	1014.8	79	0	2.6	10.2	22.2	-	o			
7	25	30.5	22.2	1016.3	79	0	2.6	10.9	22.2	-			o	
8	24.3	30.3	21.2	1015.4	81	0	2.4	10.4	16.5	-				o
9	21.7	26.6	18	1014.9	89	0	2.4	8	18.3	-	o		o	
10	18.6	20.9	17.4	1015.9	99	14.99	1.9	8.3	14.8	-	o			
11	18.7	21.8	16.4	1017	88	16	1	4.6	11.1	-	o			
12	18.3	25.1	13.6	1016.3	68	0	2.4	4.4	11.1	-				
13	17.2	24.7	11	1016.6	52	0	2.7	9.1	16.5	-				
14	16.9	24.5	10.2	1015.1	51	0	2.7	6.5	11.1	-				
15	17.9	26.5	9.3	1013.2	58	0	2.6	4.3	7.6	-				
16	20	30.3	11.4	1010.9	61	0	3.1	4.8	9.4	-				
17	22.3	32.3	12.7	1009.3	64	0	2.7	8.9	14.8	-				
18	23.2	32.2	16.5	1009	78	0	2.3	10.2	22.2	-				o
19	23.8	31.3	18.8	1009.9	75	0	2.6	13.9	25.9	-				
20	24.4	32.1	17.7	1010.9	77	0.25	2.4	9.1	16.5	-	o			
21	22	27.4	18	1013	74	0	1.9	5.4	9.4	-				
22	19.8	26.5	14.1	1015.3	66	0	1.8	7.8	11.1	-				
23	20.6	28.6	13.1	1014.4	68	0	1.6	3.3	7.6	-				
24	22.7	30.8	14.6	1013.5	72	0	1.6	6.5	16.5	-				
25	22.8	29.8	17.4	1013.4	77	0	1.4	5.9	14.8	-				o
26	23.8	31.2	17.5	1013	76	0	1.6	5.4	11.1	-				o
27	22.8	27.8	18.4	1013.6	71	0	1.6	5.6	11.1	-				o
28	22.7	29.5	16.8	1013.4	67	0	1.8	7	14.8	-				
29	22.7	27.6	17.6	1014.2	66	0	2.6	7.2	9.4	-				
30	22.7	28.3	18	1015.4	59	0	1.9	9.8	14.8	-				
31	21.7	27.9	16.2	1016.2	52	0	1.9	7	14.8	-				
Monthly means and totals:														
	22.1	28.7	16.8	1013.8	71.5	35.3	2.1	7.4	14.3		6	0	2	8

February(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	21.6	28.7	14.5	1015.9	50	0	1.9	6.3	14.8	-				
2	20.4	27.6	14	1017	55	0	1.9	5.9	14.8	-				
3	20.3	28.2	13.1	1015.8	56	0	1.9	3.9	7.6	-				
4	21.5	29.7	13.6	1014.7	57	0	1.9	4.6	9.4	-				
5	22.4	32.3	14.4	1014.2	64	0	2.1	3.9	7.6	-				
6	24.4	34.6	16.1	1012.9	59	0	2.3	5	9.4	-				
7	24.6	35	16.1	1012.2	54	0	2.7	9.1	14.8	-				
8	24.2	34.7	15.4	1010.4	50	0	2.6	11.3	20.6	-				
9	23.9	31.7	16.8	1011.1	61	0	1.9	8	16.5	-				
10	21.7	28.4	18	1013.4	56	0	1.9	11.5	22.2	-				
11	21.7	26.2	16.5	1013.8	67	0	1.9	6.5	11.1	-				
12	23.5	30.6	16.7	1013.8	68	0	1.9	6.7	16.5	-				
13	24.9	32.1	19.8	1014.1	71	0	2.1	7.8	16.5	-				
14	26.4	33.7	20.6	1012.5	74	0	2.1	9.4	16.5	-				
15	27	34.8	21.1	1010.7	72	0	1.9	11.9	22.2	-				
16	25.8	32.8	21.9	1011.1	74	0	1.8	7.6	16.5	-				o
17	25.4	32.8	19.8	1012.4	69	0	1.8	5.6	14.8	-				
18	26.2	33.5	20.1	1012.5	67	0	1.9	7.6	16.5	-				
19	26.8	34.2	21.1	1011.7	71	0	1.6	4.6	11.1	-				o
20	25.6	34	20.3	1010.4	58	0	1.9	6.1	9.4	-				o
21	26.7	36.6	17.2	1009.6	52	0	2.6	7.8	14.8	-				
22	27.7	38.1	17.8	1008.8	49	0	2.7	6.3	9.4	-				
23	28.1	38.4	18.4	1008.9	39	0	2.7	8	14.8	-				
24	29	38.8	17.6	1008.7	38	0	3.1	5.7	11.1	-				
25	28.5	39.9	18.3	1008	44	0	3.1	8.1	18.3	-				
26	28.8	40.1	18.5	1006.8	44	0	2.6	6.7	13	-				
27	28.1	37.2	19.5	1007.3	52	0	1.9	7.2	14.8	-				
28	27.5	37.3	19.8	1004.4	57	0	1.9	13.3	25.9	-				
29	27.3	34.6	22.6	1005	68	0	1.9	8.9	20.6	-				
Monthly means and totals:														
	25.2	33.7	17.9	1011.3	58.5	0	2.2	7.4	14.9		0	0	0	3

March(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	27.8	34.7	22.7	1006.4	75	0	1.9	10.7	22.2	-				
2	28.6	35.8	24.2	1004.7	74	0	2.6	15	31.3	-				
3	28.7	36.6	23.7	1005.5	70	0	1.8	7.2	16.5	-				o
4	28.3	35.8	20.2	1008.5	55	0	2.3	5.7	7.6	-				
5	30.6	37.6	22.3	1008	53	0	3.4	15.6	22.2	-				
6	29.6	39.6	21.5	1005.8	64	0	2.6	18	27.8	-				
7	29.2	37.3	23.6	1003.7	68	0	1.9	21.5	33.5	-				
8	28.3	35.6	21.8	1004.8	69	0	1.9	10.2	16.5	-				
9	29.1	36.6	24	1005.3	68	0	2.6	10.7	22.2	-				
10	28.2	35	22.4	1008.2	70	0	1.6	6.7	13	-				o
11	28.1	34	23.6	1010.9	68	0	1.9	8.9	16.5	-				
12	28.8	36.1	20.8	1012.9	60	0	1.9	8	18.3	-				
13	28.9	35.7	24.5	1011.7	69	0	1.8	12.4	24.1	-				
14	28.9	35.7	24.1	1011.8	64	0	1.9	8	11.1	-				
15	27.2	35.4	20.6	1012.1	56	0	1.9	10.2	22.2	-				
16	28.4	36.6	21.6	1010.6	73	0	1.9	13.7	22.2	-				
17	29.7	39.4	22.7	1009.2	58	0	2.4	12.6	25.9	-				
18	29.8	39	24	1008.2	70	0	2.6	13.9	22.2	-				
19	30	39.2	22.4	1008.1	66	0	1.8	9.3	22.2	-				
20	30.3	40.2	24.4	1008.4	65	0	2.6	10	22.2	-				
21	30.3	39.4	24.8	1007.7	73	0	2.4	15.2	24.1	-				
22	30.7	40.7	24.8	1007.9	70	0	2.7	14.8	22.2	-				
23	29.5	37.4	25.4	1010.1	67	0	1.9	9.6	24.1	-				
24	30.1	38.9	24.5	1010.4	64	0	1.6	9.4	18.3	-				
25	29.5	38.3	22.6	1010.6	69	0	1.9	12	25.9	-				
26	29.7	38.9	23.5	1010.7	65	0	2.6	16.3	24.1	-				o
27	29.3	40	22.5	1011.4	60	0	2.4	16.1	25.9	-				o
28	30.2	40.1	23.5	1011.7	60	0	2.6	18.1	29.4	-				o
29	30.6	41.2	23.5	1009.6	56	0	3.2	16.1	20.6	-				
30	30.1	37.9	25.4	1008.7	70	0	2.7	16.5	22.2	-				
31	30.2	37.6	24.2	1010.5	60	0	1.9	7	11.1	-				
Monthly means and totals:														
	29.3	37.6	23.2	1008.8	65.5	0	2.2	12.2	21.5		0	0	0	5

April(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	30	37.1	24.2	1011	57	0	2.7	9.1	18.3	-				
2	30.3	39.1	23.6	1011	55	0	2.6	9.4	18.3	-				o
3	30.8	39.7	24.6	1010.6	64	0	2.9	16.7	24.1	-				
4	30.4	38.9	24.4	1009.2	71	0	3.1	20.6	31.3	-				
5	30.7	37.7	25.8	1008.2	70	0	2.7	20.4	27.8	-				
6	30.8	39.6	23.4	1007.6	49	0	2.7	15	25.9	-				
7	30.7	38.2	25.6	1007.1	69	0	2.7	21.1	27.8	-				
8	30.6	37.4	26.8	1006.5	71	0	3.2	26.1	35.2	-	o			
9	31.3	39.5	27	1006.7	69	0	3.2	28.5	40.7	-				
10	28.6	38.5	20.2	1006.9	76	0.25	2.7	24.4	38.9	-	o		o	
11	28.4	34.6	18.8	1007.5	76	44.96	3.1	21.9	35.2	-			o	
12	30.2	36.9	23.7	1005.1	63	0	3.5	18.9	24.1	-				
13	27.5	38.1	22.4	1007.3	73	4.06	2.6	13.1	20.6	-	o		o	
14	29.4	37.5	21	1008.9	69	0	3.2	9.3	16.5	-				
15	31.2	39.1	25.8	1007.6	64	0	3.2	15.6	20.6	-				
16	30.4	38.8	25.6	1005.8	74	0	3.5	14.4	20.6	-	o			
17	30.6	39.4	26	1004.6	77	0	3.2	15.2	22.2	-			o	
18	30.6	38.9	26.9	1004	77	4.06	3.5	21.1	29.4	-				
19	30.7	37.5	27.2	1004.9	77	0	3.5	22.8	29.4	-				
20	31.5	38.6	26.8	1006	75	0	3.7	20.6	27.8	-				
21	32.5	41.2	26.8	1005.4	66	0	3.7	10.7	22.2	-				
22	31.4	39.1	27.6	1003.9	74	1.02	3.1	18.7	31.3	-	o		o	
23	31.6	38	26.2	1004.9	65	0	3.7	13.7	22.2	-				
24	32.1	40.1	26.4	1005.1	65	0.25	3.1	22.6	29.4	-			o	
25	32.1	39.4	26.5	1006.6	67	0	4	20.7	25.9	-				
26	31.4	38.1	28	1007	71	0	4	19.6	33.5	-	o		o	
27	32.1	40	25.6	1004.9	63	0	4	19.3	29.4	-				
28	28.6	36.8	25	1003.4	84	35.05	2.7	15.2	20.6	-	o		o	
29	30.2	36.2	24.1	1003.4	72	0	3.7	21.5	29.4	-				
30	31.6	38.1	26.6	1002.5	71	-	3.1	18.5	29.4	-	o			
Monthly means and totals:														
	30.6	38.4	25.1	1006.5	69.1	89.65	3.2	18.2	26.9		8	0	8	1

May(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	31.4	38.3	27.1	1003.2	76	0	2.7	25.2	35.2	-			o	
2	32.6	41.6	27.2	1003.2	69	0	2.6	19.3	27.8	-				
3	31.8	38.6	28.3	1003	73	0	2.6	17.2	20.6	-	o		o	
4	27.8	36.7	22.8	1003.6	75	0	2.6	15.9	27.8	-	o		o	
5	28.1	34.5	18.4	1005.9	74	7.11	3.5	9.3	18.3	-				
6	30.4	36.6	24.2	1005.2	70	0	3.5	10.6	22.2	-				
7	30.7	38.4	23.6	1004	64	0	3.7	10.7	24.1	-				
8	31.7	39	26.1	1004.1	75	0	3.2	20.2	24.1	-				
9	29.3	37	22.6	1006.5	79	12.95	2.7	18.9	29.4	-	o		o	
10	29.8	35.8	22	1007.2	76	0	3.5	11.5	18.3	-				
11	30.7	37.4	25.8	1004.9	73	0	3.7	17.4	25.9	-				
12	30.9	36.9	27	1002.9	70	0	3.5	22.6	33.5	-				
13	32.2	39.1	26.4	1002.6	70	0	3.7	16.1	22.2	-				
14	32.3	40.2	27.8	1002.9	71	0	3.1	18.5	27.8	-	o			
15	33	40.1	26.5	1003.3	66	0	3.2	11.9	18.3	-				
16	33.9	42.6	28.7	1001.2	67	0	3.1	13.1	22.2	-				
17	33.3	40.7	28.1	1000.8	69	0	3.7	15.4	18.3	-				
18	33	41.4	28.2	1001.8	73	-	3.1	12.4	29.4	-	o		o	
19	33.6	40.6	28.2	1003.1	69	0.25	2.9	19.3	24.1	-			o	
20	33.6	41.6	28.5	1002.2	65	0	3.2	13.1	27.8	-				
21	33.1	40.4	27.9	1002.5	71	0	3.7	19.4	25.9	-				
22	33.4	40	28.7	1002	70	0	3.1	24.3	29.4	-				
23	33.5	40.2	29	1000.8	70	0	2.7	25	35.2	-				
24	34	42.6	27.1	999	64	0	3.2	17.4	25.9	-				
25	33.7	42	28.5	999.1	71	0	3.2	18.3	27.8	-				
26	33.4	40.6	29.6	999.9	70	0	3.2	20.4	27.8	-				
27	33.6	40.1	28.5	999.5	70	0	3.1	17.6	29.4	-				
28	33.5	42.5	29.1	999.8	63	0	2.6	16.7	31.3	-	o			
29	32.2	36.4	27.8	1000.6	77	0	2.6	12.2	20.6	-				
30	34.2	42.1	28.5	998.2	70	0	3.2	21.5	27.8	-				
31	33.4	39.5	28.8	997.3	70	0	2.3	20.9	27.8	-				
Monthly means and totals:														
	32.2	39.5	26.8	1002.3	70.6	20.31	3.1	17.2	26		6	0	6	0

June(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	32.9	38.5	28.8	997.8	75	-	2.6	19.4	25.9	-	o			
2	33	42.7	25.6	996.9	68	0	2.4	12.8	22.2	-	o		o	
3	33.1	40.4	23.2	996.5	66	6.1	2.7	15	25.9	-	o		o	
4	36.4	45.9	27	996.7	52	0.76	3.7	16.3	25.9	-				
5	37.4	46.7	28.5	996.9	46	0	3.2	15.9	24.1	-				
6	36.3	46.6	29.4	996.4	55	0	3.1	20.4	33.5	-				
7	36.3	45.6	28.8	997.8	50	0	3.5	13.5	29.4	-				
8	33.9	41	27.5	998.8	56	0	4	16.1	25.9	-			o	
9	33.9	40.5	27.2	997.7	60	0	3.5	11.3	27.8	-			o	
10	35	44.1	29	996.6	59	0	3.2	16.5	27.8	-			o	
11	31.3	40	25.8	998	73	3.05	2.9	12.2	18.3	-			o	
12	32.8	39.3	27.8	999	74	0	2.7	13.9	22.2	-				
13	32.6	39	28.4	1000.7	71	0	3.1	19.8	27.8	-				
14	32.9	39.5	28.1	1001.2	70	0	3.2	24.8	31.3	-				
15	31.3	41.3	28	999.3	78	23.11	2.6	19.4	27.8	-	o		o	
16	31.8	40	25.2	997.8	72	-	3.2	20.2	29.4	-	o		o	
17	28.9	32.8	23	998.2	85	42.93	3.2	11.5	22.2	-	o			
18	26.8	33.6	24	997.8	92	0	2.7	8.5	14.8	-	o		o	
19	27	29.2	22.8	996.6	93	57.91	3.1	10.9	16.5	-	o			
20	27.6	29.7	25	995.6	86	0.25	4	9.4	18.3	-	o			
21	26.3	29.3	23	996.6	93	26.92	3.2	11.5	18.3	-	o		o	
22	26.3	27.6	23.6	999.4	95	2.03	3.1	14.1	20.6	-	o			
23	27.7	30.3	23.2	999.5	90	12.95	3.2	15.9	27.8	-	o			
24	27.4	29.6	24.6	1000.7	94	0.25	1.9	14.1	22.2	-	o			
25	28.4	34.5	24.4	1001.5	88	4.06	2.6	23.3	40.7	-	o		o	
26	29	34.2	22.8	1000.3	88	21.08	2.7	18.3	33.5	-			o	
27	30	34.5	25.8	1000.6	83	0	3.1	13	20.6	-				
28	32	38.7	26.2	999.5	75	0	3.7	12.8	20.6	-				
29	29.8	32	27.4	999.4	86	0	3.1	9.8	18.3	-	o			
30	28	35.5	23	997.2	86	0	2.7	11.1	18.3	-	o		o	
Monthly means and totals:														
	31.2	37.4	25.9	998.4	75.3	201.4	3.1	15.1	24.6		16	0	13	0

July(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.8	35.1	22	995.8	82	326.9	3.5	9.8	14.8	-	o		o	
2	26.6	29.6	23.8	995.8	97	51.05	3.5	6.5	9.4	-	o			
3	27.7	31.7	24.6	995.5	93	3.05	2.6	15	22.2	-	o			
4	29	34.2	24.9	997.1	87	5.08	3.5	10.9	18.3	-	o		o	
5	28.4	35.2	25.4	998.4	89	3.05	3.1	9.1	18.3	-	o			
6	27.8	30.3	23.5	997.8	94	34.04	2.6	5.7	11.1	-	o		o	
7	27.8	30.7	23.7	997.1	93	19.05	3.5	9.1	14.8	-			o	
8	27.5	31.2	24.7	997.4	92	0	2.7	8.9	14.8	-	o		o	
9	27.5	30	25	999.8	93	2.03	2.7	6.7	14.8	-	o			
10	29.2	32.6	25	1002.6	87	3.05	3.1	8.1	14.8	-				
11	29.9	33.5	25.8	1003.3	87	0	3.1	13	18.3	-				
12	28.1	35.6	25.8	1003.1	92	14.99	3.2	10.2	18.3	-	o		o	
13	29.5	35.4	25	1001.8	86	0	3.5	7.6	14.8	-			o	
14	30.1	35.5	24.9	1000.7	83	0	3.7	10.6	18.3	-				
15	30.1	33.4	26.8	1001.6	87	0.51	3.2	10.9	14.8	-	o			
16	29.5	33.3	26.4	1003.1	87	8.89	3.1	9.8	14.8	-				
17	28.1	34	24.4	1002.7	91	13.97	3.2	12.2	22.2	-	o			
18	27.7	33.6	24.3	1000.9	93	57.91	2.6	10.9	14.8	-	o		o	
19	25.9	27.7	24.1	999.5	100	3.05	1.9	12.2	27.8	-	o			
20	26.4	28.6	22.9	998.3	99	104.9	3.1	7	9.4	-	o			
21	26.9	30.6	25	998.8	97	0	2.7	10.2	22.2	-	o			
22	28.8	33.1	24.5	998.9	88	29.97	3.2	17.4	27.8	-				
23	29.7	34	25.2	998.2	83	0	3.2	13.1	18.3	-	o			
24	28.6	33.5	25.8	998.1	91	0.25	2.4	10.7	22.2	-	o			
25	26.3	27.6	25	998.7	98	25.91	1.9	12.6	22.2	-	o			
26	26.6	28	24	997.7	97	21.08	2.9	13.9	18.3	-	o			
27	28.5	32.6	25.1	997.4	91	0.76	2.6	9.6	18.3	-	o		o	
28	27.7	31.6	25.7	998.5	93	3.05	2.7	11.3	18.3	-	o			
29	26.7	29	24.6	999.1	97	27.94	3.1	12	18.3	-	o			
30	25.2	26.6	24	998.4	99	12.95	1.9	14.4	18.3	-	o			
31	25.9	27.6	21.7	999.1	97	10.92	3.1	8.5	14.8	-	o			
Monthly means and totals:														
	28	31.8	24.6	999.2	91.7	784.35	2.9	10.6	17.6		24	0	9	0

August(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	27.2	30.3	23.3	999.9	89	0.76	3.5	10.6	22.2	-	o			
2	27.6	30.3	25	998.4	90	0	3.7	10.4	18.3	-				
3	26.8	30.5	24.8	996.2	93	1.02	2.6	11.3	25.9	-	o			
4	25.8	28.2	23.6	995.4	97	4.06	1.9	11.1	18.3	-	o			
5	27.1	29.7	24.2	997	94	7.87	3.1	11.3	18.3	-	o			
6	29.2	33.4	25.6	998.7	85	7.87	3.2	11.1	22.2	-	o			
7	30.1	34.7	25.8	1001.3	83	0	3.5	15	25.9	-	o			
8	28.2	34.5	25.8	1001.4	90	2.03	2.7	9.4	14.8	-	o			
9	28.7	34	24.7	998.9	88	-	3.1	9.8	14.8	-	o		o	
10	26.4	28.8	24.2	998.5	98	33.02	2.3	8.1	14.8	-	o			
11	27.7	32.2	24	1001.3	93	7.11	2.7	9.3	22.2	-				
12	28.2	32.6	23.6	1002.8	91	14.99	2.4	10.9	22.2	-	o		o	
13	28.6	33.7	23.3	1002.5	90	12.95	3.4	11.3	27.8	-	o		o	
14	28.4	33.4	25.5	1002.5	87	2.03	3.2	11.9	25.9	-				
15	29	33.7	25	1002.3	81	0.25	3.5	12.4	18.3	-	o		o	
16	29	33	25.2	1000.7	85	0	4.2	11.9	20.6	-				
17	27.8	30.7	25.3	999.1	92	5.08	2.7	9.4	14.8	-	o		o	
18	26.1	28	23.8	997.2	99	95	3.1	9.8	22.2	-	o		o	
19	29	33.4	24.6	999.9	87	16	3.7	13.9	20.6	-	o			
20	29	32.6	24.4	1002.1	88	14.99	3.1	21.1	29.4	-				
21	29.3	33.6	26.2	1003.6	87	0	3.1	23.3	33.5	-			o	
22	28.9	34.2	26.2	1005.2	86	2.03	3.7	13.1	22.2	-			o	
23	29.6	34.4	24.5	1004.9	82	0	3.2	8.9	13	-				
24	28.5	32.6	25.2	1003.8	89	3.05	2.7	7	14.8	-	o		o	
25	27.7	30.8	24.2	1002.9	93	2.03	2.7	5	7.6	-	o		o	
26	27.5	30	24.8	1001.6	95	6.1	3.1	7.2	11.1	-	o			
27	28.9	34.2	24.8	1001.4	89	3.05	3.5	7.6	14.8	-			o	
28	29.3	33	25.4	1002.5	86	0	3.2	5.7	11.1	-			o	
29	29.6	34	25.6	1003.8	89	0	3.5	9.1	18.3	-				
30	28.8	32.7	26	1002.6	88	8.89	2.7	10.6	18.3	-	o			
31	29.6	34.1	25.2	1001.9	84	0	4	11.5	16.5	-				
Monthly means and totals:														
	28.3	32.3	24.8	1001	89.3	250.18	3.1	10.9	19.4		19	0	12	0

September(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	27.7	33.5	25.6	1001.7	94	26.92	3.1	8	11.1	-	o			
2	27	29	23.6	1000.5	97	3.05	2.7	5	11.1	-	o			
3	27.1	32	25.4	997.2	96	27.94	2.6	12.8	25.9	-	o			
4	27.4	28.9	24	998.3	98	3.05	2.4	10.9	18.3	-	o			
5	28.1	30.4	25.3	1002.2	92	0	3.1	13.1	20.6	-				
6	27.6	29.1	25.4	1005.7	95	0	1.9	3	5.4	-	o			
7	27	31.8	25.3	1005.2	95	0.51	1.8	3.9	5.4	-	o		o	
8	28.6	32.9	23.5	1003.5	87	10.92	3.5	5.7	9.4	-				
9	26.8	29.6	24.9	1002.1	97	6.1	2.4	8.7	16.5	-	o			
10	28.2	31.7	24.1	1002.7	91	29.97	3.2	6.5	9.4	-				
11	29.2	33.4	25.6	1002.9	86	0.25	3.7	9.4	16.5	-	o			
12	27.7	30.8	25	1004	93	0	2.7	8	14.8	-	o		o	
13	28.3	32.6	24.4	1004	88	4.06	3.5	10.7	14.8	-				
14	28.1	31.2	24.9	1002.8	91	0.25	2.7	8.3	14.8	-	o			
15	28.4	32.8	25.7	1001.4	88	0.76	3.5	7.8	14.8	-				
16	27.7	31.6	24.5	1002.6	93	0	2.6	4.6	7.6	-	o			
17	27.8	31	25.3	1004.8	93	11.94	1.9	3.9	7.6	-	o			
18	29.1	33.4	24.2	1005.2	85	2.03	3.2	5.6	7.6	-				
19	28.8	32.4	25.2	1004.6	89	0	2.6	5.6	11.1	-				
20	30.2	35.8	24.6	1005.4	83	1.02	2.9	7.4	16.5	-	o			
21	28.7	34	25.7	1005.8	86	0	2.7	7.6	14.8	-				
22	28.9	34.7	24.6	1005.7	85	0.25	3.2	5.6	9.4	-			o	
23	28	33	25	1005.3	91	0	2.7	6.5	14.8	-	o		o	
24	28.9	33.1	23.2	1005	85	23.88	2.3	6.5	11.1	-				
25	29.2	34.6	23.4	1006.3	80	0	3.1	5.7	11.1	-				
26	28.8	34	23.8	1008.5	76	0	3.1	4.4	9.4	-				
27	28.9	34	23.8	1008.7	81	0	2.7	5.7	11.1	-				
28	29.4	34.3	25	1008.1	82	0	2.9	7	16.5	-				
29	28.9	33.6	24.3	1007.9	82	-	3.7	8.3	18.3	-	o		o	
30	29.2	34	25.8	1008.1	87	0.76	3.1	10.2	22.2	-	o			
Monthly means and totals:														
	28.3	32.4	24.7	1004.2	88.9	153.66	2.9	7.2	13.3		16	0	5	0

October (2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	28.3	33.8	25.8	1008.4	87	1.02	3.1	9.1	18.3	-			o	
2	27.9	33	24.5	1008.3	91	7.87	2.7	9.8	25.9	-	o			
3	28.6	32.3	24.6	1005.9	87	10.92	3.7	20.7	33.5	-	o			
4	27.8	33.1	23.6	1004.3	89	0	3.4	16.3	29.4	-	o		o	
5	27.7	30.7	23.4	1006.5	94	33.02	2.1	5.4	11.1	-				
6	27.7	33.1	22.5	1008.6	82	0	2.3	5.2	11.1	-				
7	27.1	31.4	21.7	1008.2	82	0	2.7	7.2	11.1	-				
8	27.6	31.4	25.2	1006.9	87	0.51	2.3	10	14.8	-	o		o	
9	27	29.2	24.7	1006.1	93	4.06	1.9	10.2	22.2	-	o		o	
10	28.1	31.4	25	1007.4	84	1.02	2.1	6.7	13	-				o
11	28.5	33.6	25	1008.5	83	0	2.6	6.9	14.8	-				
12	28.5	33.5	24.5	1009.3	83	0	2.7	7.2	18.3	-				
13	27	30.8	25.1	1010.1	89	0.76	2.6	5	9.4	-	o			
14	27.6	32.3	25	1010.7	87	-	1.9	3.5	5.4	-	o			
15	27.2	32.6	24.2	1012.5	79	0	1.9	5.6	9.4	-				
16	27.6	33.5	22.6	1013.3	76	0	2.6	4.6	11.1	-				
17	27	32.7	22.6	1012.6	71	0	2.3	6.5	11.1	-				
18	26.3	32.6	21	1012.4	73	0	3.2	5.7	9.4	-				
19	26.4	31.8	20.7	1013.1	74	0	2.4	5	9.4	-				
20	27	32.8	22.4	1013.5	76	0	1.9	7.4	13	-				
21	26.9	32.8	22.2	1013.4	75	0	2.3	6.9	13	-				
22	26.8	32.7	22	1013.2	78	0	1.9	4.8	11.1	-				
23	27.2	32.8	22.7	1012.2	79	0	1.9	5	9.4	-				
24	26.8	32.8	22.8	1011.1	78	0	1.9	3.9	9.4	-				
25	26.2	33.6	19.8	1010.6	72	0	3.1	4.3	11.1	-				
26	26.7	33.4	20.6	1011	72	0	1.9	5.2	11.1	-				
27	26.5	31.4	21.4	1011.5	78	0	1.9	5.6	9.4	-				
28	25.4	31.8	20.8	1011.8	74	0	2.3	5.6	9.4	-				
29	24	31.6	18.6	1011.3	67	0	2.7	5.7	11.1	-				
30	23.8	31.5	18.4	1010.9	70	0	2.6	6.9	14.8	-				
31	25.6	32.4	18.6	1011.3	74	0	1.9	6.9	14.8	-				
Monthly means and totals:														
	27	32.3	22.6	1010.2	80.1	59.18	2.4	7.1	13.8		7	0	4	1

November(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	26	31.8	21.6	1011.5	84	0	1.9	9.3	13	-	o			
2	26.2	31	22.8	1010.5	89	8.89	3.2	7.6	13	-	o			
3	24.1	27.4	22.2	1010.6	97	101.09	2.7	7	11.1	-	o			
4	26	29	22.2	1009.5	93	7.87	3.2	8.1	16.5	-	o			
5	24.9	28	22.6	1009.5	94	20.07	3.1	6.3	9.4	-	o			
6	26.4	30.6	23.2	1010.3	90	0.76	3.7	4.6	11.1	-	o			
7	24.9	30.9	23.2	1010.2	91	2.03	3.2	3.5	3.5	-				
8	25.2	29.9	21.8	1010	87	0	2.6	5	9.4	-				
9	23.5	30	19.2	1011.9	81	0	2.7	5.6	9.4	-				
10	23.2	30	17.2	1013.5	74	0	2.4	4.1	5.4	-				
11	22	29.4	16.4	1012.9	77	0	1.9	4.1	7.6	-				
12	21.6	29.2	15.7	1013.7	78	0	1.9	4.1	9.4	-				
13	21.3	29.8	15.4	1013.4	72	0	2.3	4.6	9.4	-				
14	22.3	29.7	15.3	1012.1	69	0	1.9	4.1	7.6	-				
15	22.3	29.5	16	1012.4	69	0	1.9	7	14.8	-				
16	21.5	29	16	1012.8	69	0	2.6	9.1	16.5	-				
17	22.8	27	18.2	1011.3	72	0	1.9	8.9	13	-				
18	23.8	27.6	21.6	1010.8	75	0	2.3	8.9	14.8	-	o			
19	26.3	31.5	21.6	1010.9	70	0	2.7	10.2	18.3	-				
20	24.5	29.2	22	1012.3	74	0	2.3	10	18.3	-				
21	23.9	29.2	20.5	1012.9	76	0	1.9	6.9	13	-				
22	24.7	31.4	19.1	1012.4	71	0	1.9	6.5	9.4	-				
23	24.7	31.4	19.6	1012.3	78	0	1.9	3.9	9.4	-				
24	24.7	31.3	20.8	1012.1	81	0	1.8	3	5.4	-				
25	22.2	29.2	19	1013.3	80	0	1.9	5.2	11.1	-				
26	20.9	30	17.5	1013.6	85	0	1.8	5.2	7.6	-				
27	22.2	30.4	16	1012.7	72	0	2.6	4.1	7.6	-				
28	22.6	30.6	16.7	1012.4	79	0	1.8	3	5.4	-				
29	21.9	29.6	17.2	1011.2	80	0	1.9	4.3	7.6	-				
30	21.4	29.5	15.7	1011.8	73	0	1.9	5	7.6	-				
Monthly means and totals:														
	23.6	29.8	19.2	1011.8	79.3	140.71	2.3	6	10.5		7	0	0	0

December(2012)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	21	29.6	15	1013	70	0	1.9	6.9	16.5	-				
2	21.1	29.8	14.3	1014.5	67	0	2.1	5.9	11.1	-				
3	20.5	29.2	14.1	1014.1	71	0	1.9	4.6	11.1	-				
4	21.5	28	14.7	1013.7	74	0	1.9	4.1	7.6	-				
5	23	32	16.5	1013.8	70	0	1.9	4.3	7.6	-				
6	23.4	33	16.9	1013.3	69	0	2.3	5	9.4	-				
7	22.9	32.4	16.2	1012.8	69	0	2.7	6.7	13	-				
8	23.4	32.1	16.2	1011.9	70	0	2.6	5.6	11.1	-				
9	24.5	32.7	16.5	1011.6	68	0	2.3	4.3	5.4	-				
10	24.8	33.2	18.2	1011.7	78	0	1.8	6.5	11.1	-				o
11	25.5	32	21.2	1011.5	81	0	2.1	8.9	16.5	-				o
12	25.5	31.6	21.3	1011.8	77	0	2.4	5	11.1	-				
13	25.8	32.8	20.6	1013.5	81	0	2.7	5.4	11.1	-				
14	25.8	32.4	20.8	1016.4	77	0	2.7	6.3	11.1	-				
15	24.7	29.6	21	1016.6	84	0	1.9	3.3	9.4	-				
16	24.6	30.1	21	1016.5	79	0	1.6	4.8	7.6	-				o
17	22.1	30	18	1015.4	70	0	2.1	4.6	11.1	-				
18	21.6	30	16.6	1014.7	67	0	2.6	6.5	9.4	-				
19	21.3	30.6	13.4	1013.2	66	0	2.7	4.1	7.6	-				
20	21.5	29.6	14.3	1013	67	0	2.6	3.1	5.4	-				
21	21.3	29.7	14.8	1013.9	70	0	2.3	5.7	9.4	-				
22	21.1	29.2	14.6	1014.4	72	0	2.6	5.9	9.4	-				
23	19.6	27.8	15	1015	67	0	1.9	8.7	18.3	-				
24	19.3	27.4	11	1014	63	0	1.9	4.4	7.6	-				
25	19.5	28.2	12.8	1012.8	72	0	1.6	5.2	7.6	-				
26	18.7	25.8	13.8	1013.5	77	0	1.1	8.1	14.8	-				
27	17.6	25.1	12.2	1013.1	73	0	1	7.8	14.8	-				
28	18.3	26.7	10.7	1012.2	71	0	1.8	5.2	7.6	-				
29	19.5	29.1	11.7	1012.7	69	0	1.8	4.3	5.4	-				
30	20.2	30	14	1012.7	73	0	1.6	3.9	7.6	-				
31	21.2	30.2	13.6	1011.8	70	0	1.6	3	7.6	-				
Monthly means and totals:														
	22	30	15.8	1013.5	72	0	2.1	5.4	10.1		0	0	0	3

Climate Bhubaneswar historical weather (2013)

Average climatic values and annual totals

To calculate annual averages, we analyzed data of 365 days (100% of year).

If in the average or annual total of some data is missing information of 10 or more days, this is not displayed.

The total rainfall value 0 (zero) may indicate that there has been no such measurement and / or the weather station does not broadcast.

Data	Valor	Computed days
Annual average temperature:	**27.0°C**	365
Annual average maximum temperature:	**33.2°C**	365
Annual average minimum temperature:	**22.1°C**	365
Annual average humidity:	**76.4%**	365
Annual total precipitation:	**1644.39 mm**	359
Annual average visibility:	**2.7 Km**	365
Annual average wind speed:	**10.0 km/h**	365

To calculate the average temperature used **2931** measurements.
To calculate the average wind speed used **2930** measurements.

Total occurrences

Number of days with extraordinary phenomena.

Total days with rain:	**116**
Total days with snow:	**0**
Total days with thunderstorm:	**86**
Total days with fog:	**26**
Total days with tornado or funnel cloud:	**0**
Total days with hail:	**0**

Days of extreme historical values in 2013

The highest temperature recorded was **42.6°C** on May 22.
The lowest temperature recorded was **11°C** on January 10.
The maximum wind speed recorded was **68.3 km/h** on October 13.

January(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	22.3	30.2	16.3	1012.6	79	0	1.6	6.7	11.1	-				o
2	24.1	31.4	18	1012.5	81	0	1.9	10.9	20.6	-				
3	25.3	31.7	21	1012.7	82	0	1.6	6.7	9.4	-				o
4	22.3	26	19	1013.1	87	0	0.8	7.2	14.8	-				o
5	22.5	29	17.2	1012	80	0	1	5.9	11.1	-				o
6	22.6	29.3	17.6	1012.6	75	0	1.8	7.8	11.1	-				
7	23.5	30	18.5	1013.2	78	0	1.3	8.7	13	-				o
8	20.4	26.3	16.4	1015	72	0.51	1	8.3	11.1	-				o
9	18.6	26.2	12.7	1015.2	64	0	1.9	6.9	14.8	-				o
10	19.1	28.5	11	1014.2	60	0	2.1	4.6	9.4	-				
11	19.2	28.6	11.3	1014.5	54	0	2.7	7.8	16.5	-				
12	19.6	28	12.3	1014.5	66	0	1.8	4.3	7.6	-				
13	20.3	28.8	12.8	1013.2	65	0	1.9	5.9	9.4	-				o
14	22.5	32.4	14	1013.1	66	0	2.4	4.4	13	-				o
15	23.1	32.8	18	1015	76	0	1.4	6.1	20.6	-				o
16	23.7	31.7	18.4	1015.8	78	0	1.4	5.2	13	-				o
17	24.1	31.5	18.7	1016.5	76	0	1.6	5	11.1	-				o
18	22.9	31.2	18	1016.4	72	0	1.4	4.6	9.4	-				o
19	22.9	32.2	16	1015.3	69	0	1.8	4.8	14.8	-				
20	23.1	30.7	15.7	1015.2	69	0	2.3	5.2	9.4	-				
21	22.1	28.6	17.2	1017.4	75	0	1.6	8.9	16.5	-				
22	21.4	27.6	15.7	1017.9	66	0	1.4	5.9	11.1	-				
23	20.7	28.8	13.7	1017.1	69	0	1.8	4.8	9.4	-				
24	20.6	28.1	15.1	1016.6	61	0	1.8	5.9	11.1	-				
25	20.6	28.6	13.5	1016.8	59	0	1.9	7.4	14.8	-				
26	20.3	28.4	13.2	1016.8	58	0	1.9	6.7	13	-				
27	20.6	29.2	13.2	1016.5	65	0	1.9	5.7	11.1	-				
28	20.4	27.7	14.3	1015.8	61	0	1.8	5.6	9.4	-				
29	20.8	29	12.7	1014.9	65	0	1.8	5.6	14.8	-				
30	21.5	30.1	14	1015.9	67	0	1.8	4.6	7.6	-				
31	21.8	30.6	14.5	1016.2	73	0	1.6	6.1	14.8	-				o
Monthly means and totals:														
	21.7	29.5	15.5	1015	69.9	0.51	1.7	6.3	12.4		0	0	0	14

February(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	22.2	30	16.5	1016.3	71	0	1.6	4.3	11.1	-				o
2	22.3	30.5	15.6	1014.9	75	0	1.6	6.5	14.8	-				o
3	23.3	31.7	16.6	1014.5	74	0	1.6	6.3	14.8	-				
4	23.9	32.2	17.4	1016.1	70	0	1.6	5.7	14.8	-				o
5	24.2	33.1	17.6	1016.6	64	0	1.8	3.9	7.6	-				
6	24.6	34	16.5	1014.6	60	0	1.8	4.4	7.6	-				
7	25.8	34.8	17	1012.2	59	0	1.9	2.8	5.4	-				
8	25.1	30.6	18.6	1013	64	0	1.9	9.1	18.3	-				
9	23.8	30.7	18.5	1013.8	58	0	1.9	9.3	13	-				
10	22.9	31.5	15.7	1014.1	55	0	3.1	6.7	11.1	-				
11	23.3	32.3	14.8	1013.8	57	0	2.7	3.9	7.6	-				
12	22.9	28.9	15.8	1013.5	58	0	1.9	3.9	7.6	-				
13	23.7	30.8	18.9	1012.7	60	0	1.9	3	7.6	-				
14	24.9	33.8	17	1012.8	53	0	1.9	7.4	14.8	-				
15	25.8	34.6	17	1012.3	53	0	2.7	7.8	13	-				
16	25.4	31.7	19.4	1011	55	0	1.9	7.8	16.5	-				
17	22.5	28.2	18.1	1010.2	76	2.03	1.9	9.3	16.5	-	o			
18	23.4	30	18.5	1012.3	68	1.02	2.6	6.5	11.1	-				
19	23	29.3	16	1013.8	67	0	2.3	6.5	9.4	-				
20	25.4	31.3	16.1	1013.5	56	0	2.4	7	18.3	-				
21	24.2	31.7	17.4	1014.5	63	0	2.7	4.4	9.4	-				
22	24.5	32.6	16.8	1015.2	55	0	2.3	5.6	9.4	-				
23	25	34	16.5	1014.4	56	0	2.7	6.9	11.1	-				
24	25.9	35.7	16.6	1014	51	0	2.7	6.7	13	-				
25	25.9	35.2	17.8	1014.4	52	0	3.1	7.8	18.3	-				
26	26.1	35	18.4	1014.1	56	0	2.7	5.4	13	-				
27	26.5	35.6	18	1012.8	53	0	3.1	5.4	9.4	-				
28	26.9	37	18	1011.4	50	0	3.1	6.5	11.1	-				
Monthly means and totals:														
	24.4	32.4	17.2	1013.7	60.3	3.05	2.3	6.1	12		1	0	0	3

March(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	26.6	36.5	18.1	1012.6	49	0	3.2	6.9	14.8	-				
2	25.4	34.6	17.4	1013.6	53	0	3.1	7.4	16.5	-				
3	25.3	35.1	16	1013.6	56	0	3.5	7.2	18.3	-				
4	26.2	35.6	17.3	1014.3	57	0	1.9	8.3	20.6	-				
5	26.8	36.3	18.2	1014.6	62	0	2.6	6.9	18.3	-				
6	27.5	37.2	18.3	1014.2	56	0	2.9	7.8	16.5	-				
7	28.7	37.9	18.5	1014	48	0	3.7	11.5	22.2	-				
8	28.4	38.2	19.3	1012.9	60	0	2.7	10.4	20.6	-				
9	28.5	38.4	17	1010.9	48	0	3.2	11.3	20.6	-				
10	29	37.5	23.3	1009.7	68	0	3.4	9.6	18.3	-	o			
11	29.1	38	22.8	1010.2	71	0	2.7	17	24.1	-				
12	29.3	40.2	22.3	1009.5	64	0	2.6	17.2	27.8	-				
13	29.4	39.3	21.5	1010.2	64	0	2.7	9.3	18.3	-				
14	29.4	38	22.6	1011.4	69	0	2.6	10.6	22.2	-				
15	28.8	36.1	23	1012.7	61	0	1.9	6.1	14.8	-				
16	29.2	36.3	21.2	1013.6	62	0	1.9	8.3	20.6	-				
17	27.8	35.5	22.4	1012.4	71	0	1.8	7.6	22.2	-				o
18	29.2	37.1	19.9	1009.6	56	0	2.9	10.2	22.2	-				
19	28	39.2	20.7	1009.6	63	0	3.1	10.9	22.2	-				
20	29.6	40.1	20.6	1009.7	60	0	2.3	8.7	16.5	-				
21	29.8	39	21.6	1007.7	66	0	2.7	12	22.2	-				
22	29.9	38.4	23.5	1006.5	69	0	2.7	20.6	25.9	-				
23	29.8	38	24.4	1009.1	76	0	3.2	16.7	27.8	-				
24	29.7	38.1	23.1	1009.4	70	0	2.7	16.1	22.2	-				
25	31	40.6	24	1006.7	62	0	3.1	13.9	18.3	-				
26	31.8	41.2	23.3	1006	61	0	2.6	11.1	18.3	-				
27	30.4	38.7	24.1	1007.4	70	0	3.7	8.9	18.3	-				
28	30.2	38.2	25.6	1008	67	0	3.5	9.4	20.6	-	o			
29	30.2	36.8	24.2	1008.8	60	0	3.1	11.3	14.8	-				
30	30.6	39.8	24.4	1006.4	62	0	3.5	15.6	22.2	-				
31	30.4	37	26.2	1007	71	0	3.5	15	24.1	-				
Monthly means and totals:														
	28.9	37.8	21.4	1010.4	62.3	0	2.9	11.1	20.4		2	0	0	1

April(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	30.2	38	25.6	1008.5	72	0	3.7	11.9	24.1	-	o		o	
2	30.2	37.8	25	1008.8	75	0	3.2	14.3	22.2	-				
3	31.2	40.7	24.2	1007.8	61	0	3.2	15.7	22.2	-				
4	33.1	41.4	25.5	1004.9	55	0	3.1	9.3	14.8	-				
5	32.3	42.2	25.3	1004.9	49	0	3.5	8	18.3	-				
6	32.3	42	25.5	1005.6	58	0	2.7	13	20.6	-				
7	32.2	42	25.3	1005.3	55	0	3.1	15.7	27.8	-				
8	32.5	41.4	26	1006.3	63	0	2.9	15.6	25.9	-				
9	31.7	40.5	26.7	1006.9	70	0	3.1	20.9	25.9	-				
10	31.8	40.7	26.9	1006.2	69	0	3.2	21.1	29.4	-				
11	32.1	40.6	26.7	1006.4	61	0	3.1	17.8	29.4	-				
12	31.3	39.2	25.8	1007.9	64	0	3.7	22.6	33.5	-				
13	31.5	40.4	23.5	1008.5	50	0	3.5	21.1	35.2	-				
14	30.2	38.8	24.3	1008.5	57	0	3.5	13.5	24.1	-				
15	30.7	40.2	22.2	1006.3	57	0.76	3.2	17.4	29.4	-	o		o	
16	30.5	39.7	26.9	1002.5	75	0	2.6	19.4	29.4	-	o		o	
17	31.8	40.4	25.7	1002	70	0.76	1.9	19.6	27.8	-				
18	30.8	38.7	25.4	1003.7	69	0	2.6	19.6	31.3	-	o		o	
19	28.4	37.6	22.6	1005.7	71	0	2.7	21.3	40.7	-	o		o	
20	25.4	31.2	20	1008.8	74	8.89	3.1	14.6	25.9	-	o		o	
21	24.6	33.6	21	1009.4	81	1.02	2.6	8.3	16.5	-	o		o	
22	27.1	34.4	20.4	1010	77	39.88	2.9	8.9	16.5	-				
23	29.6	36.6	23.4	1010.5	72	0	3.7	10.7	25.9	-				
24	30.4	38.2	24.7	1010.1	70	0	4	11.1	22.2	-				
25	31.4	38.4	26.4	1009.6	70	0	3.5	14.4	20.6	-				
26	31.8	39.4	26.4	1008.6	71	0	3.7	12.8	22.2	-				
27	31.9	39.6	24.8	1006.6	69	0	3.2	20.7	25.9	-				
28	32.2	40.1	27.4	1004.8	72	0	3.7	21.1	25.9	-				
29	32.8	39.5	28.4	1005.3	72	0	2.9	26.3	33.5	-				
30	31.9	39.4	28.3	1005.2	72	0	2.7	21.5	33.5	-			o	
Monthly means and totals:														
	30.8	39.1	25	1006.9	66.7	51.31	3.2	16.3	26		7	0	8	0

May(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	32.4	40.6	27.4	1002.9	72	0	3.5	24.4	33.5	-				
2	32.9	41.2	27.6	1000.5	69	0	4	25.2	29.4	-				
3	32.7	40.2	28	1001.4	68	-	4	29.4	33.5	-	o		o	
4	31.9	39.3	28	1002.7	73	0	4	31.7	40.7	-				
5	32.2	38.8	28.4	1005	68	0	4	33.3	42.4	-				
6	32.1	39.2	28.4	1004.5	68	0	4	32.2	40.7	-				
7	30.9	36.8	23	1003.9	77	14.99	3.7	25	37	-	o		o	
8	31.9	38.6	27.7	1002.7	75	0	4	31.5	35.2	-				
9	32.8	39.7	28	1002.6	71	0	4	24.8	29.4	-				
10	32.8	40	28.1	1002.2	73	0	4	28.3	33.5	-				
11	33.4	41	28.8	1001.1	71	0	2.7	24.3	29.4	-				
12	30.7	39.4	24.4	1003.9	76	14.99	3.1	21.5	33.5	-			o	
13	30.2	35.7	22.4	1003.7	80	0	3.2	8	18.3	-				
14	31.2	36	27	1002.1	73	0	4	9.1	14.8	-				
15	30.2	33.3	26.8	1000.8	81	0	4	6.3	9.4	-				
16	31.6	37.7	25.8	1001.2	71	0	3.1	13.7	22.2	-				
17	32.8	38.8	27.6	1002.7	76	0	2.7	26.7	33.5	-				
18	33.1	40.2	28.7	1002.7	73	0	2.7	28.5	37	-				
19	32.9	40.2	26.7	1001.7	71	0	3.7	29.6	40.7	-				
20	33.3	40.4	28.2	1001.1	71	0	3.7	31.5	64.8	-				
21	32.5	38.4	28.4	1001.8	76	-	3.2	29.6	42.4	-	o			
22	34	42.6	27.8	999.9	68	0	3.2	19.1	29.4	-				
23	33.9	41.3	28.8	999.2	70	0	2.7	19.4	33.5	-				
24	34.1	41.8	28.7	998.2	70	0	3.1	19.6	27.8	-				
25	34.2	42	28.8	998.7	68	0	2.7	10.2	18.3	-				
26	29.4	39	24	1000	82	24.89	2.6	9.3	14.8	-	o		o	
27	28.7	34.9	22.4	1001.4	82	0.25	3.5	4.6	11.1	-			o	
28	29.5	37.2	24.2	1000.5	76	2.03	3.1	9.3	14.8	-	o		o	
29	27.8	32.4	22.3	999.4	86	5.08	2.7	10	24.1	-	o		o	
30	30.9	37.2	23.6	997.7	79	0	3.1	12.4	22.2	-				
31	30.2	33.8	25.8	1001.1	79	0	3.1	16.1	25.9	-				
Monthly means and totals:														
	31.8	38.6	26.6	1001.5	74	62.23	3.4	20.8	29.8		6	0	7	0

June(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	31.3	36.9	26.8	1003.1	73	0	2.7	21.7	27.8	-	o			
2	31	35.8	26.8	1002.8	79	0	4	12.6	18.3	-	o			
3	31.4	37.4	26.1	1002.4	74	7.11	4	12.2	24.1	-				
4	31.6	37.6	25.4	1002.9	71	0	4	10	22.2	-				
5	32.2	38.8	25.8	1002.6	67	0	4	12.6	22.2	-				
6	32.5	38.6	26.8	1001.7	68	0	4	13.9	24.1	-				
7	32.4	39.2	26.4	1001.1	72	-	3.7	11.1	25.9	-	o		o	
8	30.1	35.2	23.4	1000.3	81	9.91	3.2	8.5	16.5	-	o			
9	29.4	37.8	25	999.1	86	0	2.3	10.9	14.8	-	o		o	
10	31.2	36.4	25	999	74	9.91	4	8.3	18.3	-				
11	27.9	35	26	998.8	88	0	2.7	4.8	9.4	-	o		o	
12	27	29.5	23.9	994.7	89	7.11	1.8	12.8	16.5	-	o			
13	26.8	30.1	23.8	993.8	97	27.94	2.3	12.4	22.2	-	o		o	
14	27.8	29.7	24	995.1	93	26.92	1.9	10	13	-	o			
15	28.7	32	24.3	998.7	86	10.92	1.9	15.6	25.9	-			o	
16	30.5	35.5	24.9	1000.9	80	0	3.7	14.6	22.2	-				
17	30.7	35.9	24	1000.8	80	0	3.1	14.6	22.2	-			o	
18	30.7	37.2	26.2	998.5	81	0	3.5	10.2	14.8	-			o	
19	30.1	36.8	24.2	999	79	-	3.2	9.4	20.6	-	o		o	
20	28.4	36	21.5	999.5	87	72.9	3.1	10.2	18.3	-	o		o	
21	28	31.2	21.6	998.9	92	77.98	4	12.6	25.9	-				
22	29	32.2	24.2	997.3	84	0	2.7	8.3	14.8	-	o		o	
23	29.1	33	24	995.1	87	1.02	2.6	7.6	11.1	-	o		o	
24	28.1	31.8	24.8	992.8	93	3.05	2.1	18.5	38.9	-	o		o	
25	29.7	35	23.6	997.7	87	32	3.7	24.6	31.3	-	o			
26	30.4	34.2	26	1000.2	81	0	3.7	25	31.3	-			o	
27	30.5	35.4	26	1000.3	85	0	4	18.3	27.8	-				
28	30.3	34.6	25.2	1000.2	80	0	3.5	13.1	25.9	-			o	
29	28.9	31.1	24.6	1000.6	88	0.25	3.2	11.9	18.3	-	o			
30	28.3	31.2	25.4	1000.1	90	1.02	2.7	13.7	18.3	-	o		o	
Monthly means and totals:														
	29.8	34.7	24.9	999.3	82.4	288.04	3.2	13	21.4		17	0	15	0

July(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.2	33	22.6	998	85	5.08	3.1	9.4	18.3	-	o			
2	27.3	28.5	23.4	998.6	93	0	1.9	3.9	9.4	-	o			
3	29.9	33.2	25.2	999.7	87	1.02	3.5	13.5	25.9	-	o		o	
4	30	35.5	25.2	1000	84	0	3.7	11.9	20.6	-				
5	30	35.2	25.2	1000.6	83	0	2.7	4.6	9.4	-			o	
6	28.4	34.2	25.4	1002.8	93	21.08	2.4	5.6	7.6	-	o		o	
7	29.7	36.3	24.3	1002.8	80	0	3.5	12	18.3	-				
8	29.8	37.2	24.2	1000.9	82	0.25	3.1	5.9	11.1	-				
9	29.9	35.9	24.4	998.4	82	0	3.5	7.2	20.6	-			o	
10	28.5	35.5	25.4	996.6	86	3.05	3.4	7.2	20.6	-	o		o	
11	28.7	32.8	24	996	89	11.94	2.4	10	20.6	-	o		o	
12	29	33.6	24.3	999.2	88	0.76	3.7	16.1	27.8	-	o			
13	28.5	32.5	24.1	1000.1	87	2.03	3.2	10.9	18.3	-	o		o	
14	28	31.5	24	999	91	4.06	2.6	7.4	20.6	-	o		o	
15	28.2	33.2	23.8	998.6	93	0.51	3.5	5	7.6	-	o		o	
16	27.3	29.3	23.6	998	93	10.92	2.6	6.1	11.1	-	o			
17	29.2	32.4	23.6	998.2	85	1.02	3.7	9.3	14.8	-				
18	29.2	33.1	24.3	996.1	87	0	4	5.6	11.1	-	o			
19	27.8	30.7	24.8	995.9	96	0	2.1	4.3	11.1	-	o		o	
20	27.8	31.6	23.7	997.3	96	71.88	3.2	6.1	11.1	-	o		o	
21	28.1	31	23.6	995	94	7.87	3.7	7.8	13	-	o			
22	27.8	31.1	24.1	993.5	95	3.05	2.3	10.6	20.6	-	o			
23	28.7	31.8	23.8	995.4	90	13.97	3.5	8.5	14.8	-	o		o	
24	27.1	29.5	23.8	997.2	96	29.97	2.6	10.7	14.8	-	o		o	
25	26.8	28.8	23.5	996.3	97	9.91	1.9	11.3	16.5	-	o			
26	27.2	28.6	23	996.6	94	6.1	3.7	19.6	33.5	-	o			
27	29.1	32.8	24.2	1000.6	86	1.02	3.2	21.1	27.8	-	o		o	
28	29.3	32.5	23.6	1001.6	89	12.95	2.7	15.9	22.2	-				
29	27.4	29.6	26	998.4	93	0	2.7	9.3	14.8	-	o			
30	26	28.2	25	993.9	98	17.02	2.6	14.3	22.2	-	o			
31	27.3	30.2	24.9	994.4	93	3.05	3.1	14.6	20.6	-	o			
Monthly means and totals:														
	28.4	32.2	24.2	998.1	89.8	238.51	3	9.9	17.3		24	0	14	0

August(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	27.8	30.5	25.4	998.1	88	0.51	4	13.7	25.9	-				
2	29.5	34.5	25.4	1001.1	83	0	4	12.6	20.6	-				
3	29.5	34	26.2	1001.6	83	0	3.1	7.4	11.1	-			o	
4	27.8	33.4	26.4	1000.8	91	0	3.5	5.9	11.1	-			o	
5	27.6	33.4	26	1000.6	92	8.89	2.7	5	13	-	o			
6	28.4	32.2	25.5	1001.7	91	10.92	3.5	11.3	18.3	-	o		o	
7	28.3	31.3	25.6	1002.8	92	11.94	4	13.3	22.2	-	o			
8	27.7	29.2	26.8	1002.2	95	0	1.9	7.6	16.5	-				
9	29.2	33	26.4	1002.4	90	1.02	3.5	4.6	9.4	-				
10	29.3	33.2	26.4	1002.7	88	0	3.2	5.2	7.6	-	o		o	
11	27.3	28.3	26.4	1003.9	96	0.51	1.9	4.6	9.4	-	o		o	
12	27.8	32.8	25.8	1002.7	84	7.87	3.4	7.4	16.5	-	o			
13	27.9	31.5	25.6	1002.2	93	12.95	3.5	6.3	11.1	-	o			
14	28.7	32.9	26.2	1002.1	88	2.03	4	5.4	7.6	-			o	
15	29.2	35.2	26.5	1002.3	87	6.1	4	7.4	25.9	-	o		o	
16	29.9	35	27	1000.7	82	0	3.7	9.4	16.5	-				
17	28.1	34.5	25.6	1000.1	89	11.94	3.1	8.3	14.8	-	o		o	
18	27.7	32.2	25.2	999.8	92	0.25	3.7	7	11.1	-	o		o	
19	27.4	30.8	25.3	997.6	91	0.25	3.2	16.7	27.8	-	o			
20	27.2	29	25.6	996.1	92	2.03	3.5	13.3	24.1	-	o		o	
21	28.3	32	25.8	997	87	2.03	4	11.5	22.2	-				
22	29.7	34.2	25.8	999.2	80	0	4	9.6	16.5	-				
23	30.3	34.6	27.6	1001.1	79	-	4	10	18.3	-	o			
24	29.6	34	27.2	1002	84	0	4	7.2	11.1	-				
25	29.6	35.2	26.4	1001.4	80	0	4	10	20.6	-				
26	29.3	33	26.4	1001	85	0	4	7	11.1	-	o		o	
27	27.7	29.7	27	1001.9	95	0.51	2.3	6.3	11.1	-	o			
28	25.6	27	24.4	1004.5	98	40.89	3.2	5.7	11.1	-	o		o	
29	27.3	32.5	25	1005.5	91	5.08	3.1	7.4	16.5	-	o			
30	29.3	33.8	25.7	1004.9	82	8.89	3.7	12.6	25.9	-				
31	29.1	34.1	26.5	1004.5	85	0	4	10.6	24.1	-			o	
Monthly means and totals:														
	28.5	32.5	26	1001.4	88.2	134.61	3.5	8.7	16.4		17	0	13	0

September(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	29.9	35.6	25.9	1004.6	83	0	3.5	11.9	22.2	-	o		o	
2	28.8	30.7	27	1005.2	92	0.76	2.4	6.9	14.8	-	o			
3	27.6	32.2	24.1	1005.1	91	26.92	2.7	9.3	18.3	-	o		o	
4	28.7	33.2	25.3	1004.7	86	0	3.1	8.5	14.8	-	o			
5	29.6	37.2	25.7	1003.3	83	0.25	3.5	9.6	14.8	-			o	
6	29.2	33.5	25.6	1005.2	84	0	3.1	4.6	11.1	-			o	
7	27.6	33	25.2	1006.2	90	45.97	1.9	3.9	9.4	-	o		o	
8	26.7	29.1	24.6	1007.2	92	1.02	2.6	6.9	13	-	o		o	
9	26.8	32	25	1007.8	93	0.76	2.3	4.1	7.6	-	o		o	
10	27.9	32.2	25.3	1006.1	89	7.87	3.7	5.2	11.1	-	o		o	
11	29.1	34	25.5	1006.4	83	0	3.7	5.9	14.8	-	o		o	
12	29.6	34.4	26	1007.4	82	0	3.7	8	16.5	-				
13	29.7	34.3	26.3	1006.9	82	0	4	6.5	16.5	-				
14	29.9	34.9	25.8	1004	82	0	4	8.1	16.5	-				
15	27.7	34.4	25.8	1002	90	0	2.6	3.7	7.6	-	o		o	
16	26.2	32.2	25	1002.1	97	55.88	2.1	5.7	9.4	-	o		o	o
17	27.3	33.6	24.3	1001.5	92	9.91	2.7	7.8	22.2	-	o		o	
18	26.6	30.8	24.4	1001.2	95	17.02	2.3	7.2	11.1	-			o	
19	26.3	30	25	999.4	97	23.11	2.4	9.4	16.5	-	o		o	
20	27.1	30.2	24.5	1000.5	92	21.08	2.6	11.3	18.3	-	o			
21	27.3	30.8	24.4	1001.8	92	26.92	2.6	11.1	22.2	-			o	
22	28.5	32.7	25.2	1001.7	89	7.87	2.7	8.9	18.3	-	o			
23	28.8	32.7	25.7	1002.7	87	0	3.2	6.5	11.1	-				
24	29.4	33.8	26.2	1004.4	84	0	3.5	6.9	9.4	-				
25	29.4	34.6	26.5	1006.3	83	0	3.2	7.6	11.1	-				
26	29.7	34	25.5	1006.9	84	0	3.7	8	11.1	-				
27	27.3	32.9	25	1006.3	91	48.01	3.1	6.5	11.1	-	o		o	
28	27	30.6	24.2	1004.1	94	-	2.1	6.9	11.1	-	o		o	
29	26.6	29	24	1001.1	97	22.1	1.9	4.6	7.6	-	o		o	
30	26.8	30.8	25	1001	94	6.1	2.4	3	9.4	-	o		o	
Monthly means and totals:														
	28.1	32.6	25.3	1004.1	89	321.55	2.9	7.2	13.6		19	0	19	1

October (2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	26.6	28.2	25.4	1003.3	97	0	1.9	5.6	9.4	-	o		o	
2	27.3	30.6	24.3	1006.8	93	0.51	2.6	5.7	11.1	-	o			
3	26.8	31.2	25.2	1007.5	91	0.25	2.3	8.7	27.8	-	o		o	
4	28.3	32.2	24.5	1007.1	89	9.91	3.2	12.6	25.9	-	o			
5	28.7	33.7	26	1006	86	0	3.1	9.1	18.3	-	o		o	
6	28.3	34.1	25.4	1007.1	89	0.51	3.1	9.1	22.2	-	o			
7	28.9	34.2	25.6	1007.9	85	4.06	2.6	4.3	9.4	-			o	
8	27.6	31.4	25.8	1008.6	89	0	3.1	5.7	14.8	-	o		o	
9	26.8	31.2	24	1008.4	92	10.92	2.3	5.6	11.1	-	o		o	
10	27.7	31.7	24.3	1009	89	9.91	2.6	8.1	14.8	-	o			
11	26.4	30.7	24.2	1005.5	90	0	2.3	15.4	18.3	-	o		o	
12	24.4	26	23	995.1	99	59.94	1.1	36.1	50.4	-	o			
13	27	30.8	23	999.3	93	168.91	1.8	38.5	68.3	-	o		o	
14	28.3	32.6	25.2	1005.2	91	7.87	1.9	16.3	29.4	-				
15	27.2	31.2	24.6	1008.3	86	1.02	3.1	5.7	11.1	-	o			
16	27.4	31	24	1008.4	86	0	2.3	2.8	9.4	-				
17	27.7	32.3	23.4	1009.5	84	0	2.4	4.6	7.6	-				
18	28.4	32.9	24	1010.2	83	0	2.1	4.3	7.6	-				
19	28.3	33.6	24.8	1010.7	80	0	2.4	5	14.8	-				
20	26.5	33.4	25	1009.7	92	20.07	2.1	3.3	7.6	-	o		o	
21	25.5	31.8	22.8	1008.8	94	42.93	2.3	7.2	11.1	-	o		o	
22	24.4	26.8	22.5	1010	99	41.91	2.1	11.1	14.8	-	o			
23	24.3	25.6	23.2	1010.5	99	59.94	2.1	12.6	20.6	-	o			
24	24	26	23.4	1009.9	100	74.93	1.8	9.4	14.8	-	o			
25	24.2	25	23.1	1008.7	100	18.03	2.1	8.5	14.8	-	o			
26	25	27.8	23.6	1009.2	98	0.51	2.6	7.6	13	-	o			
27	22.9	24.2	22	1009.3	99	8.89	1.9	6.9	11.1	-	o			
28	24.9	29.2	21.2	1009.8	90	3.05	3.7	6.1	11.1	-				
29	26.5	31.5	22.2	1012.1	84	0	3.1	4.6	11.1	-				
30	25.4	31	21.8	1013.3	77	0	4.3	6.9	11.1	-				
31	24.6	30.8	19.3	1014.2	78	0	1.9	5.9	11.1	-				
Monthly means and totals:														
	26.5	30.4	23.8	1008	90.4	544.07	2.5	9.5	17.2		21	0	10	0

November(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	25.1	32.2	21.4	1013.9	73	0	1.9	5	7.6	-				
2	24.6	32.8	19.6	1013.6	75	0	1.9	3.3	9.4	-				
3	23.7	31.6	18.7	1014.8	73	0	1.9	3.5	5.4	-				o
4	24.2	32.2	17.3	1015.9	73	0	2.6	4.1	5.4	-				
5	25.1	30.6	19.3	1015.9	79	0	1.9	5.6	11.1	-				
6	25.2	30.8	20.2	1015.1	80	0	2.1	4.8	9.4	-				
7	24.4	29.6	20.8	1013.9	80	0	1.9	5	7.6	-				
8	24.2	29.7	20	1012.7	79	0	1.9	5	9.4	-				
9	23.8	29.5	19.1	1012.6	78	0	1.9	4.6	11.1	-				
10	23.6	30.1	19.5	1012	76	0	2.3	5.9	9.4	-				
11	22.8	29.8	18	1011	69	0	3.1	6.3	9.4	-				
12	22.5	29.5	16.6	1012.2	71	0	2.7	4.8	9.4	-				
13	22	29.4	17	1012.3	68	0	2.3	7.2	14.8	-				
14	21.4	29	15.2	1013.1	70	0	1.6	5.4	11.1	-				
15	22.3	28.6	15.6	1013.6	65	0	1.9	5.7	7.6	-				
16	22.2	26.6	17.8	1014.2	77	0	1.9	5.7	9.4	-	o			
17	24.6	30.2	19	1013.9	67	0	2.6	6.7	18.3	-				
18	23.2	29.6	18.6	1014.2	71	0	2.4	7.8	18.3	-				
19	23.4	29.6	16.7	1013.7	67	0	1.9	9.6	22.2	-				
20	22.8	28	19	1011.7	70	0	1.9	8.3	18.3	-				
21	23.2	27.4	18.1	1011.6	65	0	1.9	11.3	18.3	-				
22	23.7	29.2	20	1013.1	66	0	1.8	7.6	18.3	-				
23	23.7	32.1	18.3	1013.2	75	0	1.8	1.7	9.4	-				
24	26.2	33.6	19.7	1013	72	0	2.4	4.8	11.1	-				
25	23.5	29.6	19	1011.1	79	0	1.4	5.4	9.4	-				o
26	22.3	29.8	16.3	1010.4	71	0	1.4	4.1	7.6	-				
27	23.6	29.2	16.4	1012.4	63	0	1.9	5.9	9.4	-				
28	24.4	27.8	21.4	1014.8	70	0.51	1.9	9.1	14.8	-	o			
29	26.3	31.8	20.2	1013.9	79	0	2.3	4.8	11.1	-				
30	26.5	30.8	23.4	1013.6	83	0	1.6	3.9	7.6	-				o
Monthly means and totals:														
	23.8	30	18.7	1013.2	72.8	0.51	2	5.8	11.4		2	0	0	3

December(2013)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	24.7	29.2	21.4	1014.7	81	0	1.1	5.7	14.8	-				o
2	22.2	29.2	18.2	1014.8	71	0	1.8	5.4	11.1	-				o
3	21.4	28.4	16	1014.2	63	0	1.9	5.9	9.4	-				
4	21.2	28.2	15.5	1014	68	0	1.8	4.6	9.4	-				
5	20.4	28.2	14.9	1012.9	63	0	1.9	6.5	11.1	-				
6	20.3	27.4	12.8	1012.6	61	0	2.6	5.9	11.1	-				
7	20.6	28.8	12.8	1013.1	66	0	1.9	5.4	7.6	-				
8	20.4	26.6	14.6	1012.3	74	0	1.9	5.7	11.1	-				
9	22.2	27	16.1	1010.7	68	0	1.9	7	13	-				
10	23.1	28.4	17.9	1010.3	67	0	1.9	10.9	22.2	-				
11	23.1	29.2	18.5	1011.6	66	0	1.9	8.3	14.8	-				
12	21.7	28.7	17.2	1011.9	72	0	1.9	4.8	7.6	-				
13	20.2	29.2	13.8	1012.5	60	0	1.9	5.9	9.4	-				
14	20.3	29.2	12.7	1011.8	60	0	2.6	5.4	9.4	-				
15	20	28.8	13.9	1013.8	63	0	1.6	3.9	11.1	-				
16	20.5	29.1	13.7	1015	68	0	1.9	4.8	7.6	-				
17	20.7	29.3	13.6	1013.3	71	0	1.9	4.8	7.6	-				o
18	20.4	29.8	14.3	1012.4	70	0	1.8	3.7	9.4	-				
19	21.1	29.8	15	1013.2	72	0	1.8	4.4	11.1	-				
20	22.1	30.6	17	1014.4	73	0	1.9	6.5	16.5	-				
21	22.1	30.5	16.8	1016	72	0	1.8	5.7	11.1	-				
22	22.5	30.2	16.8	1017.3	71	0	1.9	5.2	13	-				
23	22.8	29.8	17	1017.8	66	0	1.8	4.6	11.1	-				
24	22	29.4	14.3	1017.7	72	0	1.8	5.6	9.4	-				
25	22.1	27.8	18.5	1017.3	80	0	1.4	3.9	9.4	-				
26	21.1	27.8	17.6	1016.6	74	0	1.4	4.3	7.6	-				
27	20.7	28.4	16.4	1016.1	69	0	1.4	4.1	7.6	-				
28	21.3	30.1	15.2	1015.6	69	0	1.6	3.1	7.6	-				
29	21.9	30.9	16.2	1015.5	66	0	1.8	5.6	11.1	-				
30	21.7	29.4	17	1017.2	74	0	1.1	6.5	9.4	-				o
31	21.2	29.2	16.4	1017.5	73	0	1.1	5.7	9.4	-				
Monthly means and totals:														
	21.5	29	15.9	1014.3	69.1	0	1.8	5.5	10.7		0	0	0	4

Climate Bhubaneswar historical weather (2014)

January(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	21.8	28.9	16.2	1016.4	75	0	1.4	3.3	7.6	-				
2	22.3	29.2	17	1016.3	72	0	1.6	4.6	7.6	-				
3	22	28.8	17.6	1016.2	77	0	1.3	4.6	9.4	-				
4	21.2	26.7	17.2	-	75	0	1.4	6.1	11.1	-				
5	21.8	29.5	16.4	1012.8	72	0	1.4	4.1	7.6	-				o
6	23.3	30.7	17.4	1013.4	76	0	1.6	5	11.1	-				o
7	22.7	28.2	19.4	1015.3	79	0	1.4	8.1	11.1	-				
8	20.9	27.4	16	1016.7	70	0	1.8	9.3	16.5	-				
9	20.4	29.2	15.2	1015.4	73	0	1.8	5.7	7.6	-				
10	22.2	29.4	16	1015.4	71	0	1.4	5.6	11.1	-				
11	23.9	31.2	17	-	65	0	1.6	8.3	14.8	-				
12	23.2	29.4	19	1017	75	0	1.6	7.4	11.1	-				
13	21.8	27.7	18.5	1017	72	0	1.4	7.2	14.8	-				
14	22.2	28.8	17.2	1015.8	72	0	1.9	5.7	13	-				
15	22.5	28.2	18	1016.4	75	0	1.8	9.3	14.8	-				
16	21.8	27	18.9	1017.3	81	0	1.3	8	11.1	-				
17	20.9	27.6	16	-	72	0	1.6	7.6	14.8	-				
18	21.8	29.5	15	1018.1	71	0	1.4	6.7	13	-				
19	23.5	31.9	16.6	1019.5	65	0	1.8	5.2	13	-				
20	22.8	29.3	17.8	1019.5	76	0	1.9	5.2	9.4	-				
21	22.1	29.2	17.4	1018.4	70	0	1.8	7.6	14.8	-				
22	21.4	28.5	16.6	1018	66	0	1.8	5.7	9.4	-				
23	21.8	30.2	14.7	1017.5	64	0	1.8	6.7	14.8	-				
24	22.4	30.2	16.2	1015.6	66	0	1.8	5	11.1	-				
25	22.3	29.2	16.4	-	68	0	1.9	6.3	13	-				
26	21.7	30	16	1016.2	67	0	1.9	7	14.8	-				
27	21.8	28.8	16	1016.2	69	0	1.8	5.2	7.6	-				
28	21.6	27.3	16.8	1016	67	0	1.8	6.3	11.1	-				
29	19.8	27.9	16	1016.7	72	0	1.6	6.9	14.8	-				
30	21.5	29.3	13.9	1016.6	65	0	1.6	5.6	9.4	-				
31	21.4	29.6	15.1	1016.9	66	0	1.6	5.6	9.4	-				
Monthly means and totals:														
	22	29	16.7	1016.5	71.1	0	1.6	6.3	11.6		0	0	0	2

February(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	21.8	29.4	16	1016.5	66	0	1.8	5.6	11.1	-				
2	21.9	30	16	1014.6	62	0	1.9	3.9	9.4	-				
3	22.1	30.5	15.4	1011.8	68	0	1.8	4.6	7.6	-				
4	24.3	33.5	16	1009.8	59	0	2.4	5.6	14.8	-				o
5	24.3	32.6	17.4	1010.1	64	0	1.9	4.8	7.6	-				o
6	25.9	34.3	19.7	-	54	0	2.6	5	11.1	-				
7	25.6	36.7	18.2	1009.7	56	0	2.7	7.8	16.5	-				
8	26.4	36.3	17.8	1008.3	56	0	2.7	9.3	20.6	-				
9	26.6	37	20.6	1007.8	59	0	2.6	7.8	18.3	-				
10	26	32.6	20.8	1008.5	66	0	1.9	8.7	14.8	-				
11	25.7	32.4	21.6	1009	75	0	1.8	9.1	16.5	-				
12	24.4	29.9	20.1	1010.7	61	0	1.8	10.9	18.3	-				
13	24.9	32	19.4	1013.3	69	0	1.9	9.8	18.3	-				
14	25.2	33.2	21	1012.3	73	0	1.9	10.9	22.2	-				
15	25.8	33.1	20.2	1010.6	70	0	2.6	13.9	25.9	-				
16	23.9	31.4	19.8	1010.7	83	1.02	2.3	13	37	-	o			
17	21.3	27.5	15.7	1014.8	58	0	3.7	8.3	13	-				
18	21.1	27.7	15.2	1017.3	50	0	3.2	6.9	11.1	-				
19	21.4	28.4	15	1015.6	56	0	2.9	5.9	9.4	-				
20	23.6	30.7	16	1014.5	58	0	2.4	5.2	18.3	-				
21	23.9	32.3	17.2	1014.6	66	0	2.6	7	20.6	-				
22	22.7	33	18	1015.2	71	0	3.1	5.4	16.5	-				
23	24.6	30.5	19	1016.1	69	0	1.9	6.3	14.8	-				
24	25.4	33.4	19.8	1016.3	62	0	2.3	6.7	14.8	-				
25	25.7	33.5	20	1016.1	64	0	1.8	5.9	16.5	-				
26	26	34.7	20.6	1013.7	66	0	2.7	9.6	20.6	-				o
27	26.2	35.2	22	1013.9	70	0	2.9	8.9	18.3	-				
28	25.7	32.2	21.9	1014.7	69	0	3.1	9.3	18.3	-				
Monthly means and totals:														
	24.4	32.3	18.6	1012.8	64.3	1.02	2.4	7.7	16.5		1	0	0	3

March(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	25.1	32.2	20.2	1013.9	76	0	2.3	9.3	18.3	-				
2	22.7	32.2	19	1013.4	86	-	2.7	5.2	9.4	-	o			
3	24.2	30.2	20	1014.1	81	0	2.1	3.7	11.1	-				
4	24	31.4	19.1	1015.4	76	0	1.9	10	16.5	-			o	
5	23.6	30	17	1014.9	76	0	3.4	5.9	11.1	-				
6	25.1	31.2	20.4	1014.3	72	-	2.7	7	16.5	-	o			
7	25.3	31.2	20.2	1015.1	68	0	2.6	6.9	14.8	-				
8	26.1	32.7	21	1016	72	0	1.9	6.9	14.8	-			o	
9	25.9	31.4	22.2	1014.8	76	0	2.6	4.4	9.4	-				
10	24.1	31.2	21	1015	77	0	2.3	5.9	18.3	-				
11	25.9	33.8	20	1014.8	67	0	2.7	7.8	20.6	-				
12	27.8	35.8	21.4	1014.1	64	0	2.7	9.4	16.5	-				
13	27.4	33.2	23	1013.3	69	0	2.3	3.3	5.4	-				
14	28.5	35.4	22.2	1013.2	65	0	2.6	6.3	16.5	-				
15	29	35.6	23.6	1014.5	69	0	2.6	6.5	16.5	-				
16	29.6	37.7	25	1014.3	68	0	2.6	9.1	16.5	-				o
17	28.8	36.5	23.6	1012.9	66	0	1.9	6.1	11.1	-				
18	29.6	39	22.2	1012.1	64	0	3.1	13	22.2	-				
19	29.2	35.7	23	1011.2	60	0	2.7	9.1	16.5	-				
20	28.9	37.5	24.2	1010.1	73	0	2.1	9.4	16.5	-				
21	28.8	35	25.4	1008.5	77	0	1.9	9.6	18.3	-				
22	28.5	35.9	25.1	1006.7	79	0	2.6	18.7	25.9	-				
23	29.3	37.8	25	1009	68	0	3.1	11.9	24.1	-				
24	29.8	37.2	24.4	1010.5	70	0	3.4	16.1	24.1	-				
25	29.4	36	24.6	1010.3	72	0	2.9	18	24.1	-				
26	29.8	37.4	24.6	1009.8	75	0	2.9	14.1	20.6	-				
27	29.8	39.4	25	1009	70	0	2.6	11.5	24.1	-				
28	33.7	41.3	24.6	1008.3	50	0	2.9	7.6	14.8	-				
29	32.8	41.9	25.6	1007.7	53	0	2.3	6.1	14.8	-				
30	32.3	42	25.8	1006.7	60	0	2.1	11.3	22.2	-				
31	30.5	40.5	25	1006	68	0	1.9	8.9	20.6	-				
Monthly means and totals:														
	27.9	35.4	22.7	1011.9	69.9	0	2.5	9	17.2		2	0	2	1

April(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	31.1	37.4	24.8	1005.5	60	0	1.9	9.1	18.3	-				
2	30.1	38.2	23.8	1006.4	63	0	2.1	8.9	20.6	-				
3	29.9	38.3	25	1007.1	76	0	2.1	17	22.2	-				
4	30.1	38.7	25	1008.2	67	0	1.9	8.7	16.5	-				
5	32	40.6	25.2	1008.7	47	0	2.7	11.7	20.6	-				
6	31.8	39.7	25.2	1009.1	65	0	2.7	18.3	25.9	-				
7	30.9	39.7	27.1	1008.1	74	0	2.7	20.4	29.4	-				
8	31.1	40.4	26.7	1006.6	74	0	2.7	11.9	24.1	-				
9	32.1	39.2	26.8	1007.8	49	-	1.9	9.8	18.3	-	o			
10	31.5	39	25.7	-	49	0	2.6	8.1	18.3	-				
11	29.6	39.3	24.4	1009.4	65	0	2.7	10.9	20.6	-				
12	30.4	39.2	26	1008.8	64	0	2.7	11.5	22.2	-				
13	29.3	37.8	24.3	1009.9	69	0	2.4	19.1	29.4	-				
14	29.6	38.4	22.6	1010.6	65	0	3.1	11.5	22.2	-				
15	29.4	39.7	25	1009.8	75	0	2.6	11.1	20.6	-				
16	31.7	40.2	27	1008	70	0	2.7	18	25.9	-				
17	31.7	40.4	27	1007.6	71	0	2.6	13.1	24.1	-				
18	32.3	39.8	26.8	1009.2	66	0	2.7	11.3	20.6	-				
19	32.1	40.4	25.6	1008.9	65	0	2.6	7	18.3	-				
20	30.1	41.7	24.4	1008.5	69	-	2.3	9.3	14.8	-	o		o	
21	31.3	39.8	24.4	1009.3	63	0	3.1	7.6	16.5	-				
22	32.4	41.2	26.6	1010.2	58	0	2.6	10.7	16.5	-				o
23	32.2	42.3	26.4	1008.1	59	0	2.9	13.5	24.1	-				
24	33.9	42.8	27.6	1006	59	0	3.4	18.1	25.9	-				
25	34.2	42.7	27.6	-	60	0	3.1	14.4	24.1	-				
26	33.4	40.8	28.6	1006.6	67	0	3.2	18.3	24.1	-				
27	32.6	40.7	27.8	1007.1	70	0	3.1	20.4	27.8	-				
28	32.6	41.6	27.6	1006.7	68	0	3.4	16.3	29.4	-				
29	32.5	40.9	27	1006.3	68	0	3.2	15.7	33.5	-				
30	33.6	42.2	26.6	1006.2	57	0	3.4	16.3	29.4	-				
Monthly means and totals:														
	31.5	40.1	26	1008	64.4	0	2.7	13.3	22.8		2	0	1	1

May(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	32.5	41.2	27.6	1005.8	70	0	3.2	20.2	29.4	-				
2	31.9	40.6	26.4	1006.5	61	0	3.1	17.6	31.7	-				
3	32.3	40.7	27.8	1006.8	63	0	3.7	25.4	42.4	-				
4	32.1	40	27.1	1007.3	58	0	3.1	27.4	51.9	-			o	
5	31.8	39.3	26.4	1008.6	62	0	3.7	16.3	25.9	-				
6	31.9	38.8	27	1008.9	66	0	3.4	18.5	27.8	-				
7	32.6	40.8	26.9	1006.9	63	0	3.7	25.9	33.5	-				
8	33.3	42.2	28.2	1005.1	62	0	3.2	27	33.5	-				
9	32.5	41.6	28.3	1003.7	62	0	3.7	17.6	33.5	-				
10	27.8	31.4	26.6	1005.4	87	-	2.3	12	25.9	-	o		o	
11	30.9	37.8	24.3	1005.2	75	18.03	3.7	13	25.9	-				
12	33.2	43.2	27	1004.7	65	0	3.2	12.2	24.1	-				
13	33.3	41.4	28.4	1004.7	68	0	2.6	15.4	22.2	-				
14	33.9	42.6	28.8	1003.6	62	0	3.1	13.9	22.2	-				
15	34.8	43.7	28.4	1002.6	52	0	3.4	11.9	24.1	-				
16	33.9	42.7	28.8	1004.1	57	0	3.1	13.1	22.2	-				
17	33.6	43.9	28.2	1005.8	62	0	3.2	18.5	27.8	-				
18	32.2	40.9	28.1	1006.1	69	0	2.9	13	29.4	-			o	
19	32.3	39	27.6	1006	71	0	2.7	18.7	25.9	-				
20	32.4	42.7	24.4	1005.8	66	-	2.7	12.8	18.3	-	o		o	
21	34.2	44.2	28.2	1002.1	59	0	2.6	10.2	18.3	-				
22	32.7	41.4	28.7	1000.9	63	0	1.9	6.3	14.8	-			o	
23	32.7	40.4	28	1002.6	63	0	2.7	12	25.9	-				
24	32.2	39.2	28	1004.4	69	-	3.5	13.1	25.9	-	o			
25	25.7	29	25	1004.9	98	-	1.8	13.3	18.3	-	o		o	
26	26.8	31.4	24.4	1004.7	94	-	2.6	18.1	33.5	-	o		o	
27	28.1	31.8	24.6	1003.4	85	0	3.5	13.5	29.4	-	o		o	
28	29.6	36.2	26.3	1005.2	82	0	3.5	11.9	24.1	-			o	
29	31.6	36.9	24.1	1005.1	79	4.06	3.2	17.6	22.2	-				
30	31.9	37.8	28.3	1002.4	81	0	2.7	24.1	29.4	-				
31	30.5	35.8	26.5	1001.7	83	-	1.9	20	31.3	-	o			
Monthly means and totals:														
	31.8	39.3	27	1004.9	69.6	22.09	3	16.5	27.4		7	0	9	0

June(2014)

Climatic mean values

Day	T	TM	Tm	SLP	H	PP	VV	V	VM	VG	RA	SN	TS	FG
1	30.6	36.2	25.3	-	80	-	3.1	18.3	33.5	-	o		o	
2	30.7	36.5	24.4	1003.8	77	0	3.2	13	22.2	-				
3	30.3	37.8	25.6	1002.6	85	0	2.7	14.8	22.2	-			o	
4	31.6	36.3	27.8	1001.8	82	0	3.7	16.3	24.1	-				
5	32.4	36.9	29.2	1000.7	77	0	3.1	20.2	25.9	-				
6	32.4	37.2	29	999.2	81	0	3.1	18.5	24.1	-				
7	31.8	36.3	29.4	998.5	81	0	1.9	18.5	24.1	-			o	
8	31.7	37.2	26.8	997.4	78	0	3.5	19.8	27.8	-				
9	31.5	37.7	26.8	1000.1	76	0	3.1	11.3	22.2	-				
10	32.8	38.4	28.8	998.5	80	0	2.7	14.3	20.6	-				
11	33.2	37.3	30.2	997.5	82	0	3.1	11.9	18.3	-				
12	35.8	41.6	30.4	996.2	63	0	3.1	9.8	14.8	-				
13	36.1	42.6	30	996.3	51	0	3.5	10.4	18.3	-			o	
14	33.1	38.8	29.6	998.3	69	0	4	18.7	51.9	-				
15	32.6	38.4	29.6	998.9	67	0	3.7	10.2	14.8	-				
16	32.7	40.7	29	998.9	66	0	3.7	8.5	14.8	-			o	
17	31.1	38.8	26.3	997.9	75	0	3.4	9.4	22.2	-			o	
18	29.7	32.6	26.6	997.6	86	0	3.7	8.7	11.1	-				
19	28.8	31.8	27.9	997.3	89	2.03	3.5	8.1	11.1	-	o		o	
20	27.9	29.8	27	998.1	92	-	2.6	11.7	16.5	-	o			
21	29.7	32.6	27	1000.3	89	-	2.9	8.3	11.1	-	o			
22	31.1	36.8	28	1001.1	85	-	2.9	13.9	22.2	-	o			
23	32	36.8	29.4	999.1	80	0	2.7	12	22.2	-				
24	30.8	40.2	24.4	-	72	-	3.2	10	18.3	-	o		o	
25	30.1	37	26.8	999.7	79	-	2.6	11.5	35.2	-	o			
26	29.6	34.3	26.4	1002.2	83	0	3.7	8.5	18.3	-				
27	28.7	31	26.9	1004	90	1.02	3.5	6.5	11.1	-	o			
28	29.9	34.4	27.4	1002.5	85	0	3.1	9.6	18.3	-				
29	30.4	35.9	26	1000.6	81	-	3.4	11.1	16.5	-	o		o	
30	25.9	29.7	24.8	1001.2	99	-	2.4	9.4	22.2	-	o		o	
Monthly means and totals:														
	31.2	36.4	27.6	999.7	79.3	3.05	3.2	12.4	21.2		10	0	10	0

Appendix II

INTERACTION TRIAL (ANOVA)

1. NUMBER OF TILLERS:

Source	df	ss	mss	F cal		SS*	MSS*	Fcal*	
Season, S	1	21.33333	21.333					8.478191	**S**
Treat	5	262.1667	52.433					20.8378	**NS**
Treat x S	5	44.16667	8.833	5.389831	S				
Error	36	59.00	**1.639**			103.17	**2.5163**		
	47								

	Sem	CD5%	Sem*	CD 5%*
Treat	**0.453**	**1.298**	**0.561**	**1.602**
Sem* and CD* are to be used if Treat*Y is NS				

2. PLANT HEIGHT (cm):

Source	df	ss	mss	F cal		SS*	MSS*	Fcal*	
Season, S	1	0.33	0.33					0.04	**S**
Treat	5	1023.42	204.68					25.83	**NS**
Treat x S	5	80.42	16.08	2.37	NS				
Error	36	244.50	**6.792**			324.92	**7.92**		
	47								

	Sem	CD5%	Sem*	CD 5%*
Treat	**0.921**	**2.642**	**0.995**	**2.842**
Sem* and CD* are to be used if Treat*Y is NS				

3. DRY WEIGHT OF SHOOT (g):

Source	**df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	430.20	430.202					121.3551	**S**
Treat	5	2349.50	469.901					132.5537	**NS**
Treat x S	5	0.11	0.022	0.0055	NS				
Error	36	145.23	**4.034**			145.34	**3.5450**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	0.710	2.036	0.666	1.901
Sem* and CD* are to be used if Treat*Y is NS				

4. RHIZOME YIELD (kg)

Source	**df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	0.002	0.002					2.011	**S**
Treat	5	0.461	0.092					76.940	**NS**
Treat x S	5	0.028	0.006	9.591	S				
Error	36	0.021	**0.001**			0.05	**0.0012**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	0.009	0.025	0.012	0.035
Sem* and CD* are to be used if Treat*Y is NS				

5. LEAF WATER POTENTIAL (ψ):

Source	**df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	7.418	7.418					560.392	**S**
Treat	5	0.972	0.194					14.693	**NS**
Treat x S	5	0.393	0.079	18.900	S				
Error	36	0.150	**0.004**			0.54	**0.0132**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	**0.023**	**0.065**	**0.041**	**0.116**
Sem* and CD* are to be used if Treat*Y is NS				

6. RWC %:

Source	**Df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	784.0025	784.003					636.1218	**S**
Treat	5	28.83266	5.767					4.678833	**NS**
Treat x S	5	20.79811	4.160	5.036327	S				
Error	36	29.73	**0.826**			50.53	**1.2325**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	0.321	0.921	0.393	1.121
Sem* and CD* are to be used if Treat*Y is NS				

7. **RWD %:**

Source	**df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	784.003	784.003					651.4075	**S**
Treat	5	30.018	6.004					4.988305	**NS**
Treat x S	5	19.612	3.922	4.749194	S				
Error	36	29.733	**0.826**			49.35	**1.2036**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	**0.321**	**0.921**	**0.388**	**1.108**
Sem* and CD* are to be used if Treat*Y is N				

8. **CHLOROPHYLL a (μg/g fw):**

Source	**Df**	**ss**	**mss**	**F cal**		**SS***	**MSS***	**Fcal***	
Season, S	1	1.208	1.208					89.901	**S**
Treat	5	0.666	0.133					9.918	**NS**
Treat x S	5	0.016	0.003	0.221	NS				
Error	36	0.535	**0.015**			0.55	**0.0134**		
	47								

	Sem	**CD5%**	**Sem***	**CD 5%***
Treat	**0.043**	**0.124**	**0.041**	**0.117**
Sem* and CD* are to be used if Treat*Y is NS				

9. **CHLOROPHYLL b (μg/g fw):**

Source	df	ss	mss	F cal		SS*	MSS*	Fcal*	
Season, S	1	0.2745	0.275					234.231	**S**
Treat	5	0.0761	0.015					12.982	**NS**
Treat x S	5	0.0107	0.002	2.063	NS				
Error	36	0.037	**0.001**			0.05	**0.0012**		
	47								

	Sem	CD5%	Sem*	CD 5%*
Treat	**0.011**	**0.033**	**0.012**	**0.035**
Sem* and CD* are to be used if Treat*Y is NS				

10.TOTAL CHLOROPHYLL (µg/g fw):

Source	df	ss	mss	F cal		SS*	MSS*	Fcal*	
Season, S	1	2.634376	2.634					165.6813	**S**
Treat	5	1.104743	0.221					13.89591	**NS**
Treat x S	5	0.027493	0.005	0.317019	NS				
Error	36	0.62	**0.017**			0.65	**0.0159**		
	47								

	Sem	CD5%	Sem*	CD 5%*
Treat	**0.047**	**0.134**	**0.045**	**0.127**
Sem* and CD* are to be used if Treat*Y is NS				

11. STOMATAL CONDUCTANCE:

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.000396	5	7.93E-05	0.293562	0.900099	4.387374
Within Groups	0.001621	6	0.00027			
Total	0.002017	11				

12. Fv/Fm:

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.000458	5	9.16E-05	0.301626	0.895268	4.387374
Within Groups	0.001822	6	0.000304			
Total	0.00228	11				

13. Ø PS II :

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.006125	5	0.001225	0.495918	0.770681	4.387374
Within Groups	0.014821	6	0.00247			
Total	0.020945	11				

14. Ø CO_2:

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00012	5	2.40027E-05	1.837772	0.239856	4.387374
Within Groups	7.84E-05	6	1.30607E-05			
Total	0.000198	11				

15. NET PHOTOSYNTHESIS RATE:

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24.19885	5	4.839771	0.707341	0.639475	4.387374
Within Groups	41.0532	6	6.8422			
Total	65.25205	11				

MANAGEMENT (Field Trial)

1. NUMBER OF TILLERS:

Source	df	SS	MSS	Fcal		SS*	MSS*	Fcal*	
Season S	1	0.002	0.002	0.00	NS				
S*Rep	4	3.719	0.930						
Treat	11	469.411	42.674	84.27	S			95.95921	S
Treat*S	11	2.178	0.198	0.39	NS				
Error	44	22.281	**0.506**			24.46	**0.4447**		

	Pooled			
	Sem	**CD5%**	**Sem***	**CD5%***
Treat	**0.182**	**0.565**	**0.272**	**0.776**
Sem* and CD* are to be used if Treat*Y is NS Sem and CD are to be used if Treat*Y is S				

DMRT: ${}^{e}T_1$ ${}^{e}T_3$ ${}^{d}T_5$ ${}^{d}T_7$ ${}^{d}T_6$ ${}^{d}T_2$ ${}^{d}T_4$ ${}^{c}T_8$ ${}^{b}T_9$ ${}^{a}T_{10}$ ${}^{a}T_{12}$ ${}^{a}T_{11}$

2. PLANT HEIGHT:

Source	Df	SS	MSS	Fcal		SS*	MSS*	Fcal*	
Season S	1	2403.556	2403.556	778.13	S				
S*Rep	4	12.356	3.089						
Treat	11	2470.538	224.594	73.23	S			23.1638	S
Treat*S	11	398.324	36.211	11.81	S				
Error	44	134.951	**3.067**			533.28	**9.6959**		

	Pooled			
	Sem	**CD5%**	**Sem***	**CD5%***
Treat	**2.457**	**7.646**	**1.271**	**3.623**
Sem* and CD* are to be used if Treat*Y is NS Sem and CD are to be used if Treat*Y is S				

DMRT: ${}^{d}T_1$ ${}^{d}T_3$ ${}^{cd}T_5$ ${}^{cd}T_7$ ${}^{bcd}T_6$ ${}^{abc}T_2$ ${}^{ab}T_4$ ${}^{ab}T_8$ ${}^{a}T_9$ ${}^{a}T_{10}$ ${}^{a}T_{12}$ ${}^{a}T_{11}$

Pooled ANOVA(Dry weight of shoot)

Source	Df	SS	MSS	Fcal	
Season S	1	13.650	13.650	1.92	NS
S*Rep	4	28.430	7.107		
Treat	11	5890.743	535.522	307.28	S
Treat*S	11	8.074	0.734	0.42	NS
Error	44	76.682	**1.743**		

DMRT: ${}^{i}T_1$ ${}^{h}T_3$ ${}^{g}T_5$ ${}^{f}T_7$ ${}^{e}T_6$ ${}^{de}T_2$ ${}^{d}T_4$ ${}^{c}T_8$ ${}^{c}T_9$ ${}^{b}T_{10}$ ${}^{b}T_{12}$ ${}^{a}T_{11}$

Pooled ANOVA (Rhizome yield)

Source	Df	SS	MSS	Fcal	
Season S	1	8.222	8.222	1087.34	S
S*Rep	4	0.030	0.008		
Treat	11	21.560	1.960	100.55	S
Treat*S	11	1.143	0.104	5.33	S
Error	44	0.858	**0.019**		

DMRT: $^{g}T_{1}$ $^{fg}T_{3}$ $^{ef}T_{5}$ $^{def}T_{7}$ $^{def}T_{6}$ $^{de}T_{2}$ $^{cd}T_{4}$ $^{cd}T_{8}$ $^{cd}T_{9}$ $^{b}T_{10}$ $^{ab}T_{12}$ $^{a}T_{11}$

Pooled ANOVA(% wilted plants)

Source	Df	SS	MSS	Fcal	
Season S	1	1780.652	1780.652	553.91	S
S*Rep	4	12.859	3.215		
Treat	11	5168.344	469.849	146.23	S
Treat*S	11	280.711	25.519	7.94	S
Error					

DMRT: $^{e}T_{11}$ $^{e}T_{12}$ $^{e}T_{10}$ $^{de}T_{9}$ $^{cd}T_{8}$ $^{cd}T_{4}$ $^{f}T_{2}$ $^{bc}T_{6}$ $^{bc}T_{7}$ $^{ab}T_{5}$ $^{a}T_{3}$ $^{a}T_{1}$

Pooled ANOVA(Germination at 30 DAS)

Source	df	SS	MSS	Fcal	
Season S	1	1.635	1.635	0.69	NS
S*Rep	4	9.419	2.355		
Treat	11	812.819	73.893	51.90	S
Treat*S	11	22.822	2.075	1.46	NS
Error	44	62.641	**1.424**		

DMRT: $^{h}T_{1}$ $^{g}T_{2}$ $^{fg}T_{4}$ $^{f}T_{3}$ $^{e}T_{8}$ $^{de}T_{7}$ $^{cd}T_{10}$ $^{bcd}T_{6}$ $^{bc}T_{5}$ $^{abc}T_{9}$ $^{ab}T_{11}$ $^{a}T_{12}$

Pooled ANOVA(Soil population)

Source	df	SS	MSS	Fcal	
Season S	1	0.115	0.115	241.07	S
S*Rep	4	0.002	0.000		
Treat	11	0.858	0.078	26.00	S
Treat*S	11	0.000	0.000	0.01	NS
Error	44	0.132	**0.003**		

DMRT: $^{f}T_{2}$ $^{ef}T_{8}$ $^{de}T_{7}$ $^{de}T_{11}$ $^{de}T_{10}$ $^{d}T_{12}$ $^{d}T_{6}$ $^{d}T_{5}$ $^{c}T_{9}$ $^{c}T_{4}$ $^{b}T_{3}$ $^{a}T_{1}$

Pooled ANOVA(Root population)

Source	df	SS	MSS	Fcal	
Season S	1	0.169	0.169	127.47	S
S*Rep	4	0.005	0.001		
Treat	11	0.570	0.052	196.67	S
Treat*S	11	0.000	0.000	0.00	NS
Error	44	0.012	**0.000**		

DMRT: $^{h}T_{9}$ $^{h}T_{10}$ $^{gh}T_{2}$ $^{g}T_{8}$ $^{f}T_{5}$ $^{e}T_{4}$ $^{de}T_{11}$ $^{d}T_{12}$ $^{d}T_{7}$ $^{c}T_{6}$ $^{b}T_{3}$ $^{a}T_{1}$

Pooled ANOVA(Root knot index)

Source	df	SS	MSS	Fcal	
Season S	1	1.681	1.681	5.26	NS
S*Rep	4	1.278	0.319		
Treat	11	93.375	8.489	25.37	S
Treat*S	11	1.819	0.165	0.49	NS
Error	44	14.722	**0.335**		

DMRT: $^{e}T_{9}$ $^{e}T_{10}$ $^{e}T_{11}$ $^{de}T_{2}$ $^{de}T_{8}$ $^{de}T_{12}$ $^{cde}T_{7}$ $^{fg}T_{6}$ $^{bc}T_{4}$ $^{b}T_{5}$ $^{a}T_{3}$ $^{a}T_{1}$

POT TRIAL

1. PLANT HEIGHT (cm):

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	268.0833	11	24.37121	5.898243	0.000142	2.216309
Within Groups	99.16667	24	4.131944			
Total	367.25	35				

DMRT: $^{e}T_{1}$ $^{de}T_{3}$ $^{de}T_{5}$ $^{cde}T_{7}$ $^{cde}T_{6}$ $^{cde}T_{2}$ $^{bcde}T_{4}$ $^{bcd}T_{8}$ $^{abc}T_{9}$ $^{ab}T_{10}$ $^{ab}T_{12}$ $^{a}T_{11}$

2. NUMBER OF TILLERS:

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	103.6389	11	9.421717	5.65303	0.000196	2.216309
Within Groups	40	24	1.666667			
Total	143.6389	35				

DMRT: $^{e}T_{1}$ $^{de}T_{3}$ $^{cde}T_{5}$ $^{bcd}T_{7}$ $^{bcd}T_{6}$ $^{cd}T_{2}$ $^{bcd}T_{4}$ $^{abc}T_{8}$ $^{ab}T_{9}$ $^{ab}T_{10}$ $^{ab}T_{12}$ $^{a}T_{11}$

3. DRY WEIGHT OF SHOOT (g):

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1944.682	11	176.7893	32.69503	9.39E-12	2.216309
Within Groups	129.7733	24	5.407222			
Total	2074.456	35				

DMRT: $^{f}T_{1}$ $^{e}T_{3}$ $^{e}T_{5}$ $^{d}T_{7}$ $^{cd}T_{6}$ $^{cd}T_{2}$ $^{cd}T_{4}$ $^{cd}T_{8}$ $^{bc}T_{9}$ $^{b}T_{10}$ $^{b}T_{12}$ $^{a}T_{11}$

4. CHLOROPHYLL a (µg/g fw):

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.599748	11	0.054523	1.160042	0.36289	2.216309
Within Groups	1.128013	24	0.047001			

Total	1.727761	35

DMRT: $^{b}T_1$ $^{ab}T_3$ $^{ab}T_5$ $^{ab}T_7$ $^{ab}T_6$ $^{ab}T_2$ $^{ab}T_4$ $^{ab}T_8$ $^{ab}T_9$ $^{ab}T_{10}$ $^{ab}T_{12}$ $^{a}T_{11}$

5. CHLOROPHYLL b (μg/g fw):

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.537076	11	0.048825	5.0237	0.0005	2.21631
Within Groups	0.233257	24	0.009719			
Total	0.770333	35				

DMRT: $^{c}T_1$ $^{bc}T_3$ $^{bc}T_5$ $^{bc}T_7$ $^{bc}T_6$ $^{bc}T_2$ $^{bc}T_4$ $^{bc}T_8$ $^{bc}T_9$ $^{b}T_{10}$ $^{a}T_{12}$ $^{a}T_{11}$

6. TOTAL CHLOROPHYLL (μg/g fw)

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.870173	11	0.170016	2.09137	0.063403	2.216309
Within Groups	1.951055	24	0.081294			
Total	3.821229	35				

DMRT: $^{c}T_1$ $^{abc}T_3$ $^{abc}T_5$ $^{abc}T_7$ $^{abc}T_6$ $^{abc}T_2$ $^{abc}T_4$ $^{abc}T_8$ $^{abc}T_9$ $^{abc}T_{10}$ $^{ab}T_{12}$ $^{a}T_{11}$

RHIZOME YIELD (kg):

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*F crit*
Between Groups	17.9125	11	1.628409	3.23625	0.007805	2.216309	2.216309
Within Groups	12.07627	24	0.503178				
Total	29.98876	35					

DMRT: $^{b}T_1$ $^{b}T_3$ $^{b}T_5$ $^{b}T_7$ $^{b}T_6$ $^{b}T_2$ $^{b}T_4$ $^{b}T_8$ $^{b}T_9$ $^{b}T_{10}$ $^{a}T_{12}$ $^{a}T_{11}$

Fig 1: Ginger rhizomes infected with *R. solanacearum*

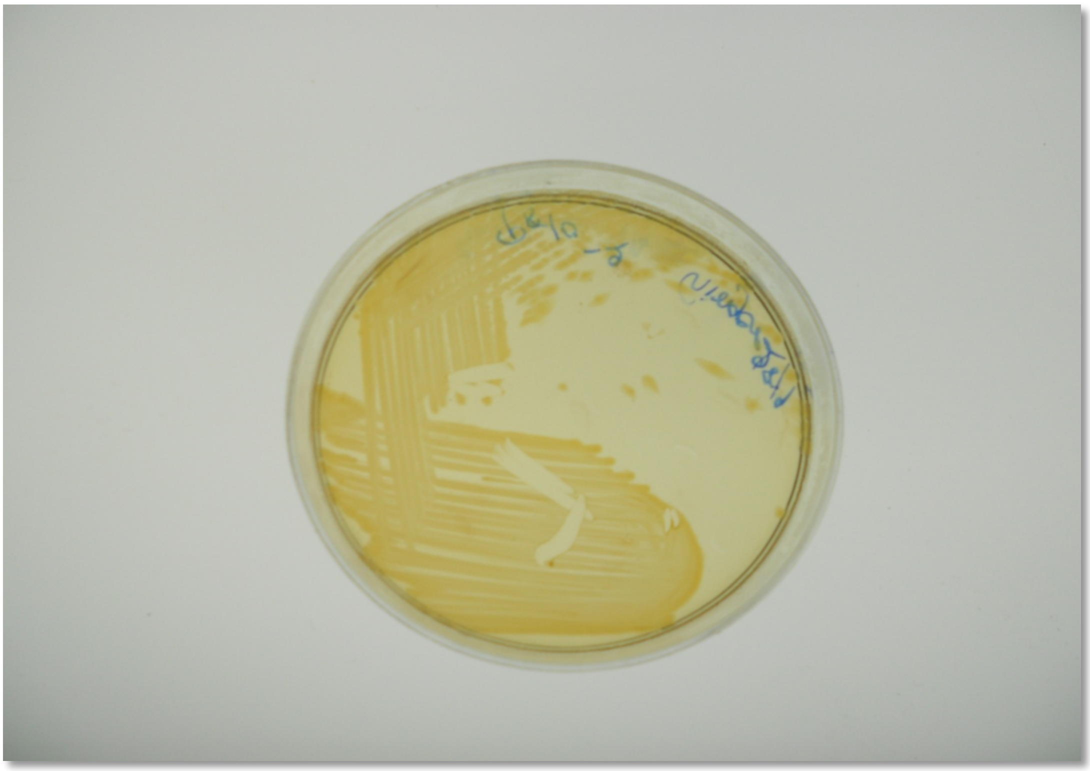

Fig 2: Colonies of *R. solanacearum* on nutrient agar

Fig 3: Planted and mulched ginger rhizomes in pots

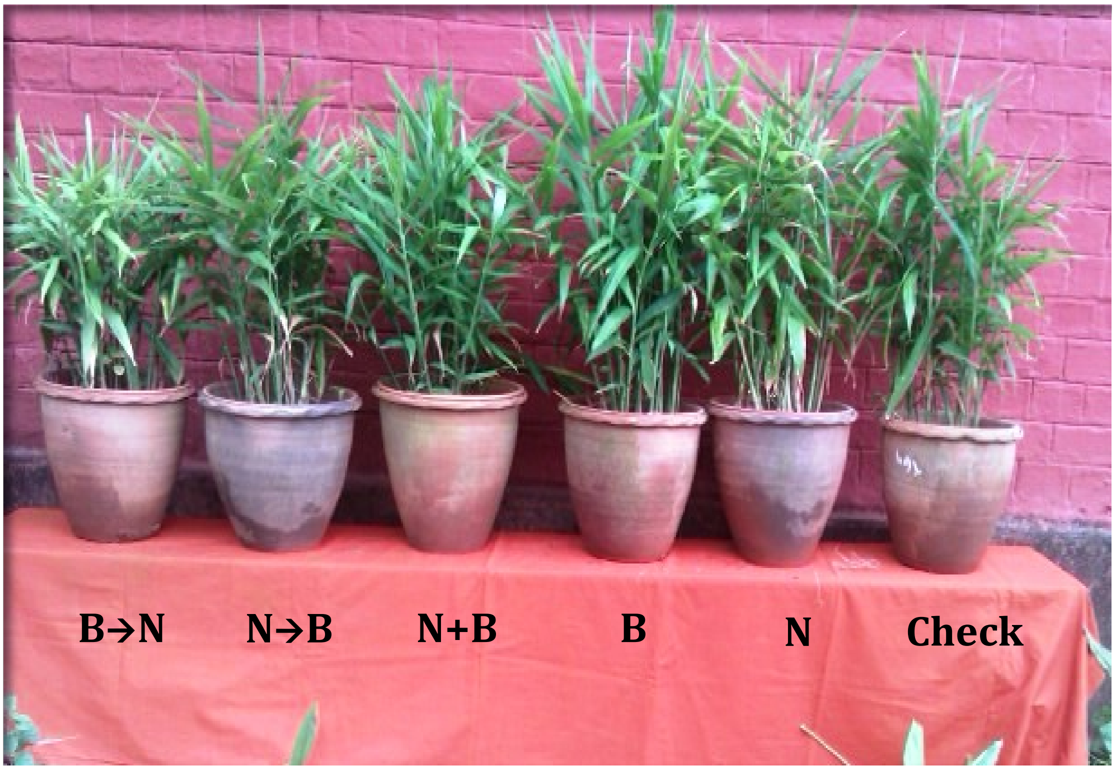

Fig 4: Experimental setup of interaction study

Fig 5: Treated (Carbofuran 3G + Streptocycline 0.02 %) and Untreated (Check)

Fig 6: Experimental setup of management trial

Fig 7: Mulched raised beds in the management trial

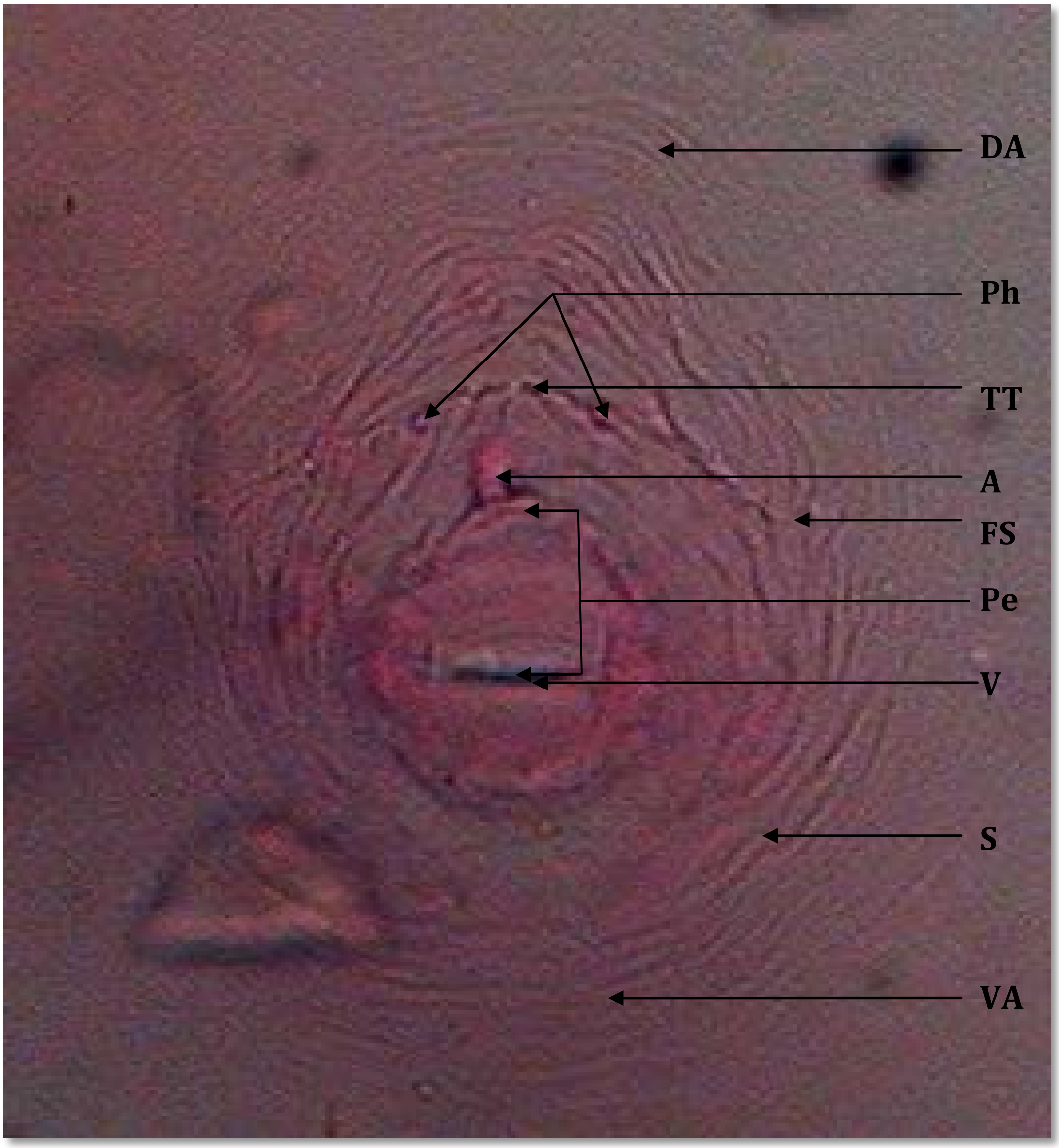

Fig 8a: Posterior cuticular pattern of *M. incognita* showing detail features

DA: Dorsal arch

Ph: Phasmid

TT: Tail tip

A: Anus

FS: Forked striae

Pe: Perineum

V: Vulva

S: Striae

VA: Ventral arch

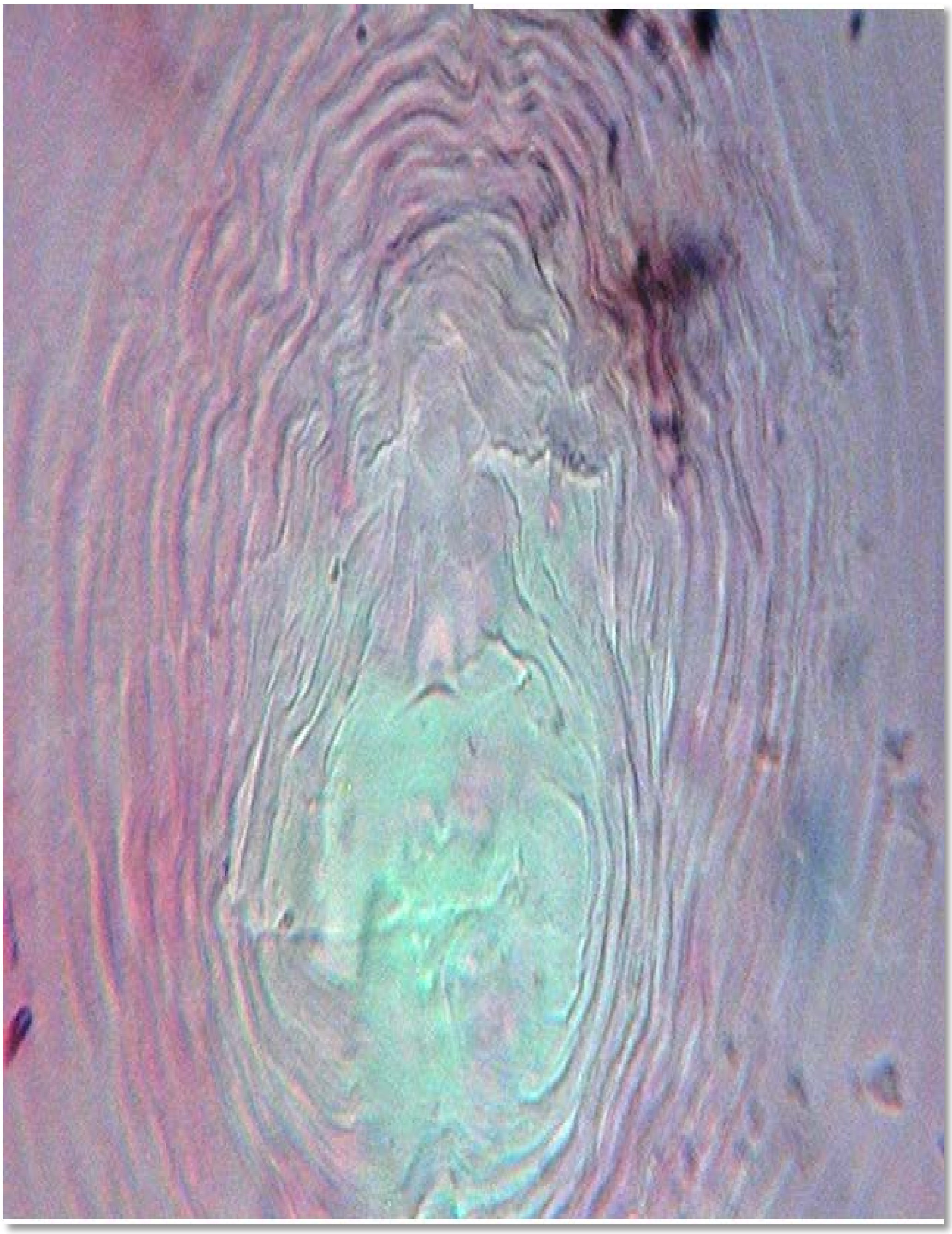

Fig 8b: Magnified view of *M. incognita* showing wavy striae

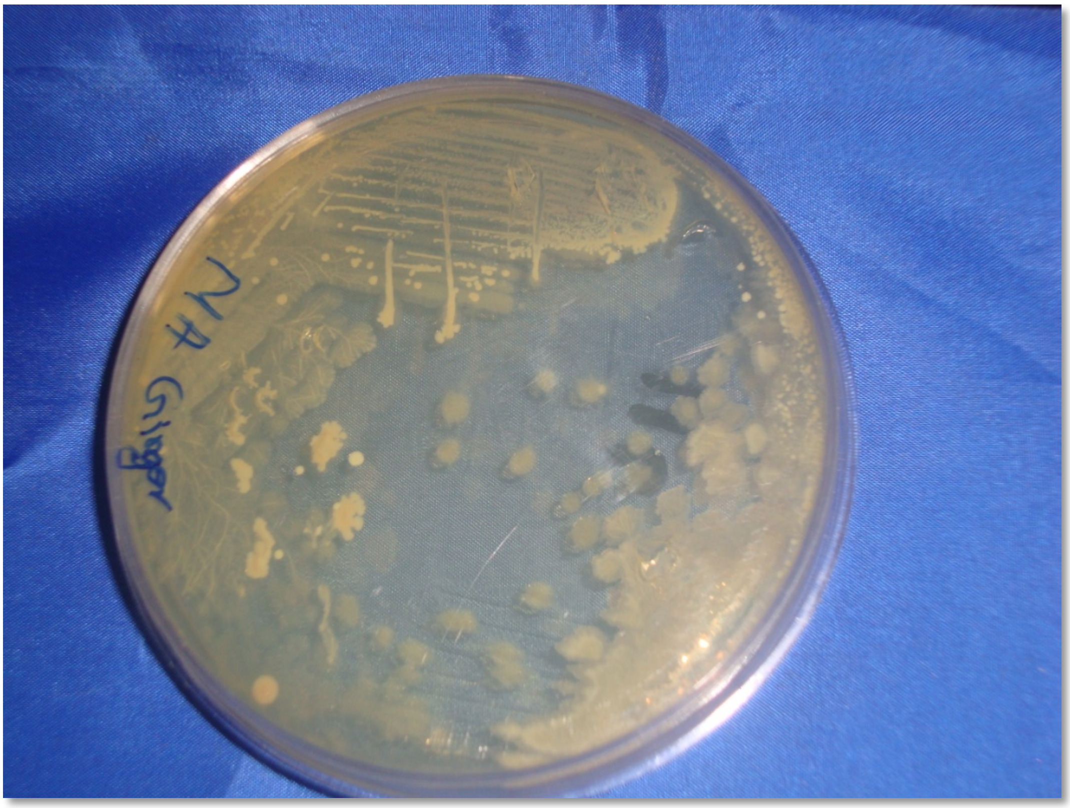

Fig 9: Fluidal colonies of *R. solanacearum*

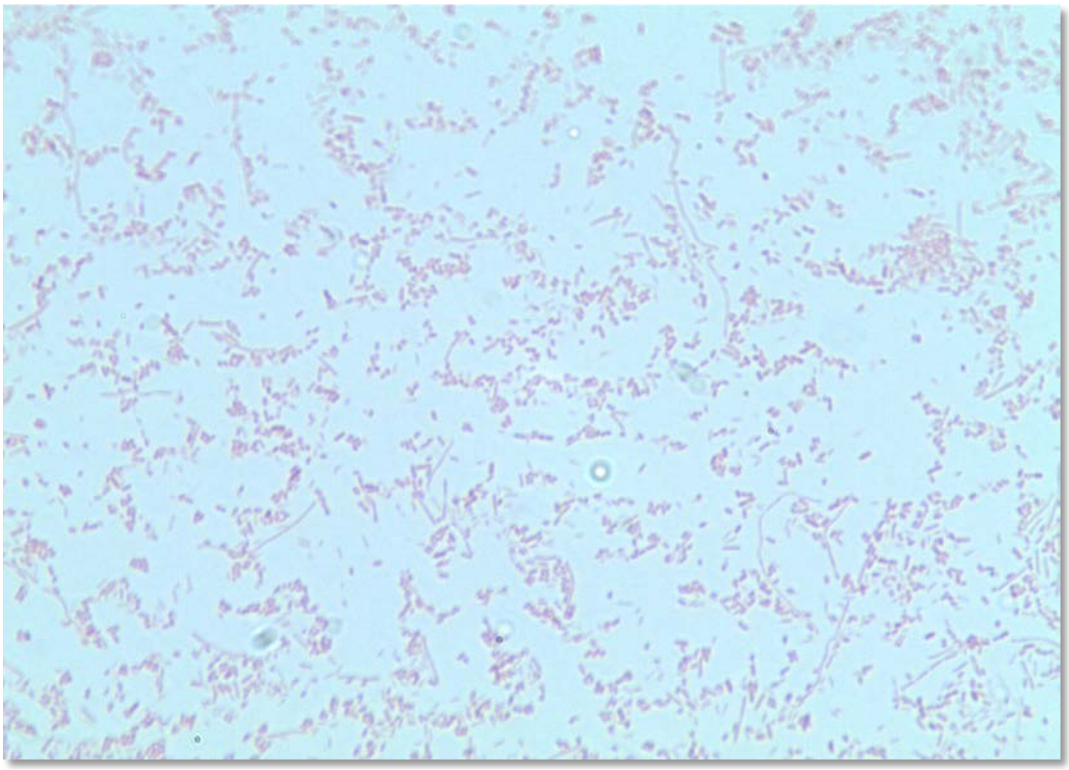

Fig 10: Rod shaped *R. solanacearum* (Stained Pink)

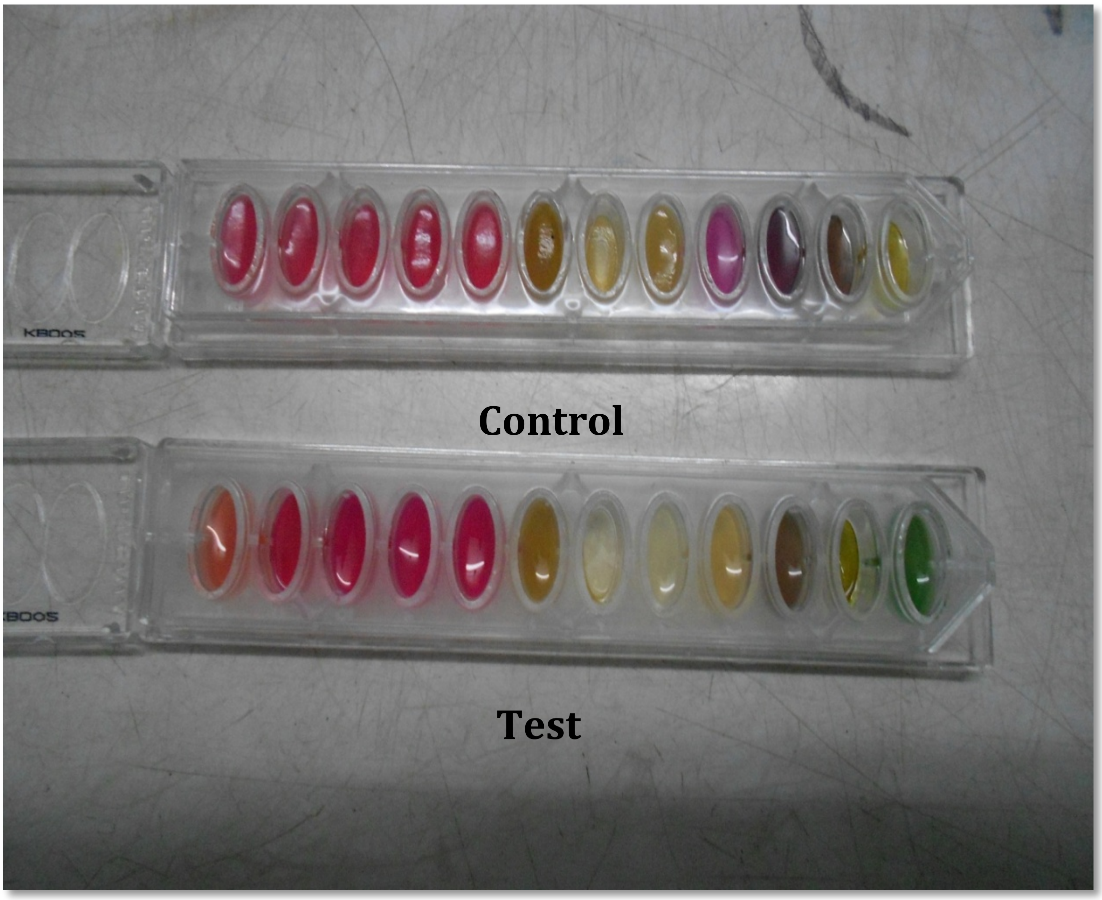

Fig 11: Hi assorted biochemical identification test
(MA, LA, AD, AR, G, H_2S, NR, PA, UR, OR, LY, CT: L→R)

MA:	**Maltose**	**H_2S**	
LA:	**Lactose**	**AD:**	**Adonitol**
AR:	**Arabinose**	**G:**	**Glucose**
NR:	**Nitrate Reductase**	**PA:**	**Phenylalanine Deamination**
UR:	**Urease**	**OR:**	**Ornithine**
LY:	**Lysine**	**CT:**	**Citrate**

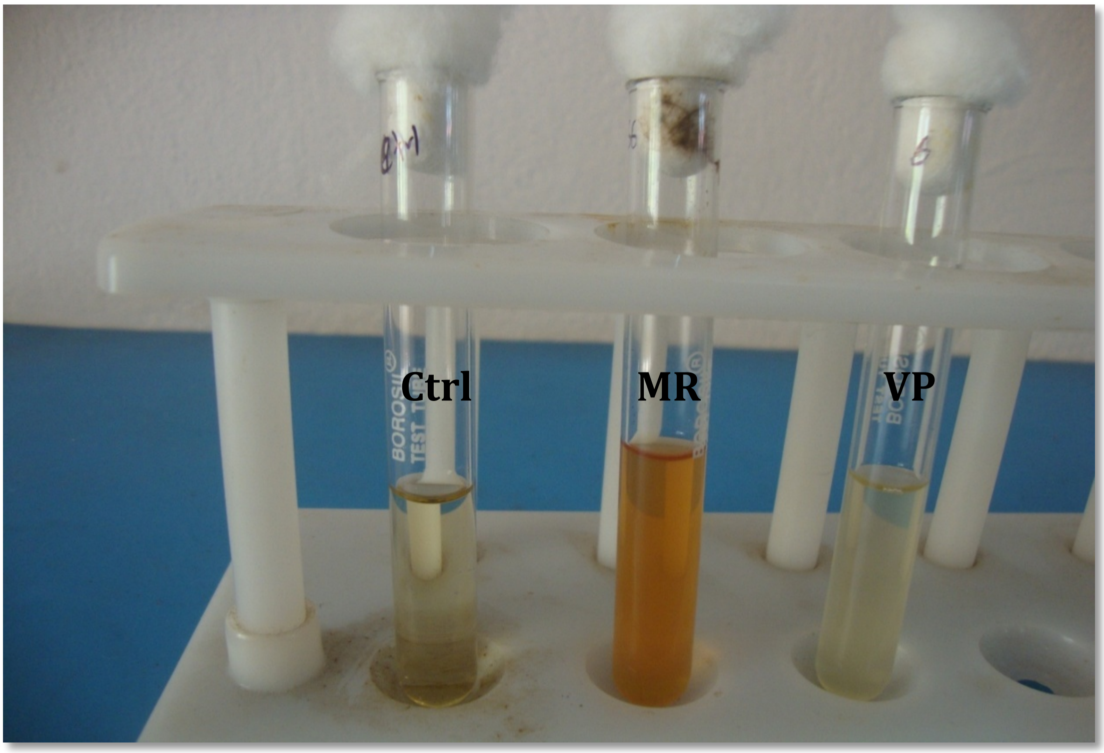

Fig 12: Control (Ctrl), Methyl Red (MR), Voges & Proskeur (VP): L→R

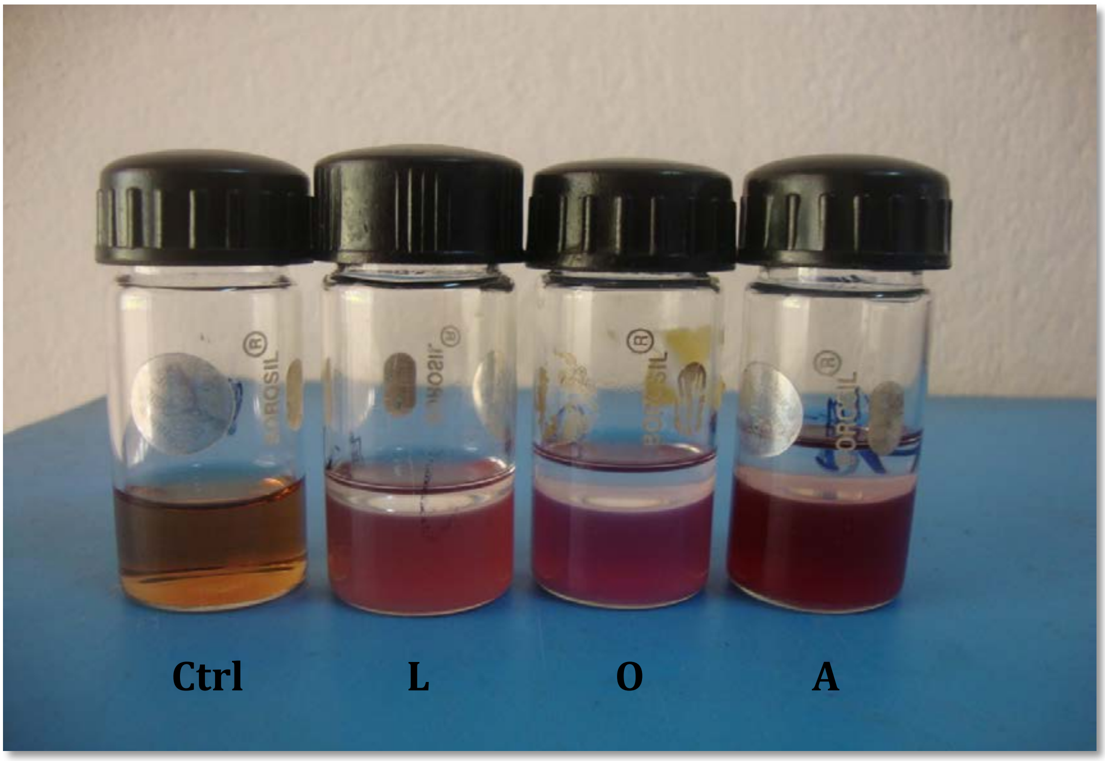

Fig 13: Amino acid decarboxylation test

[Ctrl, Lysine (L), Ornithine(O), Arginine(A) : L→R]

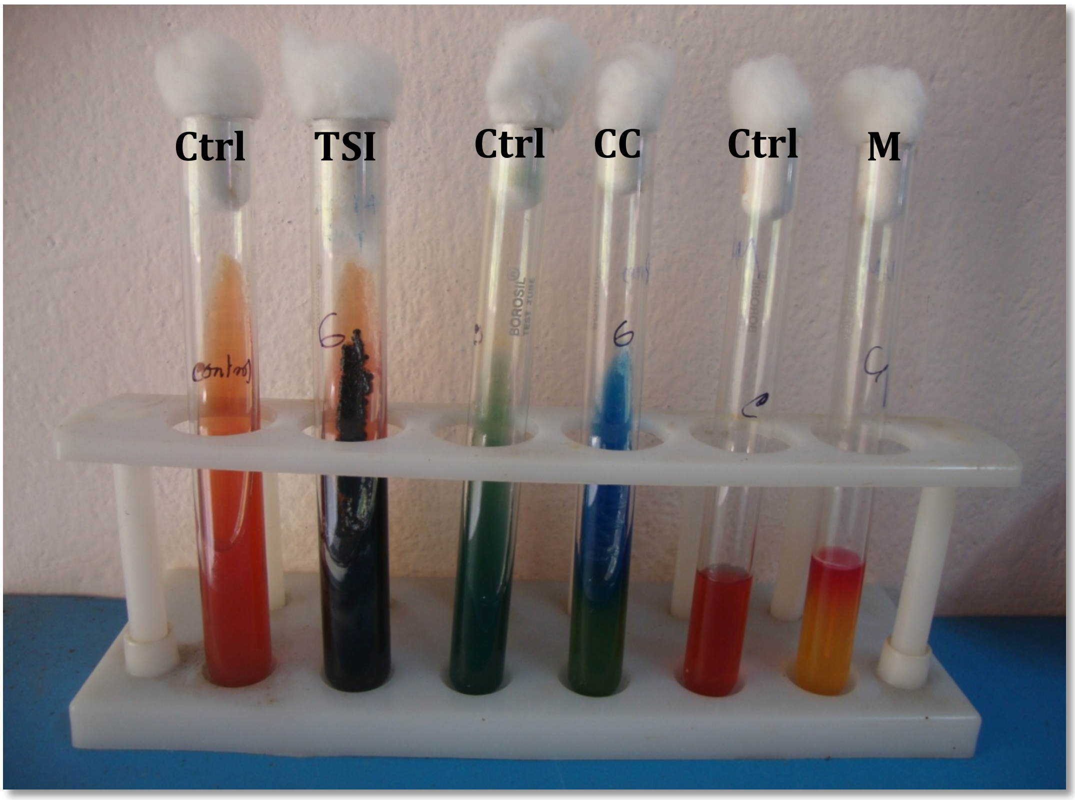

Fig 14: Citrate utilization test
Ctrl-TSI, Ctrl-Ciman citrate(CC), Ctrl-Manitol(M) : L→R

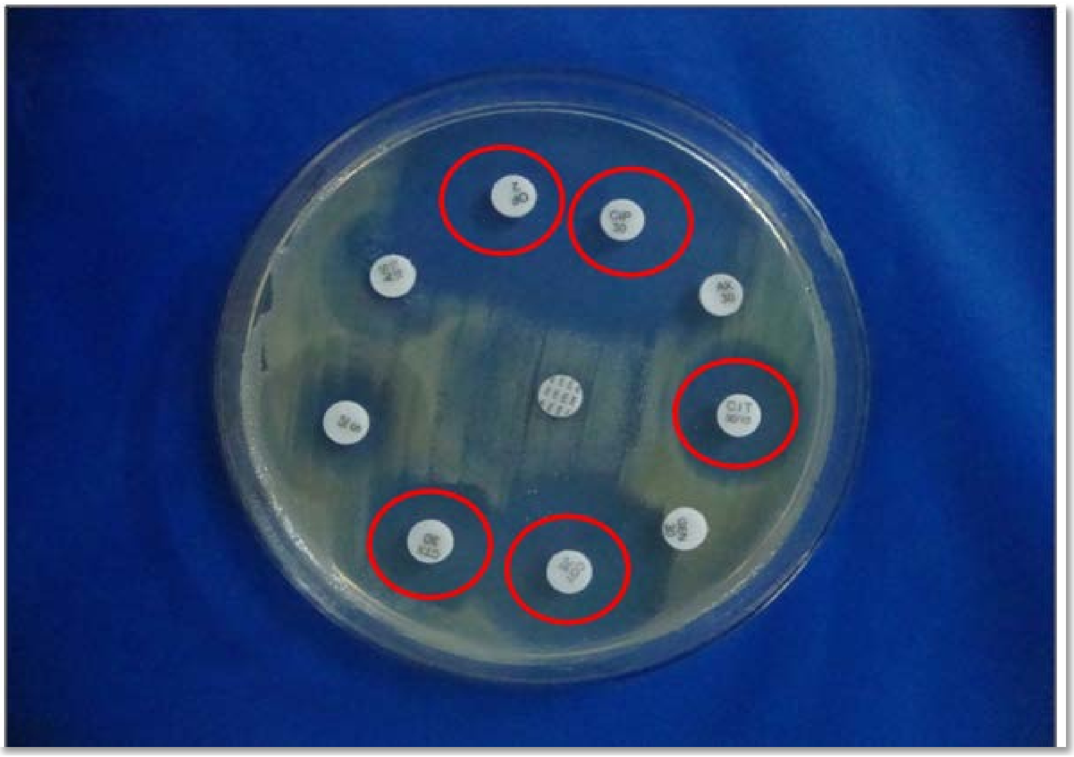

Fig 16: Antibiotics sensitivity test (Antibiotics with clear zone encircled in red are sensitive to *R. solanacearum*)

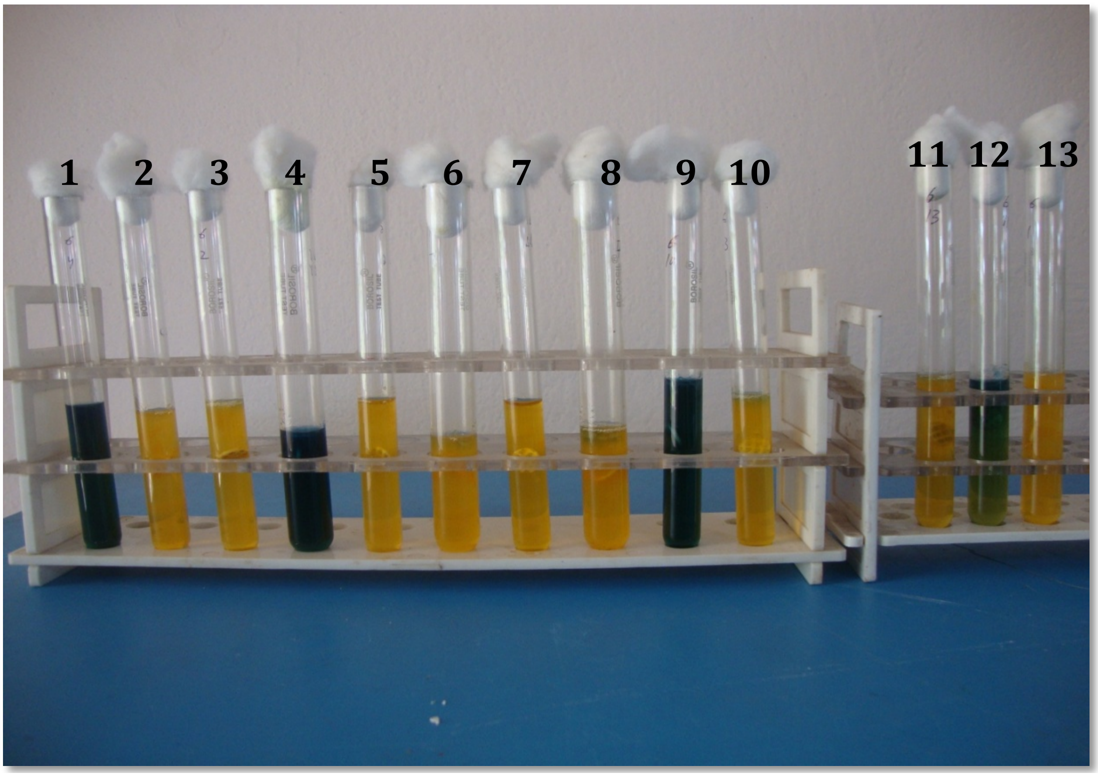

Fig 15: Sugar utilization test (Yellow: +ve; Blue: -ve)

1: **Insulin**

2: **Dextrose**

3: **Sorbitol**

4: **Raffinose**

5: **Dulcitol**

6: **Mannose**

7: **Maltose**

8: **Trehalose**

9: **Sucrose**

10: **Inositol**

11: **Rhamnose**

12: **Adonitol**

13: **Mellibiose**

Fig 17: ***M. incognita*** **infected plant exhibiting reduction in vigour and mild drooping**

Fig 18: Healthy plant

Fig 19: ***M. incognita*** **infected ginger roots exhibiting beaded galls**

Fig 20: *R. solanacearum* infected plant exhibiting wilting

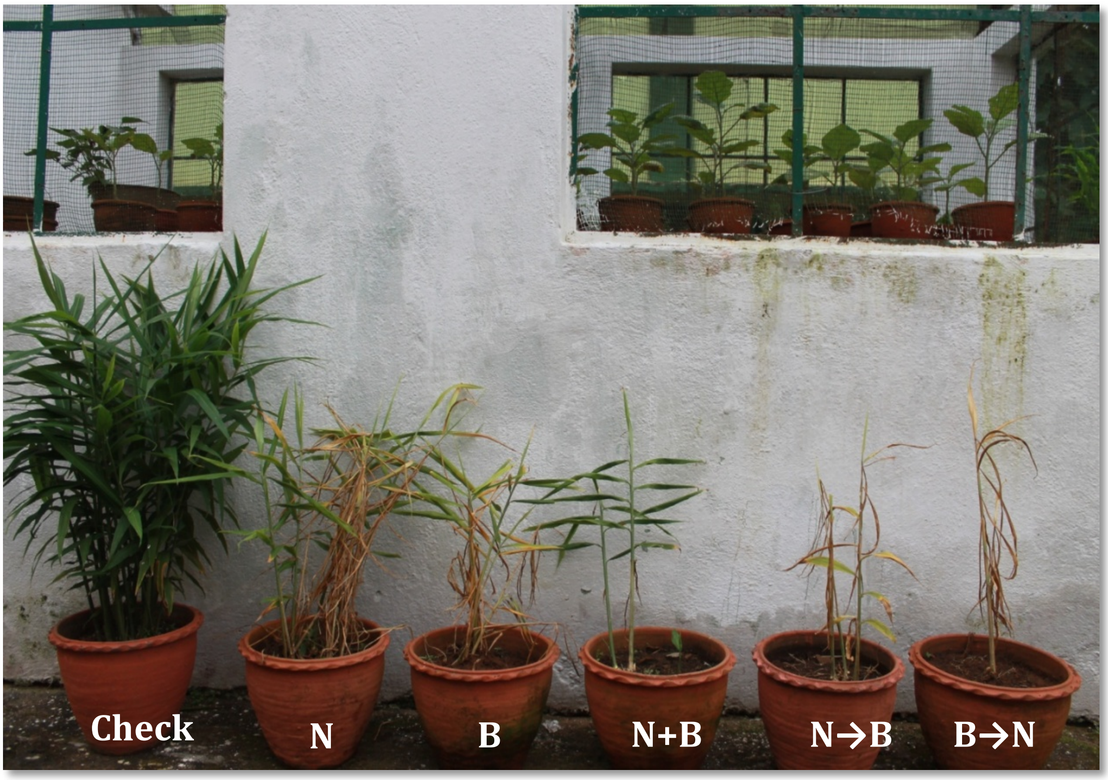

Fig 23: Growth and wilting of ginger plant in different treatments

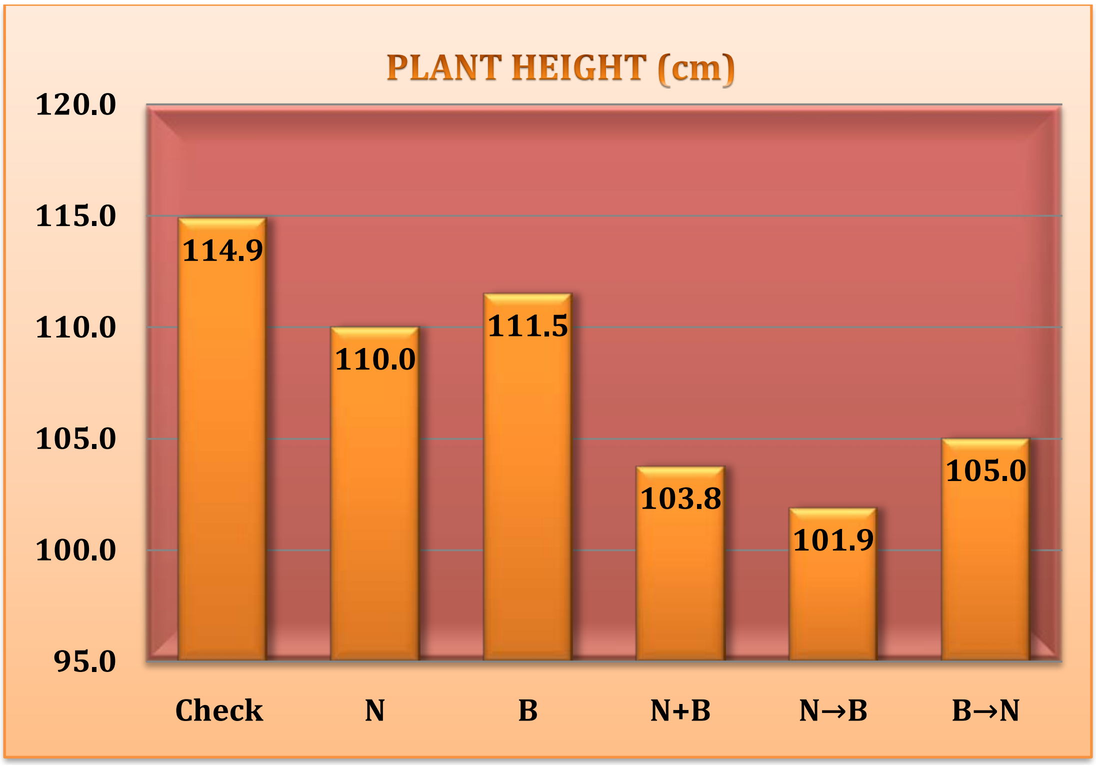

Fig 24: Histogram Showing the Effect of Different Treatments on Plant Height

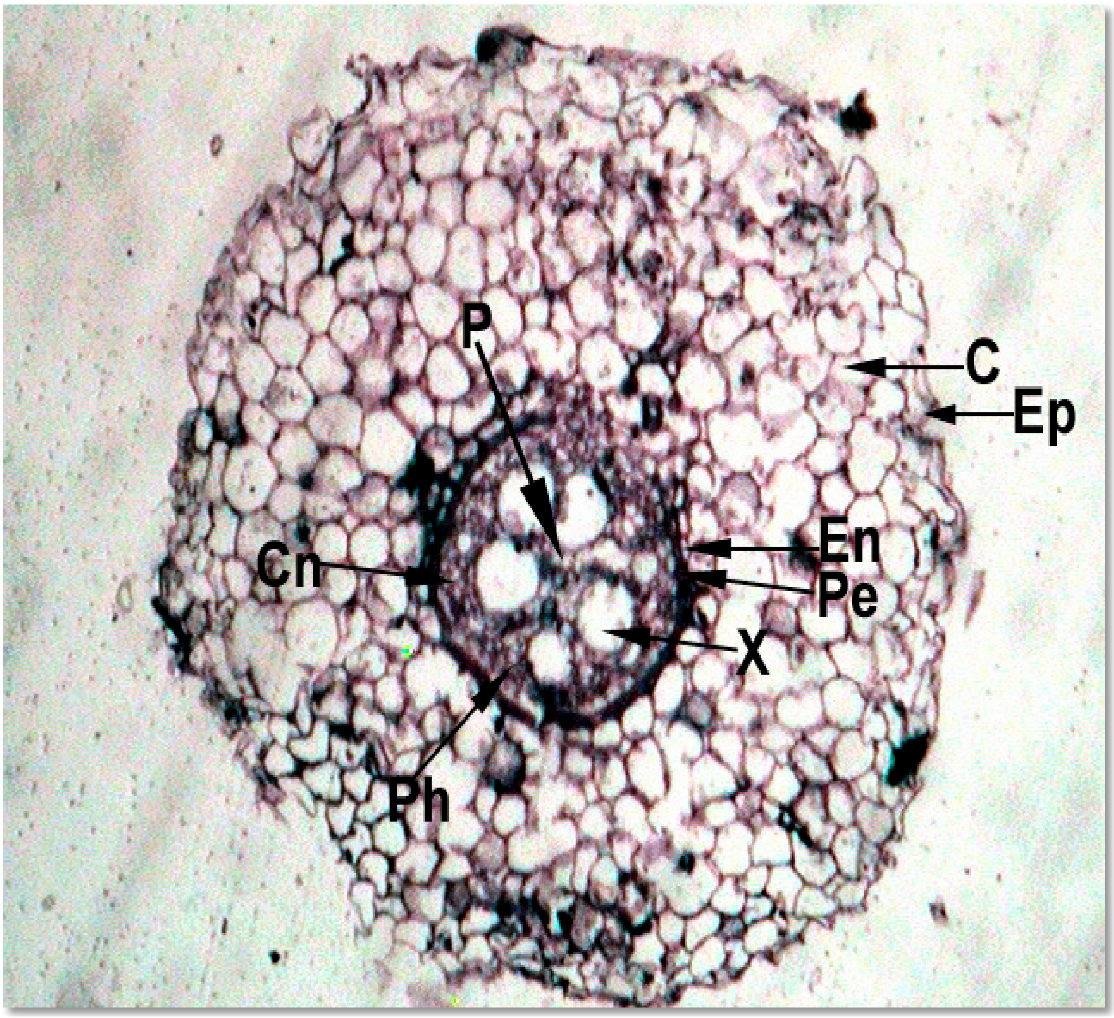

Fig 40: Transverse section of healthy roots of ginger

Ep : Epidermis	**C : Cortex**
En : Endodermis	**Pe : Pericycle**
X : Xylem	**Ph : Phloem**
Cn : Conjuctive tissue	**P : Pith**

Fig 41: Transverse section of ginger root showing multinucleated giant cells

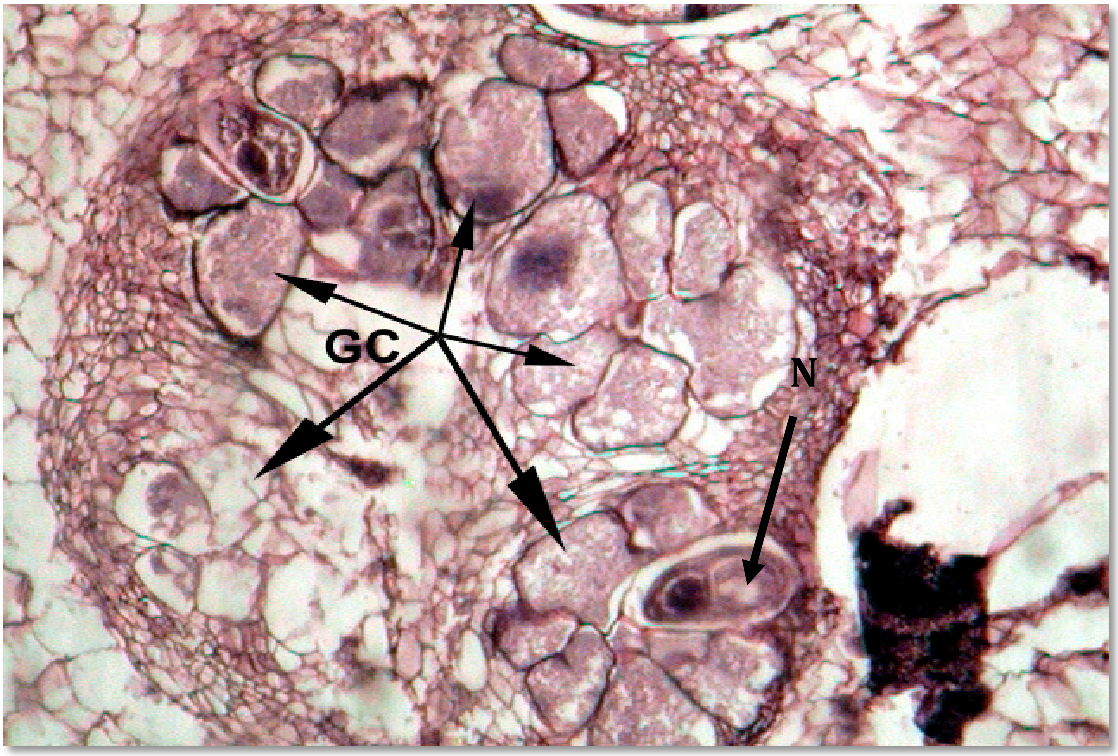

Fig 42: Transverse section of ginger root exhibiting giant cell sites GC : Giant cell; N: Nematode

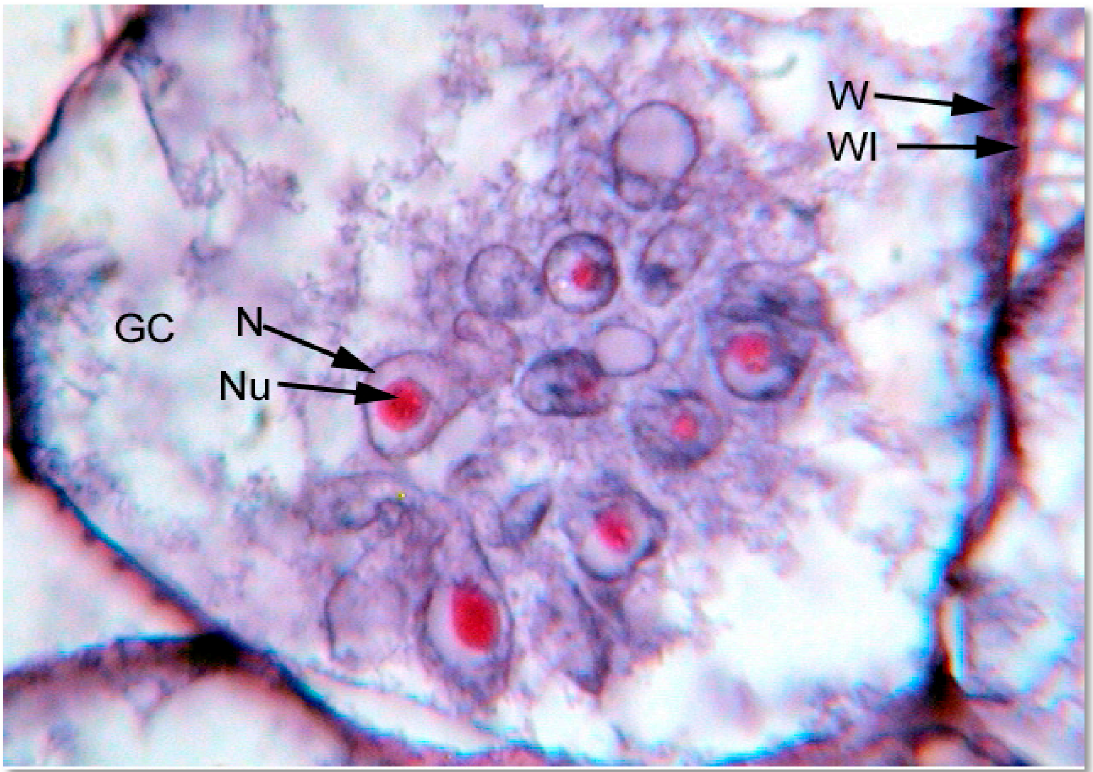

Fig 43: Transverse section showing a magnified giant cell (GC) exhibiting enlarged nuclei (N), nucleoli (Nu), wall ingrowths (WI) and dense cytoplasm

Fig 44: Transverse section showing a magnified giant cell with large number of vacuoles and reduced cytoplasm

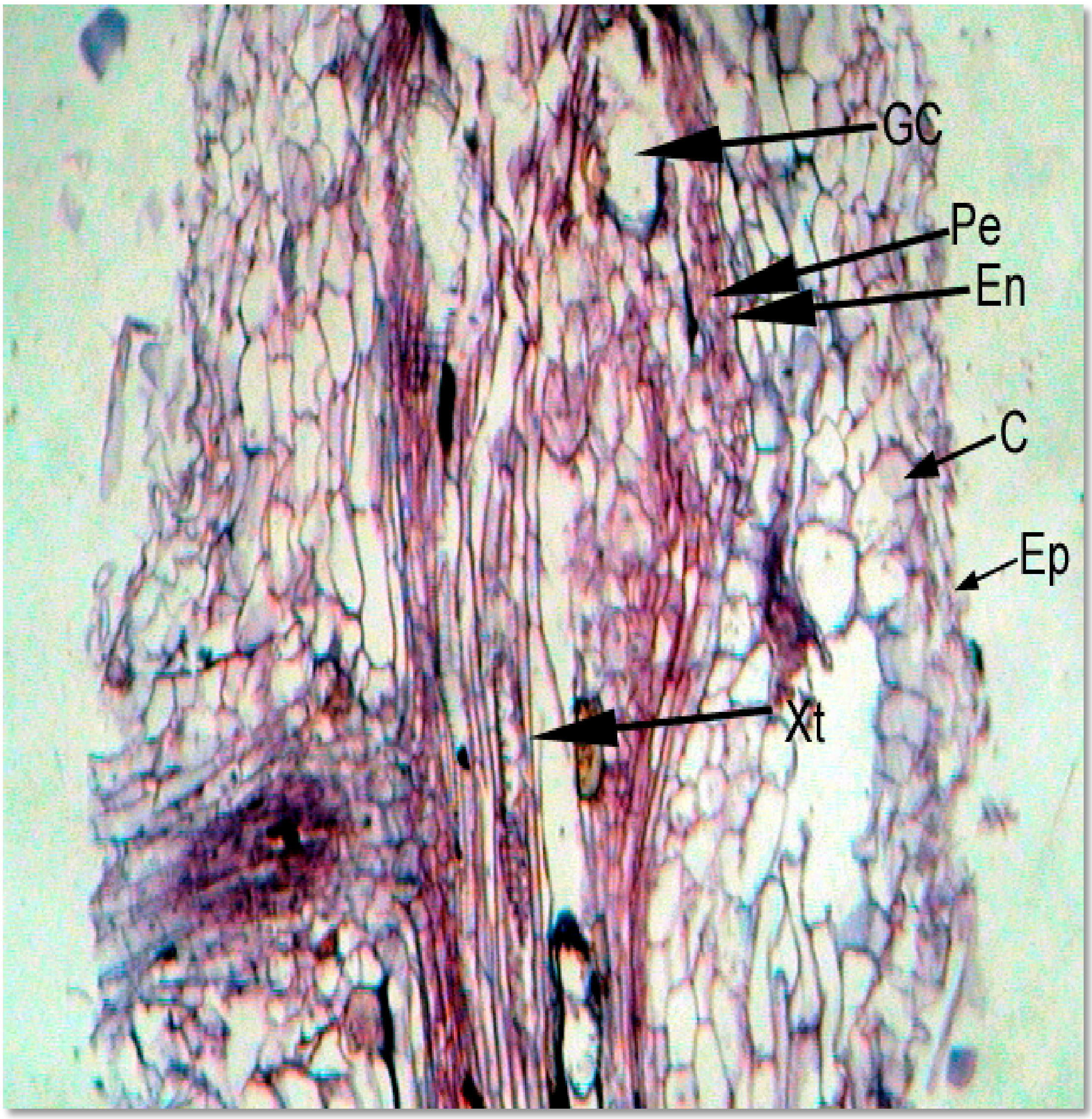

Fig 45: Longitudinal section of infected root of ginger

Ep : Epidermis **C : Cortex,**

En : Endodermis **Pe : Pericycle,**

Xt : Xylem Tracheids **GC : Giant Cells**

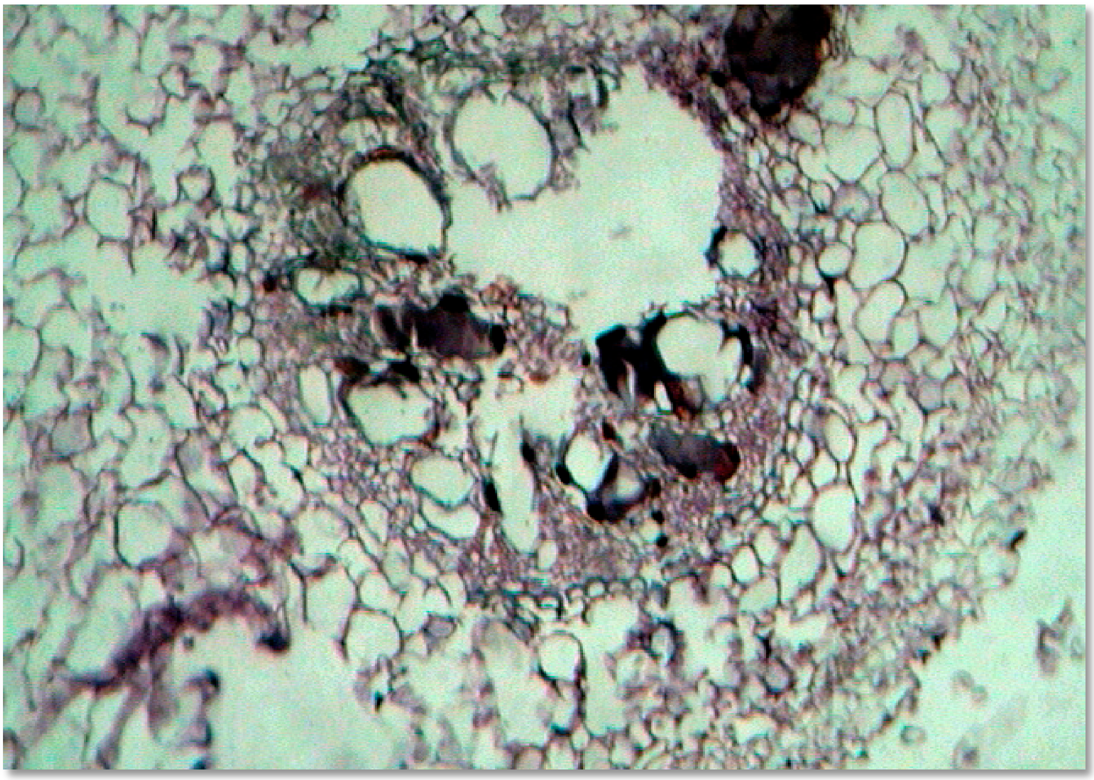

Fig 46: Transverse section of ginger root exhibiting broken endodermal cortical cells and cavities

Fig 47: Transverse section showing magnified giant cell with extensive colonization of bacteria(B)

Fig 49a: Ginger field treated with Carbofuran 3 G + Streptocycline 0.02%

Fig 49b: Untreated ginger field

Fig 68: Field showing growth of ginger in carbosulfan + *Pseudomonas fluorescens* (T$_{10}$)

Fig 67: Field showing growth of ginger in carbosulfan + phosphonic acid (T_9)

Fig 69: Field showing growth of ginger in sesame cake + phosphonic acid (T_{11})

Fig 70: Field showing growth of ginger in neem cake + phosphonic acid (T_{12})

Fig 21: Wilted plant in combined inoculation of *M. incognita* and *R. solanacearum*

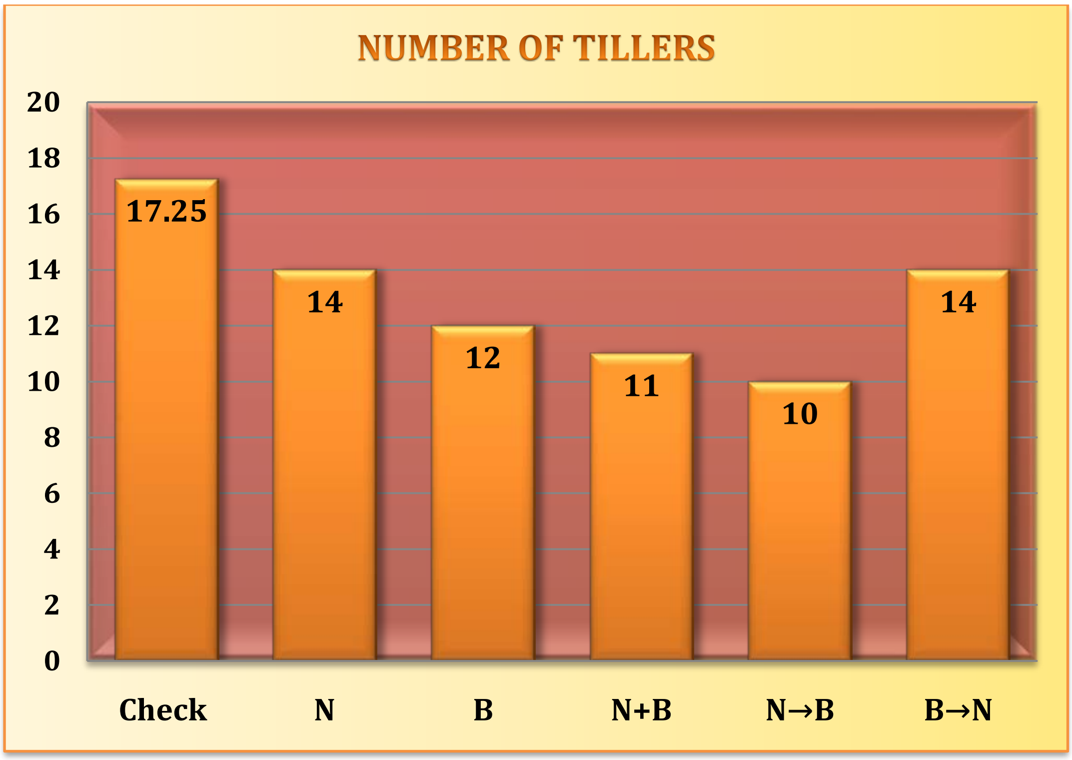

Fig 22: Histogram showing the effect of different treatments on number of tillers

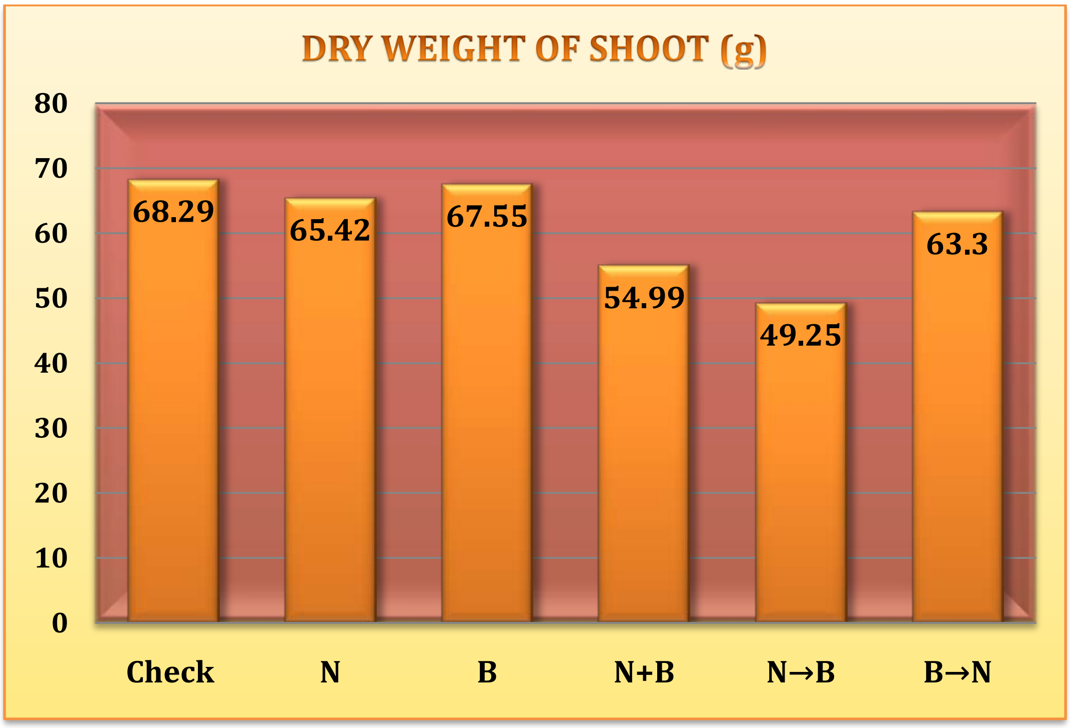

Fig 25: Histogram showing the effect of different treatments on dry weight of shoot

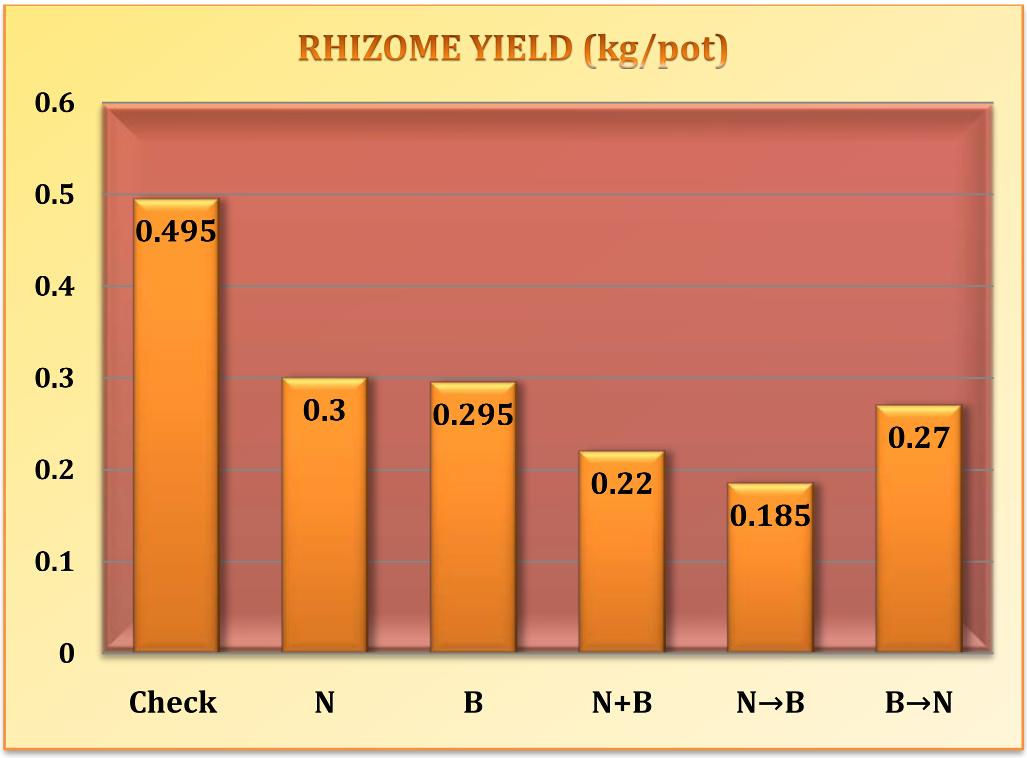

Fig 26: Histogram showing the effect of different treatments on rhizome yield

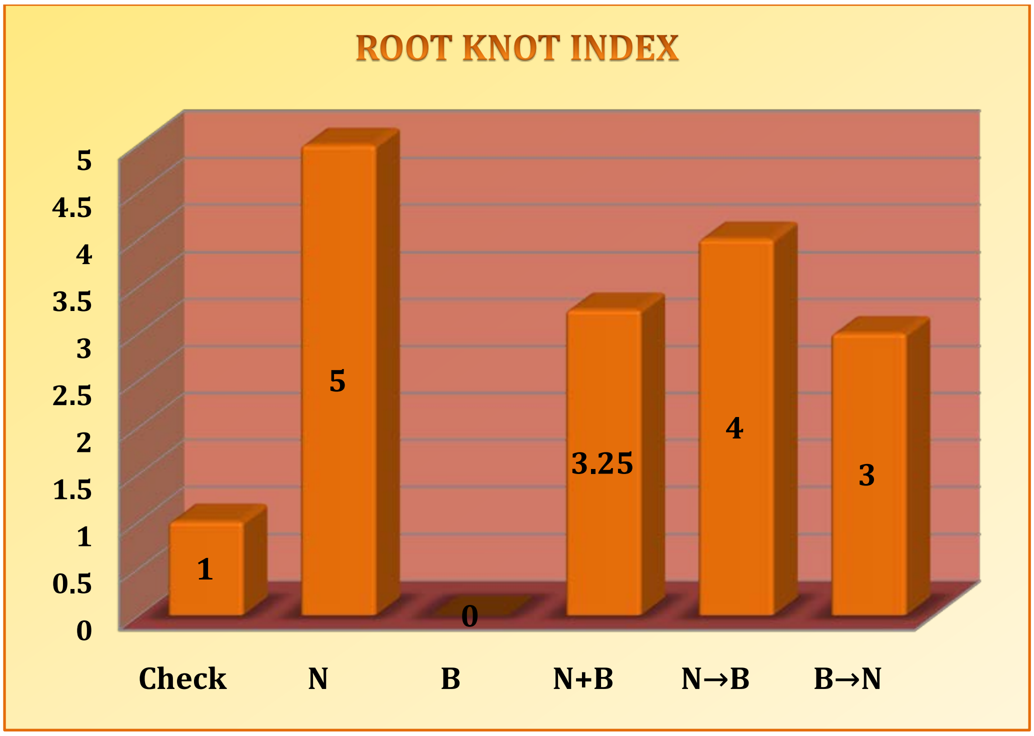

Fig 27: Histogram showing the effect of different treatments on root knot index

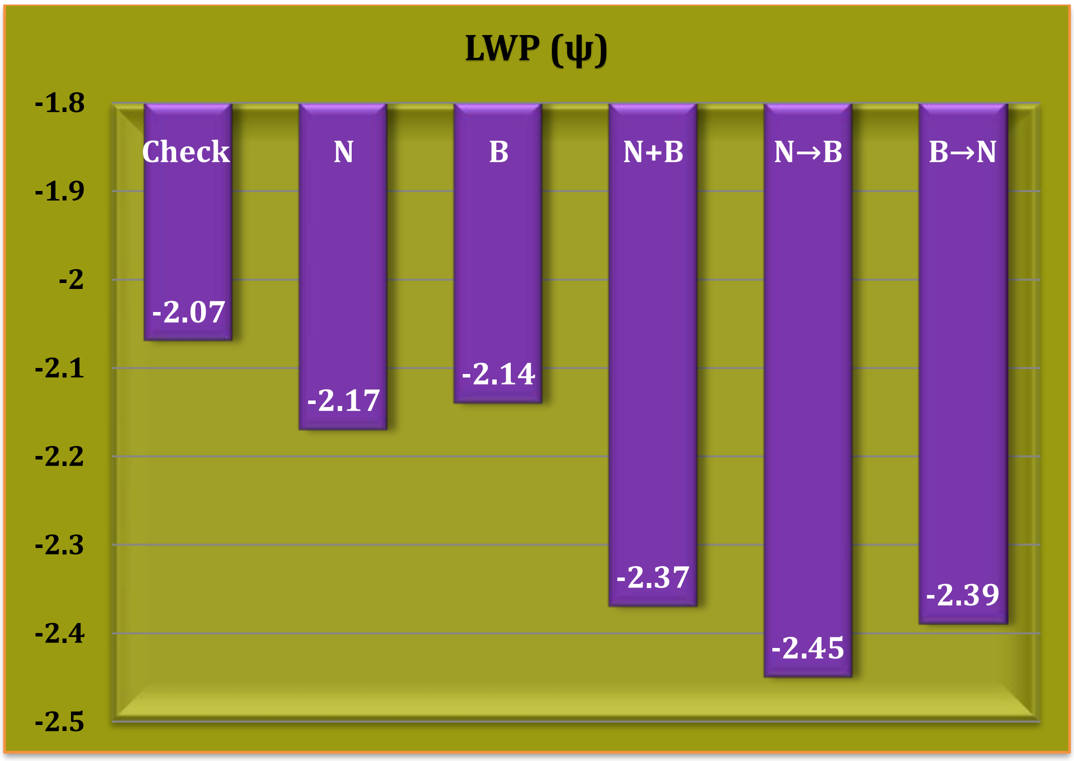

Fig 28: Histogram showing the effect of different treatments on leaf water potential

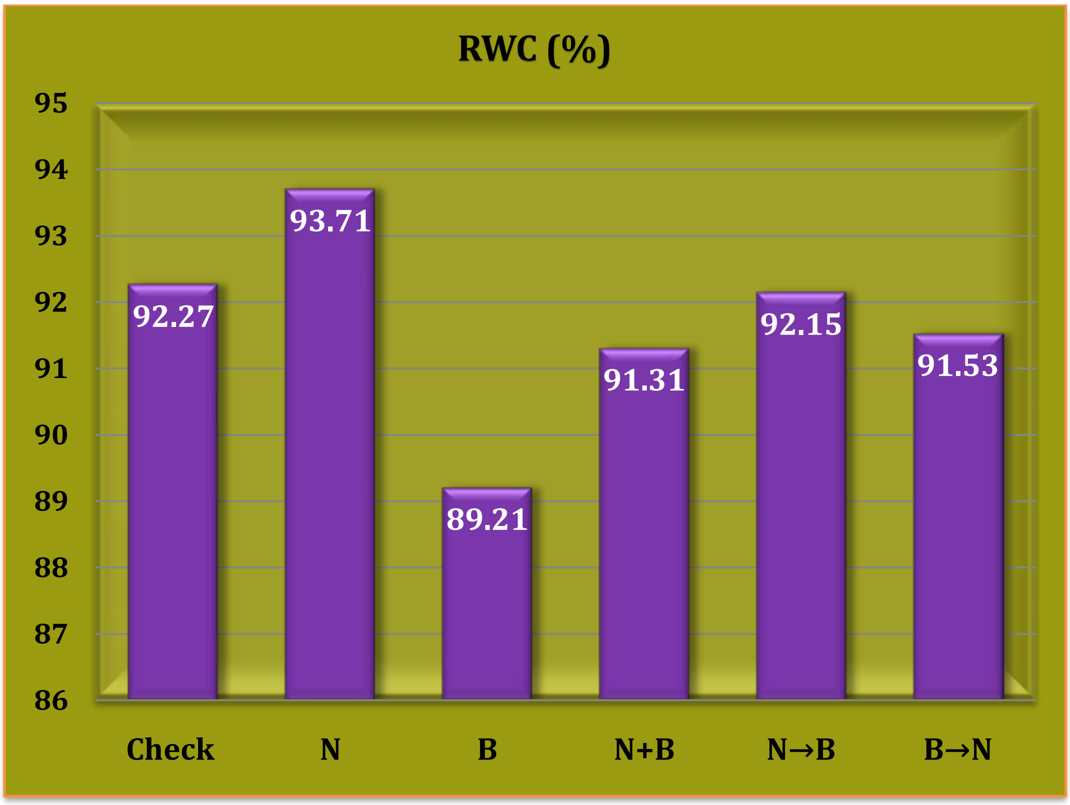

Fig 29: Histogram showing the effect of different treatments on RWC

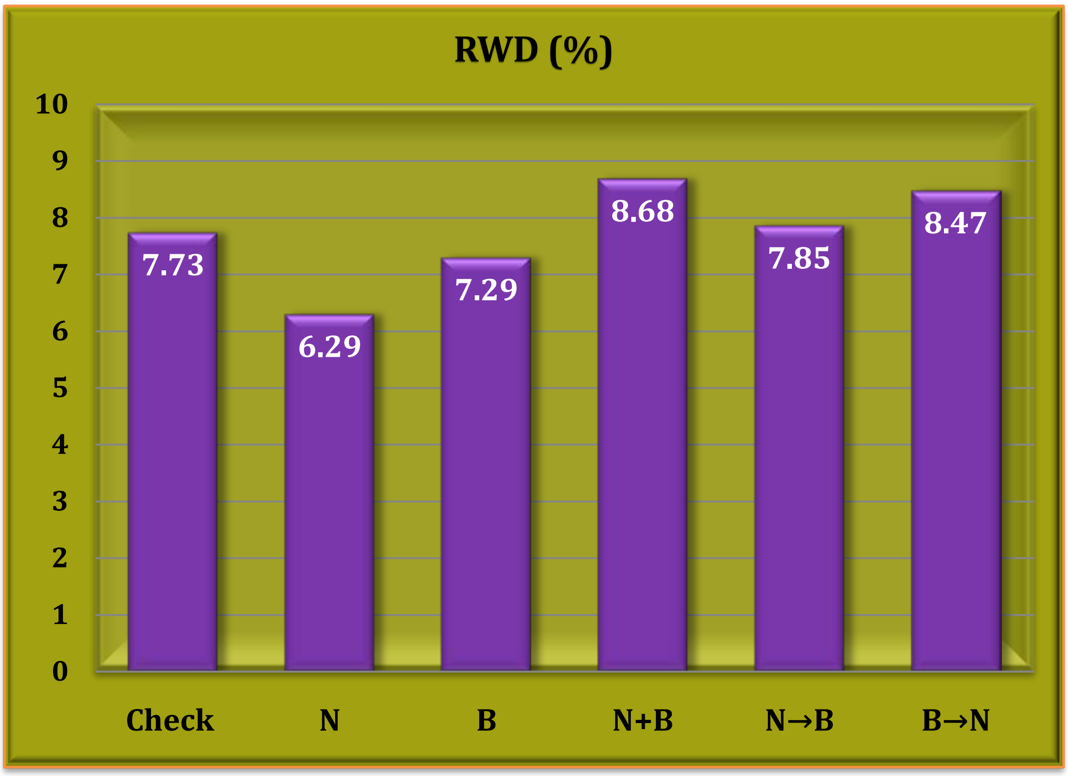

Fig 30:Histogram showing the effect of different treatments on RWD

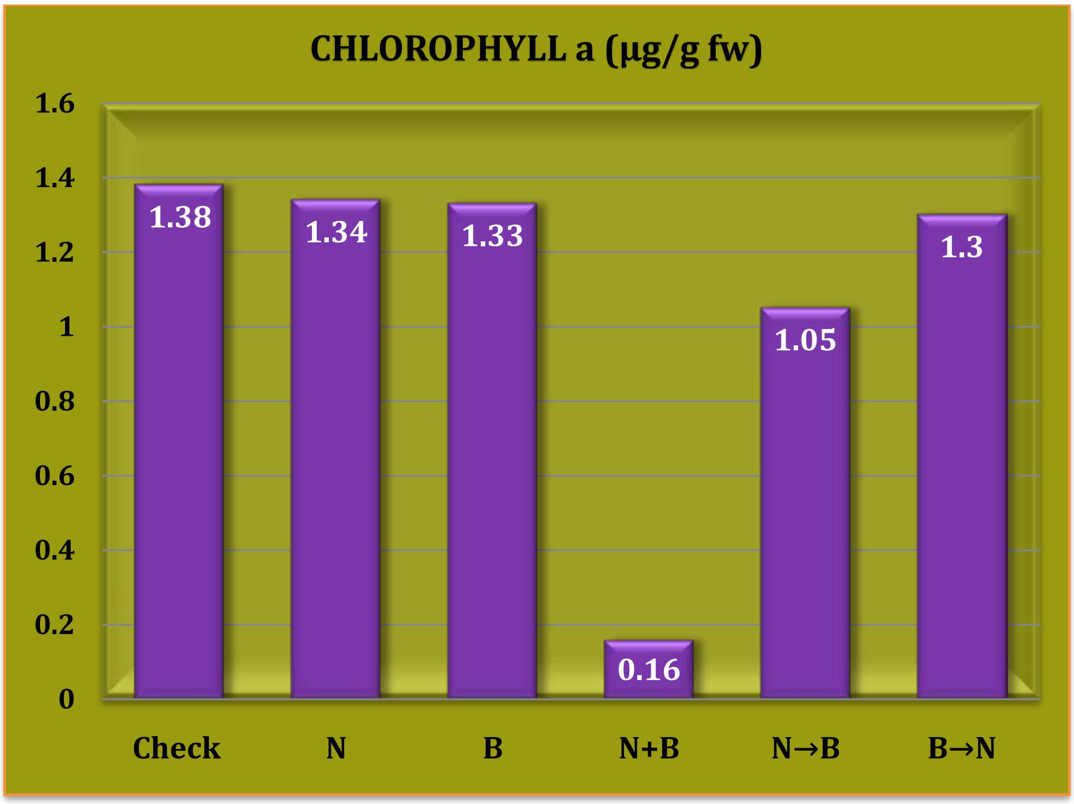

Fig 31: Histogram showing the effect of different treatments on chlorophyll a

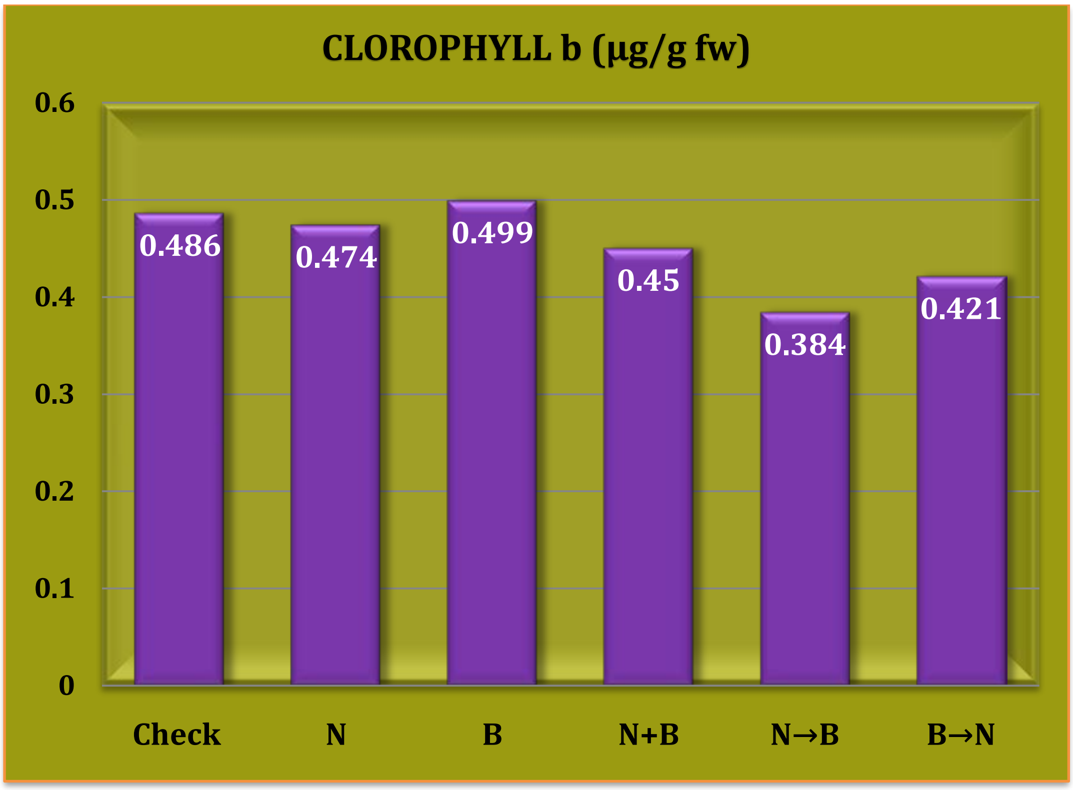

Fig 32: Histogram showing the effect of different treatments on chlorophyll b

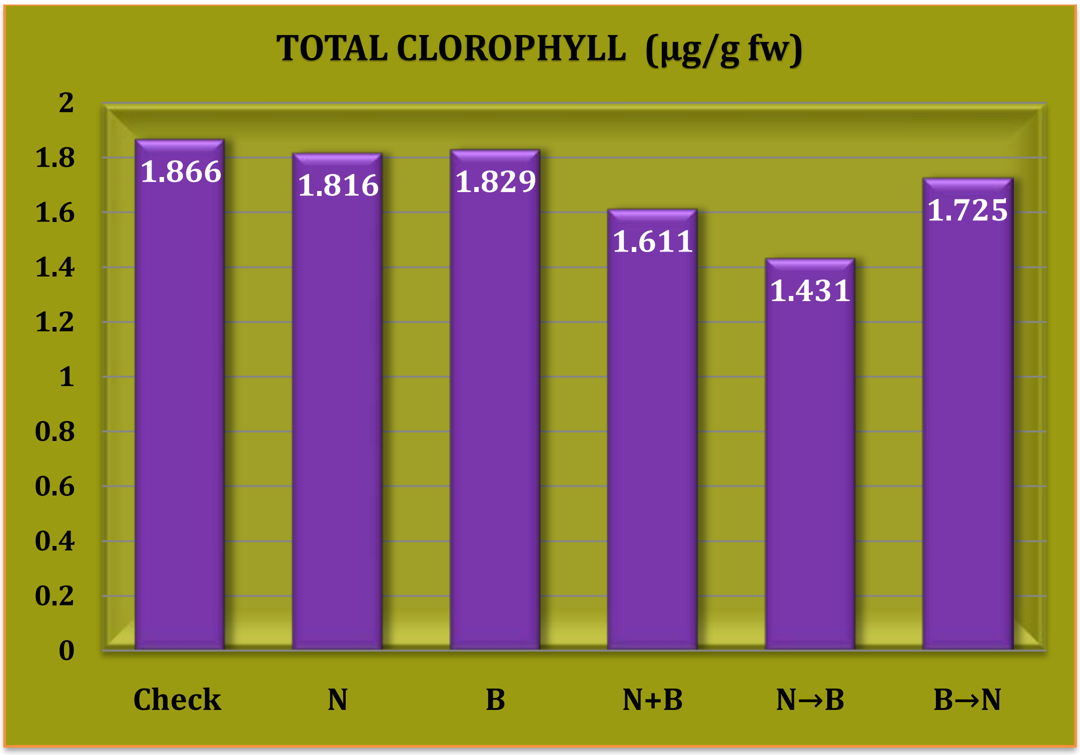

Fig 33: Histogram showing the effect of different treatments on total chlorophyll

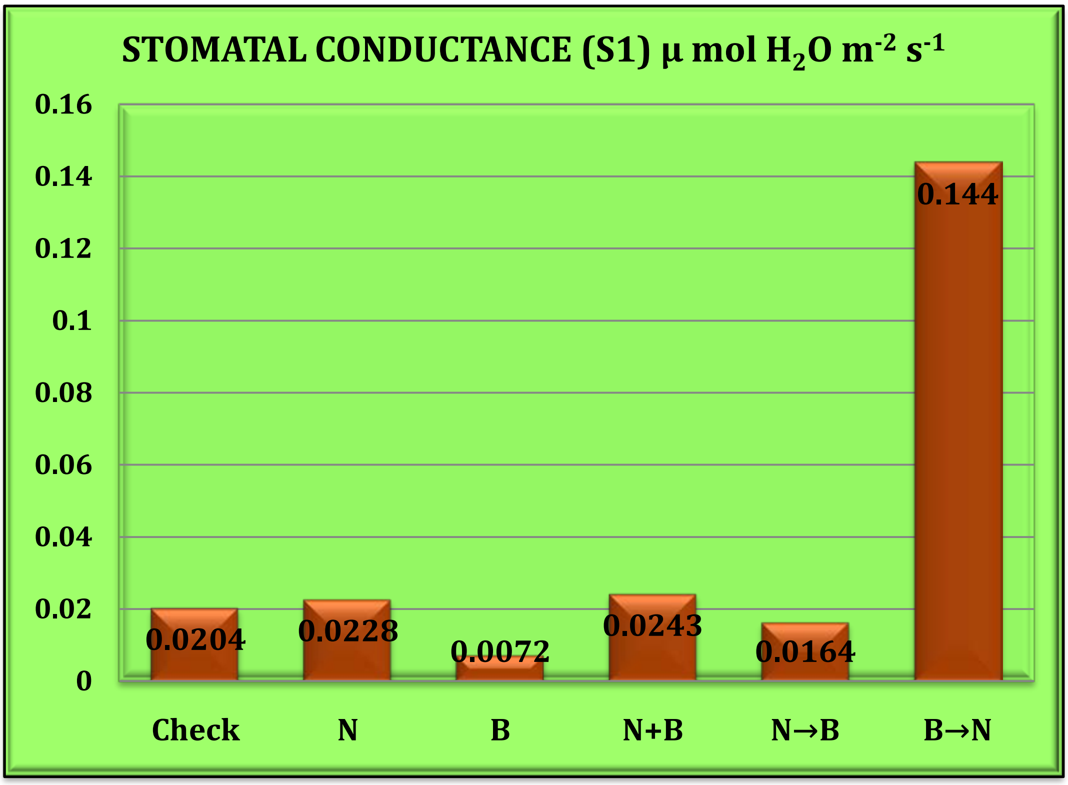

Fig 34: Histogram showing the effect of different treatments on stomatal conductance

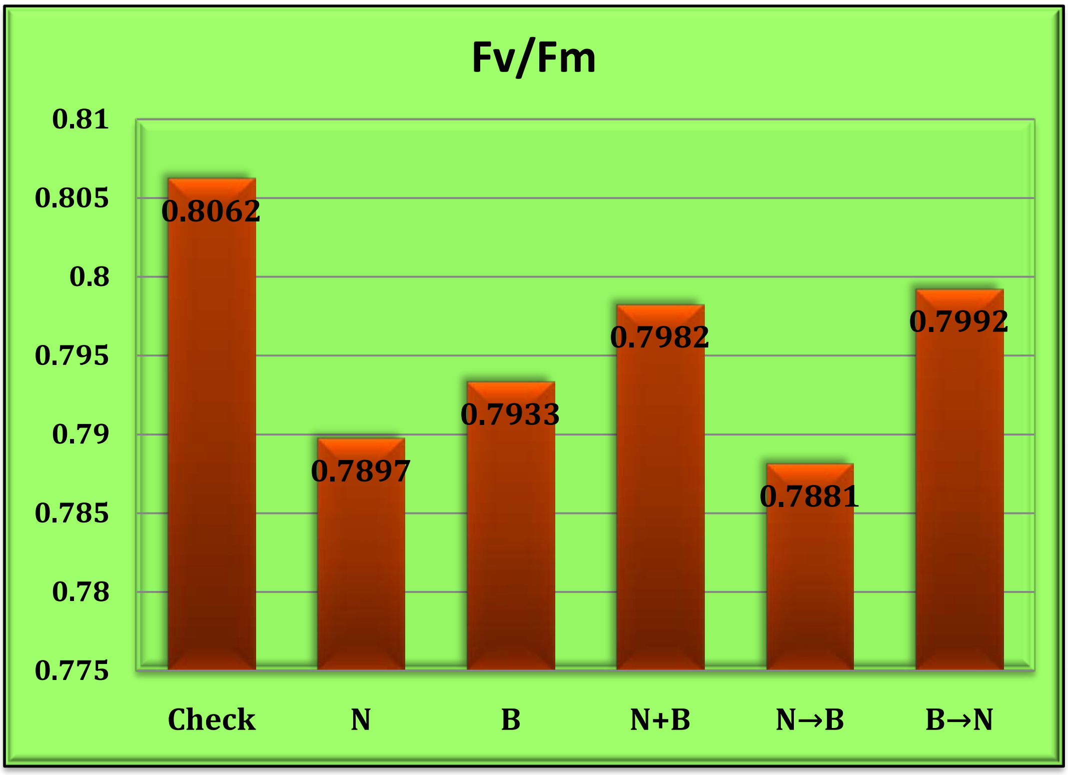

Fig 35: Histogram showing the effect of different treatments on Fv/Fm

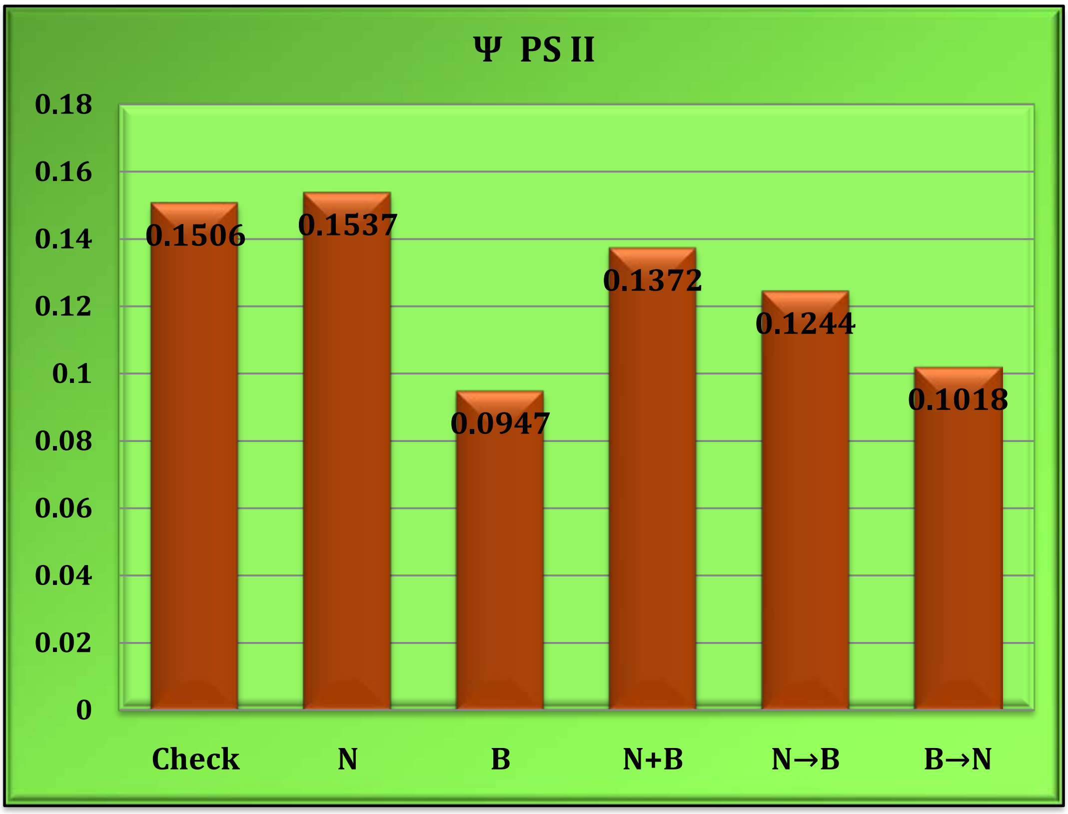

Fig 36: Histogram showing the effect of different treatments on Phi PS II

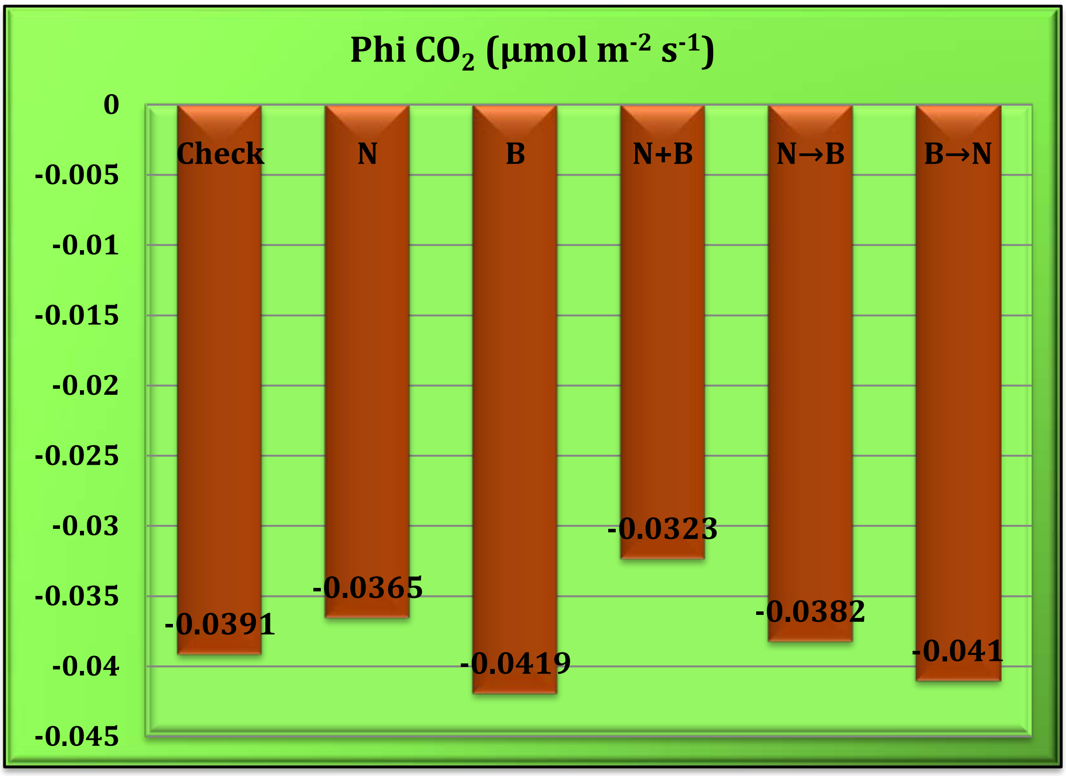

Fig 37: Histogram showing the effect of different treatments on Phi CO_2

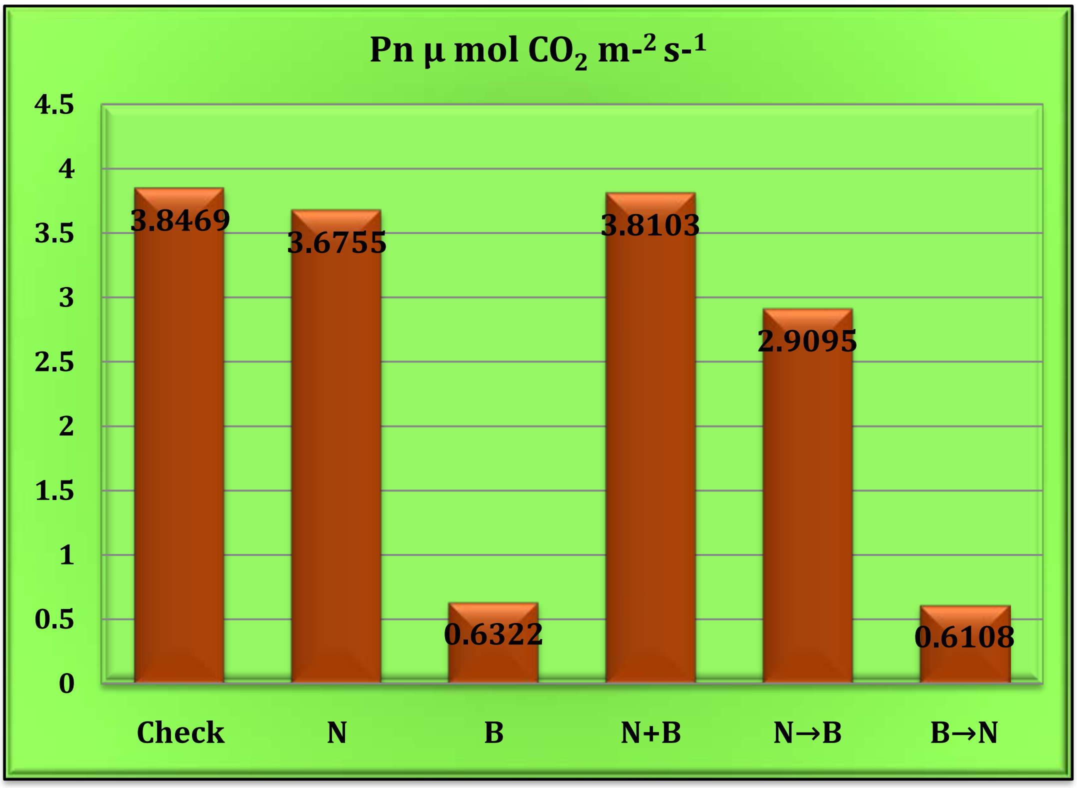

Fig 38: Histogram showing the effect of different treatments on net photosynthesis rate

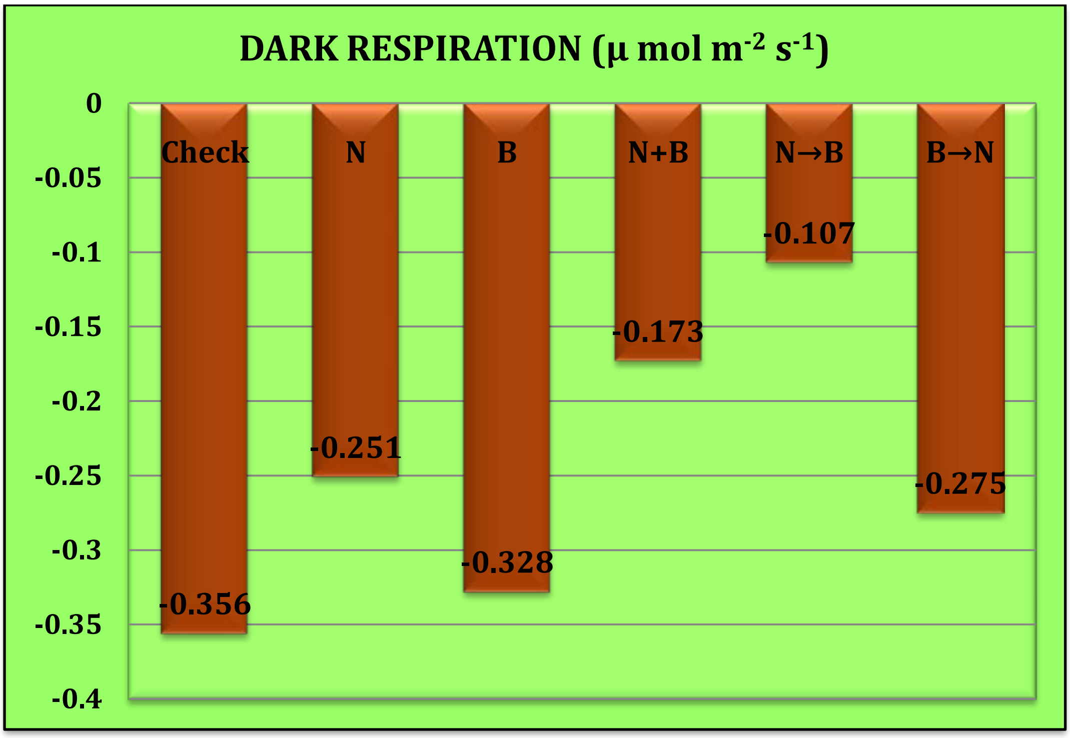

Fig 39: Histogram showing the effect of different treatments on dark respiration

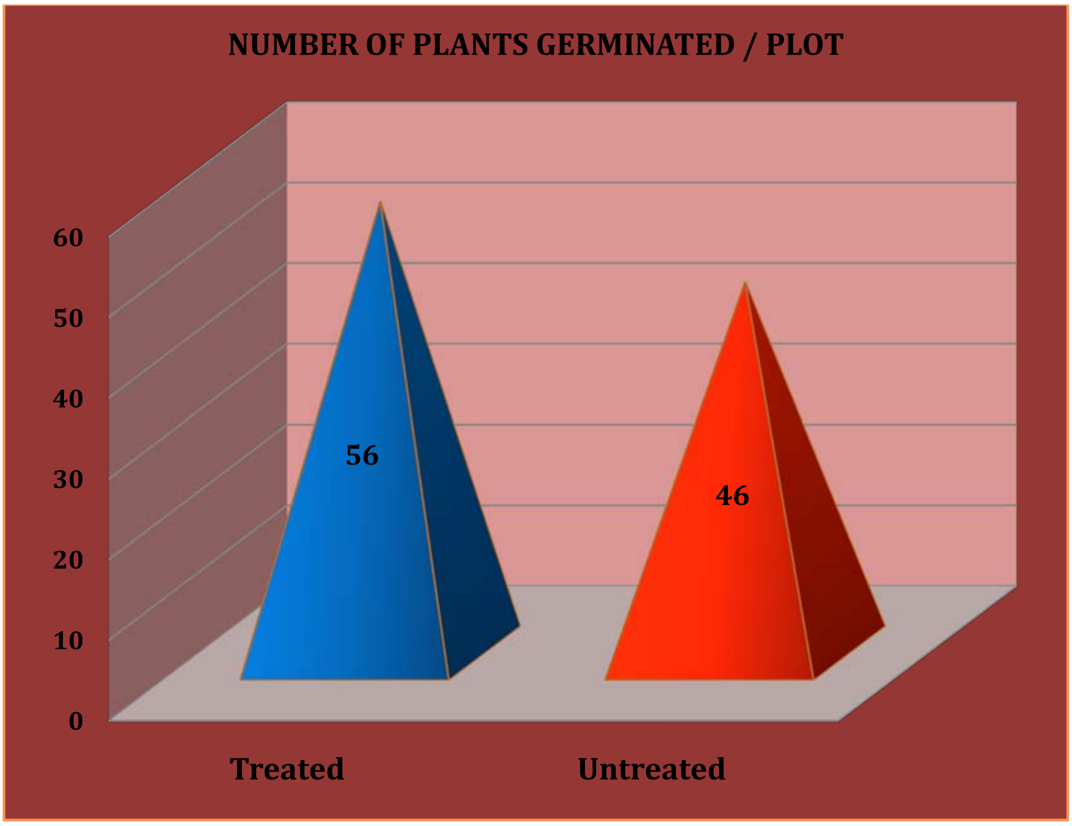

Fig 48: Histogram showing variation in germination of treated and untreated plots

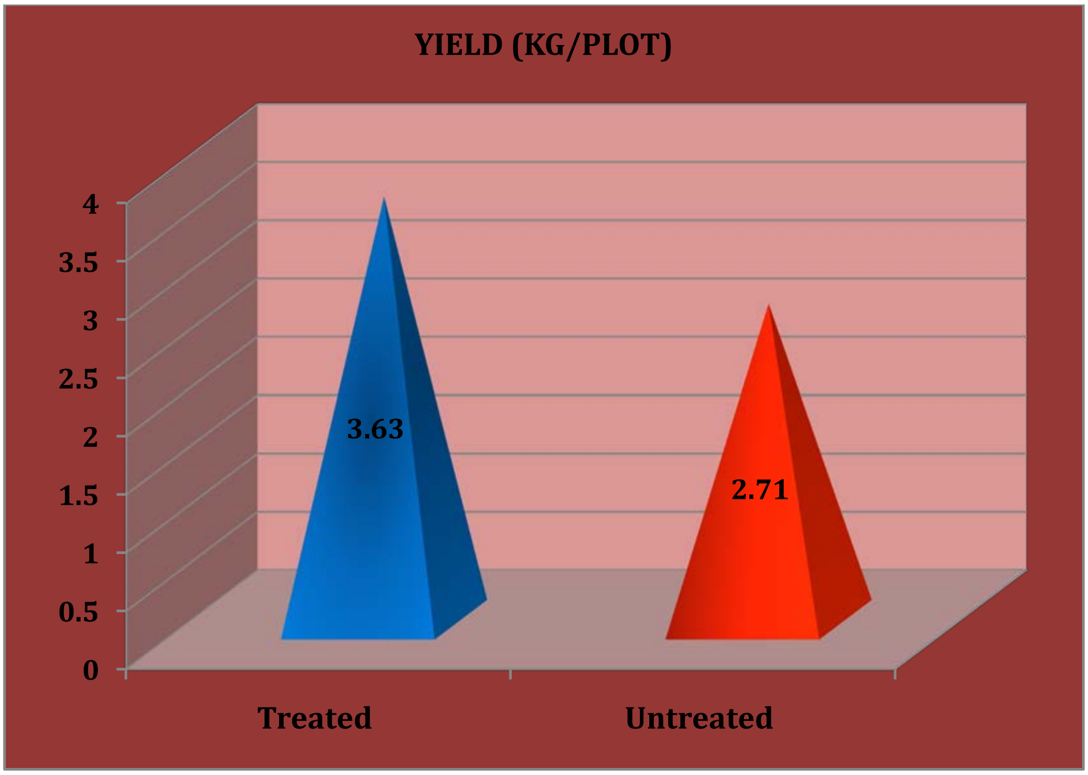

Fig 50: Histogram showing variation in yield of treated and untreated plots

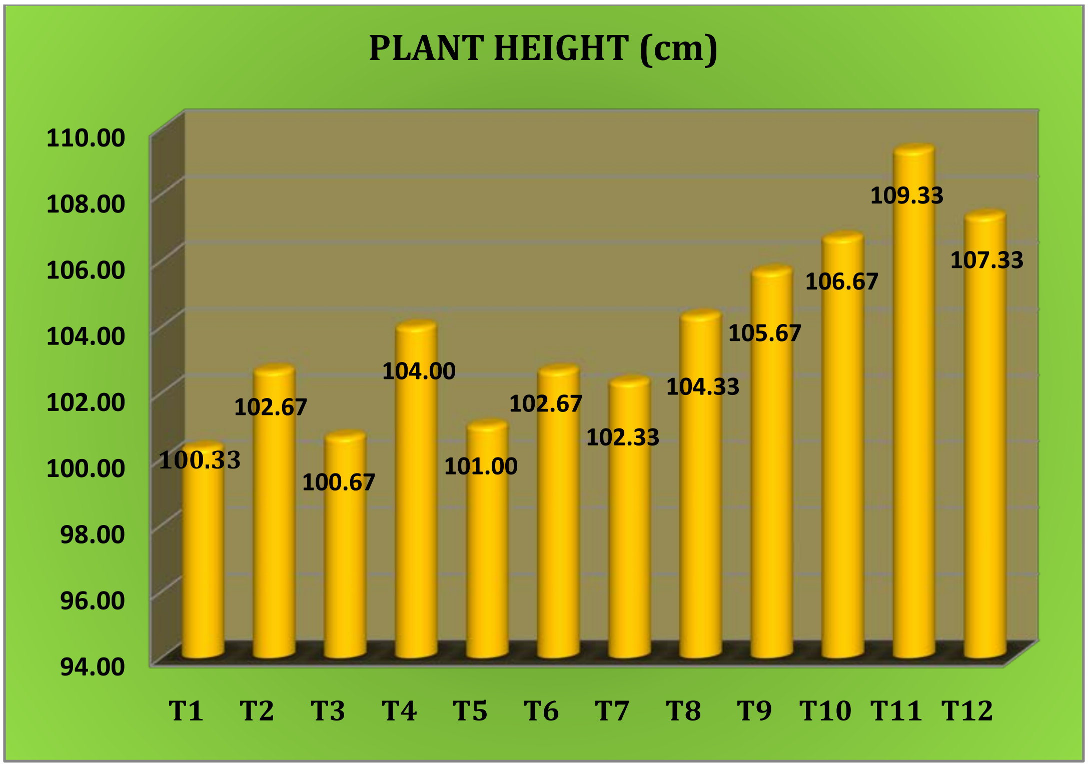

Fig 51: Histogram showing the effect of management modules on plant height

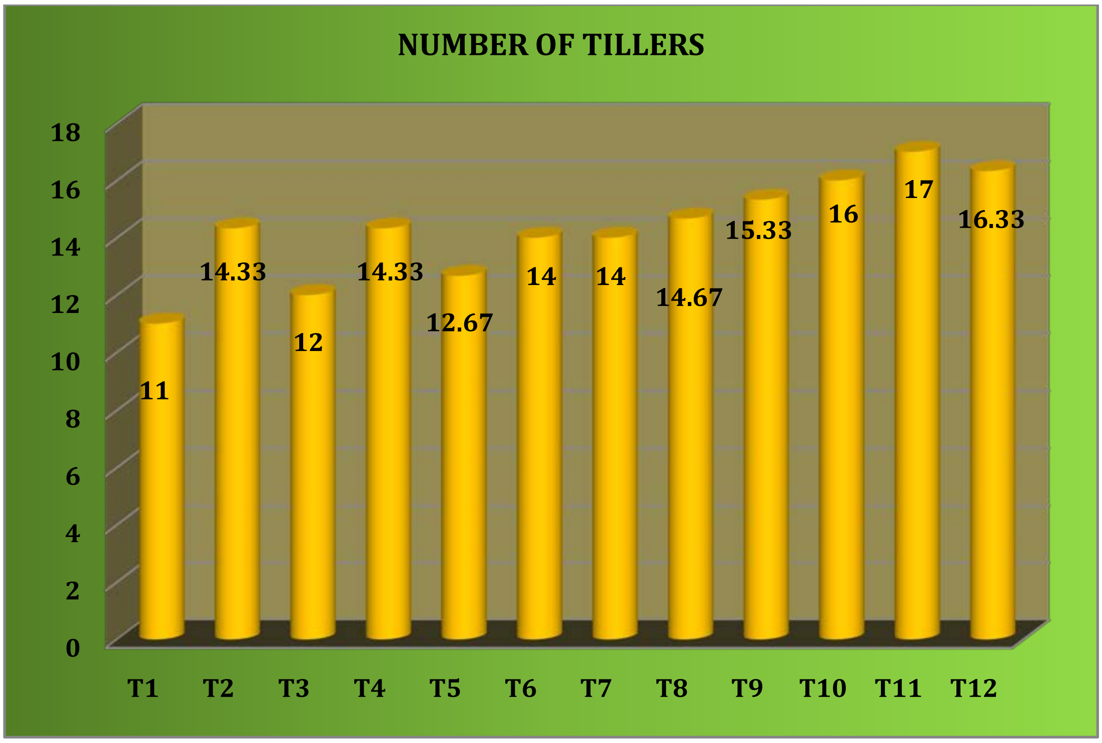

Fig 52: Histogram showing the effect of management modules on number of tillers

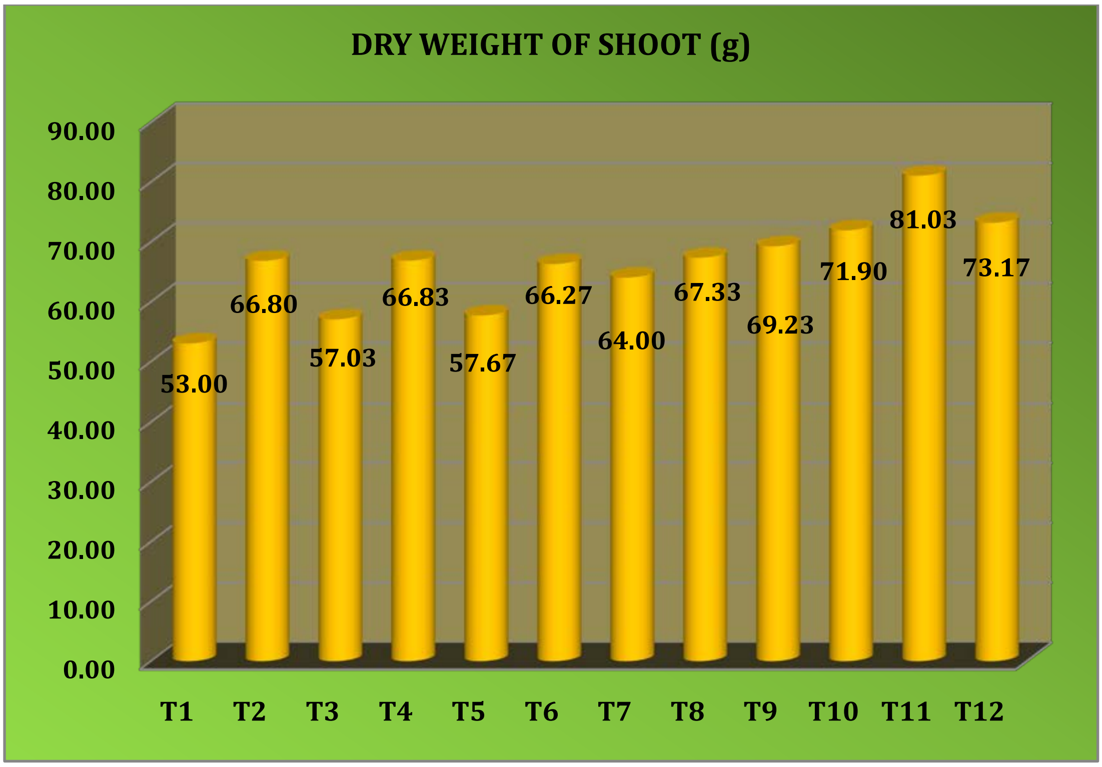

Fig 53: Histogram showing the effect of management modules on dry weight of shoot

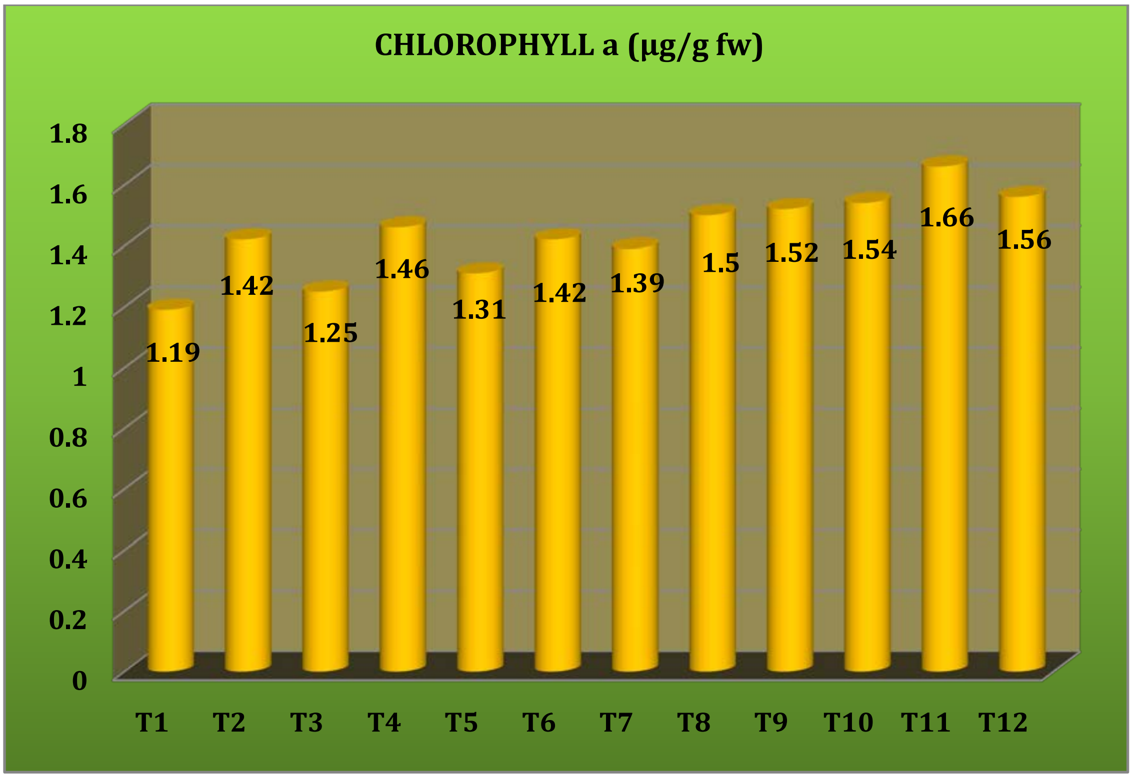

Fig 54: Histogram showing the effect of management modules on chlorophyll a

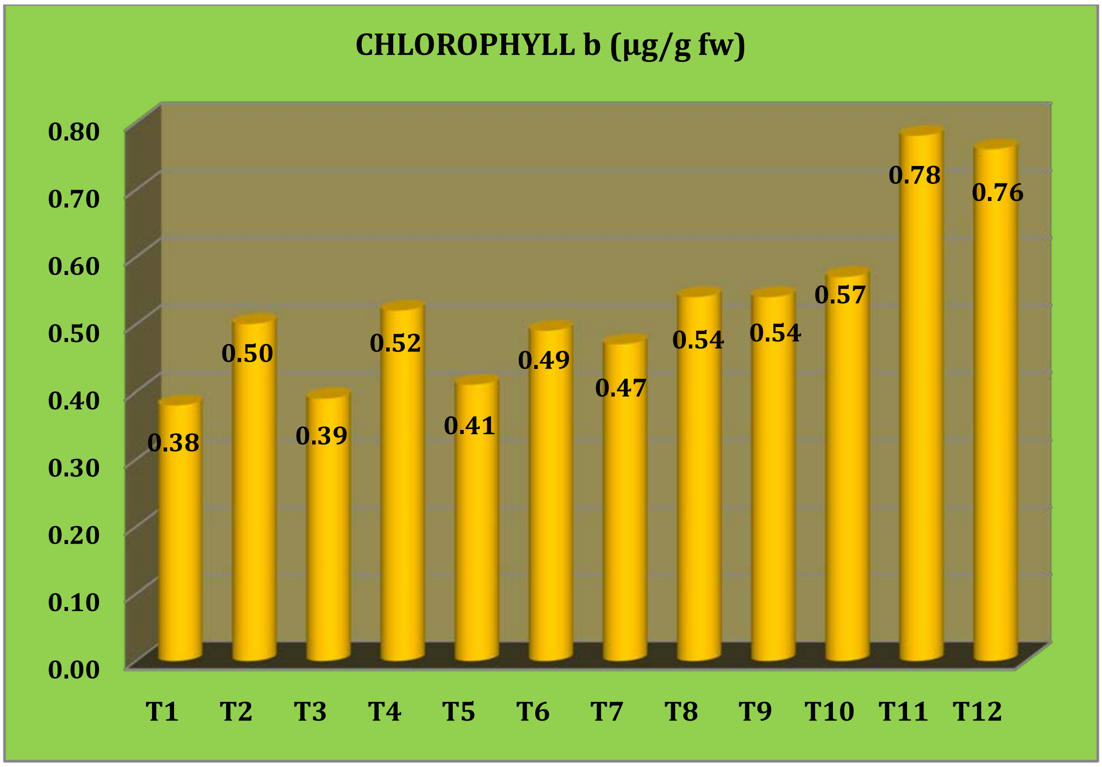

Fig 55: Histogram showing the effect of management modules on chlorophyll b

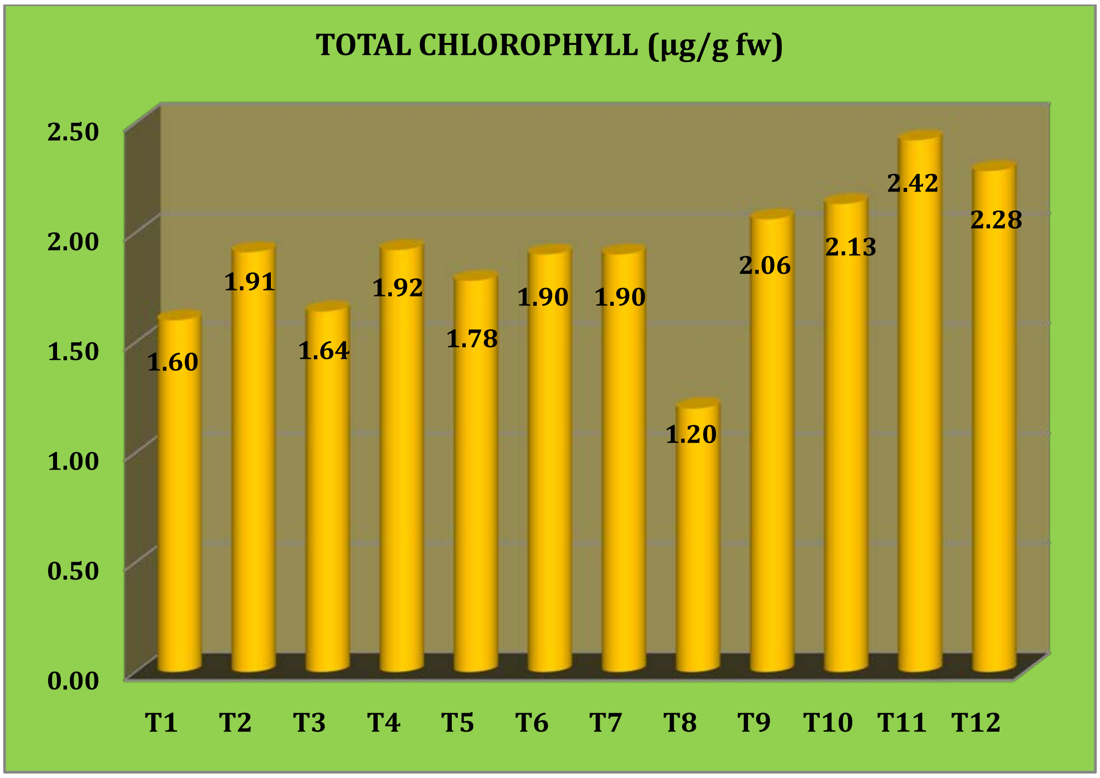

Fig 56: Histogram showing the effect of management modules on total chlorophyll

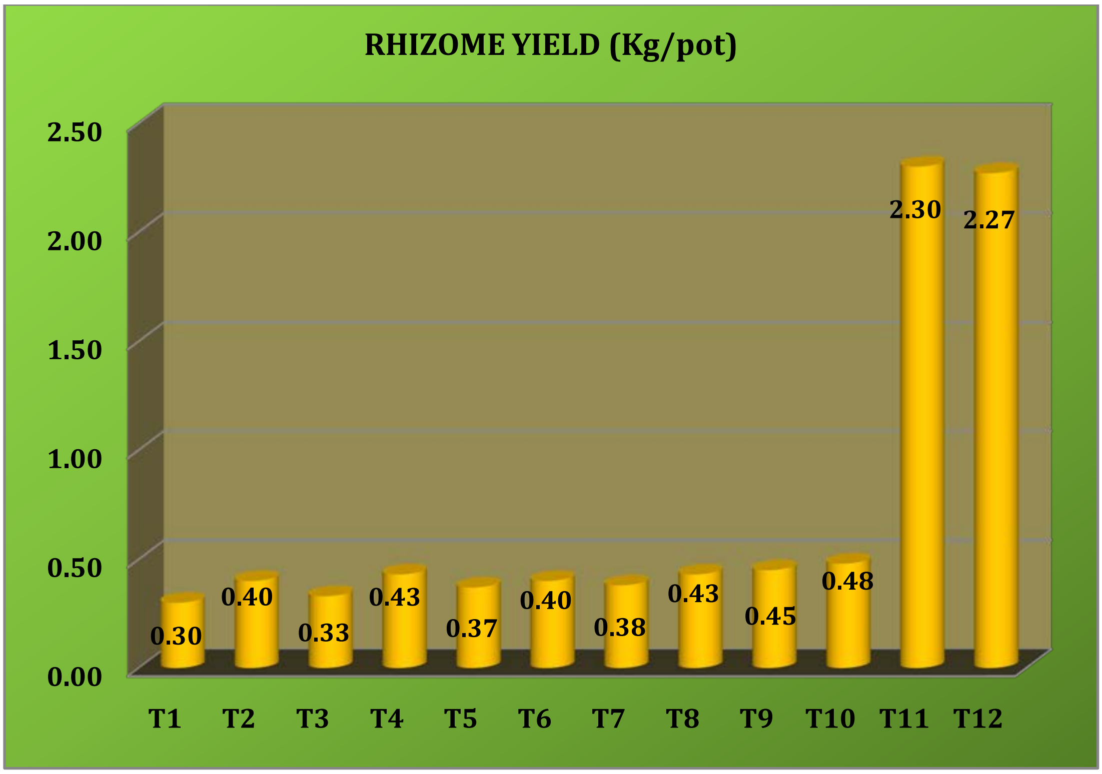

Fig 57: Histogram showing the effect of management modules on rhizome yield

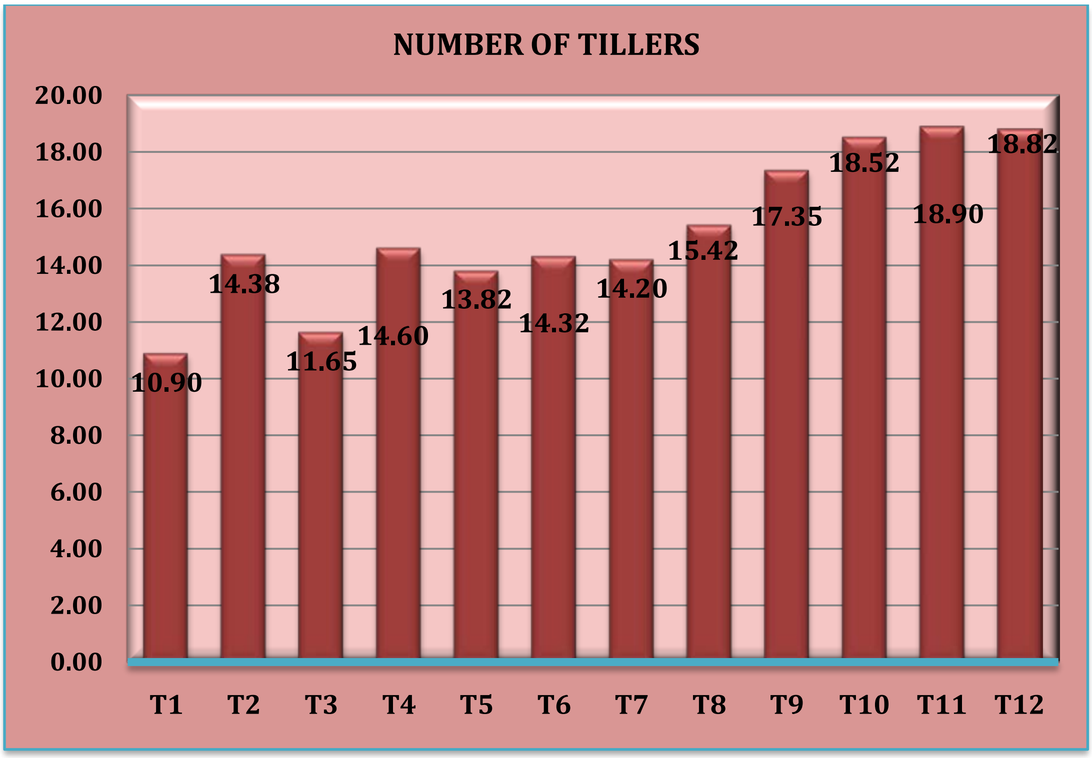

Fig 58: Histogram showing the effect of management modules on number of tillers

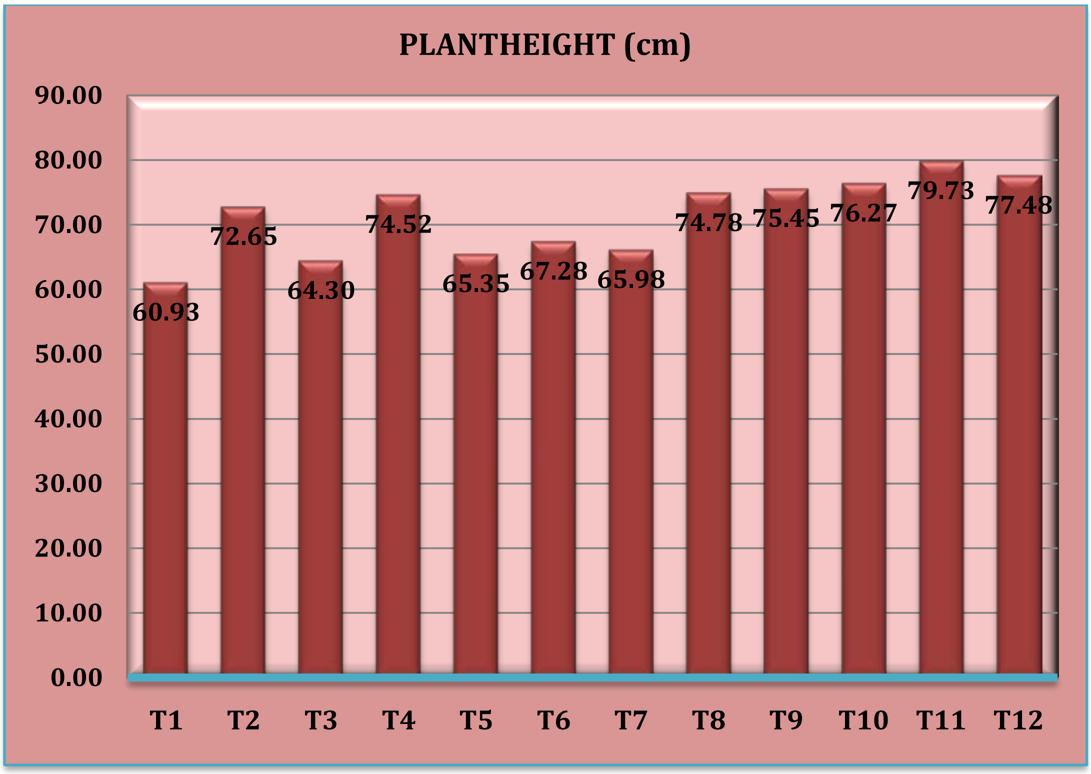

Fig 59: Histogram showing the effect of management modules on plant height

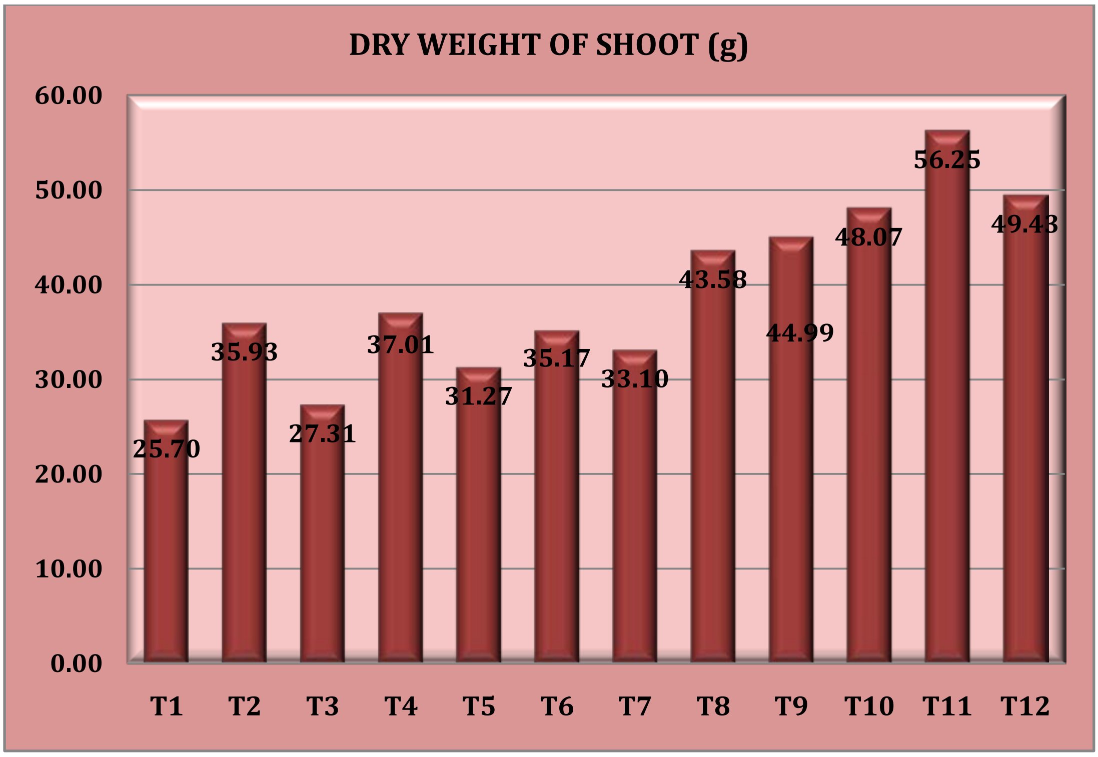

Fig 60: Histogram showing the effect of management modules on dry weight of shoot

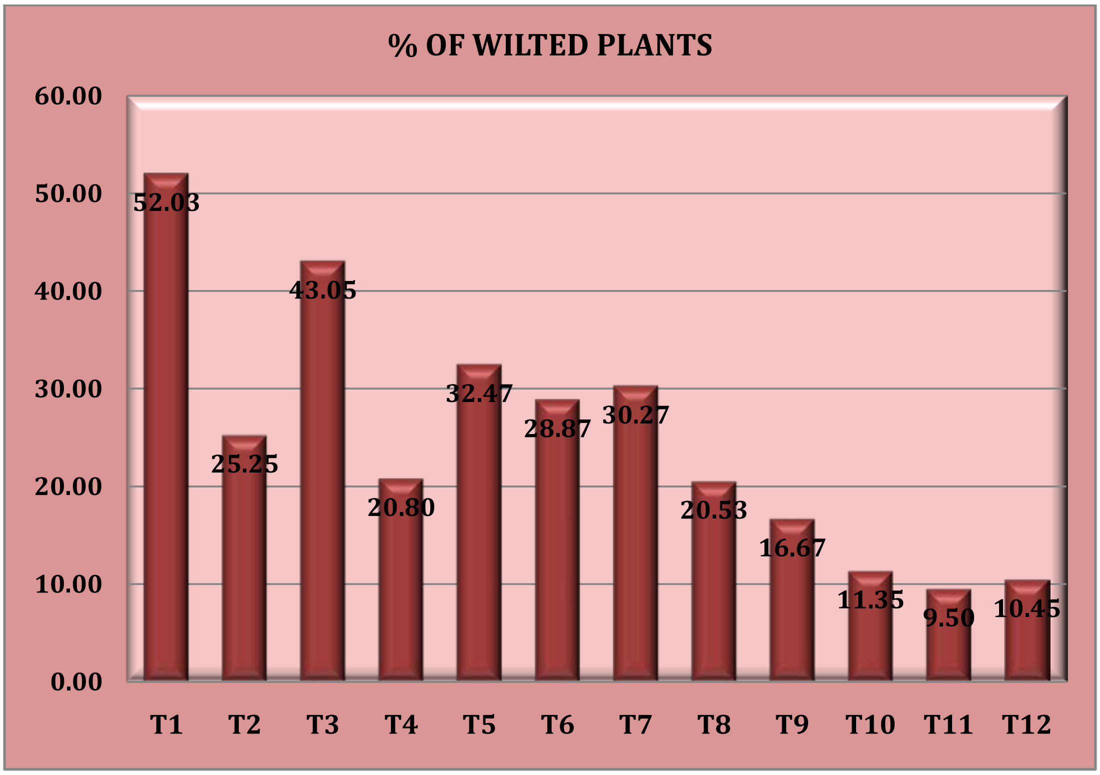

Fig 61: Histogram showing the effect of management modules on percentage wilted plants

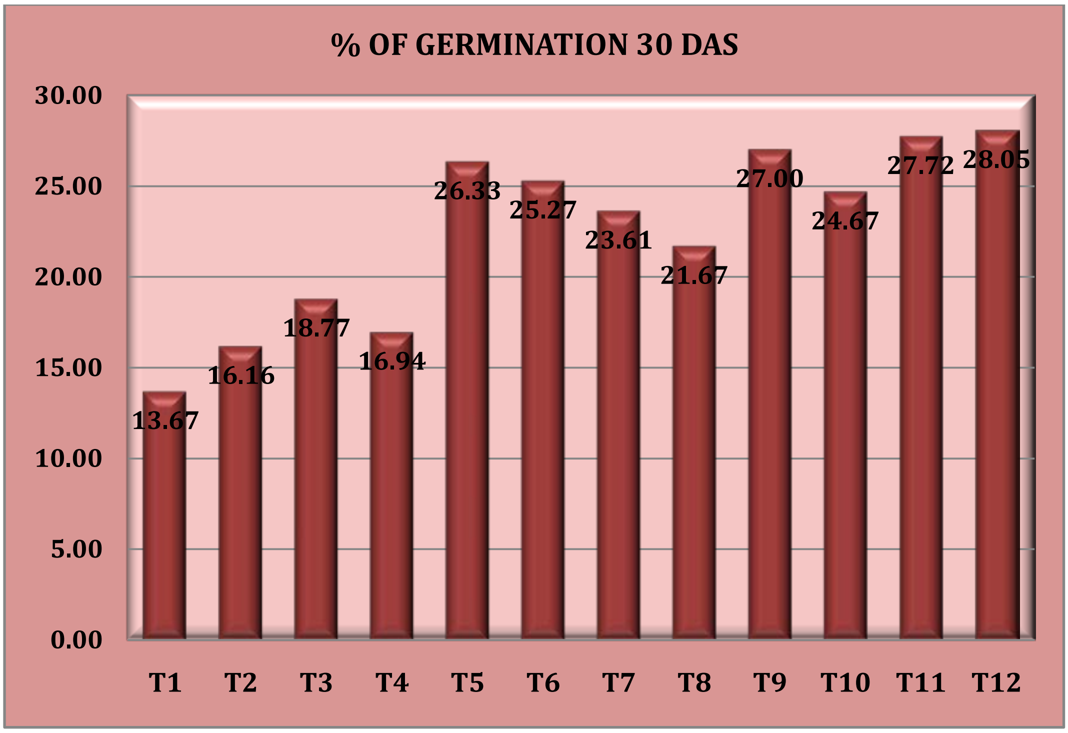

Fig 62: Histogram showing the effect of management modules on % of germination at 30 DAS

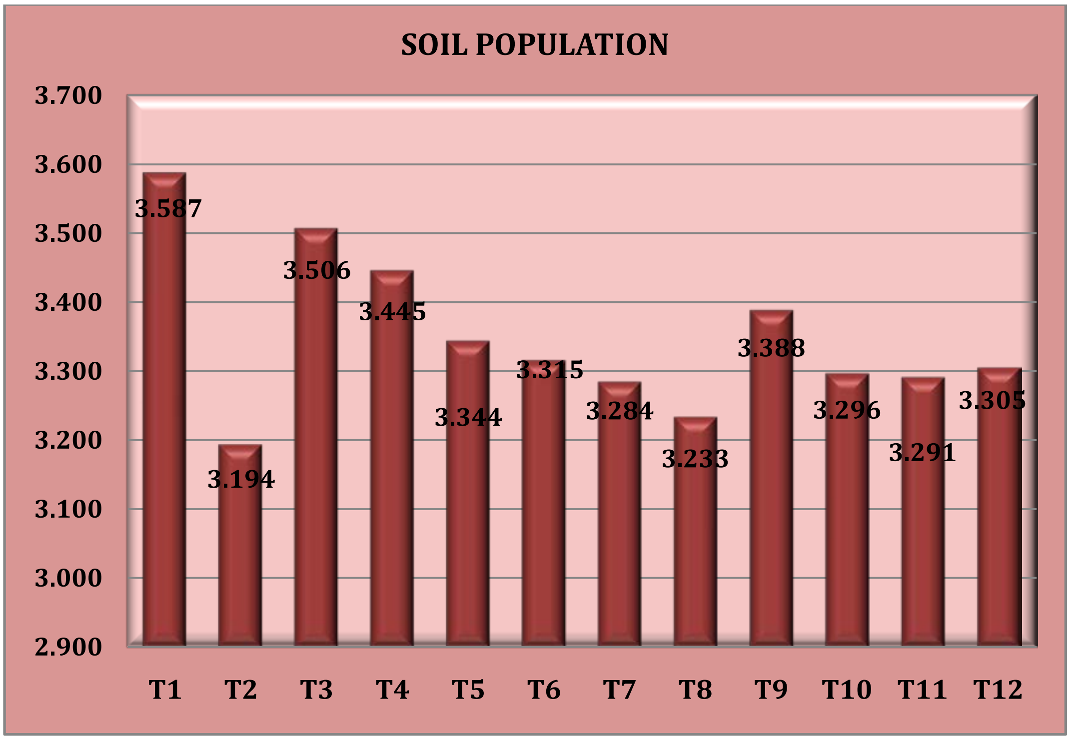

Fig 63: Histogram showing the effect of management modules on soil population

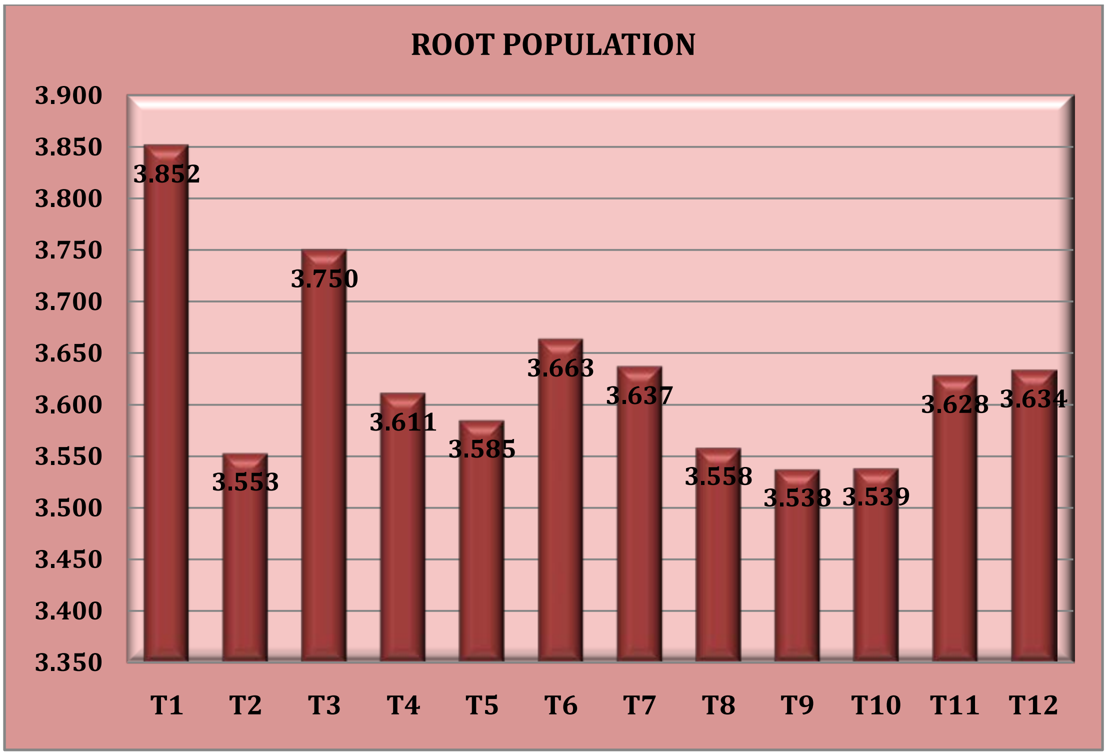

Fig 64: Histogram showing the effect of management modules on root population

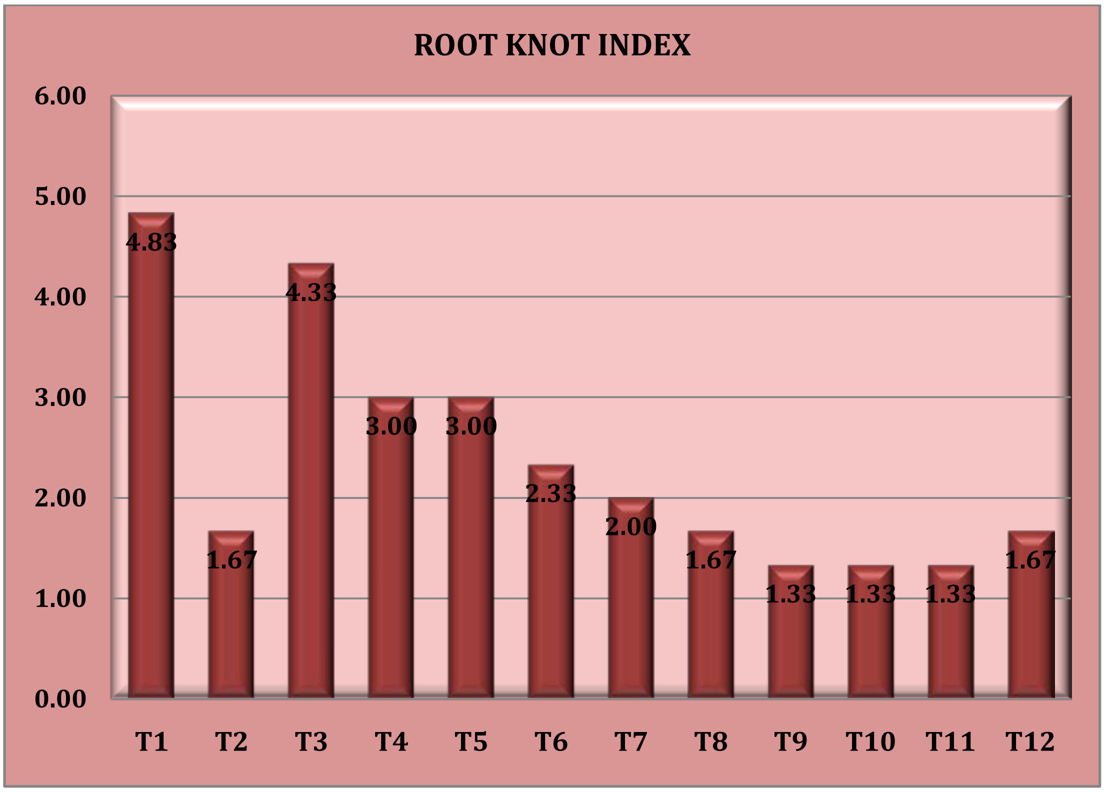

Fig 65: Histogram showing the effect of management modules on root knot index

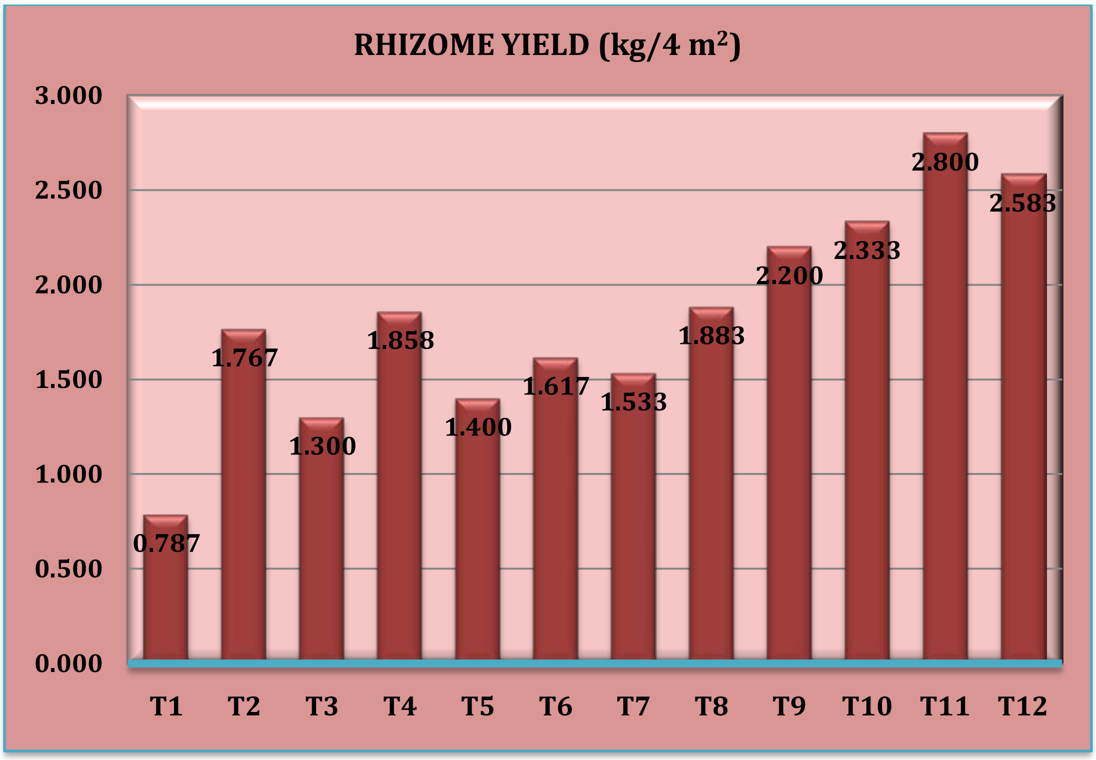

Fig 66: Histogram showing the effect of management modules on rhizome yield