INFLUENCE OF TRICHODERMA ON PHOTOSYNTHESIS,DRYMATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER

Y.RAMYASRI

B. Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE
(CROP PHYSIOLOGY)

2015

INFLUENCE OF TRICHODERMA ON PHOTOSYNTHESIS,DRYMATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER

By

Y.RAMYASRI

B. Sc. (Ag.)

THESIS SUBMITTED TO THE
PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE

(CROP PHYSIOLOGY)

CHAIRPERSON : Dr. S. NARENDER REDDY

DEPARTMENT OF CROP PHYSIOLOGY
COLLEGE OF AGRICULTURE
PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD-500030
2015

DECLARATION

I, **Y.RAMYASRI,** hereby declare that the thesis entitled **"INFLUENCE OF *TRICHODERMA* ON PHOTOSYNTHESIS, DRYMATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER"** submitted to **Professor Jayashankar Telangana State Agricultural University** for the degree of **Master Of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: **(Y.RAMYASRI)**
Date: **I.D. No.-RAM/13-061**

CERTIFICATE

Ms. Y. RAMYASRI has satisfactorily prosecuted the course of research and that the thesis entitled **"INFLUENCE OF *TRICHODERMA* ON PHOTOSYNTHESIS, DRY MATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has not been previously submitted by her for a degree of any university.

Date: **Chairperson**

CERTIFICATE

This is to certify that the thesis entitled **"Influence of *Trichoderma* on Photosynthesis, dry matter partitioning and nutrient uptake in sunflower"** submitted in partial fulfilment of the requirements for the degree of Master of Science in **Professor Jayashankar Telangana State Agricultural University**, Hyderabad is a record of the bonafide original research work carried out by Ms**. Y. RAMYASRI** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Thesis approved by the Student's Advisory Committee

Chairman	**:**	**Dr .S. Narender Reddy** Professor, Department of Crop Physiology, College of Agriculture, PJTSAU Rajendranagar, Hyderabad- 500 030	**(**Signature)
Member	:	**Dr.P. Lakshmamma** Principal Scientist, Crop Physiology, Directorate of Oil Seeds Research, Rajendranagar, Hyderabad-500 030	**(**Signature)
Member	:	**Dr .T.Dayakar Reddy** Professor & University Head (Retd.) Dept. of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyderabad-500 030	**(**Signature)

Date of final viva-voce:

ACKNOWLEDGEMENT

With immense pleasure, I wish to express my heartfelt respect and affectionate gratitude to my beloved parents Sri. ***Satyanarayana*** and Smt. ***Ramakoteswari*** and my brothers ***Gopikrishna, Arjunrao, Udayabhaskararao*** whose everlasting love, unfading faith, incessant inspiration, moral and financial support and blessings kept me enthusiastic throughout my life and molded me to the present position, and whose constant encouragement brings out the best in every one of my endeavours and without which this work could not be completed.

I humbly take this opportunity to place my profound debt of gratitude on record to my esteemed major advisor and Chairman of the Advisory Committee, ***Dr. S.Narender Reddy*** Professor, Department of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad for his valuable suggestions, encouragement, affection, personal guidance, keen interest, immeasurable help and constructive criticism given throughout my work and making it possible to bring out this thesis. It was an honor and privilege for me to be associated with him who stood by me with boundless patience in many difficult situations during my M. Sc. Degree Programme.

I am equally and deeply indebted to ***Dr. Laxmamma*** , Principal Scientist, Department of plant physiology, Directorate of Oil seeds Research, Rajendranagar, Hyderabad and co-chairman of the Advisory Committee for extending all necessary facilities to carry out the experiment from DOR and also giving me the privilege for full utilization of all laboratory facilities. Her encouragement, valuable guidance and technical suggestions throughout the period of investigation led to the perfect conduct of the experimental work and presentation of thesis.

I owe my effusive thanks to ***Dr .T.Dayakar Reddy*** Professor & Head, Department of Plant Genetics and plant breeding, College of Agriculture, Rajendranagar, Hyderabad and Member of Advisory Committee for his encouragement, co-operation and valuable suggestions during the course of my study

I express my sincere gratitude to ***Dr.P.v Rao, Dr. Vishnu Vardhan Reddy*** Head of the Department of crop physiology ***Dr. A. Siva Sankar***, Professor, Department of Crop Physiology, ***Dr.V.Padma***, Professor, Department of Crop Physiology, ***Dr. T.Ramesh***,

Professor, Department of Crop physiology , ***Dr.B.Srikanth***, assistant professor, Department of Crop physiology, ***Dr.Saida Nayak***, assistant professor, Department of Crop physiology, college of Agriculture, Rajendranagar, Hyderabad for their valuable counsel, note-worthy guidance and cordial co-operation during the course of investigation.

I am here with acknowledging the help received from the Pathology Department of Directorate of Oil Seed Research.

Not forgetting the kindness, punctuality and patience of the computer centre for cautiously carrying out all the statistical analysis in time as and when required

I am really indebted to my dear friends ***Lavanya, Anandrao***. I also fondly thank my senior friends ***Vema, Santhosh, Rambabu, Venumadhav and Laxmi prasanna, Gowthami, Rajesh, Sumalatha, Vijayalaxmi, Praneeth, Devkumar*** for providing valuable guidance and to my juniors ***Nagaraju ,Chanrashekar, Janakiramulu, Trivedika, Maliha, Fareen, Mahesh babu*** for rendering their unending co-operation and help during the course of my research.

I wish to express my heartfelt thanks and love to my dearest friends ***Rajendar, rajashekar, Susan priyadarshini, mamatha, navyatha, ragini, srimathi, Ganga, Deepika, Ajitha, Anitha, Navya*** for their lovely friendship, help and care and for making the two year study very much enjoyable and memorable.

I am thankful to Department staff , ***Anjaiah, Devender, Yesobu and Anuradha*** and other non-teaching staff of the Department of Plant Physiology for their timely assistance and cooperation.

I am highly thankful to library staff of ***PJTSAU*** for extending their co-operation.

I humbly thank the authorities of ***Professor Jaya Shankar Telangana State Agricultural University*** for giving me this opportunity to pursue my post graduation study.

and ***Government of Telangana State*** for the financial help in the form of stipend during my study period.

I convey my wholehearted thanks to all my well wishers requesting their forgiveness for not mentioning them here by name.

Above all, I am grateful to '**God**' giving me enough strength and fortitude to meet various challenges.

Needless to say omissions and errors are mine.

Date:

Place: Hyderabad **(RAMYASRI.Y)**

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LIST OF SYMBOLS AND ABBREVIATIONS

%	: Percent
@	: At the rate of
±	: Plus or minus
Mg	: Milli gram (S)
CD	: Critical difference
CD(0.05)	: Critical difference at 5% level of significance
Cm	: Centimetre
Cm	: Centimetre square
CGR	: Crop growth rate
CO_2	: Carbon dioxide
DAS	: Days after sowing
Day^{-1}	: Per day
DOR	: Directorate of oil seed research
Dw	: Dry weight
et al.	: And others
etc.	: Extra
Fig.	: Figure
Fr.wt	: Fresh weight
G	: Gram
g m^{-2} day-^{1}	: Gram per meter square per day
g/ plant	: Gram per plant
ha	: Hectare (s)
ha^{-1}	: Per hectare
i.e.	: That is
IRGA	: Infra red gas analyser
K	: Potassium
Kg	: Kilogram
Kg/ ha	: Kilo gram per hectare
km/hr	: Kilomeeter per hour
LA	: Leaf area
LAI	: Leaf area index
M	: Meter (s)

m^{-2}	: Per meter square
m^2	: Meter square
mg	: Milli gram
ml	: Millilitres(s)
min	: Minute (s)
mm	: Millimetre
mm day^{-1}	: Millimetres per day
N	: Nitrogen
^oC	: Degree celsius
RF	: Rainfall
RH	: Relative humidity
SCMR	: SPAD chlorophyll metre reading
SPAD	: Soil plant analytical development
s^{-1}	: Per second
t	: Time
TDM	: Total dry matter
Viz.,	: Namely
wt.	: Weight
RGR	: Relative growth rate
NAR	: Net assimilation rate
P	: Phosphorus

Name of the author	: **Y.RAMYASRI**
Title of the thesis	:**INFLUENCE OF TRICHODERMA ON PHOTOSYNTHESIS, DRYMATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER**
Degree	: **MASTER OF SCIENCE**
Faculty	: **AGRICULTURE**
Department	: **CROP PHYSIOLOGY**
Chair person	: **Dr. S.NARENDER REDDY**
University	: **PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY**
Year of submission	: **2015**

ABSTRACT

A research project entitled "**Influence of *Trichoderma* on Photosynthesis, drymatter partitioning and nutrient uptake in sunflower**" was conducted at the students farm, College of agriculture, Rajendranagar, Hyderabad, during *Rabi* 2014-15. The field trail was conducted following randomized block design with three replications and ten treatments viz. *Trichoderma harzianum*-Th4d, *Trichoderma asperellum*-TaS1, *Trichoderma asperellum*-Tv5, *Trichoderma sps*-Ta DOR673, *Trichoderma koningii, Trichoderma asperellum*-TaDOR7316, *Trichoderma virens, Trichoderma asperellum*- N13, *Trichoderma hamatum,* and one control. In this experiment, the morphological traits such as plant height, number of leaves and physiological indices such as LAI, CGR, RGR, NAR, SCMR and photosynthetic rate were evaluated at 15 days interval. Phenological parameters days to 50% flowering and days to physiological maturity were evaluated at flowering stage and maturity stage respectively.

Results of the morphological characteristics showed that highest and lowest plant height were recorded in *Trichoderma asperellum*-TaS1 and *Trichoderma koningii* respectively. Maximum number of leaves were recorded by *Trichoderma asperellum*-TaS1.Root parameters like root length, root volume, root weight were heighest in the *Trichoderma sps*-Ta DOR673and the lowest in control plants. Results showed that maximum LAI, CGR, SPAD were recorded for the *Trichoderma asperellum*-TaS1. Highest NAR, RGR, Photosynthetic values were found in the *Trichoderma sps*-Ta DOR673 followed by

Trichoderma asperellum-TaS1. Maximum SPAD values were recorded in *Trichoderma asperellum*-TaS1 throughout the crop growth period except at 15 DAS. At 15 DAS Maximum SPAD values were recorded in *Trichoderma sps*-Ta DOR 673.

Among treatments more number of days to 50% flowering and days to physiological maturity was recorded in *Trichoderma asperellum*-Tas1 and minimum was observed in control.

Highest total dry matter was found in the *Trichoderma asperellum*-TaS1and lowest in the untreated plants. Maximum diameter of head, head weight, no of filled seed per head, 100 seed wt, seed yield, harvest index were found in the *Trichoderma asperellum*-TaS1. Maximum nitrogen uptake was found in *Trichoderma sps*-Ta DOR673 and minimum in *Trichoderma hamatum.* Maximum phosphorus, potassium uptake was found in *Trichoderma asperellum*-TaS1. Seed treatment with *Trichoderma* resulted in increased plant height, leaf number, LAI, crop growth rate, relative growth rate, net assimilation rate. SCMR values, photosynthetic rate, root volume, root length, root weight, nutrient uptake.

Yield attributes diameter of head, head weight, number of filled seed per head, 100 seed weight and harvest index was increased in treated plants compared to control plants. Among the treatments *Trichoderma asperellum*-TaS1 and *Trichoderma sps*-Ta DOR673 recorded better values for morphological, physiological characters and yield attributes over other treatments and control plants.

CHAPTER I
INTRODUCTION

Sunflower (*Helianthus annuus*) is an important oilseed crop in India, popularly known as "Surajmukhi". It is grown in an area of 23.7 million ha in 70 countries worldwide, primarily as an oilseed. Sunflower accounts for about 14% of the world production of seed oils. It occupies fourth place among oilseed crops in terms of acerage and production. The average yield of sunflower in India is 517.2 kg/ha in 1998-99 and it has gone up to 692 kg/ha in 2011-12.

The need for increasing agricultural productivity and quality has led to an excessive use of chemical fertilizers, creating serious environmental pollution. The use of biofertilizers and biopesticides is an alternative for sustaining high production with low ecological impact. Different soil-borne bacteria and fungi are able to colonize plant roots and may have beneficial effects on the plant. Besides the classic mycorrhizal fungi and Rhizobium bacteria, other plant-growth-promoting rhizobacteria (PGPR) and fungi such as *Trichoderma* species can stimulate plant growth by suppressing plant diseases. These micro-organisms can form endophytic associations and interact with other microbes in the rhizosphere, thereby influencing disease protection, plant growth and yield.

Rhizosphere-competent fungi of the genus *Trichoderma* are widely used as biofertilizers and biopesticides in commercial formulations because of the multiple beneficial effects on plant growth and disease resistance. Recent trends in soil microbiology suggest that certain soil microbes have a positive effect on seedling growth and development.

Trichoderma spp. colonize plant roots and establish symbiotic relationships with a wide range of host plants. As a consequence, plant growth and performance is enhanced (Shoresh et al., 2010). Some *Trichoderma* strains can interact directly with roots, increasing plant growth potential, resistance to disease and tolerance to abiotic stresses. It is used in the enhanced nutrient uptake, enhanced solubilization of soil nutrients and root development, increased root hair formation, deeper rooting.

Trichoderma spp. are being employed widely in agriculture both for disease control and yield increases (Harman.,2006), even under axenic conditions (Yedidia *et al.*,2001). *Trichoderma* spp. have evolved multiple mechanisms that result in improvements in plant

resistance to diseases and plant growth and productivity (Harman *et al.,* 2004; Vinale *et al.,* 2008).

Possible explanations of this phenomenon include: control of minor population of pathogens leading to stronger root growth and nutrient uptake (Harman, 2000; Yedidia *et al.,* 2001), secretion of plant growth regulatory factors such as phytohormones (Muthukumar *et al.,* 2011) and release of soil nutrients and minerals by increased saprophytic activity of *Trichoderma* in the soil (Ousley *et al.,* 1993).

Trichoderma spp. recently was suggested as a PlantGrowth Promoting Fungi (PGPF) due to their ability to produce siderophores, phosphate-solubilizing enzymes, and phytohormones (Doni *et al*., 2013).

Trichoderma spp. are also highly rhizosphere component i.e. able to colonize on roots as they develop, thus promote plant growth (Mishra *et al.*,2014). They may also exert several other mechanism such as tolerance to stress through enhanced root and plant development. (Weeder *et al*.,2008)

Keeping this in view a research work is formulated to study the influence of various strains of *Trichoderma* on growth, development and yield of sunflower with the fallowing objectives.

OBJECTIVES:

1. To study the influence of *Trichoderma* on photosynthesis and dry matter partitioning in sunflower .
2. To study the effect of *Trichoderma* on yield and yield attributes of Sunflower.
3. Influence of *Trichoderma* on nitrogen (N), phosphorus (P), potassium (K) uptake
4. To identify best strain of *Trichoderma* for sunflower during *rabi* season

CHAPTER II

REVIEW OF LITERATURE

Trichoderma strains were tested for their effect on different growth and yield parameters in sunflower and the literature pertaining to *Trichodrma* strains and their performance are reviewed here under.

2.1 Morphological characters

2.2 Physiological parameters

2.3 Yield and yield components

2.4 Nutrient uptake

2.1 MORPHOLOGICAL PARAMETERS :

2.1.1 Plant height:

Kucuk (2014) reported that in wheat *Trichoderma harzianum* isolates T8,T15 have increased plant height. Nagaraju *et al*. (2012) found that the sunflower seed treatment with three rhizosphere fungal isolates PGPFYCM- 2, PGPFYCM-8 and PGPFYCM-14 of *Trichoderma harzianum* has resulted in increased plant height. The increase in plant height was due to increased nutrient uptake from the rhizosphere and increase in the internodal length of plants by *Trichoderma* strains.

Khair *et al*. (2011) conducted an experiment in the bean and found that *Trichoderma* species *T.hamatum* have shown highest increase of plant height (34%) followed by *T.harzianum* (26%) and T.album (23%).Similar increase in the shoot length with *Trichoderma* THR was reported in radish by Mukhopadhay and Pan (2012).

In an experiment conducted by Shamalie *et al.* (2011) on gotukola treated with combined application of *T.viridae*+compost had shown significant impact on plant growth which was attributed to increased number of roots, root length, leaf length and stalk length

Kumar *et al.*(2009) reported highest shoot length with dual inoculation of A.laevis+*T.viridae* in *Salvia officinalis.* Similar increase in *Pinus sylvestris var.mongolica* seedling with *Suillus lutes* and *Trichoderma virens* was reported by Yin *et al.* (2014)

The result of the experiment carried out by Harman *et al.* (2006) showed that the plant growth can be influenced through several mechanisms which include mycoparasitism, antibiosis, degradation of toxins, inactivation of pathogenic enzymatic pathways, resistance to pathogens, enhanced nutrient uptake, solubilization, sequestration of inorganic nutrients, and enhanced root hair development.

Increase in plant height with the application of *Trichoderma* species in rice was reported by Doni *et al.* (2014), in *Ocimum sanctum* by Padmavathi *et al.*(2013), in wine by Sandeep *et al.* (2013).

In an experiment carried out by Hohmann *et al* .(2011) in *Pinus radiata* results showed that *Trichoderma hamatum* LU592 has promoted the growth of shoots up to 16%.Similar increase in shoot length in tomato with *Trichoderma harzianum* and AMF was reported by Nzanza *et al.* (2011).

Badar and qureshi (2012) reported that maximum plant height was found when plants treated with combination of *Trichoderma hamatum* and host-specific *Rhizobium sp.*in Vigna mungo. Similar increase in plant height of BT cotton with triple inoculation of *Acaulospora laevis, Trichoderma viridae* and *Pseudomonas fluorescence* was reported by Badda *et al.* (2013)

Trichoderma harzianum treatment to cucumber and pepper seedlings has significantly increased the seedling height (Inbar *et al.*,1994). In chickpea Mishra *et al.* (2014) reported that the combined application of *T.harzianum+ T.viridae+ P.lilacinus* has increased the shoot length over the check.

2.1.2 Number of leaves:

Increase in number of leaves by the application of *T.harzianum* was reported in *Ocimum sanctum* plants by Padmavathi *et al.* (2013) and increase in the leaf number and tiller number in rice plants with *Trichoderma sps* SL7 was reported by Doni *et*

al.(2014) and combined inoculation of *T.harzianum* and *Psudomons flourescens* resulted in increasing the number of leaves in Vanilla plant (Sandeep *et al.*,2013)

Trujilllo *et al.* (2013) reported that inoculation of *Cucumis sativus L.* seedlings with *T.longibrachiatum* strain ICA-4 has resulted in the increased number of leaves compared to control plants.

Khair *et al* .(2011) reported that application of *Trichoderma* species in bean plants has resulted in increased number of leaves per plant .Azarmi *et al*.(2011) treated the tomato seed with *Trichoderma harzianum* isolate T969, T447. Results showed that increase in leaf number compared to control plants

2.1.3 Days to physiological maturity:

Nagaraju *et al*.(2012) has conducted a field trial in sunflower to study the effect of three rhizosphere fungal isolates viz PGPFYCM-2, PGPFYM-8, PGPFYCM-14 of *Trichoderma harzianum* .The results revealed that highly significant differences between the treatments in increasing days to maturity.

2.1.4 Root length:

Mishra *et al*.(2014) found that the chickpea seed treated with three fungal bioagents *Trichoderma harzianum, T.viridae* and *Paecilomyces* have accelerated root length. Maximum length of root was observed in plants treated with *Trichoderma harzianum.*

In an experiment conducted by Nzanza *et al*.(2011) in tomato (*Lycopersicum esculentum L.*) it was reported that *T.harzianum* and AMF treated plants have shown improvement shoot length ,root length.

Similar results were also reported by Badda *et al.* (2013) in BT cotton by the triple inoculation of A.laevis+ P.fluorescens+T.viridae.

Entesari *et al* .(2013) concluded that root length in soyabean was increased significantly by three fungal bio control agents including *Trichoderma harzianum* (T. AS 19-2, T. bp4, T. BS1-1), *T. virens* (T.As19-1, T.As17-4, T.As10-5) *T. atroviride* (T.As18-5, T.cs5-1, T.Cs2-1) and a bacteria; *Pseudomonas fluorescent* (utpf5). Similarly in an experiment conducted by Doni *et al*.(2014) in rice results revealed that

Trichoderma sp.SL2 treated plants showed the highest root length as compared to control.

Badar and Qureshi (2012) reported that *Vigna mungo* treated with combined inoculation of *Trichoderma hamatum* and host-specific *Rhizobium* species had shown significant increase in the length of roots. Harman *et al*. (2000) reported that *Trichoderma* helps in the control of minor population of pathogens leading to stronger root growth and nutrient uptake.

The results of an experiment conducted by Mukopadhay and Pan (2012) on radish revealed that highest root length was observed when seed is treated with *Trichoderma* strains THC,THR,TVO.

In a field experiment conducted by Mangala *et al*. (2010) on *Eclipta alba* with arbuscular mycorrhizal fungal species *Glomus mosseae* and *Acalospora laevis* in different combinations with *Trichoderma* found that the dual inoculation of *A.leavis* and and *Trichoderma viridae* has resulted in significant increase for the root length.

2.1.5 Root weight:

Rabeendran *et al* .(2000) reported that the cabbage plants treated with *Trichoderma longipile* 6sr4 and 3sr4 and *T.tomentosum* have shown greater root weight compared to the untreated plants.

Bae *et al*.(2009) conducted experiments on *Theobroma cacao* (cacao) by treating with *Trichoderma hamatum* isolate DIS 219b and found significant increase in the root dry weight. Similar results were also reported by Badda *et al*.(2013) in BT cotton with triple inoculation of *Acaulospora laevis*, *Trichoderma viride* and *Pseudomonas fluorescens* .

2.1.6 Root volume:

In an experiment conducted by Trujillo *et al*.(2013) in cucumber inoculation of seedlings with T. strain ICA-4 resulted in increase number of roots in 2^{nd},3^{rd} and 4^{th} order (256%, 237% and 222% respectively) as compared to control plants.

In an experiment conducted by Thankamani *et al*. (2005) in pepper maximum number of roots were observed when plants treated with combined application of *P. fluorescens* and *T.harzianum*. Similar results in bitterguard ,loofah and cucumber crops were also reported by Lo and Lin (2002).

2.2 Physiological parameters:

2.2.1 Total dry matter and dry matter partitioning:

In an experiment conducted by Mangala *et al*. (2010) on *Eclipta alba (L.)* it was observed that seedlings treated with combination of *Glomus mossae* and *Trichoderma viridae* had increased root and shoot fresh and dry weight as compared to control.

Hohmann *et al*. (2011) evaluated *Pinus radiata* to know the effect of two isolates of Trichoderma *T.hamatum lu*592 and *T.atriviride* lu 132. The result revealed that *Trichoderma hamatum* lu 592 has enhanced several plant growth parameters and increased the shoot and root dry weight.

Mukopadhyay and Pan (2012) reported that biopriming of radish with isolates of *Trichoderma* THC,THR,TVO has shown highest root and shoot weight compared to untreated plants.

2.2.2 Photosynthetic rate:

Vargas *et al*.(2009) reported that as a result of colonization of maize roots by *T.virens* photosynthetic rate was increased. John *et al*. (2010) reported that the enhanced root system in soyabean treated with the *Trichoderma* directly increased the nodulation and more biological nitrogen fixation which inturn has helped in increasing photosynthetic activity of plants. Similar increase in rate of photosynthesis was reported in rice and corn with *Trichoderma* species (Doni *et al*., 2014)

In a study conducted by Alexandru *et al* .(2013) in tomato treated with six strains of *Trichoderma* species has shown increase in the rate of Photosynthesis as compared to control plants.

2.2.3 Spad chlorophyll meter readings:

In an experiment conducted by Mukopadhyay and Pan (2012) results showed that the biopriming of radish with *Trichoderma* THC, THR, TVO has resulted in significant increase in chlorophyll.

Mangala *et al.* (2010) reported chlorophyll content increased significantly in seedlings treated with combination of *G.mossae* and *T.viridae* in *Eclipta alba* (L.). Similar results with *Trichoderma* were also reported in cucumber and pepper seedlings by Inbar *et al.*(1994).

Badda *et al.* (2013) reported that in BT cotton inoculation of *A.laevis+ P.flourescence* showed maximum increment in total chlorophyll content.

Similar increase in the chlorophyll content was also repored with *T.hamatum* in *Vigna mungo* by Badar and Qureshi (2012).

Lo and Lin (2002) reported that several strains of *Trichoderma* sps isolated from rhizosphere soil when treated on bitterguard and cucumber resulted in significant increase in the chlorophyll concentration.

In an experiment conducted by Entesari *et al.* (2013) in *Vigna mungo* treated with three fungal bio control agents including *Trichoderma harzianum* , *T. Virens, T. atroviride* and a bacteria; *Pseudomonas fluorescent* showed an increase in the chlorophyll content.

The results of the experiment conducted by Alexandru *et al.* (2013) on tomato reported that in the treated plants there was a significant differences in chlorophyll content .

2.2.4 Leaf area index:

Bharti *et al.*(2012) reported increased leaf area in tomato when treated with five isolates of *T.harzianum* viz.. T7, T26, T31, T35, T38. Similar increase in leaf area of radish was reported by Mukopadhyay and Pan (2012) when the seed was treated with different isolates of *Trichoderma.*

In a study conducted by Shamalie *et al* .(2011) on leafy vegetables showed that the combined application of *T.viridae*+ compost had significant impact on the plant growth which was contributed by increased leaf area.

Lo and Lin (2002) reported that in bittergaurd and cucumber application of several strains of *Trichoderma* spp have resulted in significant increase in leaf area. 50% increase in leaf area of cucumber and pepper seedlings with *Trichoderma harzianum* was reported by Inbar *et al*. (1994).

Rabeendran *et al*.(2000) reported that cabbage and lettuce plants treated with *Trichoderma longipile* 6sr4,3sr4-2 and Tomentosum 5sr2-2 had greater leaf area as compared to control. Similar results in tomato with *Trichoderma harzianum* was reported by Bharthi *et al*.(2012).

2.2.5 Crop growth rate:

Azarmi *et al*.(2011) reported that in tomato *Trichoderma* increased shoot and root fresh and dry weight. Badda *et al*.(2013) treated the BT cotton with triple inoculation of *Acaulospora laevis, Pseudomonas fluorescence* and *Trichoderma viridae* and the results revealed that increase in dry root and shoot weight. Doni *et al*. (2014) reported that in rice *Trichoderma* sp SL2 treated plants showed the greatest increase in root fresh weight.

2.2.6 Relative growth rate:

The results of the study conducted by Trujillo *et al*. (2013) on *Cucumis sativus l.,* showed that seedlings treated with *T.longibrachiatum* ICA-4 showed increase in the rate of relative growth rate (RGR) as compared to the untreated control. Similar increase in dry weight of root and shoot was reported by Windham *et al.*(1986) in tomato inoculated with *Trichoderma harzianum* and *Trichoderma koningi.*

Yin *et al*.(2014) reported that by the combined inoculation of *Suilus luteus* and *Trichoderma virens* in *Pinus sylvestris var.mongolica* fresh weight (54%),dry weight (50%) were increased in treated plants compared to the control plants.

Badda *et al*.(2013) has conducted an experiments in BT cotton and found that triple inoculation of *A.laevis+T.viridae+ P.flourescens* has shown maximum increment in fresh and dry root weight as compared to untreated plants. Similar

increase in shoot and root weight of tomato treated with *T.harzianum* was reported by Mouria *et al*.(2007)

2.3 Yield parameters:

2.3.1 Diameter of head:

Nagaraju *et al.*, (2012) reported that sunflower seed treated with three *Trichoderma harzianum* strains viz., PGPFYCM- 2, PGPFYCM-8 and PGPFYCM-14 have shown significant increase in the diameter of heads as compared to untreated plants.

2.3.2 100 Seed weight:

Nagaraju *et al* .(2012) has conducted an experiment in sunflower where in the seeds were treated with three isolates of *Trichoderma harzianum* PGPFYCM-2,PGPFYCM-8,PGPFYCM-14 and the results revealed that significant differences for 100 seed weight.

2.3.3 Seed yield:

Altomere *et al* .(1999) reported that promotion of growth and yield by T*richoderma* spp is due to increased root area which has helped the roots to explore larger volumes of soil and there by increased solubility of insoluble compounds as well as increased availability of micronutrients to the plants.

Bal and Altinus (2006) reported that *Trichoderma* sps were effective in promoting growth and yield of various crops. Increase in the yield of soyabean with *Trichoderma* was reported by John *et al* .(2010). Similar results in chickpea with *Trichoderma* treatment was reported by Mishra *et al*.(2014).

Application of *Trichoderma* spp in cucumber, bell pepper, straw berry yield was increased (Elad *et al*.,1979). In a study carried out by Yin *et al*.(2014) in *Pinus sylvestris var .mongolica* treated with *suillus luteus* and *Trichoderma virens* it was found that compared to the control pod activity was increased significantly in treatments.

2.4 Nutrient uptake:

2.4.1 Nitrogen uptake:

Medina *et al*. (2014) reported that inoculation with *T.harzianum* increased the nitrogen content in melon plants. Similar results by the inoculation of *Trichoderma* were also reported by Rudresh *et al.* (2005) in chick pea .

Increase in nitrogen uptake in Vanilla with combined inoculation of *Trichoderma harzianum* and *Pseudomonas fluorescence* was reported by Sandeep *et al*.(2013). Kadian *et al*.(2013) reported that with the triple inoculationof *F. Mosseae +A. Laevis +. Viride* has increased the nitrogen content in *Cyamopsis tetragonoloba(L.) taub*.

Trichoderma helps in the control of minor population of pathogens leading to stronger root growth and nutrient uptake (Harman *et al*.,2000).

In an experiment conducted by Entesari *et al.* (2013) on *Vigna mungo* treated with three fungal bio control agents including *Trichoderma harzianum, T. Virens, T. atroviride* and a bacteria; *Pseudomonas fluorescent* showed an increase in the nitrogen content. similar increase in nitrogen uptake in *Vigna mungo with T.hamatum* and rhizobium was reported by Badar and Qureshi (2012). Increase in the nitrogen content with *Trichoderma* treatment in bean plants was reported by Khair *et al.*(2011)

2.4.2 Phosphorus uptake:

Yedidia *et al* .(2001) reported that colonization of cucumber roots with *T.asperellum* has enhanced the availability of P and Fe to plants. *T.harzianeum* promotes plant growth by solubilising phosphate and micronutrient(Altomere *et al* .,1999). Similar solubulization of P and enhanced plant growth with *Trichoderma virens* PDR-28 was reported by Giridhar *et al*.(2014)

Azarmi *et al.* (2011) reported that in tomato soil application of *T.harzianum* T447 has resulted in increased phosphorus concentration in the root and shoot. Similar results were also reported by Carvajal *et al*.(2009) in bean.

Khair *et al*.(2011) have conducted experiments on bean and reported that with the application of *Trichoderma* sps the level of phosphorus was increased significantly compared to untreated plants. Where as Sandeep *et al*. (2013) in Vanilla reported that the dual inoculation of *Trichoderma harzianum* and *Pseudomonas fluorescens* has resulted in increased uptake of P as compared to untreated plants.

The results of the experiments conducted by Yin *et al*.(2014) on *Pinus sylvestrisvar.mongolica* seedlings treated with *Suillus luteus* and *Trichoderma virens* reported that phosphorus activity was more in treated plants as compared to control.

Badda *et al*. (2013) reported that triple inoculation of *A.laevis+ T.viridae + P.flourescens* in BT cotton showed maximum phosphorus activity. Badar and Qureshi (2012) found that in *Vigna mungo* with the application of *T.hamatum* and *Rhizobium* phosphorus concentration in leaves has increased.

2.4.3 Potassium uptake:

Khair *et al*.(2011) conducted an experiment in bean treated with four *Trichoderma* species, i.e. *Trichoderma album, Triechoderma hamatum, Trichoderma harzianum* and *Trichoderma viride*. Results revealed that significant increase in the level of potassium was observed in treated plants as compared to untreated plants.

Harman *et al*.(2004) reported that *T. harzianum* is capable of increasing the uptake of nutrients by secreting enzymes that solubilises the insoluble nutrients.

CHAPTER III
MATERIAL AND METHODS

The field experiment entitled "**Influence of *Trichoderma* on photosynthesis, drymatter production and nutrient uptake in sunflower**" was conducted during rabi 2014-15. The details of the materials used and methods followed in the investigation are presented in this chapter under appropriate heads.

3.1 Location of the Experimental site

The field experiment was conducted during *rabi* 2014-15 at student's farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad**.** The farm is geographically situated at an altitude of 542.6 m above mean sea level at 17 ^{0}19' N latitude and 78 ^{0}28' E longitude and falls under the Southern Telangana agro-climatic zone of Telangana.

3.2 WEATHER DATA DURING THE CROP GROWTH PERIOD

Weather data on rainfall ,maximum and minimum temperature, relative humidity , wind speed and, sunshine hours during crop growth period was recorded at the meteorological observatory of Agriculture Research Institute, Rajendranagar, Hyderabad and are presented in appendix-A and depicted in fig.3.2 a, 3.2 b, 3.2c, 3.2d.

The weekly mean maximum temperature during the crop growth period(01-10-2014 to 09-01-2015) ranged from 27.1 to 34.1^{0}C with an average of 29.95^{0}C. While weekly mean minimum temperature ranged from 6.2 to 21.9 ^{0}C with an average of 15.74^{0}C.

The mean morning relative humidity (RHI) during the crop growing season ranged from 67% to 89% with an average of 79%, the mean afternoon relative humidity (RHII) during the crop growth period varied from 24% to 68% with an average of 45.26%.

The weekly mean sunshine hours fluctuated between 3.4 to 8.8 hours with an average of 6.95 hours. The mean weekly pan evaporation during the cropping period ranged from 2.8 to 5.6 mm day^{-1} with an average of 4.2 mm day^{-1}.

During the crop growing season a total rain fall of 79.8 mm was received in 3 rainy days. The mean wind speed ranged from 1.2 to 3.9 Km h^{-1} with an average of 1.88 km h^{-1}

3.3 Soil characteristics of the Experimental site

Before commencement of the field experimentation, random soil samples were collected from 0 to 30 cm depth, shade dried and passed through 2 mm sieve to make a composite sample which was later analyzed for its physico-chemical properties and the results are presented in table1.

Table 3.1: Soil physico-chemical properties of experimental site.

S.No.	Soil character	Values	Method adopted
1.	pH	7.8	In 1:2.5 soil water suspension by glass electrode pH meter (Jackson, 1967).
2.	EC (dSm^{-1})	0.34	EC bridge (Jackson, 1967).
3.	Organic carbon (%)	0.45	Wet digestion method of Walkley and Black (1934).
4	Available nitrogen ($kg\ ha^{-1}$)	230.0	Alkaline permanganate method (Subbaiah and Asilja, 1956).
5	Available phosphorus ($kg\ ha^{-1}$)	23.42	Olsen's method (Olsen *et al.*1954).
6	Available potassium ($kg\ ha^{-1}$)	409.2	Neutral N NH_4 OAC as extractant (Jackson,1967).
7	Mechanical analysis		International pipette method (Piper, 1966).
	Coarse sand (%)	58.60	
	Fine sand (%)	5.40	
	Silt (%)	18.55	
	Clay (%)	17.45	
	Soil type	Sandy loam	

3.4 Experimental Details

"INFLUENCE OF TRICHODERMA ON PHOTOSYNTHESIS, DRY MATTER PARTITIONING AND NUTRIENT UPTAKE IN SUNFLOWER"

3.4.1 Design and Layout: The experiment was conducted during *rabi* 2014-15 at Students Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad.

Experimental details:

Crop	: Sunflower
Season	: *Rabi* 2014-2015
Treatments	: 10 (9 *Trichoderma* strains and one untreated control)
	T_{1-} Untreated control
	T_2 -*Trichoderma harzianum*- Th 4d
	T_3- *Trichoderma asperellum*-TaS1
	T_4 -*Trichoderma asperellum*-Tv5
	T_5 -*Trichoderma sps*-Ta DOR 673
	T_6-*Trichoderma* koningii
	T_7-*Trichoderma* asperellum- Ta DOR 7316
	T_8-*Trichoderma* virens
	T_9-*Trichoderma* asperellum-N_{13}
	T_{10}-*Trichoderma* hamatum
Genotypes	:NSFH-145 (SWATHI hybrid)
No. of Treatments	:10
Design	:RBD

Location of the field :Student farm, College of agriculture, Rajendranagar

Plot size :4.2 x 3.0 m

Spacing :60 x 30 cm

3.5 Agronomic Practices

Sunflower requires well prepared seed bed for better germination and growth. Hence the experimental area was well ploughed twice followed by harrowing. Plots of 4.2X3.0 m were prepared and irrigation channels (1m) were prepared.

3.5.1 Fertilizer requirements:

The recommended fertilizer dosage of 60 Kg N, 90 Kg P_2O_5 and 30 kg K_2O per hectare was applied. Fifty percent nitrogen and entire doses of phosphorous and potassium was applied at the time of sowing. The remaining 50% N was applied as top dressing in two equal splits at 30 and 45 days after sowing.

3.5.2 Sowing:

Sowing was done on 01-10-2014 with a spacing of 60cm between rows and 30cm between plants within the row. Two seeds per hill were sown and were thinned to one seedling per hill a week after emergence.

3.5.3 Weeding:

Manual weeding was done at 30 DAS to keep the crop weed free.

3.5.4 Irrigation:

The crop was irrigated at ten days interval during the crop growth period.

3.5.5 Plant protection measures:

The crop was protected from sucking pests by spraying monocrotophos twice @1.6 ml per L.

3.6 Harvesting:

After physiological maturity the plants were harvested manually. Later the heads were separated and threshed by beating on a threshing floor, cleaned and sundried to 10% moisture level and weight of seeds recorded.

3.7 Growth analysis:

3.7.1 Non destructive growth analysis: For non destructive analysis five plants in each plot were tagged and the following observations were taken at 15 interval

3.7.1.1 Plant height (cm):

Plant height was measured from base of the plant to the terminal bud of the plant.

3.7.1.2 Number of leaves per plant:

Total number of green leaves per plant were counted from tagged plants and averages were calculated.

3.7.1.3 Days to 50 % flowering:

It was recorded based on number of days taken for opening of flowers in 50% plants from the date of sowing.

3.7.1.4 Days to physiological maturity:

It was recorded as the number of days required for yellowing of the back of capitulum (symptom of maturity) in 50 percent of plants in a plot from the date of sowing.

3.7.1.5 Root length:

For root parameters the plants were grown in polythene bags of about 90 mm thickness. They were raised up to 45 days. After that the plant was pulled carefully from the polythene bag and the roots were washed with water without disturbing its primary and lateral roots, then the root length was measured using a standard scale from the ground level to the tip of the root.

3.7.1.6 Root volume:

After taking the root length, root volume was measured by water displacement method by dipping the properly washed roots in a 1000 ml measuring cylinder containing water up to a certain point. Root volume was determined by displaced water (in ml) in the cylinder after root dipping. Mean of 3 values was obtained and expressed as root volume in ml pl^{-1}.

3.7.1.7 Root weight:

Root weight was recorded by drying the plant roots at 80^0C in hot air oven for one week .

3.7.1.8 Photosynthetic Rate (μ moles CO_2 $m^{-2}s^{-1}$):

The photosynthetic rate was measured by using Infra Red Gas Analyser (Model-TPS-1) from leaves that had expanded recently. The net exchange of CO_2 between a leaf and the atmosphere is measured by enclosing the leaf in closed chamber and monitoring the rate at which the CO_2 concentration in chamber changes over a fairly short time interval. Photosynthetic rate was expressed in μ moles CO_2 $m^{-2}s^{-1}$.

3.7.1.9 SPAD Chlorophyll Meter Readings (SCMR):

The SPAD-502 (soil plant analytical development) meter was used for measuring the relative chlorophyll content of leaves. The SCMR values were measured from recent fully expanded leaves at three points on each leaf (upper, middle and lower part). Average of these three readings was considered as SPAD reading of the leaf. This meter enables to obtain instant readings without destroying the plant tissue.

3.7.2 Destructive growth analysis:

Five adjacent plants from each plot were uprooted carefully from the third row at 15 days interval and were brought to the laboratory and separated in to the following components viz.., leaves, stems, roots and heads after measuring leaf area they were subjected to hot air oven at 80^0C for one week and dry weights were recorded.

Growth Parameter

The data got from the destructive sampling were utilized for calculating the Growth parameters by following the formulae given by Watson (1952) and Radford(1967).

3.7.2.1 Leaf Area Index:

Leaf area was measured by using LI-3100 leaf area meter (LICOR-Lincon, Nebraska, USA). From the leaf area, LAI was calculated. LAI was calculated by using the following formula.

$$LAI = \frac{\text{Leaf Area}}{\text{Ground Area}}$$

3.7.2.2 Crop Growth Rate (g m^{-2} d^{-1}): The data collected from the destructive sampling were utilized for calculating CGR, RGR, NAR

$CGR = (W_2-W_1) /(t_2-t_1) \times (1/P)$

Where W_1 and W_2 are total dry weight of plant at times t_1 and t_2 and P is the land area.

3.7.2.3Net assimilation rate (mg $cm^{-2}day^{-1}$)

NAR= **{(**W_2-W_1)/(t_2-t_1)}{(Log_eA_2-Log_eA_1)/(A_2-A_1)}

Where W_1 and W_2 are total plant dry weights at times t_1 and t_2 , Log_eA_1 and Log_eA_2 are the natural logs of leaf area A_1 and A_2 at times t_1 and t_2.

3.7.2.4 Relative growth rate (g $g^{-1}d^{-1}$)

RGR= (Log_eW_2-Log_eW_1) / (t_2-t_1)

Where Log_eW_1 and log_eW_2 are the natural log values of total dry weights at time t_1 and t_2

3.7.2.5 Dry matter and dry matter partitioning:

Total dry matter partitioning is an index of productive capacity of plant, hence 5 plants were uprooted periodically from each plot for calculating the drymatter partitioning. The leaves ,stems and flower head/capitulum (at flowering and harvest) were separated kept in labelled brown paper bag and were partially shade dried. Then they were subjected to 80^0C temperature in a hot air oven till constant weight was obtained. After complete drying ,drymatter was expressed as g $plant^{-1}$

3.8 Yield and Yield Attributes

3.8.1 Diameter of head (cm):

The diameter of the mature head at its maximum width was measured from five heads in each treatment averaged and expressed in centimeters.

3.8.2 Head weight (g):

Head weight (g) of five sampled plants from each treatment was recorded and averaged to get single capitulum weight.

3.8.3 Number of filled seed per head :

Total number of filled seeds were counted in five heads from each treatment and average number of seeds per head was calculated.

3.8.4 100 seed weight (g):

Test weight (hundred seed weight) was determined by counting and weighing 100 seeds from each treatment and expressed in grams.

3.8.5 Seed yield (g/plant):

Seed yield per plant was determined after threshing the seeds and allowing it to dry up to10% moisture content. Weight of total seeds of the five heads is measured in each treatment, averaged and expressed in grams (g) per plant.

3.8.6 Harvest index:

The relationship of economic yield to the biological yield was estimated by deviding the economic yield by the biological yield and expressed in percentage as harvest index.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.9 PLANT CHEMICAL ANALYSIS

Plant **s**amples collected for recording dry matter production from 15 DAS to 90 days after sowing were dried, powdered and utilized for chemical analysis.

3.9.1 Nitrogen uptake

For estimating nitrogen in plant sample, 0.1 g of powdered plant sample was taken for which conc. H_2SO_4 was added. Later it was heated on flame by adding H_2O_2 (hydrogen peroxide) drop wise till it became colourless. The extract obtained was used to estimate nitrogen concentration in plant samples by using Kjelplus. The concentration was calculated in percent and further expressed in g plant^{-1} using following formula.

$$\text{N uptake (g plant}^{-1}) = \frac{\text{N content (\%) x Dry matter production (g plant}^{-1})}{100}$$

Wet digestion for P and K:

Diacid digestion was carried out using 9:4 mixture of HNO_3 and $HClO_4$. One gram of pounded plant material was taken into 100 ml volumetric flask and 10 ml of diacid mixture was added to this flask and mixed by swirling. The flask was placed on low heat hot plate in a digestion chamber. Later the contents of flask were heated at high temperature until the production of red NO_2 fumes ceased.

The contents were further evaporated until the volume was reduced to 3 to 5 ml but not to dryness. The completion of digestion was confirmed when the liquid became colourless. After cooling the flask, 20 ml of glass distilled water was added. The extract was finally made up to 100 ml with double distilled water, filtered and suitable aliquots were used for estimation of the P and K.

3.9.2 Phosphorus uptake

The phosphorus concentration in plant samples was determined by Vanado molybdo phosphoric yellow colour method (Piper, 1966). The intensity of the yellow colour was read using spectrophotometer (Model UV 5704SS). The concentration is calculated in per cent and further expressed in g plant^{-1} using following formula.

$$\text{P uptake (g plant}^{-1}\text{)} = \frac{\text{P content (\%) x Dry matter production (g plant}^{-1}\text{)}}{100}$$

3.9.3 Potassium uptake

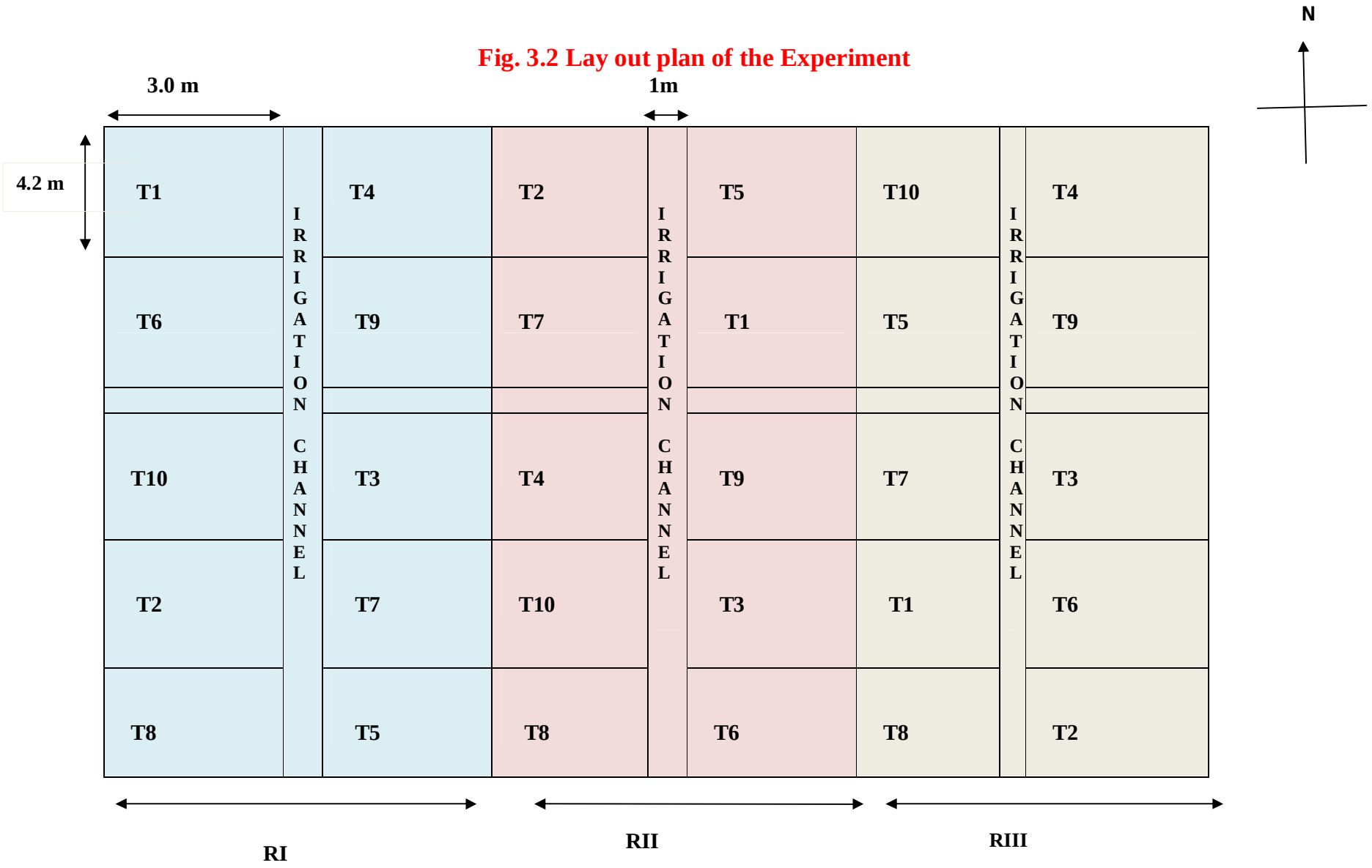
The potassium concentration in plant samples was estimated by using flame photometer Model Elico CL 361 (Piper, 1966). The concentration is calculated in per cent and further expressed in g plant^{-1} using following formula.

$$\text{K uptake (g plant}^{-1}\text{)} = \frac{\text{K content (\%) x Dry matter production (g plant}^{-1}\text{)}}{100}$$

3.9 Statistical analysis:

The data on the observations made were analyzed statistically by applying the technique of analysis of varience for randomized block design and significance was tested by F-test (Fisher ,1948). Critical difference for examining significance was calculated at 5 percent level of probability.

Fig. 3.2 Lay out plan of the Experiment



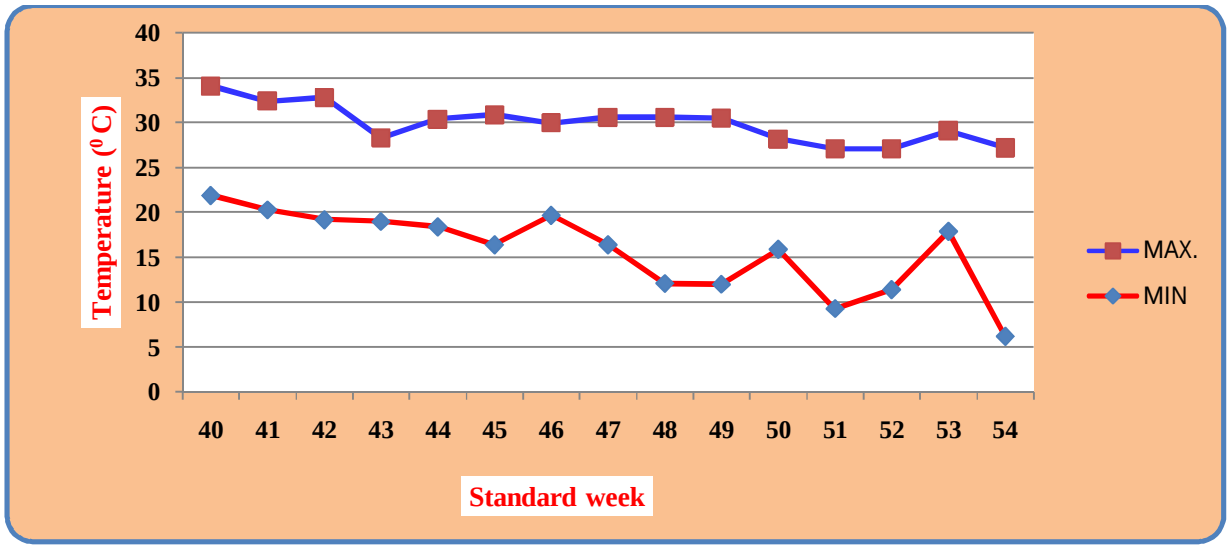


Fig: 3.2a. Weekly mean temperature during crop growth period of sunflower during *rabi* (Oct-Jan)

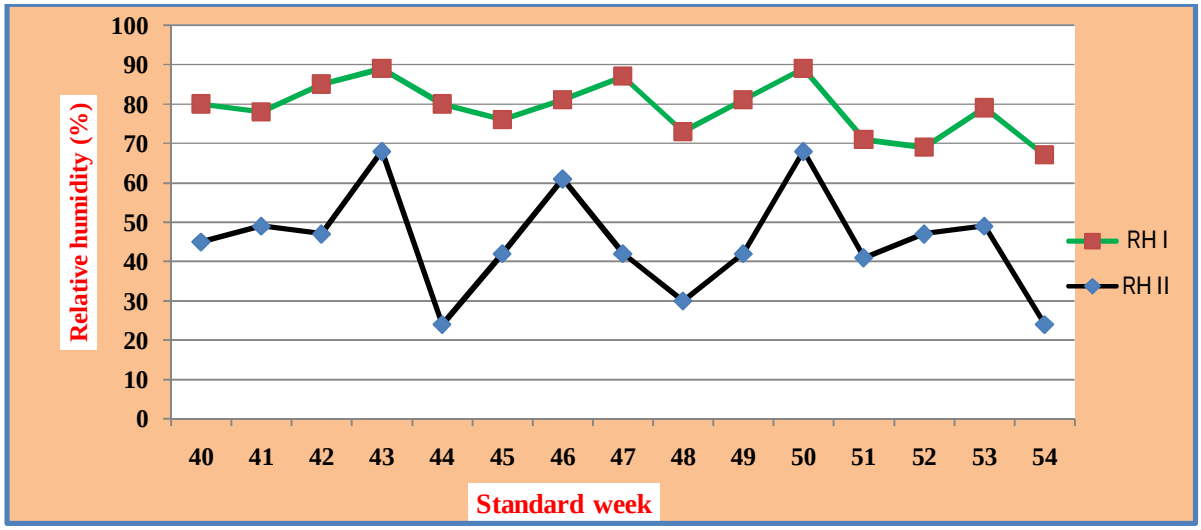


Fig. 3.2b. weekly mean relative humidity during crop growth period of sunflower during *rabi* (Oct-Jan)

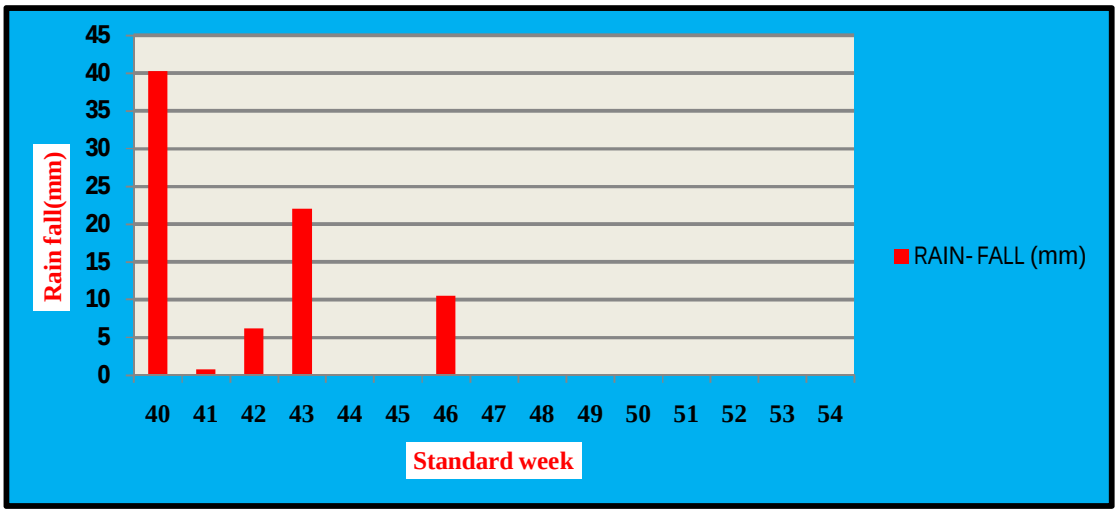


Fig. 3.2c. weekly rain fall during crop growth period of sunflower during *rabi* (Oct-Jan)

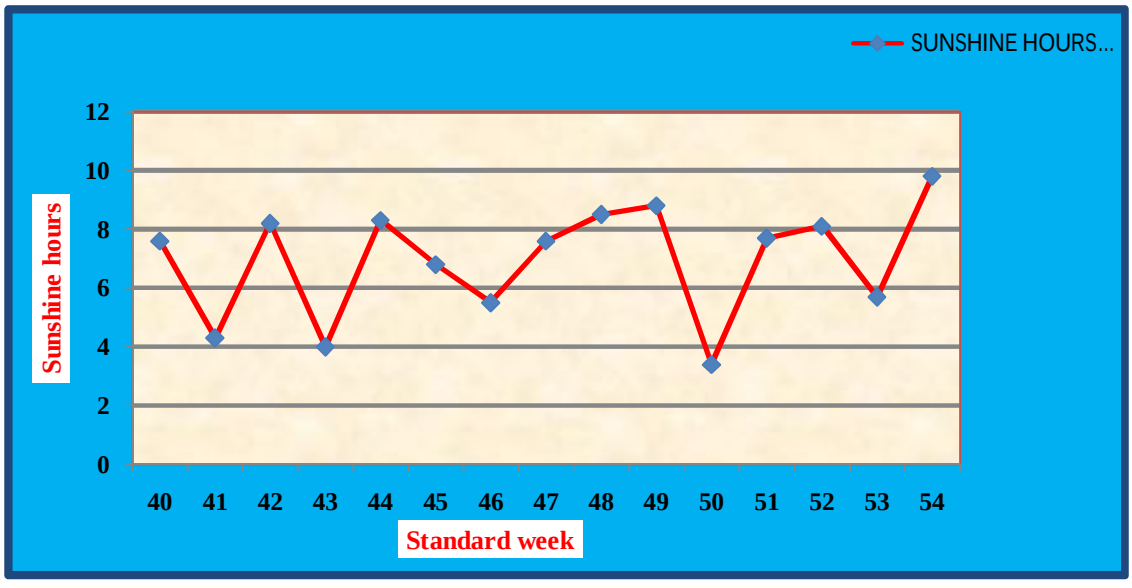


Fig.3.2 d weekly sunshine hours during crop growth period of sunflower during *rabi* (Oct-Jan)

CHAPTER IV
RESULTS AND DISCUSSION

The study was carried out during *Rabi* 2014-2015 at student's farm, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad. The data collected were analyzed, presented and the trends of values obtained are discussed in this chapter under different headings.

4.1 Morphological parameters:

4.1.1 Plant height

Data on Effect of *Trichoderma* on plant height in sunflower is presented in table 4.1.1and depicted in figure 4.1.1. The data on plant height shows that there was significant difference for the plant height among the treatments throughout the growth stages. Growth in terms of plant height was increased rapidly up to 75 DAS in all the genotypes . Maximum plant height was recorded in *Trichoderma asperellum* –TaS1(132.6 cm) followed by *Trichoderma* sps.Ta DOR 673(130.8 cm) and minimum plant height was recorded in *Trichoderma koningii*.(105.8 cm). Plant height was increased due to the increase in internodal length. *Trichoderma* strains helps in increasing the penetration of root and increasing the uptake of nutrients there by helps in increasing the number of internodes.

Different *Trichoderma* strains showed different responses to crops. Increase plant height by the inoculation of *Trichoderma harzianum* was also reported by Kucuk in wheat (2014) and Mukopadhyay and Pan in radish (2012).

4.1.2 Number of leaves

The data on number of leaves was presented in table 4.1.2 and depicted in figure 4.1.2. The number of leaves per plant was significantly different among the treatments .Gradual increase was found for number of leaves up to 75 DAS there after declined up to 90 days. The size of photosynthetic surface in terms of number of leaves per plant was found significantly different in all the treatments. *Tichoderma* supplies more amount of nutrients to the plants and helps in the increasing the number of leaves.

The decrease in leaf number towards maturity can be attributed to senescence of older leaves. Maximum number of leaves was recorded in *Trichoderma asperellum* –TaS1 at 15,45,60,75,90 DAS except 30 DAS. At 30 DAS highest number of leaves was found in *Trichoderma koningii* and *Trichoderma hamatum.* At harvest stage lowest number of leaves

was in untreated plants .similar results for number of leaves were also reported by the Khair *et al*.(2011) in bean plants.

4.1.3 Days to 50% flowering

The data on days to 50% flowering was presented in table 4.1.3 and depicted in figure 4.1.3.The results revealed that there was a significant difference for days to 50% flowering. The highest number of days taken for 50% flowering was recorded in T3-*Trichoderma asperellum*-TaS1(64) followed by T5-*Trichoderma* sps-Ta DOR 673(62).

The increase in the time taken for days to 50% flowering was due to sufficient availability of nutrients.

4.1.4 Days to physiological maturity

The data on days to physiological maturity was presented in table 4.1.3 and depicted in figure 4.1.4.There was a significant difference for days to maturity. *Trichoderma asperellum* –TaS1 took maximum no of days to reach the maturity (94 days) where as minimum days to reach maturity was observed in control plants (88). Similar results were also reported by Nagaraju *et al.* (2012) .

4.1.5 Root length

Root length as influenced by different *Trichoderma* strains was presented in table 4.1.4 and depicted in figure 4.1.5.There was a significant variation for root length among the treatments. Maximum root length was observed in *Trichoderma* sps –Ta DOR 673(38cm) and fallowed by T3-Trichoderma asperellum-TaS1(36 cm). Minimum root length was observed in untreated plants and plants treated with *Trchoderma harzianum*-Th4d (26 cm). The result for the root length was in agreement with the results of Khan *et al*. (2014). *Trichoderma* increases the root length and no of lateral roots.

Trichoderma increases soil pulverisation, number of lateral roots there by increases the extension of roots in to deeper layers of soil and increase in root length.

4.1.6 Root volume

Root volume showed significant variation among the treatments. Root volume as influenced by different *Trichoderma* species was presented in table 4.1.4 and depicted in figure 4.1.6. Among the strains studied highest root volume of 95 cm was recorded in *Trichoderma* sps –Ta DOR 673 followed by *Trichoderma asperellum* –TaS1(80 cm). Where as lowest root volume of 30 cm was observed in *Trichoderma asperellum*-N13.The increase in root volume can be attributed to more no of secondary and tertiary roots. Present study confirm the views of Lo and Lin (2002), Trujillo *et al*.(2013) and Thankamani *et al*. (2005)

that the *Trichoderma* strains increase the number of lateral roots. Root volume and root weight determines the ability of a plant to exploit the resources such as nutrient supply, moisture etc.

Trichoderma strains are always associated with plant roots and root ecosystems and as plant symbiont opportunistic avirulent organisms, able to colonize plant roots by mechanisms similar to those of mycorrhizal fungi and to produce compounds that stimulate growth and plant defense mechanisms (Harman *et al.*, 2004).

Chacon *et al.* (2007) stated that *Trichoderma harzianum* is able to promote tomato plant growth by colonizing the roots, increasing the foliar area and secondary roots, as well as changing the rootsystem architecture under sterile condition.

4.1.7 Root weight

Root weight as influenced by different *Trichoderma* species was presented in table 4.1.41 and depicted in figure 4.1.7. Data on Root dry weight has shown significant differences among the treatments. Maximum root dry weight of 10.8 gm was observed in *Trichoderma* sps –Ta DOR 673 followed by 9.83 gm in *Trichoderma asperellum* – TaS1.Minimum root weight was observed in control treatment.

Sunflower plants with better developed roots, particularly with adventitious root morphology such as higher root weight with greater root volume together with increased root length enable nutrient acquisition from deeper soil depth hence increase in yield.

4.2 PHYSIOLOGICAL PARAMETERS:

4.2.1 Total dry matter and dry matter partitioning

The data on total dry matter was presented in table 4.2.7 and depicted in figure 4.1.8 and data on total dry matter partitioning was presented in table 4.2.8 and depicted in figure 4.2.8. There was a significant differences among the treatments for total dry matter production and it has increased gradually up to maturity. Highest dry matter was recorded in *Trichoderma asperellum* –TaS1(124.5 g pl^{-1}) followed by *Trichoderma sps* –Ta DOR 673with (120 g pl^{-1}) at 90 DAS. Lowest dry matter was observed in control plants (109.2 g pl^{-1})

The increase in the total dry matter due to *Trichoderma* treatment can be attributed to the cumulative effect of increased leaf area index, SCMR values, increased nutrient uptake and increased rate of photosynthesis.

A perusal of the data on drymatter partitioning reveals that up to 30 DAS among the component parts leaves have received more photosynthates than the stems. Highest leaf dry matter values were observed in *Trichoderma asperellum*-TaS1 and *Trichoderma* sps-Ta DOR673. From 45 DAS to 75 DAS among the component parts leaves, stems and head highest dry matter partitioning has occurred in to stems followed by heads. Highest values were observed in *Trichoderma* asperellum-TaS1(52.58 g) followed by *Trichoderma* sps.Ta DOR 673(51.56 g). At 90 DAS among the component parts maximum dry matter partitioning has occurred in to sunflower heads followed by stems and leaves.

Highest dry matter partitioning toward head can be attributed to preferential translocation of photosynthates to head under the influence of *Trichoderma* treatment. Lowest partitioning in leaves at this stage is due to senescence of leaves where the nutrients and organic constituents of the leaves are remobilised to head. Similar results were also reported by Hohmann *et al.*(2011) and Mukopadhyay and Pan (2012).

4.2.2 Photosynthetic rate (µ moles CO_2 $m^{-2}s^{-1}$):

The data on photosynthetic rate is presented in table 4.2.3 and depicted in figure 4.2.3. The photosynthetic rate increased irrespective of treatments up to 75 DAS and decreased later. The data revealed significant variation in photosynthetic rate among treatments at 30, 45,60,75,90 DAS except at 15 DAS.

Trichoderma treatments showed significantly superior photosynthetic rates over control plants. Significant difference for photosynthetic rate was observed among the treatments at 45,60,75 and 90 DAS. *Trichoderma sps*-Ta DOR 673(24 µ moles CO_2 m^{-2} s^{-1}) followed by *Trichoderma asperellum*-TaS1(22 µ moles CO_2 m^{-2} s^{-1}) recorded highest photosynthetic rate at 75DAS.

Trichoderma helps in the development of better root system with production of some organic acids in the rhizosphere such as gluconic, citric and/or fumaric acids which decrease soil pH, lead to increased solubility of the insoluble compound and an availability of micronutrient, as well as an increase in plant nutrient uptake. Improvement of plant nutrient uptake and its transport from root to aerial parts, together with the produced plant stimulators, might result in higher photosynthetic rates. (Azarmi *et al.*,2011)

The photosynthetic rate was increasing due to the increase in leaf area of plants, better root development and root penetration in to soil might have helped in increased nutrient

uptake and increased chlorophyll content as observed in SCMR values. These results are in agreement with Vargas *et al.*(2009), John *et al.*(2010).

4.2.3 SPAD chlorophyll meter readings (SCMR):

The data on SPAD chlorophyll meter readings was presented in table 4.2.4 and depicted in figure 4.2.4. Significant difference was observed for SPAD values throughout growth period among the treatments. No specific trend was observed for SPAD values throughout the crop growth period. But at maturity SCMR values were decreased due to the decrease in chlorophyll content and translocation of photosynthates in to the seed.

Maximum SPAD values were recorded in *Trichoderma asperellum*-TaS1 throughout the crop growth period except at 15 DAS. At 15 DAS Maximum SPAD values were recorded in *Trichoderma sps*-Ta DOR 673. Present study conform the views of Entesari *et al* .(2013), Badda *et al.*(2013), Lo and Lin (2002).

4.2.4 Leaf Area Index (LAI):

The data pertaining to leaf area index as affected by *Trichoderma* treatments is given in table 4.2.5 and depicted in figure 4.2.5. Leaf area index was significantly affected by *Trichoderma* treatments. The data pertaining to leaf area index indicated significant increase in total leaf area in treatments compared with control. There was significant difference between control and treatments in leaf area index at 45, 60,75 and 90 DAS. Leaf area was increasing gradually up to 60 DAS after that decreases up to maturity.

Highest LAI was recorded in *Trichoderma asperellum*-TaS1(7.6) followed *Trichoderma sps*-Ta DOR 673(7.4) at 60 DAS. Minimum LAI of 6.1 was observed in control treatment at 60 DAS . Leaf area index was increasing due to the increase in number of leaves per plant under the influence of sufficient nutrient uptake in treated plants as compared to control. Similar results were obtained in tomato by Bharti *et al.*(2012), Lo and Lin *et al.*(2002).

4.2.5 Crop growth rate (g $m^{-2}day^{-1}$):

The data pertaining to CGR as influenced by *Trichoderma* is given in table 4.2.6 and depicted in figure 4.2.6. The crop growth rate values differed significantly among the treatments at 15-30, 30-45, 45-60,60-75 and 75-90 DAS. CGR values increased up to 40-60 DAS there after decreased gradually. Highest crop growth rate was recorded in *Trichoderma asperellum*-TaS1(17.50 g $m^{-2}day^{-1}$) followed by *Trichoderma sps*-Ta DOR 673(16.46 g m^{-}

$^{2}day^{-1}$) at 45-60 DAS. Lowest CGR value was recorded in control plants (13.80 g $m^{-2}day^{1}$) at 45-60 DAS.

In the present study the increase in crop growth rate can be attributed to cumulative effect of high leaf area index values, light interception and increase in rate of photosynthesis and dry matter production. After reaching the maximum CGR it decreases till maturity due to ageing of leaves and leaf shedding. Maximum crop growth rate was observed at 45-60 DAS. The present findings are in agreement with results of Azarmi *et al.*(2011) in tomato.

4.2.6 Net assimilation rate :

Net assimilation rate values are presented in table 4.2.7 and depicted in figure 4.2.7. The results revealed significant differences for net assimilation rate at all the stages of crop growth period. Net assimilation rate has increased gradually from 15-30 DAS to 45-60 DAS and later declined.

Highest NAR value was recorded in *Trichoderma sps*-Ta DOR 673(0.905 mg $cm^{-2}d^{-1}$) followed by *Trichoderma asperellum*-TaS1(0.850 mg $cm^{-2}d^{-1}$) at 45-60 DAS. Whereas lowest value were recorded by *Trichoderma koningii* (0.723 mg $cm^{-2}d^{-1}$) followed by control plants (0.731 mg $cm^{-2}d^{-1}$). The increase in NAR is due to increase in the LAI, photosynthetic rate per unit leaf area which in turn have increased the dry matter produced per unit leaf area per unit time.

4.2.7 Relative growth rate:

The data on relative growth rate was presented in table 4.2.8 and depicted in figure 4.2.8.There were significant differences for relative growth rate among the treatments throughout the crop growth period except at 75-90 DAS. Maximum relative growth rate was recorded in all treatments and control plants at 15-30 DAS. In general the RGR values have gradually reduced from 15-30 DAS to 75-90DAS.

The highest RGR values were recorded in *Trichoderma sps*-Ta DOR 673(0.168 g $g^{-1}d^{-1}$) followed by *Trichoderma asperellum*-TaS1(0.157 g $g^{-1}d^{-1}$) at 15-30 DAS. And lowest RGR values of 0.133 g $g^{-1}d^{-1}$ were recorded in *Trichoderma hamatum* and control plants. The reason for this decrease in RGR values with the age of plant was due to senescence of leaves and decrease in metabolic activities particularly photosynthetic rate. These findings are

in agreement with the findings of Windham *et al*.(1986), Yin *et al*.(2014), Mouria *et al*.(2007).

4.3 Yield and Yield Components:

4.3.1 Diameter of head

Significant variation in head diameter was exhibited between control and treated plants. Data on diameter of head was presented in table 4.3.1 and depicted in figure4.3.1. Maximum head diameter of 17.7 cm was recorded in *Trichoderma asperellum* –TaS1 followed by *Trichoderma* sps –Ta DOR 673(17.6 cm) where as least was observed in T7-*Trichoderma asperellum*-TaDOR7316 (16.1 cm).

The increase in the diameter of head may be attributed to increase in leaf area index and increased photosynthetic activity leading to more translocation of photosynthates from source to sink at flower bud intiation stage. The results are in accordance with findings of Nagaraju *et al*.(2012) in sunflower crop with the application of *Trichoderma* strains.

4.3.2 Head weight

The data on head weight is presented in table 4.3.1 and depicted in figure 4.3.2. The data pertaining to head weight as effected by *Trichoderma* indicated that there was significant variation among the treatments. Among the treatments *Trichoderma asperellum* –TaS1showed higher head dry weight (83.89 g) followed by *Trichoderma asperellum*-N13 (82.16g). Lowest head weight was recorded by *Trichoderma hamatum*(71.83g). *Trichoderma* strains helps in increased translocation of assimilates for developing sinks there by increase percentage of filled grains leading to increase in capitulum diameter. The increase in number of filled seed causes increase in head diameter. This is further supported by findings of Wahid *et al*.(2007).

4.3.3 Number of filled seed per head

The data on number of filled seed per head is presented in table 4.3.1 and depicted in figure 4.3.3. Data indicated significant variation among different treatments for number of filled seed per head . *Trichoderma asperellum* –TaS1 (638) followed by *Trichoderma*

asperellum-N13(636) had more total number of seeds per capitulum over other treatments. Least number of filled seed per capitulum (467) was recorded in control.

Increase in number of filled seed per capitulum can be attributed to higher pollen fertility, increased fertilization, increase in effective leaf area, rate of photosynthesis and increased translocation assimilates in to head to increase the formation of seeds. Increase in number of filled seeds by *Trichoderma* treatment was also reported by Khair *et al*.(2011)

4.3.4 100 seed weight

Data on 100 seed weight is presented in table 4.3.2 and depicted in figure 4.3.5. The data on 100 seed weight indicated that the *Trichoderma* treatment has shown significant difference between treatments. Higher 100 seed weight was recorded in *Trichoderma asperellum* TaS1 (5.91) followed by *Trichoderma* sps –Ta DOR 673(5.65) where as lowest 100 seed wt of 4.62 g has recorded in control. Similar increase in 100 seed weight with *Trichoderma* was also reported by Nagaraju *et al* .(2012)

The increase in test seed weight due to *Trichoderma* may be attributed to increase in the nutrient uptake, rate of photosynthesis and preferential translocation of assimilates in to seeds.

4.3.5 Seed yield (g pl^{-1})

Data on seed yield is presented in table 4.3.2 and depicted in figure 4.3.4. The indicated that among treatments there was significant difference in seed yield per plant. *Trichoderma asperellum* –TaS1 recorded highest seed yield per plant (37.8g) followed by *Trichoderma* sps –Ta DOR 673 (36.0 g). Control plants recorded lowest seed yield per plant (28.3g).

The highest seed yield values in *Trichoderma* treatment can be attributed to the cumulative effect of the yield components viz., more head diameter, more no of filled seed per head, more 100 seed weight all these factors are in turn due to increased nutrient uptake by the roots, increased SCMR values, photosynthetic rate and translocation of more photosynthates in to seeds. Similar increase in the yields were also supported by Altomere *et al*.(1999), Bal and Altinus (2006), Mishra *et al*.(2014) and Elad *et al*.(1979).

4.3.6 Harvest index

Data on harvest index was presented in table 4.3.2 and depicted in figure 4.3.6. There was no significant differences among the treatments for harvest index. Highest harvest index value was observed in *Trichoderma asperellum* –TaS1(30.48 %) followed by *Trichoderma* sps –Ta DOR 673(30.0 %). Lowest HI was observed in untreated plants (27.43%). The increase in harvest index in *Trichoderma* treatments can be attributed to preferential translocation of current photosynthates and remobilized photosynthates in to the economic part i.e seed.

4.4 Nutrient uptake:

4.4.1 Nitrogen uptake: Data on nitrogen uptake was presented in table 4.4.1 and depicted in figure 4.4.1. There was significant differences among the treatments for nitrogen uptake. In general nitrogen uptake has increased up 90 DAS.

Highest nitrogen uptake at 90 DAS was observed in Trichoderma sps-Ta DOR 673(182 kg ha^{-1}) followed by 176 kg ha^{-1} in *Trichoderma asperellum* –TaS1 and *Trichoderma asperellum*-TaDOR7316 where as minimum was observed in *Trichoderma hamatum* (152 kg ha^{-1}) . Increase in nitrogen uptake is due to increase in root penetration , number of lateral roots and increased uptake of nutrients there by increased dry matter production. Similar results were also reported by Medina *et al*.(2014) ,Sandeep *et al*.(2013),Kadian *et al*.(2013).

4.4.2 Phosphorus uptake:

Phosphorus uptake as influenced by *Trichoderma sps* was presented in table 4.4.2 and depicted in figure 4.4.2. There was a significant difference among the treatments for phosphorus uptake. It was increased up to 60 DAS there after decreases gradually up to maturity. Highest phosphorus uptake was observed in *Trichoderma asperellum* –TaS1(6.50 kg ha^{-1}) followed by *Trichoderma sps*-Ta DOR 673 (6.33 kg ha^{-1}) and minimum (5.06 kg ha^{1}) was observed in untreated plants at 75 DAS. Similar results were also reported by Yedidia *et al* .(2001) Altomere *et al* .(1999) Azarmi *et al* (2011), carvajal *et al*. (2009), Khair *et al*.(2011), Sandeep *et al*.(2013) ,Giridhar *et al*.(2014).

4.4.3 Potassium uptake

Data on potassium uptake was presented in table 4.4.3 and depicted in figure4.4.3 There was a significant difference among the treatments for potassium uptake. It was increased up to maturity. Highest potassium uptake was observed in *Trichoderma asperellum* –TaS1 (43 kg ha^{-1}) followed by *Trichoderma sps*-Ta DOR 673(39 kg ha^{-1}) and minimum of 29 kg ha^{-1} observed in *Trichoderma hamatum* followed by controlled plants (30 kg ha^{-1}) Similar results were also reported by Benitez *et al.* (2004) , Khair *et al.* (2011).

Azarmi *et al* (2011) stated that *Trichoderma* helps in the development of better root system with production of some organic acids in the rhizosphere such as gluconic, citric and/or fumaric acids which decrease soil pH, lead to increased solubility of the insoluble compound and an availability of micronutrient, as well as an increase in plant nutrient uptake.

Table 4.1.1: Plant height (cm) of sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T1-Untreated control	13.2	18.8	44.3	84.1	108.2	120.2
T2-*Trichoderma harzianum*-Th 4d	12.7	21.3	46.6	88.7	116.9	117.5
T3-*Trichoderma asperellum*-TaS1	18.1	23.6	65.0	104.5	132.2	132.6
T4-*Trichoderma asperellum*-Tv5	13.9	23.6	56.1	97.7	119.8	120.1
T5-*Trichoderma* sps-Ta DOR 673	17.4	26.4	61.1	102.3	130.4	130.8
T6-*Trichoderma koningii*	16.9	23.3	49.2	85.9	105.3	105.8
T7-*Trichoderma asperellum*-Ta DOR 7316	16.1	24.1	52.2	92.0	115.1	118.0
T8-*Trichoderma virens*	16.6	23.4	56.9	88.6	107.0	112.9
T9-*Trichoderma asperellum*-N13	17.1	24.9	56.5	92.9	105.7	105.9
T10-*Trichoderma hamatum*	16.5	28.0	56.6	94.5	119.4	122.6
SE(m)±	0.78	0.84	1.4	2.77	2.76	0.96
CD(p=0.05)	1.64	2.51	4.39	5.83	8.21	2.88

Table 4.1.2: Number of leaves plant $^{-1}$ in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T1-Untreated control	9	12	13	17	18	14
T2-*Trichoderma harzianum*-Th 4d	10	14	15	19	21	17
T3-*Trichoderma asperellum*-TaS1	12	14	20	23	25	20
T4-*Trichoderma asperellum*-Tv5	8	14	16	18	21	16
T5-*Trichoderma* sps-Ta DOR 673	11	13	17	22	23	18
T6-*Trichoderma koningii*	7	16	16	20	22	15
T7-*Trichoderma asperellum*-Ta DOR 7316	7	13	14	19	21	18
T8-*Trichoderma virens*	7	11	15	17	20	18
T9-*Trichoderma asperellum*-N13	8	14	16	19	22	17
T10-*Trichoderma hamatum*	10	16	17	21	20	15
SE(m)±	0.6	0.7	0.7	0.68	0.74	0.6
CD(p=0.05)	1.8	2.3	2.3	2.06	2.2	2.07

Table 4.1.3: Days to 50% flowering and days to physiological maturity in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	**Days to 50% flowering**	**Days to maturity**
T1-Untreated control	59	88
T2-*Trichoderma harzianum*-Th 4d	61	91
T3-*Trichoderma asperellum*-TaS1	64	94
T4-*Trichoderma asperellum*-Tv5	61	92
T5-*Trichoderma* sps-Ta DOR 673	62	93
T6-*Trichoderma koningii*	60	91
T7-*Trichoderma asperellum*-Ta DOR7316	59	92
T8-*Trichoderma virens*	60	90
T9-*Trichoderma asperellum*-N13	61	92
T10-*Trichoderma hamatum*	60	90
SE(m)±	0.81	1.18
CD(p=0.05)	2.42	3.53

Table 4.1.4: Root length (cm), Root volume (ml plant^{-1}), Root weight(g plant^{-1}) of sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	**Root length (cm)**	**Root volume (ml plant^{-1})**	**Root weight (g plant^{-1})**
T1-Untreated control	26	32	5.63
T2-*Trichoderma harzianum*-Th 4d	26	54	7.23
T3-*Trichoderma asperellum*-TaS1	36	80	9.83
T4-*Trichoderma asperellum*-Tv5	34	63	8.61
T5-*Trichoderma* sps-Ta DOR 673	38	95	10.08
T6-*Trichoderma koningii*	33	43	7.16
T7-*Trichoderma asperellum*-Ta DOR7316	34	71	8.58
T8-*Trichoderma virens*	32	39	7.94
T9-*Trichoderma asperellum*-N13	29	30	8.48
T10-*Trichoderma hamatum*	32	49	8.53
SE(m)±	0.83	1.79	0.50
CD(p=0.05)	4.51	5.36	10.61

4.2 Physiological parameters:

Table 4.2.1: Total dry matter(g plant^{-1}) in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	0.38	2.29	18.05	50.96	64.36	109.2
T2-*Trichoderma harzianum*-Th 4d	0.32	3.03	19.87	62.05	85.70	115.3
T3-*Trichoderma asperellum*-TaS1	0.57	1.07	27.38	74.25	104.54	124.5
T4-*Trichoderma asperellum*-Tv5	0.37	3.25	24.36	64.94	89.27	110.9
T5-*Trichoderma* sps-Ta DOR 673	0.48	3.54	26.54	71.45	98.36	120.4
T6-*Trichoderma koningii*	0.33	2.81	21.87	59.62	77.63	115.8
T7-*Trichoderma asperellum*-Ta DOR7316	0.34	2.78	22.90	60.90	85.27	118.1
T8-*Trichoderma* virens	0.39	2.76	28.87	64.54	81.82	111.0
T9-*Trichoderma asperellum*-N13	0.44	3.47	24.65	69.45	92.72	112.5
T10-*Trichoderma hamatum*	0.42	2.96	22.54	67.45	80.09	118.9
SE(m)±	0.44	0.14	1.27	1.72	1.40	1.14
CD(p=0.05)	0.13	0.42	3.82	5.31	4.20	3.41

4.2.2 Total dry matter partitioning in sunflower as influenced by *Trichoderma* strains during *rabi* season.

Treatments	15 DAS		30 DAS		45 DAS		60 DAS			75 DAS			90 DAS		
	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Head	Leaves	Stem	Head	Leaves	Stem	Head
T1-Untreated control	0.127	0.054	1.47	0.72	9.56	8.72	14.9	21.27	14.54	16.72	25.81	21.81	27.02	37.34	46.24
T2-*Trichoderma harzianum*-Th 4d	0.163	0.054	2.21	0.83	9.98	10.52	19.45	27.45	16.24	23.63	33.09	29.63	30.58	38.14	48.21
T3-*Trichoderma asperellum*-TaS1	0.342	0.231	2.92	1.18	13.01	14.36	21.81	30.90	22.18	30.90	40.54	36.54	32.72	39.27	52.58
T4-*Trichoderma asperellum*-Tv5	0.236	0.127	2.36	0.98	11.58	12.90	20.32	27.27	19.81	26.54	31.27	30.72	28.36	33.09	49.63
T5-*Trichoderma sps*-Ta DOR 673	0.272	0.163	2.58	0.96	12.83	13.27	20.47	29.09	19.63	29.45	37.81	30.90	30.90	38.18	51.56
T6-*Trichoderma koningii*	0.218	0.109	1.74	1.14	9.56	12.54	21.27	26.63	18.54	22.46	27.63	28.36	31.48	38.14	45.24
T7-*Trichoderma asperellum*TaDOR7316	0.218	0.090	1.32	1.12	10.41	12.54	17.63	24.21	19.09	22.72	33.63	28.90	30.58	38.12	50.0
T8-*Trichoderma virens*	0.309	0.072	1.92	0.78	10.05	10.72	18.54	26.72	19.45	17.63	30.90	33.45	29.43	33.29	49.21
T9-*Trichoderma asperellum*-N13	0.327	0.090	2.47	1.10	12.18	12.36	21.09	30.72	18.36	28.54	33.27	31.45	28.90	34.86	49.34
T10-*Trichoderma hamatum*	0.272	0.127	2.27	0.85	10.90	11.81	18.72	28.14	20.72	25.81	30.90	31.27	30.62	38.14	50.03
SE(m)±	0.013	0.056	0.039	0.044	0.194	0.409	0.501	1.136	0.54	1.50	1.58	0.78	1.551	1.42	0.90
CD	0.039	0.168	0.116	0.131	0.581	1.226	1.501	3.40	1.64	4.49	4.74	2.36	0.12	4.26	2.70

Table 4.2.3: Photosynthetic rate (µ moles CO_2 $m^{-2}s^{-1}$) of sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T1-Untreated control	7	11	13	13	15	13
T2-*Trichoderma harzianum*-Th 4d	12	16	19	19	19	19
T3-*Trichoderma asperellum*-TaS1	11	18	20	22	22	16
T4-*Trichoderma asperellum*-Tv5	9	12	15	18	18	14
T5-*Trichoderma* sps-Ta DOR 673	11	20	21	22	24	20
T6-*Trichoderma koningii*	9	13	17	19	20	15
T7-*Trichoderma asperellum*-Ta DOR7316	10	14	18	19	19	17
T8-*Trichoderma virens*	10	14	15	16	18	13
T9-*Trichoderma asperellum*-N13	10	13	13	15	16	14
T10-*Trichoderma hamatum*	8	15	18	18	20	14
SE(m)±	0.54	0.6	0.9	1.14	1.19	0.92
CD(p=0.05)	1.62	1.91	2.79	3.42	3.58	2.78

Table 4.2.4: SPAD chlorophyll meter readings (SCMR) of sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T1-Untreated control	29.38	30.34	29.77	37.19	33.33	28.15
T2-*Trichoderma harzianum*-Th 4d	24.89	21.18	31.21	35.85	34.77	28.37
T3-*Trichoderma asperellum*-TaS1	36.18	38.08	35.39	38.68	37.72	31.71
T4-*Trichoderma asperellum*-Tv5	35.17	36.35	33.14	35.86	34.18	25.57
T5-*Trichoderma s*ps-Ta DOR 673	39.24	35.89	34.67	37.24	37.49	27.91
T6-*Trichoderma koningii*	35.21	37.66	32.69	35.00	37.44	26.54
T7-*Trichoderma asperellum*-Ta DOR 7316	32.54	36.86	32.19	36.25	35.98	25.19
T8-*Trichoderma virens*	31.85	34.71	34.48	37.64	36.22	27.16
T9-*Trichoderma asperellum*-N13	31.54	35.61	34.44	36.00	36.54	23.81
T10-*Trichoderma hamatum*	30.54	34.13	33.33	38.19	37.01	27.20
SE(m)±	1.21	1.11	0.99	0.71	0.90	1.05
CD(p=0.05)	2.98	5.56	5.11	2.12	2.69	3.12

Table 4.2.5: Leaf area index (LAI) in sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T1-Untreated control	0.04	1.2	5.0	6.1	5.3	3.0
T2-*Trichoderma harzianum*-Th 4d	0.06	1.3	5.2	6.5	5.9	3.4
T3-*Trichoderma asperellum*-TaS1	0.08	2.0	6.9	7.6	6.6	4.5
T4-*Trichoderma asperellum*-Tv5	0.07	1.5	5.9	6.5	5.3	4.0
T5-*Trichoderma* sps-Ta DOR 673	0.08	1.8	6.1	7.4	6.3	4.1
T6-*Trichoderma koningii*	0.05	1.3	5.7	6.8	5.6	3.6
T7-*Trichoderma asperellum*-Ta DOR7316	0.03	1.3	5.2	6.5	5.7	4.0
T8-*Trichoderma* virens	0.06	1.4	5.6	6.8	6.0	3.8
T9-*Trichoderma asperellum*-N13	0.07	1.8	5.8	6.2	5.9	4.1
T10-*Trichoderma hamatum*	0.03	1.4	5.2	6.3	5.9	3.7
SE(m)±	0.010	0.153	0.06	0.08	0.22	0.17
CD(p=0.05)	0.030	0.458	0.20	0.22	0.668	0.057

Table 4.2.6: Crop growth rate (g $m^{-2}d^{-1}$) in sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T1-Untreated control	0.70	4.83	13.80	5.21	4.72
T2-*Trichoderma harzianum*-Th 4d	1.05	6.15	15.16	8.90	5.75
T3-*Trichoderma asperellum*-TaS1	1.21	8.60	17.50	11.79	8.88
T4-*Trichoderma asperellum*-Tv5	1.09	6.96	15.16	9.16	7.49
T5-*Trichoderma* sps-Ta DOR 673	1.25	8.53	16.46	10.13	8.46
T6-*Trichoderma koningii*	1.14	7.46	13.80	6.42	7.14
T7-*Trichoderma asperellum*-Ta DOR 7316	1.08	7.83	14.23	8.24	7.61
T8-*Trichoderma virens*	0.87	7.13	16.20	6.51	5.63
T9-*Trichoderma asperellum*-N13	1.15	7.61	16.43	8.56	7.07
T10-*Trichoderma hamatum*	1.12	7.29	16.26	7.83	5.80
SE(m)±	0.03	0.38	1.05	0.66	0.22
CD(p=0.05)	0.10	1.14	3.14	2.04	0.66

Table 4.2.7: Net assimilation rate (mg $cm^{-2}d^{-1}$) of sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T1-Untreated control	0.567	0.597	0.731	0.647	0.347
T2-*Trichoderma harzianum*-Th 4d	0.577	0.653	0.773	0.712	0.410
T3-*Trichoderma asperellum*-TaS1	0.610	0.716	0.850	0.776	0.423
T4-*Trichoderma asperellum*-Tv5	0.443	0.671	0.751	0.751	0.393
T5-*Trichoderma* sps-Ta DOR 673	0.680	0.782	0.905	0.834	0.583
T6-*Trichoderma koningii*	0.550	0.648	0.723	0.735	0.393
T7-*Trichoderma asperellum*-TaDOR7316	0.510	0.651	0.757	0.739	0.413
T8-*Trichoderma virens*	0.433	0.629	0.807	0.712	0.407
T9-*Trichoderma asperellum*-N13	0.570	0.690	0.843	0.764	0.413
T10-*Trichoderma hamatum*	0.467	0.657	0.773	0.767	0.320
SE(m)±	0.029	0.016	0.018	0.019	0.017
CD(p=0.05)	0.086	0.049	0.055	0.062	0.052

Table 4.2.8: Relative growth rate (g $g^{-1}d^{-1}$) of sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T1-Untreated control	0.133	0.129	0.053	0.022	0.012
T2-*Trichoderma harzianum*-Th 4d	0.146	0.130	0.062	0.025	0.013
T3-*Trichoderma asperellum*-TaS1	0.157	0.149	0.077	0.032	0.015
T4-*Trichoderma asperellum*-Tv5	0.136	0.142	0.066	0.025	0.016
T5-*Trichoderma* sps-Ta DOR 673	0.168	0.156	0.083	0.022	0.016
T6-*Trichoderma koningii*	0.147	0.147	0.064	0.026	0.014
T7-*Trichoderma asperellum*TaDOR7316	0.141	0.134	0.066	0.022	0.016
T8-*Trichoderma* virens	0.149	0.128	0.073	0.016	0.013
T9-*Trichoderma asperellum*-N13	0.152	0.142	0.065	0.021	0.016
T10-*Trichoderma hamatum*	0.133	0.121	0.071	0.019	0.012
SE(m)±	0.001	0.002	0.002	0.001	0.001
CD(p=0.05)	0.003	0.005	0.007	0.004	NS

4.3 Yield parameters:

Table 4.3.1: Diameter of head (cm), head weight(g), no of filled seed head^{-1} in sunflower as influenced by *Trichoderma* species during *Rabi* season

Treatments	Diameter of head (cm)	Head weight (g)	No of filled seed head
T1-Untreated control	16.6	74.41	467
T2-*Trichoderma harzianum*-Th 4d	16.6	73.78	536
T3-*Trichoderma asperellum*-TaS1	17.7	83.89	638
T4-*Trichoderma asperellum*-Tv5	16.5	74.69	541
T5-*Trichoderma* sps-Ta DOR 673	17.6	82.16	585
T6-*Trichoderma koningii*	16.3	75.61	594
T7-*Trichoderma asperellum*-TaDOR7316	16.1	72.57	557
T8-*Trichoderma virens*	17.3	76.67	566
T9-*Trichoderma asperellum*-N13	16.4	78.15	636
T10-*Trichoderma hamatum*	16.9	71.83	548
SE(m)±	0.14	2.052	2.33
CD(p=0.05)	0.44	4.652	6.98

Table 4.3.2: 100 seed weight(g), seed yield, harvest index (%) in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	100 Seed wt (g)	Seed yield (g plant^{-1})	Harvest index (%)
T1-Untreated control	4.62	29.9	27.43
T2-*Trichoderma harzianum*-Th 4d	5.39	32.8	28.52
T3-*Trichoderma asperellum*-TaS1	5.93	37.8	30.48
T4-*Trichoderma asperellum*-Tv5	5.44	32.9	29.90
T5-*Trichoderma* sps-Ta DOR 673	5.61	36.0	30.00
T6-*Trichoderma koningii*	4.70	34.0	29.56
T7-*Trichoderma asperellum*-Ta DOR 7316	5.08	33.3	28.24
T8-*Trichoderma virens*	4.96	32.5	29.27
T9-*Trichoderma asperellum*-N13	5.34	32.7	29.19
T10-*Trichoderma hamatum*	5.33	34.7	29.40
SE(m)±	0.257	0.83	1.54
CD(p=0.05)	8.531	2.51	NS

4.4Nutrient uptake:

Table 4.4.1: Nitrogen uptake in sunflower (kg ha^{-1}) as influenced by *Trichoderma* strains during *Rabi* season

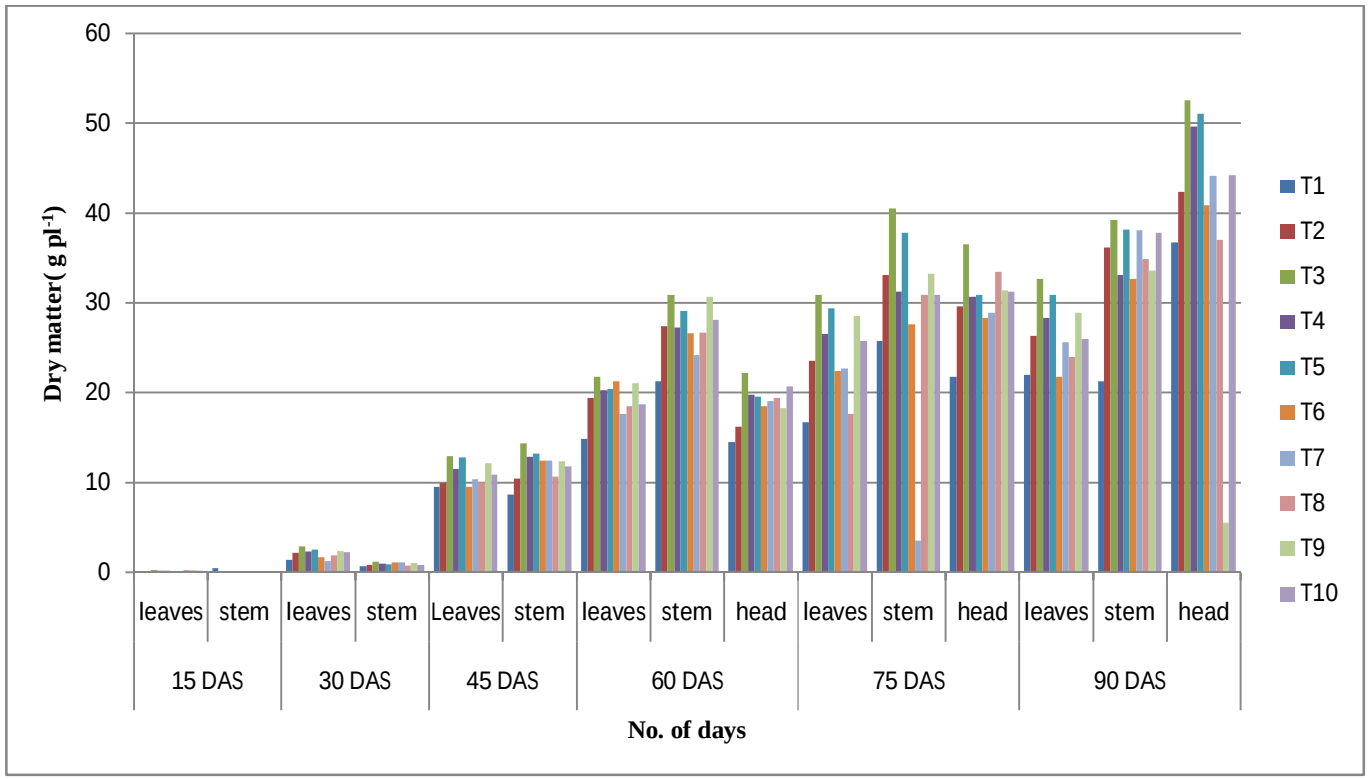
Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	63	100	116	138	144	152
T2-*Trichoderma harzianum*-Th 4d	74	112	128	151	168	172
T3-*Trichoderma asperellum*-TaS1	79	125	148	167	171	176
T4-*Trichoderma asperellum*-Tv5	71	111	133	154	160	169
T5-*Trichoderma* sps-Ta DOR 673	78	116	144	162	175	182
T6-*Trichoderma koningii*	69	103	122	160	168	173
T7-*Trichoderma asperellum*-TaDOR7316	69	113	123	145	167	176
T8-*Trichoderma virens*	66	101	124	144	162	166
T9-*Trichoderma asperellum*-N13	73	113	131	150	158	163
T10-*Trichoderma hamatum*	71	109	132	144	161	120
SE(m)±	1.341	1.18	2.26	2.0	1.92	2.54
CD(p=0.05)	4.01	3.55	6.78	5.98	5.75	7.6

Table 4.4.2: Phosphorus uptake in sunflower (kg ha^{-1}) as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	1.53	2.23	4.03	5.06	2.75	2.13
T2-*Trichoderma harzianum*-Th 4d	2.51	3.60	4.41	5.36	3.20	3.13
T3-*Trichoderma asperellum*-TaS1	3.08	4.06	4.46	6.50	4.41	3.46
T4-*Trichoderma asperellum*-Tv5	3.06	3.36	4.13	5.53	3.52	2.90
T5-*Trichoderma sps*-Ta DOR 673	3.10	4.16	5.25	6.33	4.96	3.81
T6-*Trichoderma koningii*	2.86	3.46	5.19	6.16	4.37	3.36
T7-*Trichoderma asperellum*-Ta DOR 7316	2.48	3.26	4.84	5.26	3.82	2.96
T8-*Trichoderma virens*	2.73	3.16	4.26	6.13	3.83	2.03
T9-*Trichoderma asperellum*-N13	2.14	3.05	3.40	5.53	3.47	1.23
T10-*Trichoderma hamatum*	2.03	2.64	3.16	4.92	2.41	1.36
SE(m)±	3.21	0.13	0.17	0.18	0.29	0.21
CD(p=0.05)	0.65	0.41	0.50	0.56	0.88	0.63

Table 4.4.3: Potassium uptake in sunflower (kg ha^{-1}) as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	1.06	4.54	9.31	16.30	23.42	30.42
T2-*Trichoderma harzianum*-Th 4d	1.05	6.49	10.46	19.88	28.75	33.56
T3-*Trichoderma asperellum*-TaS1	1.16	8.25	13.28	22.64	32.29	43.81
T4-*Trichoderma asperellum*-Tv5	1.06	7.32	12.40	17.65	26.93	33.28
T5-*Trichoderma* sps-Ta DOR 673	1.03	7.64	13.41	25.33	30.12	39.64
T6-*Trichoderma koningii*	1.24	7.36	11.13	13.22	24.41	31.49
T7-*Trichoderma asperellum*-Ta DO7316	1.02	4.68	9.47	17.90	29.56	28.96
T8-*Trichoderma virens*	1.22	6.49	10.46	16.19	25.77	38.41
T9-*Trichoderma asperellum*-N13	1.05	5.54	12.44	17.54	30.98	36.83
T10-*Trichoderma hamatum*	1.10	6.22	12.35	13.26	25.42	29.19
SE(m)±	0.04	0.13	0.122	1.49	1.22	1.67
CD(p=0.05)	0.13	0.39	0.36	4.47	3.67	5.0



4.2.1 Total dry matter partitioning in sunflower as influenced by *Trichoderma* strains during *rabi* season.

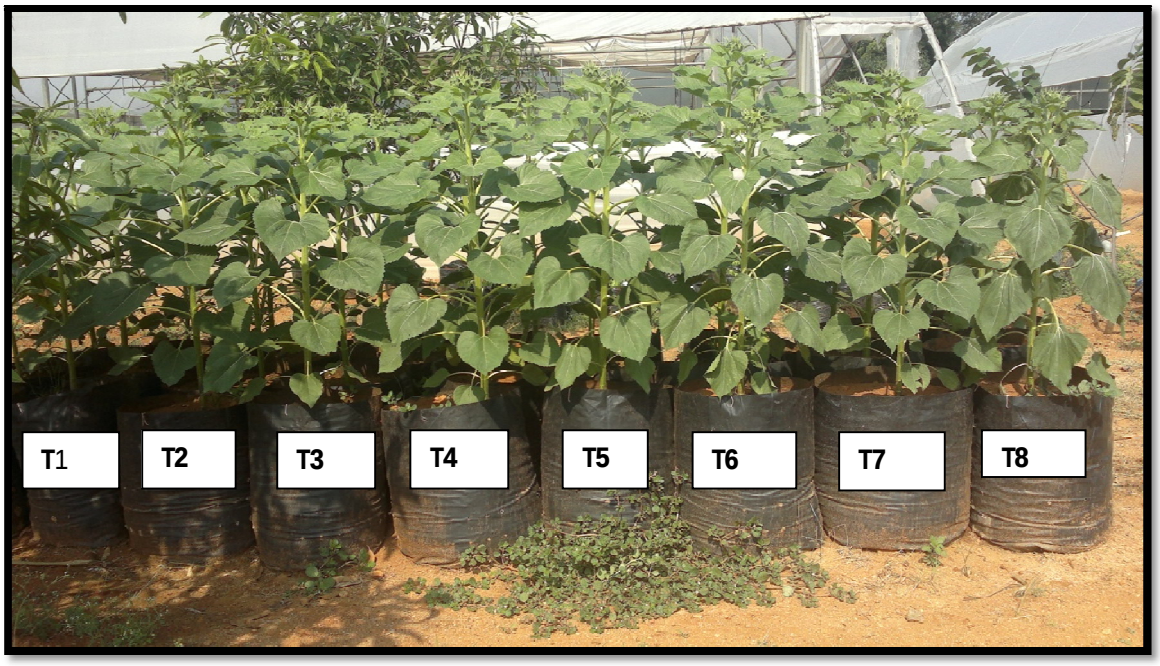


Fig. 1. Raising of sunflower plants for root studies at 45 DAS

Fig. 2 Root samples taken for measurement of root volume, root length and root weight

Fig 4.1.1: Plant height (cm) of sunflower at different growth stages as influenced by *Trichoderma* strains during *rabi* season:

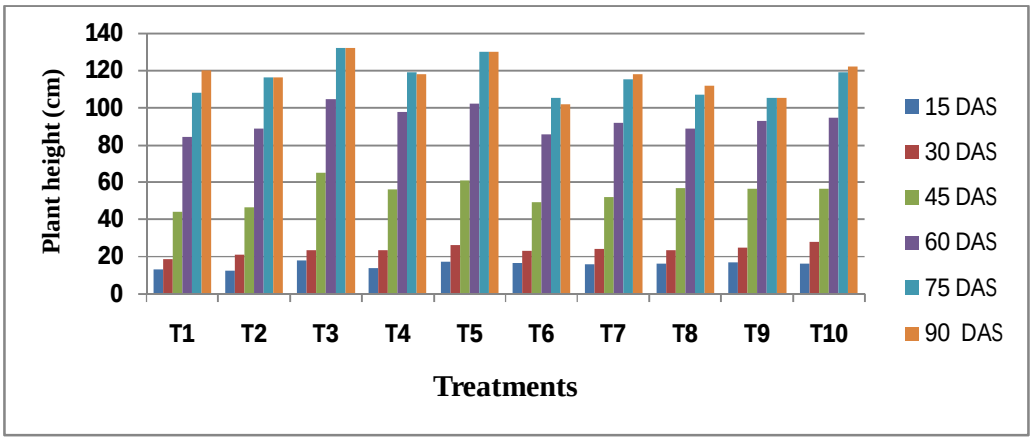


Fig 4.1.2 : Number of leaves of sunflower at different growth stages as influenced by *Trichoderma* strains during *rabi* season

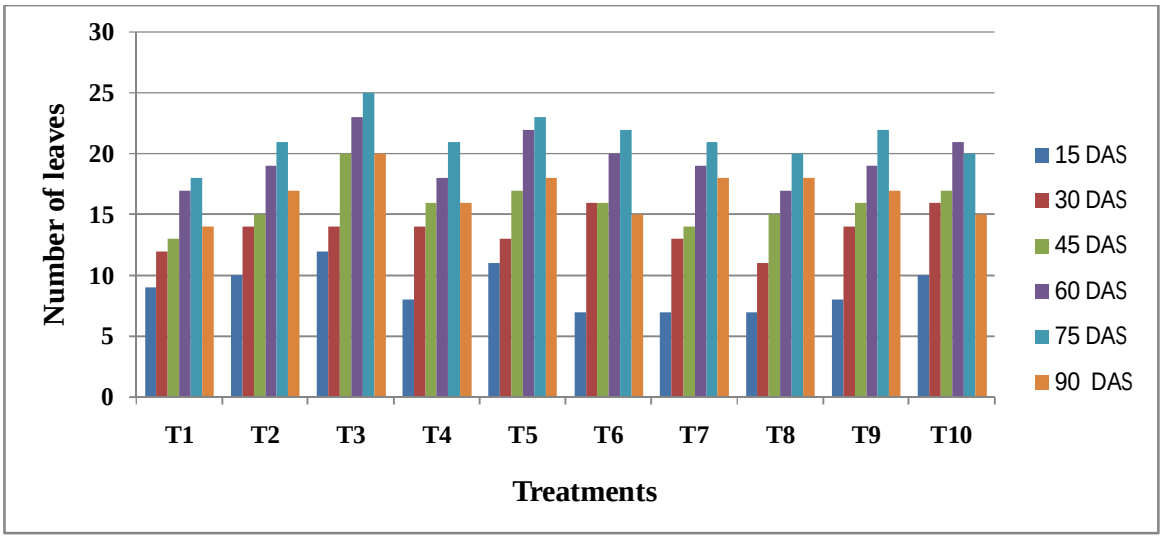


Fig 4.1.3: Days to 50% flowering in sunflower as influenced by *Trichoderma* strains during *rabi* season

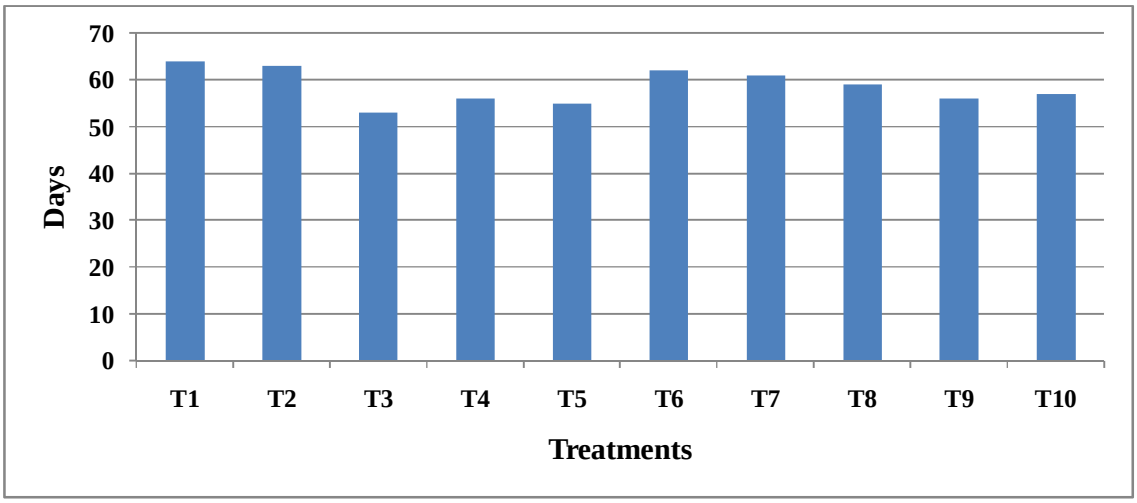


Fig 4.1.4: Days to physiological maturity in sunflower as influenced by *Trichoderma* strains during *rabi* season

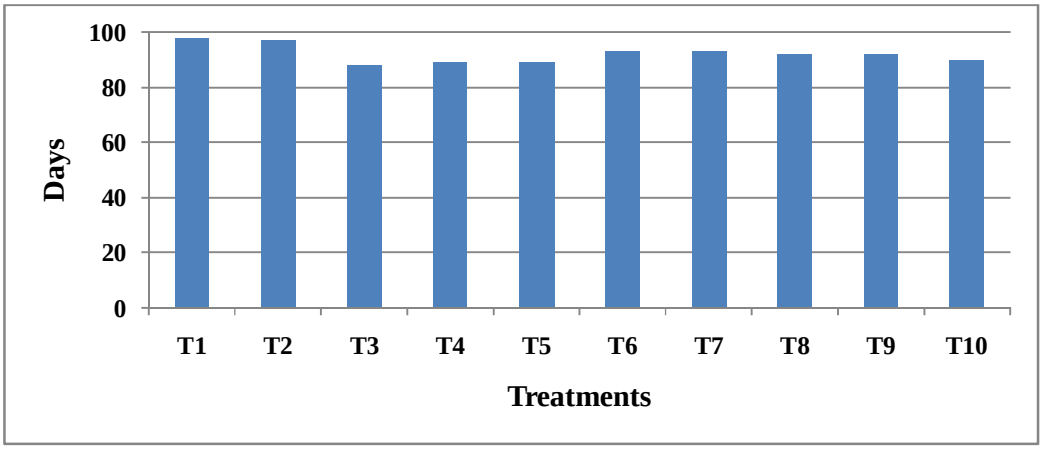


Fig 4.1.5: Root length (cm) in sunflower as influenced by *Trichoderma* strains during *rabi* season

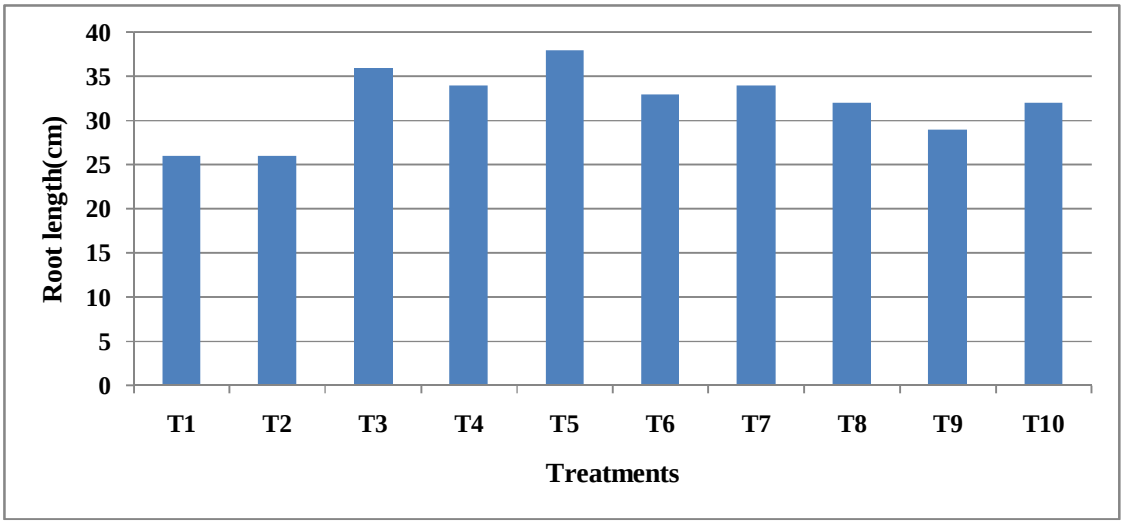


Fig 4.1.6: Root volume (ml plant^{-1}) of sunflower as influenced by *Trichoderma* strains during *rabi* season

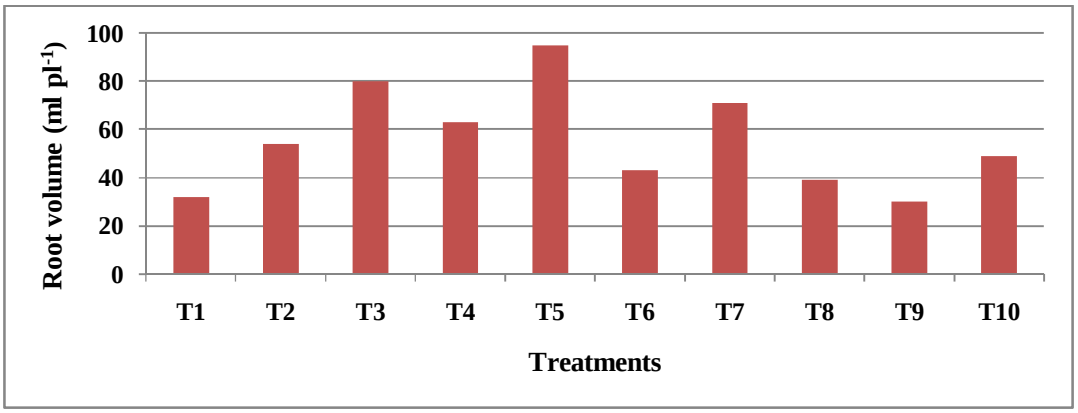


Fig 4.1.7: Root weight of sunflower as influenced by *Trichoderma* strains during *rabi* season

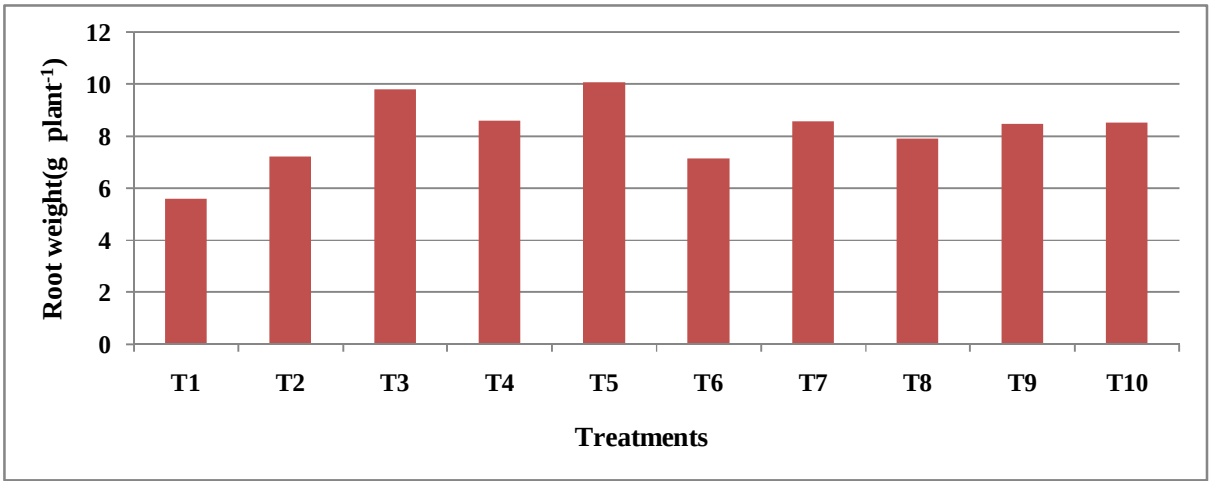


Fig 4.2.3: Photosynthetic rate(µ moles CO_2 $m^{-2}s^{-1}$) of sunflower as influenced by *Trichoderma* strains in *rabi* season

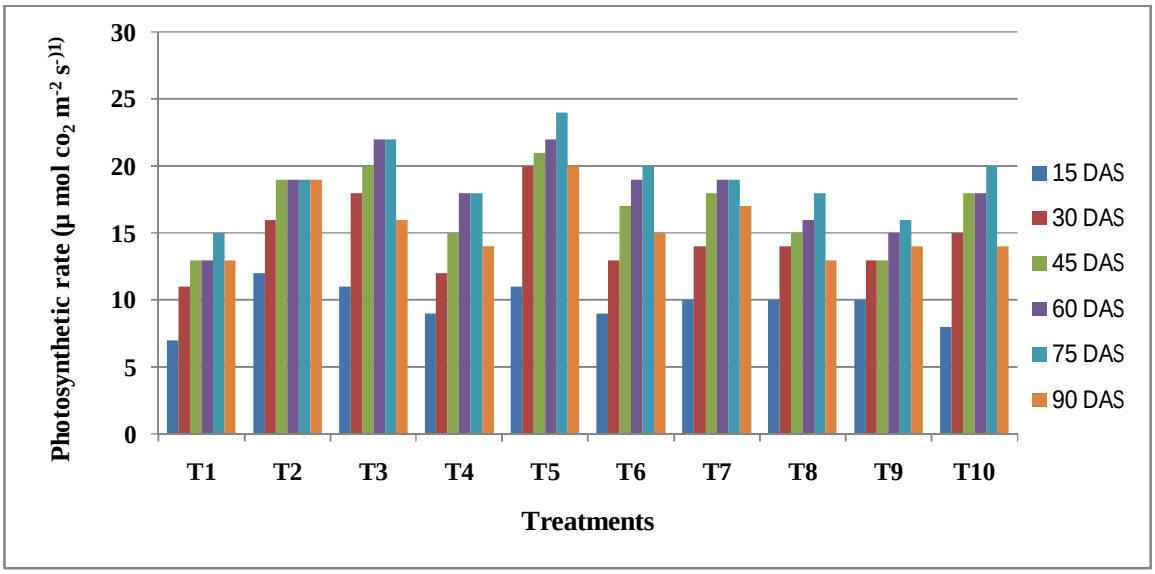


Fig 4.2.4: SCMR values of sunflower as influenced by *Trichoderma* strains in *rabi* season

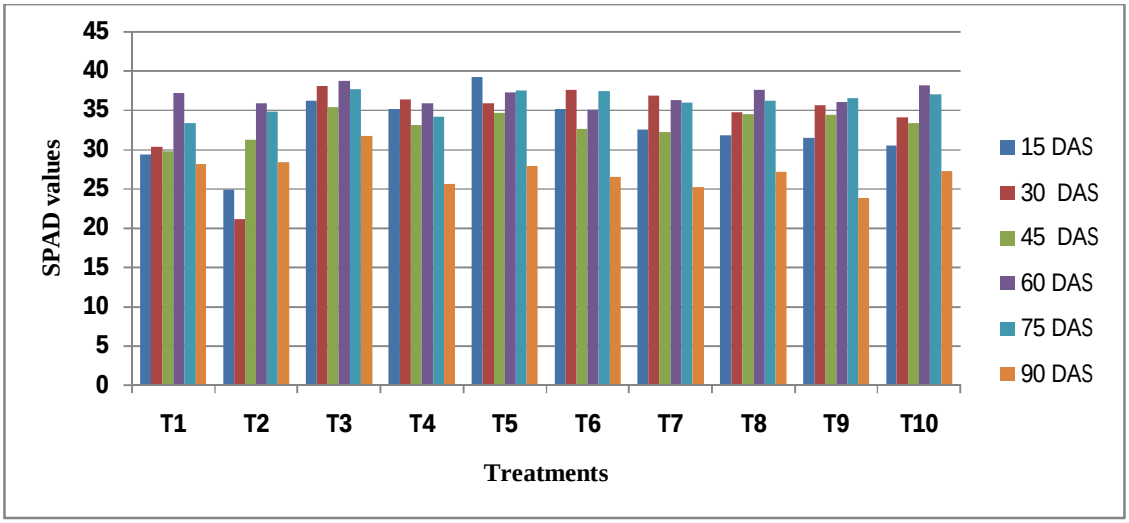


Fig 4.2.5: Leaf area index(LAI) in sunflower as influenced by *Trichoderma* strains in *rabi* season

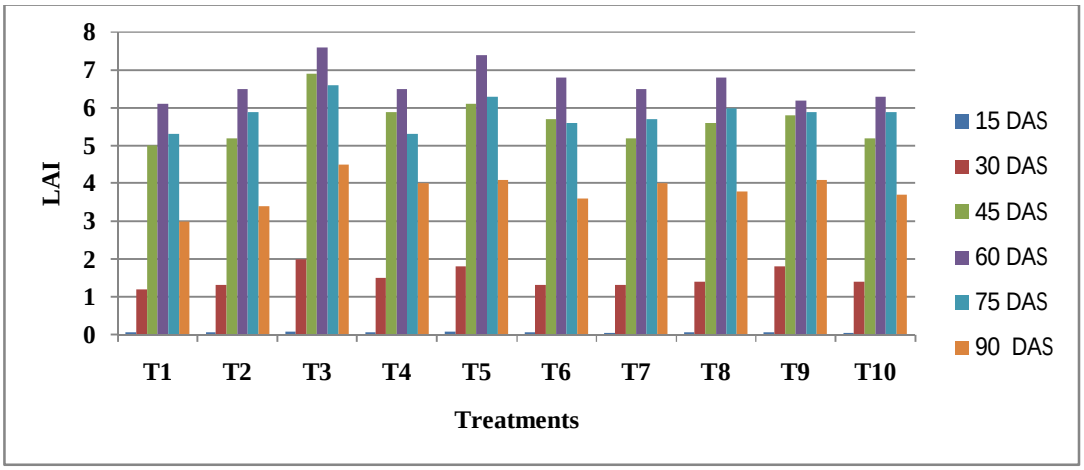


Fig 4.2.6 : Crop growth rate(g $m^{-2}d^{-1}$) in sunflower as influenced by *Trichoderma* strains in *rabi* season

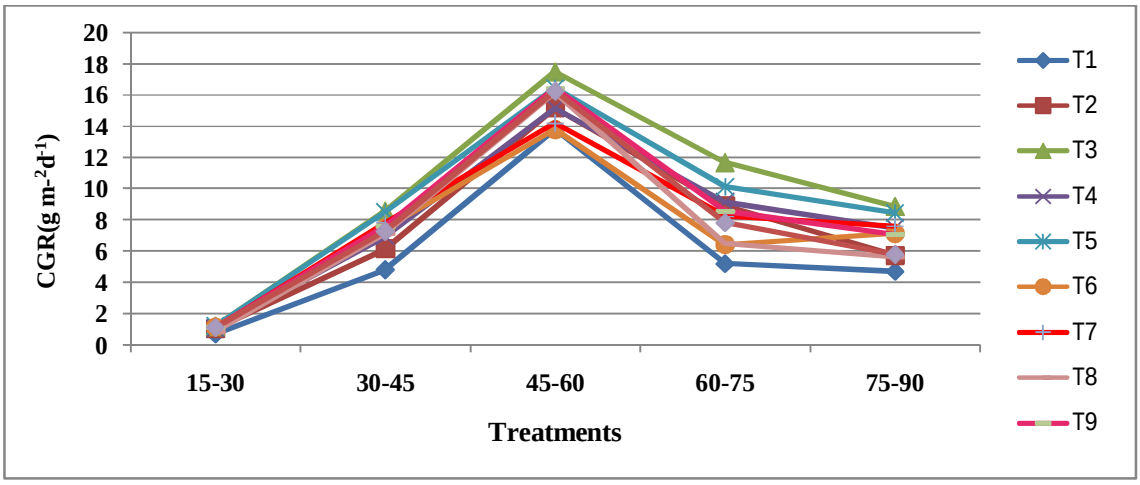


Fig 4.2.7: Net assimilation rate (mg $cm^{-2}d^{-1}$) of sunflower as influenced by *Trichoderma* during *rabi* season

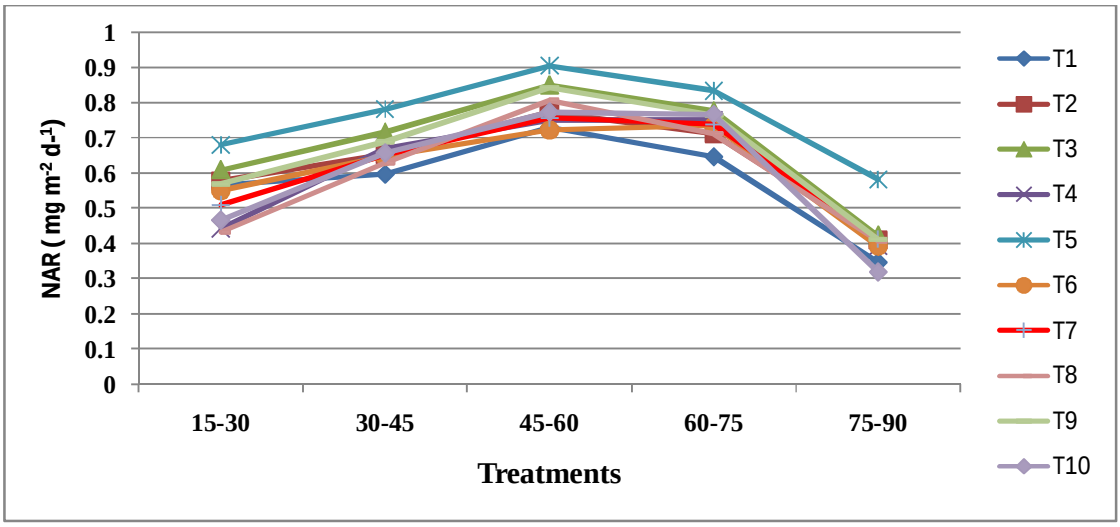


Fig 4.2.8: Relative growth rate (g $m^{-2}d^{-1}$) of sunflower as influenced by *Trichoderma* strains during *rabi* season

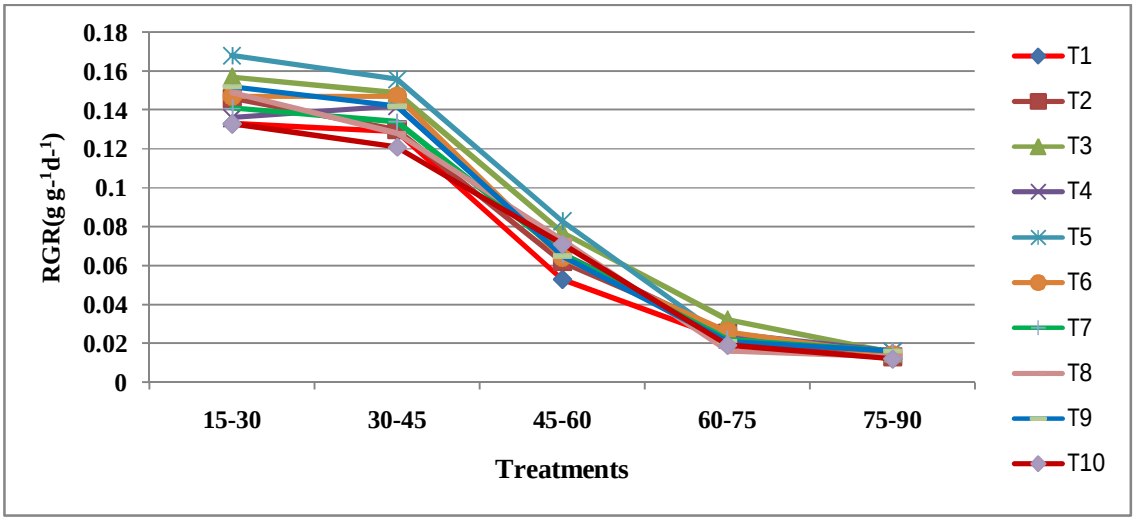


Fig 4.2.1: Total dry matter (g plant^{-1}) in sunflower as influenced by *Trichoderma* strains during *rabi* season

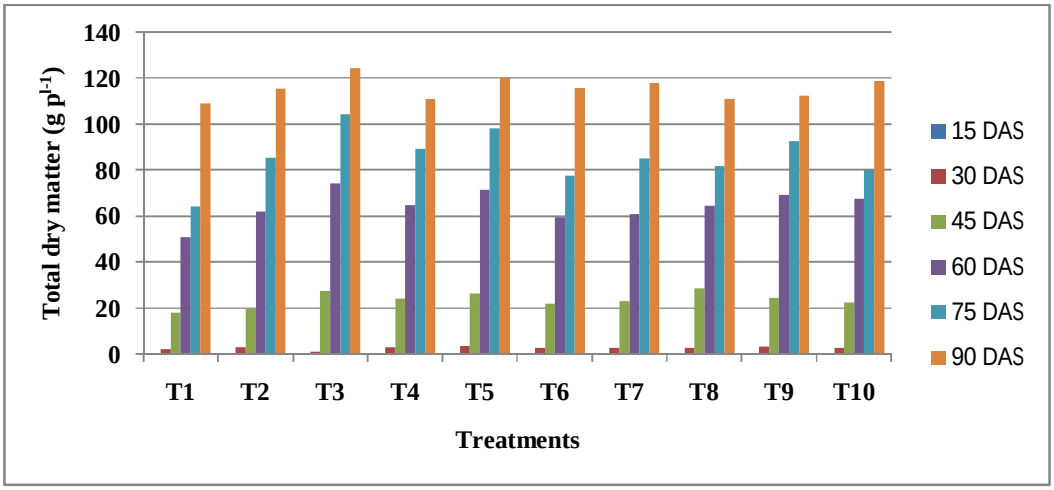


Fig 4.3.1: Diameter of head in sunflower as influenced by *Trichoderma* strains during *rabi* season

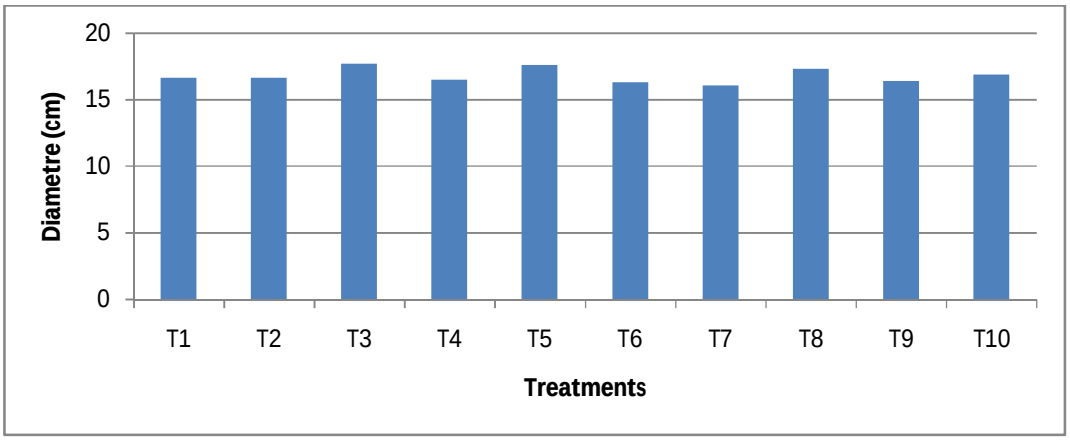


Fig 4.3.2: Head wt in sunflower as influenced by *Trichoderma* strains during *rabi* season

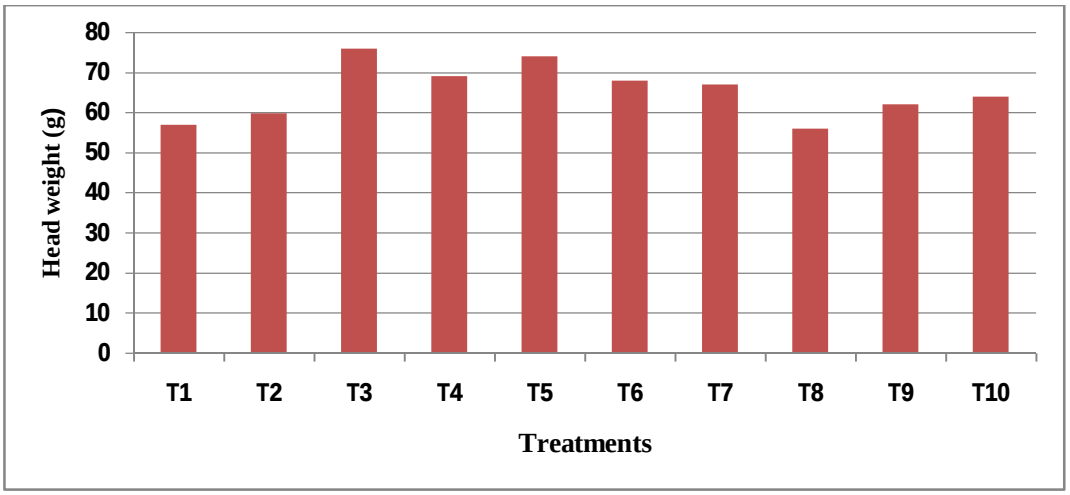


Fig 4.3.3: No of filled seed per head in sunflower as influenced by *Trichoderma* strains during *rabi* season.

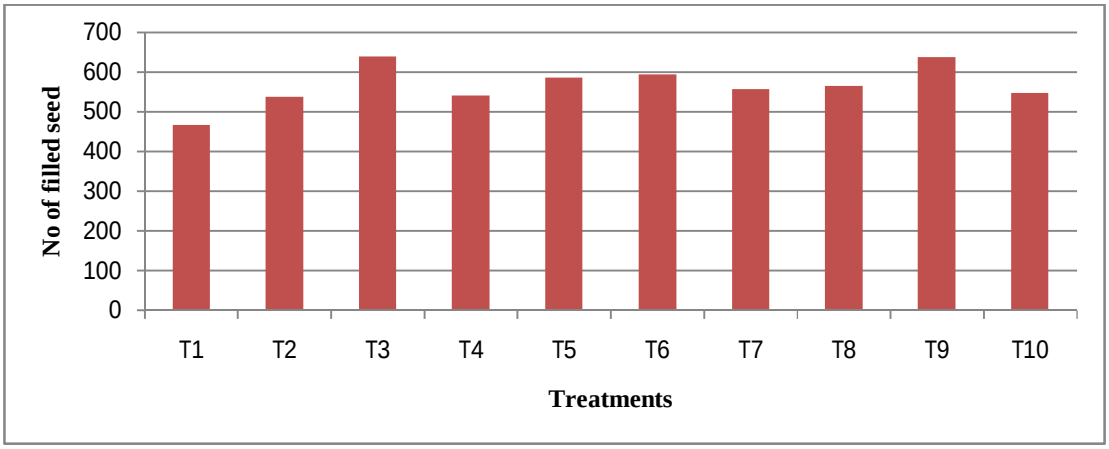


Fig 4.3.4: Seed yield (g plant^{-1}) of sunflower as influenced by *Trichoderma* strains during *rabi* season

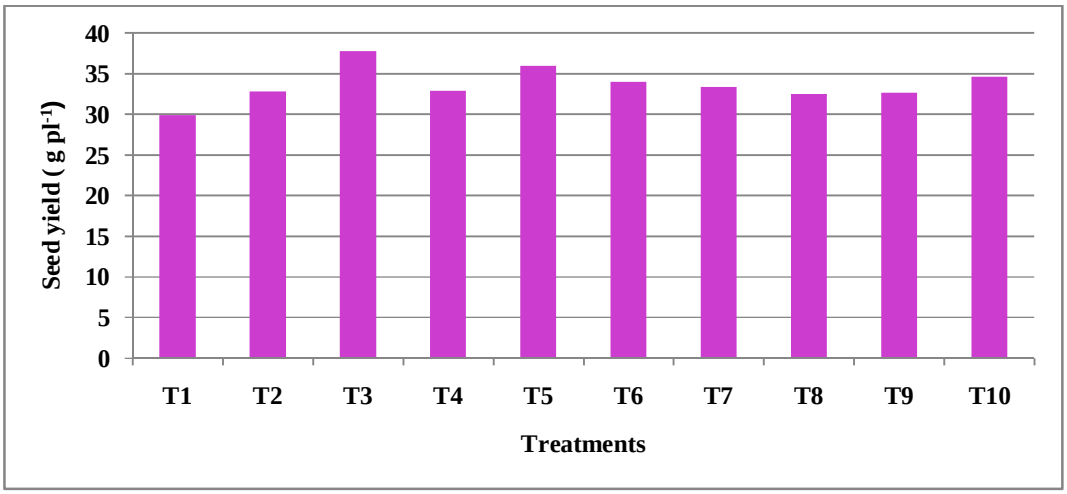


Fig 4.3.5: 100 seed weight (g) of sunflower as influenced by *Trichoderma* strains during *rabi* season

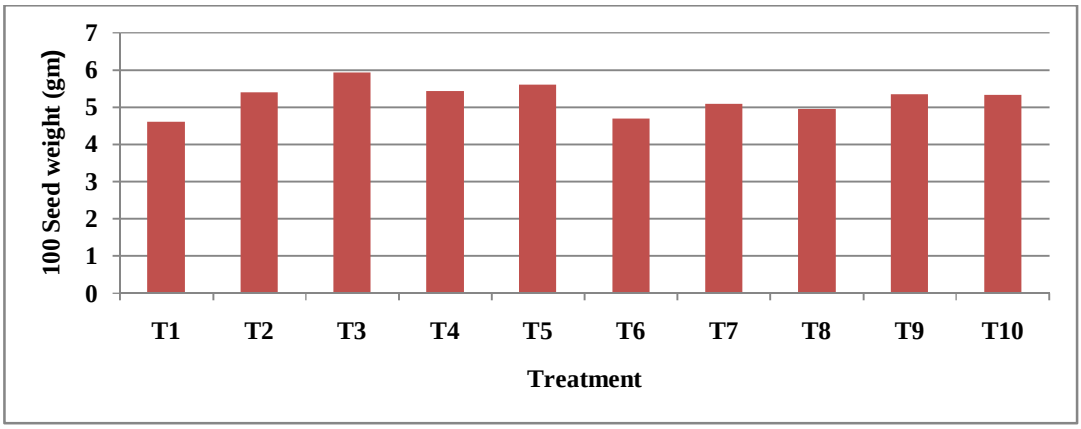


Fig 4.3.6 : Harvest index (%) of sunflower as influenced by *Trichoderma* during *rabi* strains season

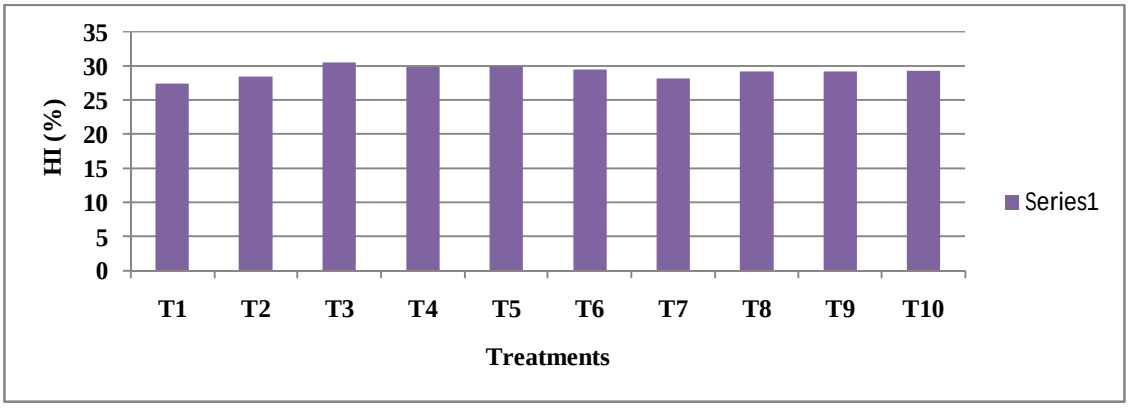


Fig 4.4.1: Nitrogen uptake (kg ha^{-1})of sunflower at different growth stages as influenced by *Trichoderma* strains during *rabi* season

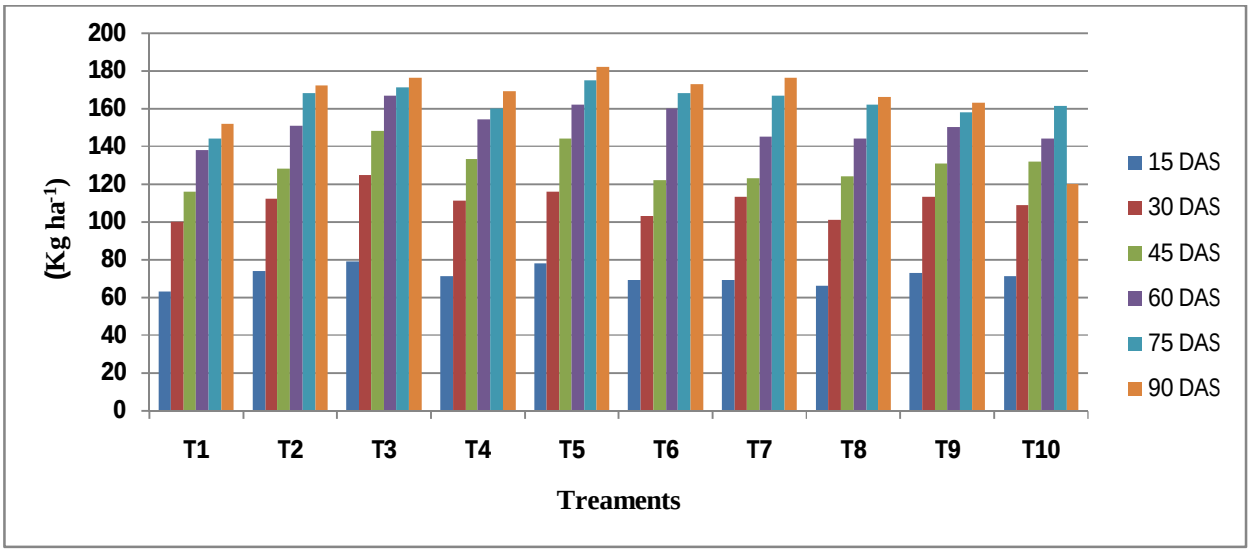


Fig 4.4.2 :Phosphorus uptake (kg ha^{-1}) of sunflower at different growth stages as influenced by *Trichoderma* strains during *rabi* season

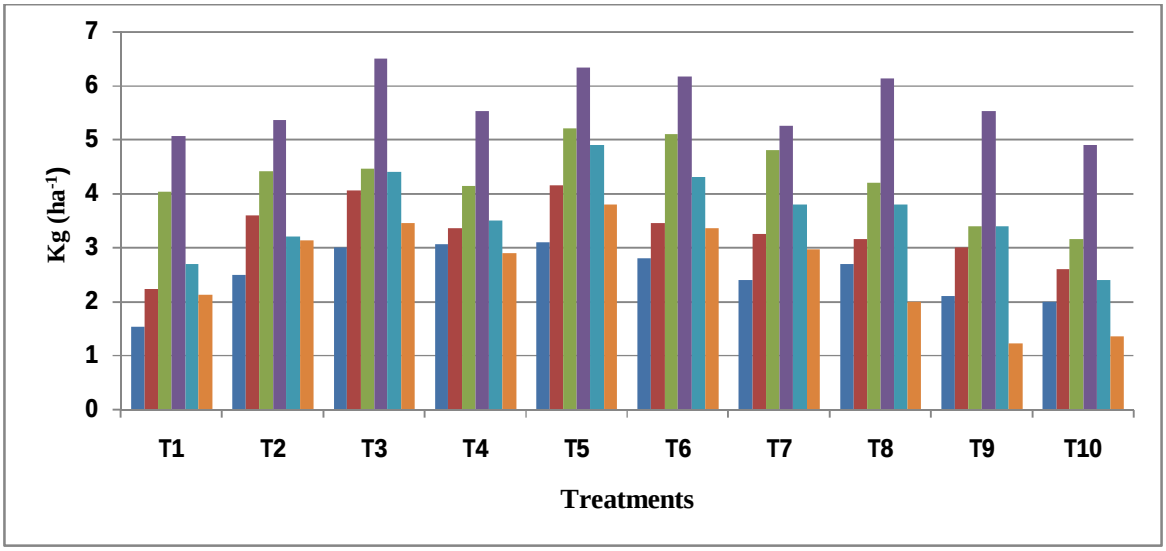
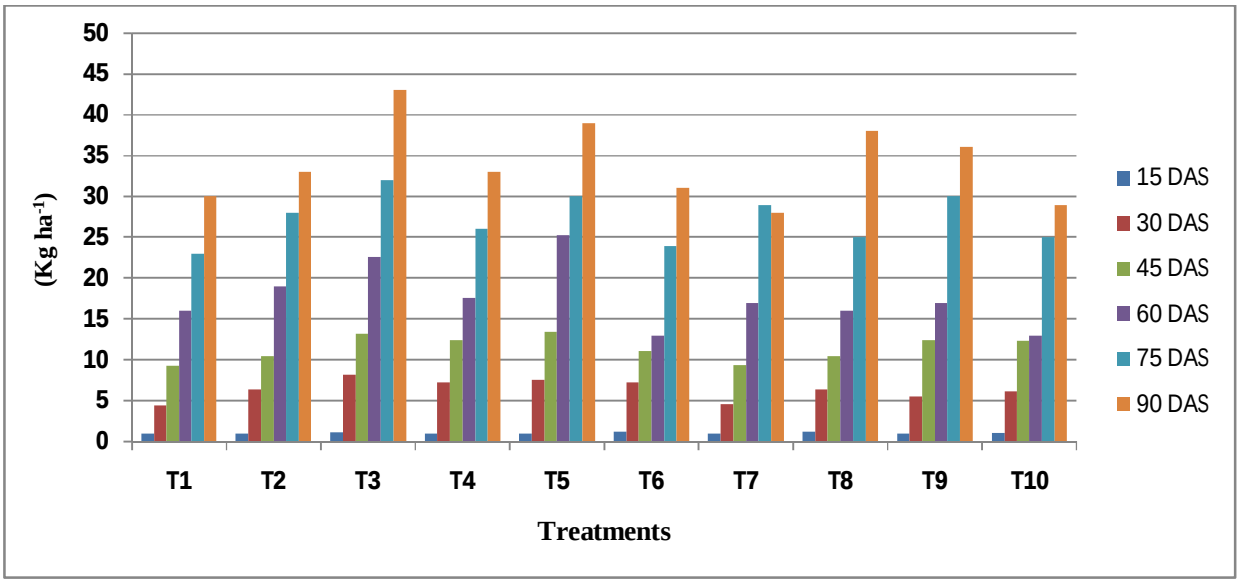


Fig 4.4.3: Potassium uptake (kg ha^{-1})of sunflower at different growth stages as influenced by *Trichoderma* strains during *rabi* season



CHAPTER V

SUMMARY AND CONCLUSIONS

The field experiment entitled" Influence of *Trichoderma* on drymatter production, Photosynthesis and Nutrient uptake in sunflower " was conducted during *rabi* ,2014-2015 at students farm, College of Agriculture, Rajendranagar, Hyderabad. The experiment was laid out in a randomized block design with nine *Trichoderma* sps one control and replicated thrice. In the present investigation an effort was made to understand physiological, morphological parameters. yield components and nutrient uptake in sunflower .The salient findings of the above study are presented in this chapter.

All *Trichoderma* strains showed significant variation for plant height, total number of leaves, days to 50% flowering, days to physiological maturity, root volume, root length, root weight, photosynthetic rate, SPAD chlorophyll meter readings, CGR,RGR,NAR,LAI and diameter of head, number of filled seed per head, 100 seed weight, seed yield and harvest index.

Maximum plant height at final harvesting was recorded in the *Trichoderma asperellum* TaS1 and minimum plant height was recorded in the *Trichoderma koningi.* Leaf number increased from 15DAS to 60 DAS thereafter declined and maximum number of leaves per plant was recorded in *Trichoderma asperellum* during at DAS and minimum number of leaves was found in *Trichoderma virens*

Trichoderma species showed significant difference for the days to 50% flowering and days to physiological maturity. Among treatments more number of days to 50% flowering and days to physiological maturity was recorded in *Trichoderma asperellum*-Tas1 and minimum was observed in control.

Physiological indices viz. LAI, CGR, RGR, NAR, SCMR and photosynthetic rate was varied significantly among the treatments. Highest LAI was recorded in *Trichoderma asperellum*-TaS1(7.6) followed by *Trichoderma sps*-Ta DOR 673 (7.4) at 60 DAS. Leaf area index has increased up to 60 DAS there after that it decreases up to maturity.

Significant variations were observed for root length, root volume and root weight among the treatments. Maximum Root length, root volume and root weight was recorded in *Trichoderma sps*-Ta DOR 673.

Leaf area index values have increased up to 60 days after sowing there after decreased gradually up to maturity. Highest crop growth rate was recorded in *Trichoderma asperellum*-TaS1 followed by *Trichoderma sps*-Ta DOR 673 at 45-60 DAS. Photosynthetic rate increased up to 75 DAS there after it has reduced gradually. Highest photosynthetic rate values were recorded in *Trichoderma sps*-Ta DOR 673(24 µ moles CO_2 m^{-2} s^{-1}) followed by *Trichoderma asperellum*-TaS1(22 µ moles CO_2 m^{-2} s^{-1}) at 75DAS.

Net assimilation rate increased up to 60 DAS there after it decreased up to maturity in all the treatments. At 60 days highest NAR values were recorded by *Trichoderma* sps-Ta DOR 673. RGR decreased with the age of the crop. Highest RGR value was recorded by *Trichoderma* sps-Ta DOR 673 followed by *Trichoderma asperellum*-TaS1

SPAD values differed significantly among the treatments and highest SCMR values were found in the *Trichoderma asperellum*-TaS1.But at 15 DAS maximum SCMR value was found in *Trichoderma* sps-Ta DOR 673.

There was significant increase in total dry matter in all the stages till maturity the highest dry matter production was recorded in *Trichoderma asperellum* –TaS1 followed by *Trichoderma sps* –Ta DOR 673 at 90 DAS. Dry matter partitioning among the component parts revealed that up to 30 days leaves received more photosynthates, from 45-75 DAS maximum dry matter partitioning was towards stems and at 90 DAS head recorded more dry matter values as compared to leaves and stems.

Yield components varied significantly among the *Trichoderma* treatments. Highest diameter of head , head weight, number of filled seed per head,100 seed weight seed yield and harvest index was recorded in *Trichoderma asperellum* –TaS1 Followed by *Trichoderma* sps-Ta DOR 673.

Nitrogen ,phosphorus and potassium uptake differed significantly among the treatments. Highest nitrogen, phosphorus and potassium uptake was recorded in *Trichoderma asperellum* –TaS1 followed by *Trichoderma* sps-Ta DOR 673 and minimum in control plants. Where as the phosphorus uptake has increased up to 60 DAS there after reduced. Nitrogen and potassium uptake increased up to maturity.

Based on performance of morpho physiological parameters and nutrient uptake out of the nine *Trichoderma* strains studied, two strains viz., *Trichoderma asperellum* –TaS1, *Trichoderma* sps-Ta DOR 673 were found to be better strains and have shown good plant growth, photosynthesis, root characters and nutrient uptake finally increases yield during *Rabi* season

LITERATURE CITED

Alexandru, M., Lazar, D., Ene, M and Sesan, T. E. 2013. Influence of some *Trichoderma* species on photosynthesis intensity and pigments in tomatoes. *Romanian Biotechnological Letters.* 18: (4).

Altomare, C., Norvell, W. A., Bjorkman, T and Harman, G. E. 1999. Solubilisation of phosphates and micronutrients by the plant-growth-promoting and bio-control fungus *Trichoderma harzianum rifai. Applied and Environmental Microbiology*. 65: 2926-2933.

Azarmi, R., Hajieghrari, B and Giglou, A. 2011. Effect of *Trichoderma* isolates on tomato seedling growth response and nutrient uptake. *African Journal of Biotechnology*. 10(31): *Plant Physiology*. 5850-5855.

Badar , R and Qureshi. S. A. 2012.Comparative effect of *Trichoderma hamatum* and host specific *Rhizobium* species on the growth of *Vigna mungo*. *Journal of Applied Pharmaceutical Science.* 2(4).

Badda, N., Yadav, K., Kadin, N and Agarwal, A. 2013. Impact of arbuscular mycorrhizal fungi with *Trichoderma viridae* and *Pseudomonas fluorescens* on growth enhancement of genetically modified Bt cotton (*Bacillus thuringinsis*). *Journal of Natural Fibers*. 10 (4): 309-325.

Bae, H., Sicher, R. C., Kim, M. S., Kim, S. H., Strem, M. D., Melnick, R. L and Bailey, B. A. 2009. The beneficial endophyte *Trichoderma hamatum* isolate DIS 219b promotes growth and delays the onset of the drought response in *Theobroma cacao*. *Journal of Experimental Botany*. 60 (11): 3279-3295.

Bal, U and Altinus, S. 2006. A positive side effect from *Trichoderma harzianum*, the biological control agent: increased yield in vegetable crops. *Journal of Environmental Protection and Ecology*. 7(2): 383-387.

Bharti, M. A., Sharama, A. K., Pandey, A. K and Mall, R. 2012. Physiological and biochemical basis of growth suppressive and growth promontory effect of *Trichoderma* strains in tomato plants. *The National Academy of Sciences*. 35(5): 355-359.

Carvajal, L., Orduz, S and Bissett, J. 2009. Growth stimulation in bean (*Phaseolus vulgaris L.)* by *Trichoderma*. *Biological Control.* 51: 409–416.

Chacon. M. R., Rodriguez. G. O., Beritez. T., Sousa. S., Rey. M., Lobell. A and Delagado. J. J. 2007. Microscopic and transcriptome analyses of early colonization of tomato roots by *Trichoderma harzianum*. *Int microbial*. 10: 19-27.

Doni, F., Al-shorgani, N. K. S., Tibin, E. M., Noureldaim, A., Isahak, A., Zain, C. C and Yusoff, W. M. W. 2013. Microbial Involvement in Growth of Paddy**.** *Current Research Journal of Biological Sciences* 5(6): 285-290.

Doni, F., Isahak, A., Zain, C. R. C. M., Ariffin, S. M., Mohamad, W. W and Yousoff W. W. 2014. Enhancement of rice seed germination and vigour by *Trichoderma* spp. *Research Journal of Applied Sciences, Engineering and Technology*. 7(21).

Elad, Y., Chet, I and Katan, J. 1979. Trichoderma harzianum: a biocontrol agent effective against *Sclertium rolfsii* and *Rhizoctonia solani*. *Disease Control and Pest Management.*

Entesari, M., Sharifzadeh, F., Ahmadzadeh, M and Farhangfar, M. 2013. Seed Biopriming with *Trichoderma* Species and *Pseudomonas fluorescent* on Growth Parameters, Enzymes Activity and Nutritional Status of Soybean. *International Journal of Agronomy and Plant Production.* 4 (4): 610-619.

Fisher, R. A. 1948. *Statistical method for research workers.* Har. New. Pub. Co. Inc. Newyork.

Giridhar, B. A., Jaehong, S., Soo, B. K., Patrick, S and Taek, O. B. 2014. *Trichoderma virens* PDR-28: a heavy metal-tolerant and plant growth-promoting fungus for remediation and bioenergy crop production on mine tailing soil. *Journal of Environmental Management.* 132:129-34.

Harman, G. E. 2006. Overview of mechanisms and uses of *Trichoderma* spp. *Phytopathology* .

Harman, G. E., Petzoldt, R., Comis, A and Chen, J. 2004. Interactions between *Trichoderma harzianum* strain t22 and maize inbred line mo17 and effects of

these interactions on diseases caused by *Pythium ultimum* and *Colletotrichum graminicola*. *Journal of Phytopathology*. 94:147-153.

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I and Lorito, M. (2004). *Trichoderma* species-opportunistic, avirulent plant symbionts. *Nature Reviews* 2: 43-56.

Harman, G. E. 2000. Myths and dogmas of biocontrol-changes in perceptions derived from research on *Trichoderma harzianum* T-22. *Plant disease*. 84: 77-393.

Hohmann. P., Jones. E. E., Hill, R. A and Stewart, A. 2011. Understanding *Trichoderma* in the root system of pinus radiata: associations between rhizosphere colonisation and growth promotion for commercially grown seedlings. *Fungal Biology*. 115(8): 759-767.

Inbar, J., Abramsky, M., Cohen, D and Chet, I. 1994. Plant growth enhancement and disease control by *Trichoderma harzianum* in vegetable seedlings grown under commercial conditions. *European Journal of Plant Pathology*. 100: 337-342.

Jackson, M. L. 1967. *Soil chemical analysis*. Prentice-Hall, Indian Private Ltd., New Delhi. 183-192.

John, R. P., Tyagi, R. D., Prevost, D., Satinder, K., Brar, S. K., Pouluer, S and Surampally, R. Y. 2010. Mycoparasitic *Trichoderma viride* as a biocontrol agent against *Fusarium oxysporum f. sp*. *adzuki* and *Pythium arrhenomanes* and as a growth promoter of soybean. *Crop Protection*. 29: 1452-1459.

Kadian. N., Yadav. K and Aggarwal. A. 2013. significance of bioinoculants in promoting growth, nutrient uptake and yield of *Cyamopsis tetragonoloba* (L.) "Taub.". European *Journal of Soil Biology*. 58: 66-72.

Khair, A. E., Khalifa, H. R. Kh. M and Haggag, K. H. E. 2011. Effect of trichoderma species on damping off diseases incidence, some plant enzymes activity and nutritional status of bean plants. *Journal of American science*. 6(9).

Khan, M. S., Zaidi, A and Ahmed, E. 2014. Mechanism of phosphate solubilisation and physiological functions of phosphate solubilising microorganisms. *Phosphate solubilising microorganisms.*

Kucuk, C. 2014. Enhanced root and shoot growth of wheat (*Triticum aestivum L.*) by *Trichoderma harzianum* from turkey. *Pakistan Journal of Biological Sciences*. 17 (1). 122-125.

Kumar, A., Aggarwal, A and Kaushish, S. 2009. Influence of arbuscular mycorrhizal fungi and *Trichoderma viride* on growth performance of *Salvia Officinalis Linn. Journal of Applied and Natural Science* 1(1): 13-17.

Lo, C. T and Lin, C. Y. 2002. Screening strains of *Trichoderma* spp for plant growth in Taiwan. *Plant Pathology*. 11: 215-220.

Mangala, C., Kumar, A and Agrwal, A. 2010. Potential of AM fungi (*glomus mosseae* and *acaulospora laevis*) and *Trichoderma viridae* in enhancing growth and development of eclipta (L.). *Indian Phytopathology*. 63(3).

Medina, A. M., Roldan, A and Pascual, J. A. 2014. Interaction between arbuscular mycorrhizal fungi and *Trichoderma harzianum* under conventional and low input fertilization field condition in melon crops. *Applied Soil Ecology*. 47(2): 98-105.

Mishra, K. K., Dwivedi, S and Pandre, P. K. 2014. Evaluation of Fungal Bio-agents on plant growth and *M. incognita* infestation on chick pea. *Chemistry and Materials Research*. 6 (3).

Mouria, B., Quezzami, T. A. and Douira, A. 2007. Effect of *Trichoderma* strains on the growth of tomato plants in greenhouses and their aptitude to colonize roots and substrate. *Phyto Protection*. 88: 103-110

Mukhopadhay, R and Pan, S. 2012. Effect of Biopriming of radish (*Raphanus sativus*) seed with some antagonistic isolates of *Trichoderma*. *The Journal Of Plant Protection Sciences.* 4(2): 46-50.

Muthukumar, A., Eswaran, A and Sanjeevkumas, K. 2011. Exploitation of *Trichoderma* species on the growth of *pythium aphanidermatum* in chilli. *Brazalian Journal of Microbiology.* 42: 1598-1607.

Nagaraju, A., Sudisha, J., Murthy, S. M and Ito, S. I. 2012. Seed priming with *Trichoderma harzianum* isolates enhances plant growth and induces resistance against *Plasmopara halstedii*, an incitant of sunflower downy mildew disease. *Australian Plant Pathology.* 41: 609-620.

Nzanza, B., Marias, D and Soundy, P. 2011. Tomato (*Solanum lycopersicum L.*) seedling growth and development as influenced by *Trichoderma harzianum* and *Arbuscular mycorrhizal* fungi. *Microbes and Environment*. 26(2): 128-34.

Olsen, S. R., Cole, C. V., Watanabe, F. S and Dean, L. S. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA circulation*. 939.

Ousley, M. A., Lynch, J. M and Whipps, J. M. 1993. Effect of *Trichoderma* on plant growth, a balance between inhibition and growth promotion. *Microbial Ecology*. 26(3): 277-285

Padmavathi, T. 2013. Study on growth and biomass of *ocimum sanctum* plants and protein profiling of *Trichoderma harzianum*. *International Journal of Pharma and Bio Sciences*. 4(1): 671-672.

Piper, C. S. 1966. *Soil and plant analysis*. Hans publishers. Bombay. 47-49 and 81-111.

Rabeendran, N., Moot, D. J., Jones, E. E and Stewart, A. 2000. Inconsistent growth promotion of cabbage and lettuce from *Trichoderma* isolates. *New Zealand Plant Protection*. (53): 8-10.

Radford, D. J. 1967. Growth analysis formulae: their use and abuse. *Crop science*. 7:171-175.

Rudresh, D. L., Shivaprakash, M. K and Prasad, R. D. 2005. Effect of combined application of Rhizobium, phosphate solubilizing bacterium and *Trichoderma* spp. On growth, nutrient uptake and yield of chickpea (*Cicer aritenium L.*). *Applied Soil Ecology*. (28): 139-146.

Sandeep, A. R., Asok, A. K and Jisha, M. S. 2013. Combined inoculation of pseudomonas fluorescens and *Trichoderma harzianum* for enhancing plant growth of vanilla *(vanilla planifolia*). *Pakistan Joural of Biological Sciences*. 16(12): 580-584.

Shamalie, B. V. T., Fonseka, R. M and Rajapaksha, R. G. A. S. 2011. Effect of *Trichoderma viride* and carbofuran (curator) on management of root knot nematodes and growth parameters of gotukola (*centella asiatica L.*). *Tropical Agricultural Research*. 23(1): 61-69.

Shoresh, M., Harman, G. E and Mastouri, F. 2010. Induced systemic resistance and plant responses to fungal biocontrol agents. *Annual Review of Phytopathology*. 48: 21–43.

Subbaiah, B. V and Asija, G. 1956. A rapid procedure for estimation of available nitrogen in soil. *Current Science*. 25: 258-260.

Thankamani, C. K., Sreekala, K and Anandaraj, M. 2005. Effect of *Pseudomonas fluorescens* (IISR-6) and *Trichoderma harzianum* (P-26) on growth of black pepper (*Piper nigrum L.)* in the nursery. *Journal of Spices and Aromatic Crops* 14 (2) : 112–116.

Trujillo, V. M., Bejarano, E. V., Angulo, J. C. V., Mendoja, D. G., Jaurez, O. G., Rojas, R. T and Sanchez, E. R. 2013. Development physiological and stimulation of roots architecture in *Cucumis sativus l*. plants inoculated with *Trichoderma longibrachiatum*. *Journal of Pure and Applied Microbiology*. 7(2).

Vargas, W. A., Mandave, J. C and kenerley, C. M. 2009. Plant derived sucrose is a key element in the symbiotic association between *Trichoderma virens* and maize plants. *Plant Physiology*. 151: 792-808.

Vinale, F., Sivasithamparam, K., Ghisalberti. E. L., Marra. R., Woo, S. L and Lorito M, 2008. *Trichoderma*–plant–pathogen interactions. *Soil biology and biochemistry*. 40: 1-10.

Wahid, O. A., Moustafa, A and Mohamed, R. M. 2007. Enhancement of growth through implementation of different *Trichoderma* species. *Proceeding of the Second Scientific Environmental Conference*. pp: 43-59.

Walkley, A and Black, C. A. 1934.Estimation of organic carbon by chromic acid titration methods. *Soil Science*. 37: 29-38.

Watson, D. J. 1952. The physiological basis of variation in yield. *Advances in Agronomy*. 4: 101-145.

Weeder, C. R., Shelton, A. M and Hoftman, M. P. (2008). Biological Control, A guide to natural enemies in North America. PP: 1-14.

Windham, M. T., Elad, Y and Baker, R. 1986. A mechanism for increased plant growth induced by *Trichoderma* spp. *Phytopathology*. 76: 581-521.

Yedida, I., Srivastava, A. K., kapulnik, Y And chet, I. 2001. Effect of *Trichoderma harzianum* on microelement concentrations and increased growth of Cucumber plants. *Plant Soil.* 235: 235-242

Yin, D., Deng, X., Chet, I and Song, R. 2014. Physiological responses of *Pinus sylvestris var. mongolica* seedlings to the interaction between *Suillus luteus* and *Trichoderma virens. Current Microbiology*. 69(3): 334-42.

APPENDIX -A

WEEKLY MEAN METEOROLOGICAL DATA RECORDED DURING THE CROP GROWTH PERIOD OF *RABI* 2014-15

WEEK	PERIOD	TEMPERATURE (^{0}C)		R.H. (%)		RAIN-FALL (mm)	RAINY DAYS (No)	SUN SHINE (hs.)	WIND SPEED (Km h^{-1})	EVAPORATION (mm)	MEAN TEMPERATURE (^{0}C)
		MAX.	MIN.	I	II						
40	01-07 OCT	34.1	21.9	80	45	40.2	1	7.6	1.3	5.3	28
41	07-14	32.4	20.3	78	49	0.8	0	4.3	3.9	4.5	26.3
42	15-21	32.8	19.2	85	47	6.2	1	8.2	2.5	5.6	26
43	22-28	28.3	19	89	68	22	1	4	2	4	23.7
44	29-04 NOV	30.4	18.4	80	24	0	0	8.3	2.3	4.8	24.4
45	05-11	30.9	16.4	76	42	0	0	6.8	2.3	5.4	23.6
46	12-18	30	19.7	81	61	10.6	1	5.5	1.8	4.5	24.8
47	19-25	30.6	16.4	87	42	0	0	7.6	1.2	4.6	23.5
48	26-02 DEC	30.6	12.1	73	30	0	0	8.5	1.7	4.1	21.3
49	03-09	30.5	12	81	42	0	0	8.8	1.6	4.1	21.2
50	10-16	28.2	15.9	89	68	0	0	3.4	1.5	2.8	22
51	17-23	27.1	9.3	71	41	0	0	7.7	1.8	2.8	18.2
52	24-31	27.1	11.4	69	47	0	0	8.1	1.5	2.9	19.3
53	1-6 JAN	29.1	17.9	79	49	0	0	5.7	1.6	3.9	23.6
54	7-14	27.2	6.2	67	24	0	0	9.8	1.2	3.7	16.7
	Total	449	236.1	1185	679	79.8	4	104.3	28.2	63	342.6
	Mean	29.95	15.74	79	45.26	5.32	0.26	6.95	1.88	4.2	22.84