

**NUTRIENT MANAGEMENT IN *RABI*  
SUNFLOWER (*Helianthus annuus.L*)  
IN RELATION TO DIFFERENT  
TILLAGE PRACTICES  
IMPOSED DURING *KHARIF*.**

**K.SRIDHAR**

**B.Sc.(Ag.)**

**MASTER OF SCIENCE IN AGRICULTURE  
(AGRONOMY)**



**2012**

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**By**

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**THESIS SUBMITTED TO THE ACHARYA N.G. RANGA  
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**CHAIRPERSON: Dr. M. YAKADRI**



**DEPARTMENT OF AGRONOMY  
COLLEGE OF AGRICULTURE  
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY  
RAJENDRANAGAR, HYDERABAD - 500 030**

**2012**

## **CERTIFICATE**

**Mr. K.SRIDHAR** has satisfactorily prosecuted the course of research and that the thesis entitled “**NUTRIENT MANAGEMENT IN *RABI* SUNFLOWER (*Helianthus annuus. L*) IN RELATION TO DIFFERENT TILLAGE PRACTICES IMPOSED DURING *KHARIF*” 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 been previously submitted by him for a degree of any University.**

Date:

**(Dr. M. YAKADRI)**  
Chairperson

## CERTIFICATE

This is to certify that the thesis entitled “**NUTRIENT MANAGEMENT IN RABI SUNFLOWER (*Helianthus annuus.L*) IN RELATION TO DIFFERENT TILLAGE PRACTICES IMPOSED DURING KHARIF**” submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide original research work carried out by **Mr. K.SRIDHAR** 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 investigations have been duly acknowledged by the author of the thesis.

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## DECLARATION

I, **K.SRIDHAR**, hereby declare that the thesis entitled “**NUTRIENT MANAGEMENT IN RABI SUNFLOWER (*Helianthus annuus.L*) IN RELATION TO DIFFERENT TILLAGE PRACTICES IMPOSED DURING KHARIF**” submitted to the **Acharya N.G. Ranga 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: Hyderabad

Date :

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**I.D. NO. RAM/10-07**

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(K.SRIDHAR)

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## LIST OF SYMBOLS AND ABBREVIATIONS

cm	:	Centimetre
m	:	Metre
g	:	Gram
kg	:	Kilogram
t	:	Tonne
ha	:	Hectare
kg ha <sup>-1</sup>	:	Kilogram per hectare
t ha <sup>-1</sup>	:	Tonne per hectare
kmph	:	Kilometre per hour
m	:	Million
ds m <sup>-1</sup>	:	Decisiemen per metre
@	:	At the rate of
B:C	:	Benefit: cost ratio
SEd ±	:	Standard error of difference
CD(P=0.05)	:	Critical difference at 5 percent level
DAS	:	Days after sowing
<i>et al.</i>	:	And others
hr	:	Hour
%	:	Per cent
NS	:	Non significant
°C	:	Degree Celsius
N	:	Nitrogen
P <sub>2</sub> O <sub>5</sub>	:	Phosphorus
K <sub>2</sub> O	:	Potassium
OC	:	Organic carbon
pH	:	Pussancea hydrogen
EC	:	Electrical conductivity
<i>viz.,</i>	:	Namely
Rs	:	Rupees
g cc <sup>-1</sup>	:	Gram per cubic centimetre
number m <sup>-2</sup>	:	Number per square metre

SSP	:	Single super phosphate
MOP	:	Muriate of potash
Max	:	Maximum
Min	:	Minimum
day <sup>-1</sup>	:	Per day
mm	:	Millimetre
RDF	:	Recommended dose of fertilizers
FYM	:	Farm yard manure
Fig.	:	Figure
hour <sup>-1</sup>	:	Per hour
q	:	Quintal
a.i	:	Active ingredient
ml lit <sup>-1</sup>	:	Millilitre per litre
cm <sup>2</sup>	:	Square centimetre
NO <sub>3</sub> <sup>-</sup>	:	Nitrate
RDN	:	Recommended dose of nitrogen
IPNS	:	Integrated plant nutrient system
No.	:	Number
vis-à-vis	:	In relation to
F-test	:	Fisher's test

S.No	Operation	Unit cost
1	Ploughing	1550
2	Harrowing	1000
3	Sunnhemp seed and incorporation	68.9
4	N	5.62
5	P	4.8
6	K	11.86
7	Seeds and sowing	250(200 + 50 for sowing)
8	Herbicide spray	200
9	Hoeing	800
10	Hand weeding	1000
11	Monocrotophos	855
12	Bird scaring	1500
13	Harvest and threshing	1000

### APPENDIX – III

#### CALENDER OF OPERATIONS

S.No	Field Operation	Date of operation
1.	Ploughing in conventional tillage block	04-06-2011
2.	Harrowing	13-06-2011
3.	Layout of the field	01-07-2011
4.	Sowing of sunnhemp	07-07-2011
5.	Incorporation of sunnhemp	24-07-2011
6.	Fertilizer application and sowing of sunflower	16-09-2011
7.	Pendimethalin spray in minimum tillage block	17-09-2011
8.	Hoeing in all plots	12-10-2011
9.	Hoeing in conventional tillage block	31-10-2011
10.	Hand weeding in reduced tillage block	31-10-2011
11.	Spraying monocrotophos	09-11-2011
12.	Harvest	30-12-2011

## APPENDIX – II

### Cost of cultivation (Rs ha<sup>-1</sup>)

		N1			N2			N3			N4			N5		
		T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
S.no	Operation															
1	Ploughing	1550	0	0	1550	0	0	1550	0	0	1550	0	0	1550	0	0
2	Harrowing	2000	2000	1000	2000	2000	1000	2000	2000	1000	2000	2000	1000	2000	2000	1000
3	Sunnhemp seed and incorporation	689	689	689	344.5	344.5	344.5	0	0	0	0	0	0	344.5	344.5	344.5
4	N	0	0	0	98.35	98.35	98.35	196.7	196.7	196.7	134.88	134.88	134.88	134.88	134.88	134.88
5	P	0	0	0	240	240	240	240	240	240	144	144	144	144	144	144
6	K	0	0	0	415.1	415.1	415.1	415.1	415.1	415.1	0	0	0	0	0	0
7	Seeds and sowing	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125
8	Herbicide	0	0	200	0	0	200	0	0	200	0	0	200	0	0	200
9	Hoeing	1600	0	800	1600	0	800	1600	0	800	1600	0	800	1600	0	800
10	Hand weeding	0	1000	0	0	1000	0	0	1000	0	0	1000	0	0	1000	0
11	Monocrotophos	855	855	855	855	855	855	855	855	855	855	855	855	855	855	855
12	Bird scaring	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
13	Harvest and threshing	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Total	12319	10169	9169	12727.95	10577.9	9577.95	12481.8	10331.8	9331.8	11908.88	9758.88	8758.88	12253.38	10103.3	9103.38

**APPENDIX – I**

**Weekly Meteorological data during crop growth period ( 16-09-2011 to 30-12-2011)**

Standard Meteorological  Week No.	Date and Month	Air Temperature		Relative Humidity		Wind Speed  (kmph)	Sunshine Duration  (hrs day <sup>-1</sup> )	Rainfall  (mm)	Rainy Days	Mean Pan Evaporation  (mm)
		Max.	Min.	I	II					
		(°C)	(°C)	(%)	(%)					
37	Sep 10-16	32.1	21.1	86.0	52.7	10.2	6.5	11.8	1	5.1
38	Sep 17-23	30.9	20.0	85.3	51.0	11.7	5.6	0.0	0	4.6
39	Sep 24-30	31.7	20.0	89.4	56.3	6.5	5.2	44.1	4	3.6
40	Oct 01-07	31.9	21.5	85.3	50.4	6.4	5.9	2.6	1	4.5
41	Oct 08-14	33.2	21.4	81.6	51.3	5.8	6.4	1.2	0	4.1
42	Oct 15-21	32.7	21.3	81.6	50.4	4.1	7.3	60.4	2	5.0
43	Oct 22-28	31.8	19.8	77.3	42.1	6.5	8.3	0.0	0	5.2
44	Oct 29-Nov 04	30.9	19.5	85.7	49.3	5.1	7.2	0.3	0	4.4
45	Nov 05-11	31.8	15.4	64.9	30.4	4.4	9.3	0.0	0	4.8
46	Nov 12-18	31.5	15.5	69.9	31.1	4.3	9.6	0.0	0	4.9
47	Nov 19-25	30.6	13.4	71.1	36.3	4.5	9.9	0.0	0	4.8
48	Nov 26- Dec 02	29.7	18.2	78.6	49.7	6.7	3.0	0.0	0	3.7
49	Dec 03-09	31.3	14.0	76.6	34.6	3.1	8.7	0.0	0	4.1
50	Dec 10-16	30.8	15.5	83.7	39.6	3.2	6.9	0.0	0	4.2
51	Dec 17-23	29.3	11.5	83.9	32.4	3.6	8.7	0.0	0	3.4
52	Dec 24-31	30.4	12.3	68.1	27.8	3.2	8.8	0.0	0	3.8
Total or Average		31.29	17.53	79.31	42.84	5.58	7.33	120.4	8	70.2

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## **ABSTRACT**

A field experiment entitled “**Nutrient management in *Rabi* Sunflower (*Helianthus annuus. L*) in relation to different tillage practices imposed during *Khariif*” was conducted at Research farm, RARS, Bijapur on a clayey soil with strongly alkaline in reaction, low in organic carbon, nitrogen and phosphorus & medium in potassium during *rabi* season of 2011 with an objective to study the effect of different tillage practices and nitrogen sources on sunflower growth, yield and economics. The treatments consist of three tillage practices (Conventional tillage (**T<sub>1</sub>**), Reduced tillage (**T<sub>2</sub>**) and Minimum tillage (**T<sub>3</sub>**) as main plots and five nutrient management practices (**N<sub>1</sub>**- In-situ Sunnhemp green manure incorporation @ 5 t ha<sup>-1</sup>, **N<sub>2</sub>**- In- situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through urea, **N<sub>3</sub>**-100% RDF through fertilizer(35:50:35 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg ha<sup>-1</sup>), **N<sub>4</sub>**- Farmer’s practice (24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) and **N<sub>5</sub>**- Farmer’s practice + In situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup>) as sub plots. The experiment was laid out in split plot design and replicated thrice.**

The results of the experiment revealed that tillage practices had no significant effect on growth and yield of sunflower crop. Interaction effect due to tillage and nutrient management was also non significant except for dry matter at 20DAS.

Among the three tillage practices, dry matter production only during the initial stages was significantly higher with reduced tillage (**T<sub>2</sub>**) over conventional (**T<sub>1</sub>**) and minimum tillage (**T<sub>3</sub>**).

The yield attributes *viz.*, number of seeds per head and seed weight per head was significantly higher with minimum tillage (**T<sub>3</sub>**) while tillage practices did not have significant influence on rest of the yield attributes, seed yield and stalk yield.

Sunflower fertilized with 100% RDF through fertilizer (**N<sub>3</sub>**) recorded significantly higher germination percentage, plant height, number of leaves, LAI and dry matter production over rest of the treatments while being on par with **N<sub>2</sub>**(In- situ

Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through fertilizer) in most of the parameters mentioned above.

Head diameter was significantly higher with 100% RDF through fertilizer (N<sub>3</sub>) but on par with N<sub>2</sub> and N<sub>1</sub> and number of seeds per head was higher with 100% RDF through fertilizer (N<sub>3</sub>), but on par with N<sub>2</sub>. While test weight was higher with 100% RDF through fertilizer (N<sub>3</sub>) but on par with N<sub>1</sub>(In -situ Sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup>) and N<sub>2</sub>(In- situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDF through fertilizer). Seed and stalk yield of sunflower were significantly higher with 100% RDF through fertilizer (N<sub>3</sub>) over N<sub>4</sub>-Farmers' practice (24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) but was on par with rest of the treatments. NPK content in plant and NPK uptake by sunflower were higher with 100% RDF through fertilizer (N<sub>3</sub>). Maximum gross returns (38061Rs ha<sup>-1</sup>), net returns (28729Rs ha<sup>-1</sup>) and benefit-cost ratio (3.08) were recorded with minimum tillage along with 100% RDF through fertilizer (T<sub>3</sub>N<sub>3</sub>). Interaction effect on growth and yield attributes was not significant.

From the present investigation, it is inferred that sunflower cultivation is successful with minimum tillage of one harrowing followed by one herbicide (Pendimethalin @ 1 kg a.i ha<sup>-1</sup>) spray after sowing with 100% RDF through fertilizer during *rabi* season in northern dry zone of Karnataka (Bijapur). A few more years of field testing is however necessary before making it a general recommendation for similar agro-climatic conditions of Bijapur.

## Chapter I

# INTRODUCTION

Agriculture is the backbone of Indian economy as nearly 60 % of the population depends directly or indirectly on agriculture. Agriculture and allied sectors are providing 52% of the gainful employment in India. In India, rainfed agriculture occupies nearly 58% of the cultivated area, contributes 40% of the country's food production and supports 40% of the human and 60% of the livestock population. Much of the acreage under coarse cereals (85%), pulses (83%) and oilseeds (70%), substantial area under rice (42%) and nearly 65% of the cotton area is rainfed (Venkateswarlu and Prasad, 2012).

Oilseeds play an important role in agricultural economy of India. Oilseeds are important next only to food grains in terms of area, production and value (Hegde, 2012). Oilseeds rank second next to food grains for fulfilling the energy requirements. Yet, the production of oilseeds in India is below the target levels. The shortage of edible oils has become a problem in India with increasing demographic pressure. During 2010-11, the country imported about 9.2 m t of vegetable oils costing around Rs. 38,000 crores (Hegde, 2012). Sunflower can play a key role in meeting out the shortage of edible oils in the country. Among oilseed crops, sunflower has gained much popularity and the area under its cultivation is gradually increasing because of its short duration, photo-insensitivity, wider adaptability to different agro-climatic regions and soil types. In addition to higher seed multiplication ratio, its good quality oil containing more of unsaturated fatty acids and anti-cholesterol property, its tolerance to drought and production of more oil per unit area and unit time than any other oilseed crops makes it a potential oilseed crop especially under rainfed conditions.

Sunflower is native of Southern United States and Mexico. It was introduced in India during the year 1965. It has been cultivated on a commercial scale from 1975-76 onwards. It has now replaced several less profitable crops and has been suggested as a contingent crop under adverse climatic conditions, as an intercrop and as a catch crop in multiple cropping systems. The total area under sunflower cultivation in India during 2009-2010 was 1.48 m ha with a production of 0.85 m t with an average productivity of 576 kg ha<sup>-1</sup> (GOI, 2011) which is substantially lower than the world average (1424 kg

ha<sup>-1</sup>). In Andhra Pradesh, it covers an area of 3.5 lakh hectares with a production of 2.7 lakh tonnes with an average productivity of 771 kg ha<sup>-1</sup> (GOI, 2011).

Despite the impressive strides in acreage and production over the last two decades, the productivity of sunflower remained low (576 kg ha<sup>-1</sup>). The major factors attributing to less productivity of sunflower in India are that the crop is grown on marginal lands with low organic matter and poor fertility under rainfed conditions and inadequate application of major nutrients like nitrogen based on soil test and crop response values.

Nitrogen application significantly improves the yield (Singh *et al.*, 1987). Nitrogen is a major essential element responsible for increasing the photosynthetic surface area and in turn increases the translocation of photosynthates to sink and results in increased productivity. Chemical fertilizers have had a substantial impact on yield increments in the recent past, and are today an indispensable part of modern agriculture. Chemical fertilizers commonly supply only major nutrients whereas organic manures supply both micro and macro nutrients. Besides supplying nutrients, organic matter contributes in several ways *viz.*, improvement in soil organic carbon content, soil physical properties, water retention capacity and microbial activity. As soils under rainfed condition are low in organic carbon status, there is a need to enhance application of organic matter for improving productivity.

In recent years, there has been renewed focus on resource conservation technologies, *viz.*, reduced tillage, maintenance of vegetative cover and crop rotation, which in totality are called conservation agricultural practices (Venkateswarlu *et al.*, 2010). Conservation tillage reduces the cost of cultivation, controls erosion and compaction. Conservation tillage systems improve land productivity by way of improved soil physical properties, reduced soil loss and enhanced soil organic carbon and greater retention of moisture (Nyakatawa *et al.*, 2001). Incorporation of organic matter (green manure) influences the soil fertility status by nitrogen fixation, reducing erosion, increasing water holding capacity and controlling weed growth (Sharma *et al.*, 2004; Sharma *et al.*, 2010). Traditional sources of organic manure like FYM are becoming scarce as it is being used as a source of fuel. Under these circumstances, appropriate agronomic practices have to be followed for on farm generation and use of organic manures such as green manuring for stimulating various biological transformations in soil leading to improved soil fertility and sustainability. However, organic manures alone cannot fulfill the heavy nutrient demand of an intensive cropping

system because of its low nutrient content and slow nutrient release vis-à-vis fertilizers. In some of the deep black soils, cropping is restricted to *rabi* due to the difficulty in working during the *kharif* season. However, farmers do take up repeated harrowing for conserving moisture whenever the moisture conditions permit. The number of ploughings under such conditions often exceeds 6-7, when we consider the summer ploughing and other tillage measures. In recent years, it has been proved that repeated tillage measures are not beneficial. Black soil situation provide scope for introducing a green manure crop like Sunnhemp, which can contribute nitrogen for succeeding crop besides contributing positively for soil organic carbon improvement. Nitrogen contribution from green manure crop reduces the fertilizer nitrogen requirement for succeeding crop and utilizes the resources efficiently. Jeyabal and Palaniappan (2000) reported significant response of sunflower to INM than either inorganic or organic sources of nutrients. The information on different tillage systems in conjunction with integrated use of nitrogen during *Rabi* season on sunflower is inadequate.

Keeping these points in view, the present investigation “**Nutrient management in *Rabi* sunflower (*Helianthus annuus. L*) in relation to different tillage practices imposed during *Kharif*.” was conducted during *Rabi*, 2011 with the following objectives.**

1. To study the effect of different tillage practices followed in *Kharif* on *Rabi* sunflower growth, development and yield.
2. To study the effect of different sources of nitrogen on sunflower growth and yield.
3. To evaluate the interaction effect and the economics of different treatment combinations.

## CHAPTER II

# REVIEW OF LITERATURE

The literature pertaining to the present study entitled “**Nutrient management in Rabi sunflower (*Helianthus annuus. L*) in relation to different tillage practices imposed during *Kharif*” is presented in this chapter under following heads. Since the related literature on sunflower is meagre, the available literature on other arable crops is collected.**

- 2.1 Effect of tillage practices on growth of sunflower and other arable crops
- 2.2 Effect of tillage practices on yield attributes and yield of sunflower and other crops
- 2.3 Effect of tillage practices on physical and chemical properties of soil
- 2.4 Effect of different sources of nitrogen on growth of sunflower and other arable crops
- 2.5 Effect of different sources of nitrogen on yield attributes and yield of sunflower and other arable crops
- 2.6 Effect of different sources of nitrogen on physical and chemical properties of soil
- 2.7 Effect of tillage practices and sources of nitrogen on economics of sunflower and other arable crops.

## **2.1 EFFECT OF TILLAGE PRACTICES ON GROWTH OF SUNFLOWER AND OTHER ARABLE CROPS**

### **2.1.1 Plant height**

Murillo *et al.* (1998) while studying the effect of tillage systems on growth of sunflower found that plant height was higher in traditional tillage(burning the straw of preceding crop and mould board ploughing to 25-30 cm depth) than the conservation tillage( leaving the straw and chiseling to 25-30cm depth) in clay loam soil of Spain.

Pawar *et al.* (2009) reported significantly higher plant height of sorghum with disc ploughing than mould board ploughing and shallow ploughing in deep black soil of Rahuri.

In a study on effect of tillage, weed control and legume mulching in maize-wheat sequence, Sharma *et al.* (2010) reported that conventional tillage resulted in significantly higher plant height of maize whereas plant height of wheat was not significantly affected in silty loam soil of Dehradun.

### **2.1.2 LAI**

Murillo *et al.* (1998) while studying the effect of tillage systems on growth of sunflower, revealed that LAI was higher in traditional tillage than the conservation tillage.

### **2.1.3 Days to 50 % flowering**

Pawar *et al.* (2009) while studying tillage practices and green leaf manuring on sorghum, reported no significant effect of tillage practices on days to 50 % flowering in a deep black soil of Rahuri.

### **2.1.4 Dry Matter Production**

Basavarajappa *et al.* (2002) reported significantly higher total dry matter production of foxtail millet with medium tillage (15 cm deep) with ridging.

Gupta *et al.* (2011) in a study to assess the performance of zero and conventional tillage under various fertility levels and time of nitrogen application to wheat, reported that tillage systems could not significantly influence the dry matter production at different growth stages in a sandy clay loam soil of Jammu.

## **2.2 EFFECT OF TILLAGE PRACTICES ON YIELD ATTRIBUTES AND YIELD OF SUNFLOWER AND OTHER ARABLE CROPS**

### **2.2.1 1000 seed weight (Test weight)**

Basavarajappa *et al.* (2002) reported significantly higher 1000 seed weight of foxtail millet with medium tillage with ridging.

Murillo *et al.* (1998) reported no significant effect of tillage systems on 1000 seed weight of sunflower.

Pawar *et al.* (2009) reported highest 1000 seed weight of sorghum with disc ploughing which was at par with mould board ploughing in a deep black soil of Rahuri.

Meena (2010) in a study to determine the effective tillage and nutrient management in wheat, found significantly higher test weight of wheat with zero tillage (planting with

zero-till seed drill) than conventional tillage( 1 harrowing + cultivator twice) and farmer's practice( cultivator twice + planking) in a heavy textured soil of Bundi, Rajasthan.

Sharma *et al.* (2010) in a study on effect of tillage, weed control and legume mulching in maize-wheat sequence, reported that 1000 grain weight of maize and wheat was not significantly affected by tillage systems in silty loam soil of Dehradun.

Gupta *et al.* (2011) in a study to assess the performance of zero and conventional tillage under various fertility levels and time of nitrogen application to wheat, reported that tillage systems did not influence the 1000 grain weight significantly in a sandy clay loam soil of Jammu.

### **2.2.2 Seed yield**

Murillo *et al.* (1998) found no significant difference in the sunflower yields while studying tillage systems on sandy clay loam soil of Spain.

Basavarajappa *et al.* (2002) reported significantly higher foxtail millet grain yield with medium tillage with ridging than medium tillage and shallow tillage in shallow alfisol at Hanumanamatti, Karnataka.

While assessing the influence of tillage system and nitrogen fertilizer rates, Bellido *et al.* (2003) found that tillage system exerted significant effect only on grain N concentration but did not affect grain yield of sunflower in vertisol of southern Spain.

Nimbole *et al.* (2005) in a study on integrated nutrient management and tillage practices for castor-sorghum crop rotation, reported that tillage systems did not influence the grain yields of castor and sorghum thereby, significantly reducing one summer ploughing in a loamy sand soil of Gunegal in Rangareddy district.

In a study conducted to find out the impact of tillage practices on maize, Sharma *et al.* (2009) reported that grain yield in conventional and minimum tillage were statistically at par but superior to no tillage in sandy loam soil of Jammu.

While studying tillage practices and green leaf manuring, Pawar *et al.* (2009) reported significantly higher grain yield of sorghum with disc ploughing in a deep black soil of Rahuri.

In a study to determine the effective tillage and nutrient management in wheat, Meena (2010) reported that tillage system did not significantly influence the grain yields of wheat in a heavy textured soil of Bundi, Rajasthan.

In a study on effect of tillage, weed control and legume mulching in maize-wheat sequence, Sharma *et al.* (2010) reported that conventional tillage resulted in significantly higher grain yield of maize whereas wheat grain yield was not significantly affected by tillage systems in silty loam soil of Dehradun.

In a study on effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system, Singh *et al.* (2011) reported significantly higher maize and wheat grain yields with conventional tillage in a silty loam soil of Dehradun.

Gupta *et al.* (2011) reported that tillage systems did not significantly influence the grain yields of wheat in a sandy clay loam soil of Jammu.

### **2.2.3 Stalk yield**

Basavarajjappa *et al.* (2002) reported significantly higher foxtail millet straw yield with medium tillage with ridging than medium tillage and shallow tillage in shallow alfisol at Hanumanamatti, Karnataka.

Pawar *et al.* (2009) reported significantly higher stover yield of sorghum with disc ploughing in a deep black soil of Rahuri.

Tillage system did not significantly influence the straw yield of wheat in a heavy textured soil of Bundi, Rajasthan (Meena, 2010).

Sharma *et al.* (2010) reported that conventional tillage resulted in significantly higher stover yield of maize, whereas wheat straw yield was not significantly affected by tillage systems in silty loam soil of Dehradun.

In a study on effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system, Singh *et al.* (2011) reported significantly higher maize and wheat straw yields with conventional tillage in a silty loam soil of Dehradun.

Gupta *et al.* (2011) reported that tillage systems did not significantly influence the straw yields of wheat in a sandy clay loam soil of Jammu.

### **2.2.4 Harvest Index**

Basavarajjappa *et al.* (2002) reported significantly higher harvest index of foxtail millet with medium tillage with ridging than medium tillage and shallow tillage in shallow alfisol at Hanumanamatti, Karnataka.

Meena (2010), in a study to determine the effective tillage and nitrogen management in wheat, found that tillage systems did not have significant effect on harvest index of wheat in a heavy textured soil of Bundi, Rajasthan.

### **2.2.5 Oil content**

Murillo *et al.* (1998) found no significant effect of tillage on oil content of sunflower grown on sandy clay loam soil of Spain.

## **2.3 EFFECT OF TILLAGE PRACTICES ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL**

### **2.3.1 Bulk density**

Meena (2010) found that tillage systems did not have significant effect on bulk density of soil when wheat was grown in a heavy textured soil of Bundi, Rajasthan.

### **2.3.2 Moisture content**

Aase and Schaefer (1996) reported greater water storage under no tillage and minimum tillage than under conventional tillage. Similar results were reported by Peterson *et al.* (1996), Halvorson (1990), McGee *et al.* (1997), Tanaka and Anderson (1997).

In a study to find out the impact of tillage practices on maize, Sharma *et al.* (2009) reported that no tillage retained highest moisture followed by minimum tillage in sandy loam soil of Jammu.

Sharma *et al.* (2010) reported that residual moisture content after harvest of maize was not significantly affected by tillage systems in silty loam soil of Dehradun

Singh *et al.* (2011) reported significantly higher moisture content at harvest of maize with conventional tillage in a silty loam soil of Dehradun in Maize-wheat sequence.

Gupta *et al.* (2011) assessed the performance of zero and conventional tillage under various fertility levels and time of nitrogen application. They reported that zero tillage retained higher values of available soil moisture in soil profile in a sandy clay loam soil of Jammu grown with wheat.

### **2.3.3 Nutrient uptake**

According to Murillo *et al.* (1998) tillage systems did not have significant effect on the uptake of nitrogen, phosphorus and potassium in sunflower grown on sandy clay loam soil of Spain.

Bellido *et al.* (2003), while assessing the influence of tillage system and nitrogen fertilizer rates, found that tillage system exerted significant effect only on grain N concentration but did not affect total nitrogen uptake of sunflower in vertisol of southern Spain.

Sharma *et al.* (2010) reported that conventional tillage resulted in significantly higher nitrogen uptake of maize, whereas uptake of nitrogen by wheat was not significantly affected in silty loam soil of Dehradun.

Singh *et al.* (2011) reported significantly higher uptake of nitrogen, phosphorus and potassium by maize and wheat with conventional tillage in a silty loam soil of Dehradun.

### **2.3.4 Available nutrient status**

According to Murillo *et al.* (1998) tillage systems did not have significant effect on available nitrogen in soil, whereas available phosphorus was significantly higher with conservation tillage than traditional tillage and available potassium was significantly higher with traditional tillage.

Meena (2010) found significantly higher available nitrogen in soil after harvest of wheat with zero tillage than conventional tillage and farmer's practice but no significant effect on available phosphorus and potassium in a heavy textured soil of Bundi, Rajasthan.

Gupta *et al.* (2011) revealed that tillage systems did not significantly influence the available nitrogen, phosphorus and potassium after wheat in a sandy clay loam soil of Jammu.

### **2.3.5 Organic carbon**

Meena (2010) found significantly higher organic carbon in soil after harvest of wheat with zero tillage than conventional tillage and farmer's practice in a heavy textured soil of Bundi, Rajasthan.

## **2.4 EFFECT OF DIFFERENT SOURCES OF NITROGEN ON GROWTH OF SUNFLOWER AND OTHER ARABLE CROPS**

### **2.4.1 Germination %**

Byrareddy *et al.* (2008) observed highest germination percentage in sunflower with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50%RDF +50%N through FYM.

### **2.4.2 Plant height**

In an investigation on effect of crop residue recycling, Bellaki *et al.* (1997) reported that plant height of sorghum was not influenced by the crop residue treatments in a clay soil of Bijapur.

Chinnamuthu *et al.* (2004) in a study on effect of preceding *kharif* legumes on *rabi* sunflower, reported significantly higher plant height of sunflower when it was followed by groundnut than urdbean, mungbean, soybean or fallow in sandy loam soil of Coimbatore.

Aruna and Mohammad (2005) while testing the residual effect of nutrients in rice-sunflower sequence, reported that highest plant height of sunflower was recorded with 75 % of N through fertilizer and 25 % N through sunnhemp on sandy loam soil of Hyderabad.

Sumathi and Rao (2007) in a study on optimum combination of organics and inorganic, reported significantly higher plant height of sunflower where entire dose of nitrogen was supplied with urea, which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Byrareddy *et al.* (2008) recorded highest plant height in sunflower at 30, 60 and 90 DAS with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50%RDF +50%N through FYM.

Pawar *et al.* (2009) while studying tillage practices and green leaf manuring on sorghum, reported significantly higher plant height with green leaf manuring of *Glyricidia* in a deep black soil of Rahuri.

Gogoi *et al.* (2010) assessed the influence of integrated nutrient management in rainfed rice-niger sequence and found significantly higher plant height of niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

Sharma *et al.* (2010) reported that beneficial effect of live mulching with sunnhemp or leucaena was similar, while their combined application increased plant height of maize and wheat significantly in silty loam soil of Dehradun.

#### **2.4.3 Number of leaves per plant**

Byrareddy *et al.* (2008) observed highest number of leaves per plant in sunflower at 30, 60 and 90 DAS with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50%RDF +50%N through FYM.

#### **2.4.4 LAI**

Sumathi and Rao (2007) in a study on optimum combination of organics and inorganic, reported significantly higher LAI of sunflower where entire dose of nitrogen was supplied with urea, which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Sujatha *et al.* (2008) reported that sunnhemp green manuring resulted in significantly high LAI of maize over cowpea green manuring grown on black clayey soil of Dharwad, Karnataka.

#### **2.4.5 Dry Matter Production**

Shylaja *et al.* (2003) reported highest dry matter production of sunflower with 3 t ha<sup>-1</sup> of poultry manure, which was on par with 1 t ha<sup>-1</sup> of poultry manure + 75 % recommended dose of fertilizer in sandy clay loam soil of Hyderabad.

Kumar *et al.* (2007) reported highest dry matter accumulation of maize with vermicompost @ 2.5 t ha<sup>-1</sup> which was on par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

Sumathi and Rao (2007) reported significantly higher dry matter production of sunflower where entire dose of nitrogen was supplied with urea which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Sujatha *et al.* (2008) obtained significantly higher total dry matter production of maize at harvest with sunnhemp green manuring over cowpea green manuring grown on black clayey soil of Dharwad, Karnataka.

#### **2.4.6 Days to 50 % flowering**

Pawar *et al.* (2009), while studying tillage practices and green leaf manuring on sorghum, reported no significant effect of green manures on days to 50 % flowering in a deep black soil of Rahuri

### **2.5 EFFECT OF DIFFERENT SOURCES OF NITROGEN ON YIELD AND YIELD ATTRIBUTES OF SUNFLOWER AND OTHER ARABLE CROPS**

#### **2.5.1 Flower head (Capitulum) diameter**

Chinnamuthu *et al.* (2004), in a study on effect of preceding *kharif* legumes on *rabi* sunflower reported significantly higher head diameter in sunflower when it was followed by groundnut than urdbean, mungbean, soybean or fallow in sandy loam soil of Coimbatore.

Aruna and Mohammad (2005) while testing the residual effect of nutrients in rice-sunflower sequence, reported larger head of sunflower with 75 % of N through fertilizer and 25 % N through sunnhemp on sandy loam soil of Hyderabad.

Mahavishnan *et al.* (2006) in a study on residual effect of integrated nutrient management in cotton-sunflower sequence reported highest capitulum size in sunflower fertilized with 50 % recommended dose of fertilizer (40:20:20 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) + FYM @12 t ha<sup>-1</sup> + mungbean intercrop incorporation which was on par with treatment without mungbean intercrop incorporation in a sandy loam soil of IARI at New Delhi.

Sumathi and Rao (2007) reported significantly larger head of sunflower where entire dose of nitrogen was supplied through urea, which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Byrareddy *et al.* (2008) observed larger head in sunflower with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50%RDF +50%N through FYM.

#### **2.5.2 Filled seeds per capitulum**

While testing the residual effect of nutrients in rice-sunflower sequence, Aruna and Mohammad (2005) reported highest number of filled seeds per head in sunflower with 75 % level of N through fertilizer and 25 % N through sunnhemp on sandy loam soil of Hyderabad.

Sumathi and Rao (2007), in a study on optimum combination of organics and inorganic, reported significantly higher filled seeds per head of sunflower where entire dose of nitrogen was supplied through urea which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Gogoi *et al.* (2010) in a study to assess the influence of integrated nutrient management under rainfed rice-niger sequence found significantly higher number of seeds per capitulum of niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

### **2.5.3 Seed filling percentage**

Byrareddy *et al.* (2008) observed highest seed filling percentage in sunflower with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50%RDF +50%N through FYM.

### **2.5.4 Seed weight per capitulum**

Mahavishnan *et al.* (2006) in a study on residual effect of integrated nutrient management in cotton-sunflower sequence, reported higher seed weight per capitulum in sunflower fertilized with 50 % recommended dose of fertilizer + FYM @12 t ha<sup>-1</sup> + mungbean intercrop incorporation

### **2.5.5 1000 seed weight**

Bellaki *et al.* (1997), in an investigation on effect of crop residue recycling reported that 1000 grain weight of sorghum was highest with recommended dose of fertilizer which was at par with incorporation of sorghum stubbles @ 5 t ha<sup>-1</sup> in alternate year in a clay soil of Bijapur.

Chinnamuthu *et al.* (2004) in a study on effect of preceding *kharif* legumes on *rabi* sunflower, reported significantly higher 100 seed weight of sunflower when it was followed by groundnut than urdbean, mungbean, soybean or fallow in sandy loam soil of Coimbatore.

Vani and Bheemaiah (2003), in a study on cropping systems and integrated nutrient management practices, reported highest test weight of castor with *Leucaena* green leaf manuring @ 5 t ha<sup>-1</sup> which was at par with *Albizia* green leaf manuring @ 5 t ha<sup>-1</sup> at Hyderabad.

Aruna and Mohammad (2005) while testing the residual effect of nutrients in rice-sunflower sequence, recorded highest 1000 seed weight in sunflower with 75 % level of N through fertilizer and 25 % N through sunnhemp on sandy loam soil of Hyderabad.

Kumar *et al.* (2007) reported highest 100 seed weight of maize with vermicompost @ 2.5 t ha<sup>-1</sup> which was on par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

Sujatha *et al.* (2008) reported that 100 grain weight of maize was not influenced by cowpea or sunnhemp green manuring being grown on black clayey soil of Dharwad, Karnataka.

Sumathi and Rao (2007) in a study on optimum combination of organics and inorganic, reported significantly higher 1000 seed weight of sunflower where entire dose of nitrogen was supplied through urea which was on par with that supplied of 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

While studying tillage practices and green leaf manuring, Pawar *et al.* (2009) reported no significant effect of green manures on 1000 seed weight of sorghum in a deep black soil of Rahuri.

In a study to assess the influence of integrated nutrient management under rainfed rice-niger sequence, Gogoi *et al.* (2010) found significantly higher 1000 seed weight of niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

In a study on conjunctive use of *Leucaena* lopping and *Azotobacter* with graded levels of fertilizers in maize, Dhoke *et al.* (2010) reported highest test weight with 100 % recommended dose of fertilizers which was at par with 75 % recommended dose of fertilizers + *Leucaena* lopping (2.6 t ha<sup>-1</sup>) + *Azotobacter* seed treatment @ 25 g kg<sup>-1</sup> seed in a clayey soil of Akola.

Sharma *et al.* (2010), in a study on effect of tillage, weed control and legume mulching in maize-wheat sequence reported that live mulching with sunnhemp or *leucaena* and their combined application resulted in significantly higher test weight of maize and whereas combined application of sunnhemp and *leucaena* resulted in significantly higher 1000 grain weight of wheat in silty loam soil of Dehradun.

### 2.5.6 Seed yield

In an investigation on effect of crop residue recycling, Bellaki *et al.* (1997) reported that grain yield of sorghum was highest with subabul loppings @ 5 t ha<sup>-1</sup> every year which was at par with recommended dose of fertilizer in a clay soil of Bijapur.

Khatik and Dikshit (2001) evaluated the significance of integrated use of inorganic fertilizers with organic manures. They reported higher seed yield of sunflower with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> and 100 % inorganic in a clay loam soil of Jabalpur.

Kavitha and Lakshmi (2002) investigated the effect of different sources of nitrogen in sunflower and revealed that significantly higher seed yield was obtained when 50 % nitrogen was supplied through vermicompost and 50 % nitrogen in the form of urea on sandy loam soil of Hyderabad.

Sharma *et al.* (2002) in their study on effect of conjunctive use of inorganic and organic sources of nutrients on grain sorghum, reported highest grain yield with urea which was on par with urea + leucaena (1:1 ration on N basis) and urea + gliricidia (1:1 ration on N basis) in alfisol of Hyderabad.

Guled *et al.* (2003) stated that high grain yield of sorghum was recorded with application of FYM in combination with farmer's practice which was on par with in situ incorporation of sunnhemp with farmer's practice of 63 kg urea and 63 kg DAP on clayey soil of Bijapur.

Chinnamuthu *et al.* (2004) evaluated the effect of preceding *kharif* legume on *rabi* sunflower and reported significantly higher seed yield of sunflower when it was followed by groundnut than urdbean, mungbean, soybean or fallow in sandy loam soil of Coimbatore.

Vanaja and Raju (2004) reported that green manuring with cowpea or pillipesara resulted in significantly higher seed yield of sunflower compared to no green manuring in all treatments over control in a sandy loam soil of Hyderabad.

In a study on cropping systems and integrated nutrient management practice, Vani and Bheemaiah (2003) reported higher seed yield of castor with *Leucaena* green leaf manuring @ 5 t ha<sup>-1</sup> which was at par with *Albizia* green leaf manuring @ 5 t ha<sup>-1</sup> at Hyderabad.

While testing the residual effect of nutrients in rice-sunflower sequence, Aruna and Mohammad (2005) recorded highest seed yield of sunflower with 75 % level of N through fertilizer and 25 % N through FYM which was on par with 75 % level of N through fertilizer and 25 % N through Glyricidia on sandy loam soil of Hyderabad.

In a study on integrated nutrient management and tillage practices for castor-sorghum crop rotation, Nimbole *et al.* (2005) reported that supplying 50 % of recommended nitrogen to the castor and sorghum through compost or gliricidia lopping and 50 % through inorganic fertilizer resulted in yield at par with 100 % inorganic N in a loamy sand soil of Gunegal, Rangareddy district.

Paneer Selvam and Bheemaiah (2005) reported highest yield of sunflower with subabul green leaf manure @ 5 t ha<sup>-1</sup> + 30 kg N ha<sup>-1</sup> in sandy loam soil of Hyderabad.

Sarawad *et al.* (2005) reported that application of 15 kg N through sunnhemp + 20 kg N through fertilizer recorded highest sorghum grain yield.

In a study on effect of compost, green leaf manure of subabul and chemical fertilizer alone or in combination with organic residues in maize-blackgram sequence, Laddha *et al.* (2006) revealed that application of 15 kg nitrogen through compost plus 10 kg nitrogen through urea gave highest yield of maize and subsequent blackgram which was on par with 15 kg nitrogen through subabul green leaf manure plus 10 kg nitrogen through urea in an inceptisol of Arija, Rajasthan.

In a study on residual effect of integrated nutrient management in cotton-sunflower sequence, Mahavishnan *et al.* (2006) reported highest seed yield in sunflower fertilized with 50 % recommended dose of fertilizer + FYM @ 12 t ha<sup>-1</sup> + Mungbean intercrop incorporation which was on par with treatment without mungbean intercrop incorporation in a sandy loam soil of IARI at New Delhi.

Kumar *et al.* (2007) reported highest grain yield of maize with vermicompost @ 2.5 t ha<sup>-1</sup> which was on par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

Byrareddy *et al.* (2008) reported highest grain yield in sunflower with 100% RDF (62.5:75:62.5 N: P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>) which was on par with 50% RDF +50% N through FYM.

Sujatha *et al.* (2008) reported significantly higher maize grain yield with sunnhemp green manuring over cowpea green manuring grown on black clayey soil of Dharwad, Karnataka.

Maheswari *et al.* (2008) reported highest seed yield of castor with 50 % N through inorganic and 50 % through compost and 75 % N through inorganic and 25 % through Glyricidia in red sandy loam soil of Anantapur.

In a study on integrated effect of graded levels of fertilizer and green manure on sustainability of yields in rice-wheat system, Kumar and Prasad (2008) found higher grain yield of wheat with direct and residual effects of 75 % NPK through fertilizer + green manuring (green gram) than 100 % NPK through fertilizer in a clay loam soil of Pusa, Bihar.

While studying appropriate combination of organic and inorganic sources, Bombale *et al.* (2009) reported highest seed yield of sunflower with 75 % recommended dose of nitrogen + 2.5 t vermicompost ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed which was at par with 75 % recommended dose of nitrogen + 5 t FYM ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed and recommended dose of fertilizer in clayey soil of Akola.

Deshmukh *et al.* (2009) reported highest grain yield of sorghum and wheat with 50 % recommended dose of fertilizer supplied through inorganic source and 50 % through FYM which was at par with 50 % recommended dose of fertilizer supplied through inorganic source and 50 % through subabul loppings in a vertisol of Akola in sorghum-wheat sequence.

In a study on effect of insitu moisture conservation and integrated nutrient management in sunflower, Paulpandi *et al.* (2009) reported significantly higher seed yield when 75 % nitrogen was supplied through inorganic + 25 % nitrogen through composted coir pith + Azophos +0.2 % boron in clay loam soil of Aruppukkotai of Tamilnadu.

Pawar *et al.* (2009), while studying tillage practices and green leaf manuring reported highest grain yield of sorghum with Glyricidia that was at par with Sunnhemp in a deep black soil of Rahuri.

Shirale and Khating (2009), while studying the effect of combined application of organic and inorganic, reported highest grain yield of sorghum with recommended dose of

fertilizer which was at par with 25 % recommended dose of fertilizer + Glyricidia @ 5 t ha<sup>-1</sup> on a vertisol at Parbhani.

In an investigation on effect of organic in sorghum, Tolanur (2009) reported that incorporation of sunnhemp to meet 50 % nitrogen with 50 % recommended dose of nitrogen recorded the highest grain yield of sorghum in vertisol of Bijapur.

In a study to assess the influence of integrated nutrient management under rainfed rice-niger sequence, Gogoi *et al.* (2010) found significantly higher seed yield of niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

Dhoke *et al.* (2010) reported highest maize grain yield with 100 % recommended dose of fertilizers which was at par with 75 % recommended dose of fertilizer + Leucaena lopping (2.6 t ha<sup>-1</sup>) + Azotobacter seed treatment @ 25 g kg<sup>-1</sup> seed in a clayey soil of Akola.

Prasad *et al.* (2010) evaluated the effect of continuous application of chemical fertilization alone and in combination with organic source of nutrients in maize-wheat cropping system and reported significantly higher grain yields of maize, wheat and maize-wheat system under 50 % N through FYM + 50 % through chemical fertilizer than that under 100 % chemical fertilizer and was on par with 25 % N through FYM and 75 % through inorganic source in a sandy clay loam soil of Ranchi.

In a study on effect of tillage, weed control and legume mulching in maize-wheat sequence, Sharma *et al.* (2010) reported that beneficial effect of live mulching with sunnhemp or leucaena was similar, while their combined application increased grain yield of maize and wheat significantly in silty loam soil of Dehradun.

Singh *et al.* (2011) reported significantly higher maize and wheat grain yield with *in situ* grown sunnhemp mulch in a silty loam soil of Dehradun while studying effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system.

### **2.5.7 Stalk yield**

Bellaki *et al.* (1997) reported that fodder yield of sorghum was highest with subabul loppings @ 5 t ha<sup>-1</sup> every year which was at par with incorporation of sorghum stubbles @ 5 t ha<sup>-1</sup> every year in a clay soil of Bijapur.

Khatik and Dikshit (2001) reported higher stalk yield of sunflower with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> and 100 % inorganic in a clay loam soil of Jabalpur.

In a study on residual effect of integrated nutrient management in rice-sunflower cropping system, Vanaja and Raju (2004) reported that green manuring with cowpea or pillipesara resulted in significantly higher stalk yield of sunflower compared to no green manuring in all treatments over control in a sandy loam soil of Hyderabad.

Kumar *et al.* (2007) reported highest stover yield of maize with vermicompost @ 2.5 t ha<sup>-1</sup> which was on par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

In a study on optimum combination of organic and inorganic, Sumathi and Rao (2007) reported significantly higher stalk yield of sunflower where entire dose of nitrogen was supplied with urea which was on par with that under supply of 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Sujatha *et al.* (2008) reported significantly higher maize stover yield with sunnhemp green manuring over cowpea green manuring grown on black clayey soil of Dharwad, Karnataka.

In a study on integrated effect of graded levels of fertilizer and green manure on sustainability of yield in rice-wheat system, Kumar and Prasad (2008) found higher stalk yield of wheat with direct and residual effects of 100 % NPK through fertilizer which was at par with 75 % NPK through fertilizer + green manuring (green gram) in a clay loam soil of Pusa, Bihar.

Bombale *et al.* (2009), while studying appropriate combination of organic and inorganic sources, reported highest stalk yield of sunflower with 75 % recommended dose of nitrogen + 2.5 t vermicompost ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed which was at par with 75 % recommended dose of nitrogen + 5 t FYM ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed and recommended dose of fertilizer in clayey soil of Akola.

In a study on effect of *insitu* moisture conservation integrated nutrient management in sunflower, Paulpandi *et al.* (2009) reported significantly higher stalk yield when 75 % nitrogen was supplied through inorganic + 25 % nitrogen through composted coir pith + Azophos +0.2 % boron in clay loam soil of Aruppukkotai of Tamilnadu.

Pawar *et al.* (2009), while studying tillage practices and green leaf manuring on sorghum, reported no significant effect of green manure on fodder yield in a deep black soil of Rahuri.

Tolanur (2009) investigated the effect of organics in sorghum and reported that incorporation of sunnhemp to meet 50 % nitrogen plus 50 % recommended dose of nitrogen through fertilizer recorded the highest stover yield of sorghum in vertisol of Bijapur.

Gogoi *et al.* (2010) assessed the influence of integrated nutrient management under rainfed rice-niger sequence and found significantly higher stover yield of niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

In a study on conjunctive use of *Leucaena* lopping and *Azotobacter* with graded levels of fertilizer in maize, Dhoke *et al.* (2010) reported highest stover yield with 100 % recommended dose of fertilizer which was at par with 75 % recommended dose of fertilizer + *Leucaena* lopping ( $2.6 \text{ t ha}^{-1}$ ) + *Azotobacter* seed treatment @  $25 \text{ g kg}^{-1}$  seed in a clayey soil of Akola.

Sharma *et al.* (2010) reported that beneficial effect of live mulching with sunnhemp or *leucaena* was similar, while their combined application significantly increased stover yield of maize and wheat in silty loam soil of Dehradun.

In a study on effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system, Singh *et al.* (2011) reported significantly higher maize and wheat straw yields with *in situ* sunnhemp mulch in a silty loam soil of Dehradun.

### **2.5.8 Harvest Index**

Vani and Bheemaiah (2003) in their study on cropping systems and integrated nutrient management practices, reported highest harvest index of castor with *Leucaena* green leaf manuring @  $5 \text{ t ha}^{-1}$  which was at par with *Albizia* green leaf manuring @  $5 \text{ t ha}^{-1}$  at Hyderabad.

Mahavishnan *et al.* (2006) in their study on residual effect of integrated nutrient management in cotton-sunflower sequence, reported no significant effect of various integrated nutrient management treatments in sandy loam soil of IARI, New Delhi.

Sujatha *et al.* (2008) reported that harvest index of maize was not influenced by cowpea or sunnhemp green manuring grown on black clayey soil of Dharwad, Karnataka.

Kumar *et al.* (2007) also found that harvest index of maize was not influenced by various organic sources of nitrogen.

### **2.5.9 Oil content**

Khatik and Dikshit (2001) evaluated the significance of integrated use of inorganic fertilizer with organic manures and reported higher oil content of sunflower with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> and 100 % inorganic in a clay loam soil of Jabalpur.

Kavitha and Lakshmi (2002) evaluated the effect of different sources of nitrogen in sunflower and reported that highest oil content was recorded when 50 % nitrogen was supplied through vermicompost and 50 % nitrogen through urea in sandy loam soil of Hyderabad.

In a study on residual effect of integrated nutrient management in rice-sunflower cropping system, Vanaja and Raju (2004) reported that green manuring with cowpea or pillipesara gave significantly higher oil content in sunflower compared to no green manuring in all treatments over control in a sandy loam soil of Hyderabad.

Sumathi and Rao (2007) evaluated the optimum combination of organic and inorganic and reported significantly higher oil content of sunflower under unfertilized control in sandy loam soil of Tirupati.

Bombale *et al.* (2009), while studying appropriate combination of organic and inorganic sources found no significant effect of sources of nitrogen on oil content in sunflower.

## **2.6 EFFECT OF DIFFERENT SOURCES OF NITROGEN ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL**

### **2.6.1 Bulk density**

Sarawad *et al.* (2005) reported that bulk density of soil reduced with 15 kg N through sunnhemp + 20 kg N through fertilizer compared to entire nitrogen through fertilizer.

Laddha *et al.* (2006) while investigating the effect of compost, green leaf manure of subabul and chemical fertilizer alone or in combination with organic residues in maize-blackgram sequence, revealed no significant effect on bulk density after maize and 15 kg nitrogen through compost with 10 kg nitrogen through urea resulted in higher bulk density after blackgram in an Inceptisol of Arija, Rajasthan.

Sujatha *et al.* (2008) reported that bulk density of soil was not influenced by cowpea or sunnhemp green manuring grown on black clayey soil of Dharwad, Karnataka.

### **2.6.2 Moisture content**

Deshmukh *et al.* (2009) investigated the effect of organic and fertilizer alone and in combinations in sorghum –wheat sequence and reported highest water retention of soil with 50 % recommended dose of fertilizer supplied through inorganic source and 50 % through FYM which was at par with 50 % recommended dose of fertilizer supplied through inorganic source and 50 % through subabul loppings in a vertisol of Akola.

Pawar *et al.* (2009) while studying tillage practices and green leaf manuring reported higher moisture content with glyricidia green leaf manuring than sunnhemp and dhaincha in sorghum in a deep black soil of Rahuri.

Singh *et al.* (2011) while evaluating the effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system, reported significantly higher moisture content at harvest of maize in a silty loam soil of Dehradun.

### **2.6.3 Nutrient uptake**

Khatik and Dikshit (2001) evaluated the significance of integrated use of inorganic fertilizer with organic manures and reported higher uptake of nitrogen and potassium of sunflower with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> and 100 % inorganic, whereas uptake of phosphorus was highest with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> in a clay loam soil of Jabalpur.

Sharma *et al.* (2002) investigated the effect of conjunctive use of inorganic and organic sources of nutrients on grain sorghum and reported highest uptake of nitrogen by sorghum with urea which was on par with urea + leucaena (1:1 ratio on N basis) and urea + gliricidia (1:1 ratio on N basis) in alfisol of Hyderabad.

Guled *et al.* (2003) found that *in situ* incorporation of sunnhemp with farmer's practice of 63 kg urea and 63 kg DAP resulted in highest uptake of nitrogen, phosphorus and potassium on clayey soils of Bijapur.

Shylaja *et al.* (2003) reported highest nitrogen uptake of sunflower with 3 t ha<sup>-1</sup> of poultry manure which was on par with 1 t ha<sup>-1</sup> of poultry manure + 75 % recommended dose of fertilizer in sandy clay loam soil of Hyderabad. Whereas uptake of phosphorus and potassium was highest with 1 t ha<sup>-1</sup> of poultry manure + 75 % recommended dose of fertilizer.

Vani and Bheemaiah (2003) reported that uptake of nitrogen, phosphorus and potassium by castor was significantly higher with *Leucaena* green leaf manuring in alley cropping study conducted at Hyderabad.

Sawale *et al.* (2004) evaluated the effect of sunnhemp on nutrient uptake of cotton and reported highest nitrogen, phosphorus and potassium uptake with 75 % recommended dose of fertilizer + sunnhemp incorporation at 45 or 65 days after sowing at Akola.

Vanaja and Raju (2004) found the residual effect of integrated nutrient management in rice-sunflower cropping system and reported that green manuring with cowpea resulted in significantly higher uptake of nitrogen and potassium in sunflower compared to no green manuring in all treatments over control in a sandy loam soil of Hyderabad.

Aruna and Mohammad (2005) tested the residual effect of nutrients in rice-sunflower sequence and revealed highest uptake of nitrogen by sunflower with 75 % of N through fertilizer and 25 % N through FYM. While highest uptake of phosphorus and potassium was observed with 75 % of N through fertilizer and 25 % N through *Glyricidia* on sandy loam soil of Hyderabad.

Paneer Selvam and Bheemaiah (2005) in their study on integrated nutrient management practices in agroforestry systems reported highest uptake of nitrogen with subabul green leaf manure @ 5 t ha<sup>-1</sup> + 30 kg N ha<sup>-1</sup>, which was on par with recommended dose of nitrogen @ 60 kg ha<sup>-1</sup> in sandy loam soil of Hyderabad.

Sarawad *et al.* (2005) reported that substitution of nitrogen with sunnhemp or compost significantly increased the uptake of nitrogen, phosphorus and potassium.

Kumar *et al.* (2007) reported highest uptake of nitrogen, phosphorus and potassium in maize with vermicompost @ 2.5 t ha<sup>-1</sup> which was on par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

Sumathi and Rao (2007) evaluated the optimum combination of organics and inorganic and reported significantly higher nitrogen uptake of sunflower where entire dose of nitrogen was supplied through urea which was on par with 75 % N through fertilizer + 25 % N through FYM in sandy loam soil of Tirupati.

Kumar and Prasad (2008) in their study on integrated effect of graded levels of fertilizer and green manure on sustainability of yields in rice-wheat system, found significantly higher uptake of nitrogen, phosphorus and potassium by wheat with direct and residual effects of 75 % NPK through fertilizer + green gram green manuring than 100 % NPK through fertilizer in a clay loam soil of Pusa, Bihar.

Bombale *et al.* (2009) while studying appropriate combination of organic and inorganic sources, reported highest nitrogen, phosphorus and potassium uptake of sunflower with 75 % recommended dose of nitrogen + 2.5 t vermicompost ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed which was at par with 75 % recommended dose of nitrogen + 5 t FYM ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed and recommended dose of fertilizer in clayey soil of Akola.

Shirale and Khating (2009) while studying the effect of combined application of organics and inorganic, reported highest uptake of nitrogen and potassium by sorghum with recommended dose of fertilizer which was at par with 25 % recommended dose of fertilizer + Glyricidia @ 5 t ha<sup>-1</sup> on a vertisol at Parbhani whereas highest uptake of phosphorus was seen with 25 % recommended dose of fertilizer + Glyricidia @ 5 t ha<sup>-1</sup>.

In an investigation on effect of organics in sorghum, Tolanur (2009) reported that incorporation of sunnhemp to meet 50 % nitrogen resulted in highest uptake of nitrogen, phosphorus and potassium in stover of sorghum in vertisol of Bijapur whereas recommended dose of fertilizer recorded highest uptake of nitrogen, phosphorus and potassium in grain of sorghum.

Gogoi *et al.* (2010) assessed the influence of integrated nutrient management in rainfed rice-niger sequence and found significantly higher uptake of nitrogen, phosphorus and potassium by niger when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

Prasad *et al.* (2010) evaluated the effect of continuous application of chemical fertilization alone and in combination with organic source of nutrients in maize-wheat cropping system. They reported significantly higher uptake of nitrogen, phosphorus and potassium by maize, wheat and maize-wheat system under 50 % N through FYM + 50 % through chemical fertilizer than 100 % chemical fertilizers and was on par with 25 % N through FYM and 75 % through inorganic source in a sandy clay loam soil of Ranchi.

Sharma *et al.* (2010) investigated the effect of tillage, weed control and legume mulching in maize-wheat sequence and reported that beneficial effect of live mulching with sunnhemp or leucaena was similar, while their combined application significantly increased uptake of nitrogen of maize and wheat in silty loam soil of Dehradun.

Singh *et al.* (2011) evaluated the effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity in maize-wheat cropping system and reported significantly higher uptake of nitrogen, phosphorus and potassium by maize and wheat with *in situ* grown sunnhemp mulch in a silty loam soil of Dehradun.

#### **2.6.4 Available Nutrient status**

Khatik and Dikshit (2001) evaluated the significance of integrated use of inorganic fertilizers with organic manures and reported higher available nitrogen after sunflower with 50 % NPK through inorganic + 10 t compost ha<sup>-1</sup> which was on par with 50 % NPK through inorganic + 10 t FYM ha<sup>-1</sup> and higher available phosphorus with 100 % inorganic in a clay loam soil of Jabalpur.

Shylaja *et al.* (2003) reported increased availability of nitrogen, phosphorus and potassium with sunflower with 1 t ha<sup>-1</sup> of poultry manure + 75 % recommended dose of fertilizer in sandy clay loam soil of Hyderabad

Sawale *et al.* (2004) tested the effect of sunnhemp on nutrient uptake of cotton and reported highest available nitrogen, phosphorus and potassium with 75 % recommended dose of fertilizer + sunnhemp incorporation at 45 or 65 days after sowing at Akola.

Vanaja and Raju (2004) reported that green manuring with cowpea or pillipesara resulted in higher available nitrogen, phosphorus and potassium after harvest. However, significant difference was observed with respect to potassium only compared to no green manuring in all treatments over control in a sandy loam soil of Hyderabad.

Sujatha *et al.* (2008) revealed that sunnhemp green manuring in maize significantly increased the availability of nitrogen, phosphorus but not available potassium in soil.

Kumar and Prasad (2008) reported significantly higher available nitrogen and phosphorus in soil after harvest of wheat with green manuring (green gram) than that of green gram straw incorporation and no green manuring and available potassium was on par with green gram straw incorporation or green gram green manuring in a clay loam soil of Pusa, Bihar.

Bombale *et al.* (2009) reported highest available nitrogen with 75 % recommended dose of nitrogen + 2.5 t vermicompost ha<sup>-1</sup> + Azotobacter seed inoculation @ 25 g kg<sup>-1</sup> seed whereas highest available phosphorus was with recommended dose of fertilizer and highest available potassium was observed with 2.5 t vermicompost ha<sup>-1</sup> after sunflower in clayey soil of Akola.

Gogoi *et al.* (2010) in a study to assess the influence of integrated nutrient management under rainfed rice-niger sequence, found higher available nitrogen, phosphorus and potassium after niger harvest when 50 % recommended dose of fertilizer was supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

### **2.6.5 Organic carbon**

Sharma *et al.* (2002) in a study on effect of conjunctive use of inorganic and organic sources of nutrients on grain sorghum, reported significantly higher organic carbon in soil after sorghum with urea + leucaena (1:1 ratio on N basis) in alfisol of Hyderabad.

Laddha *et al.* (2006) in a study on effect of compost, green leaf manure of subabul and chemical fertilizer alone or in combination with organic residues in maize-blackgram sequence, revealed that application of 15 kg nitrogen through compost plus 20 kg nitrogen through urea resulted in highest soil organic carbon after maize and 15 kg nitrogen through subabul green leaf manure with 10 kg nitrogen through urea after blackgram in an inceptisol of Arija, Rajasthan.

Kumar and Prasad (2008) in a study on integrated effect of graded levels of fertilizer and green manure on sustainability of yields in rice-wheat system, found significantly high organic carbon in soil after harvest of wheat with green manuring (green gram) than that of green gram straw incorporation and no green manuring in a clay loam soil of Pusa, Bihar.

Gogoi *et al.* (2010) in a study to assess the influence of integrated nutrient management under rainfed rice-niger sequence, found significantly higher organic carbon in soil after harvest of niger with 50 % recommended dose of fertilizer supplied through inorganic source and 50 % through FYM in inceptisol of Jorhat.

Prasad *et al.* (2010) evaluated the effect of continuous application of chemical fertilizers alone and in combination with organic source of nutrients in maize-wheat cropping system, reported significantly higher organic carbon in soil supplied with 50 % N through FYM + 50 % through chemical fertilizer than that 100 % chemical fertilizer in a sandy clay loam soil of Ranchi.

## **2.7 EFFECT OF TILLAGE PRACTICES AND SOURCES OF NITROGEN ON ECONOMICS OF SUNFLOWER AND OTHER ARABLE CROPS.**

Desmukh *et al.* (2002) while evaluating the economics of integrated plant nutrient system (IPNS) in maize, reported highest net returns from application of 100% RDF followed by IPNS of 4 t compost or 2 t glyricidia green leaves + top dressing of 20 kg urea.

Gupta *et al.* (2011) in a study to assess the performance of zero and conventional tillage in wheat under various fertility levels and time of nitrogen application, reported that zero tillage method recorded higher net returns at termination of study in a sandy clay loam soil of Jammu.

Aglave *et al.* (2009) while studying performance of sunflower under varied cropping sequence, reported sequence cropping of mungbean-sunflower and urdbean-sunflower gave higher gross and net monetary returns compared to fallow-sunflower sequence at Latur.

Kumar *et al.* (2007) while studying judicious use of organics and inorganic in maize on clay loam soil of Raichur, reported significantly higher net returns and B: C ratio with poultry manure @ 1 t ha<sup>-1</sup> when compared to control and incorporation of sorghum residues @ 5 t ha<sup>-1</sup> but at par with green leaf manuring of pongamia @ 5 t ha<sup>-1</sup>.

According to Sujatha *et al.* (2008) sunnhemp green manuring and poultry manuring with 100 percent RDN recorded higher gross returns, net returns and B: C ratio in maize on a clay loam soil of Dharwad.

Sharma *et al.* (2009) in a study conducted to find out the impact of tillage practices on maize, reported that highest net returns and B: C ratio were obtained with minimum tillage and lowest with conventional tillage in sandy loam soil of Jammu.

Paneer Selvam and Bheemaiah (2005) in a study on integrated nutrient management practices in agroforestry systems, reported that highest net returns and B:C ratio of sunflower were recorded with recommended dose of nitrogen ( $60 \text{ kg ha}^{-1}$ ) and subabul green leaf manure @  $5 \text{ t ha}^{-1} + 30 \text{ kg N ha}^{-1}$  in sandy loam soil of Hyderabad.

Sumathi and Rao (2007) in a study on optimum combination of organics and inorganic, reported higher B:C ratio of sunflower where entire dose of nitrogen was supplied with urea which was on par with 75 percent N through fertilizer + 25 percent N through FYM in sandy loam soil of Tirupati.

Chinnamuthu *et al.* (2004) in a study on effect of preceding *kharif* legumes on *rabi* sunflower reported higher gross returns, net returns and B: C ratio of sunflower when it was followed by groundnut than urdbean, mungbean, soybean or fallow in sandy loam soil of Coimbatore.

Khatik and Dikshit (2001) in a study to evaluate the significance of integrated use of inorganic fertilizers with organic manures, reported higher net returns and B: C ratio of sunflower with 50 percent NPK through inorganic +  $10 \text{ t compost ha}^{-1}$  which was on par with 50 percent NPK through inorganic +  $10 \text{ t FYM ha}^{-1}$  and 100 percent inorganic in a clay loam soil of Jabalpur.

Meena (2010) in a study to determine the effective tillage and nutrient management in wheat, found significantly higher net returns and B: C ratio of wheat with zero tillage than conventional tillage and farmer's practice in a heavy textured soil of Bundi, Rajasthan.

## CHAPTER III

# MATERIAL AND METHODS

The details of the materials used and methods adopted in the present investigation entitled “**Nutrient management in *Rabi* sunflower (*Helianthus annuus. L*) in relation to different tillage practices imposed during *Kharif*” are given under the appropriate headings.**

### 3.1 LOCATION OF THE EXPERIMENTAL SITE

The experiment was conducted at VIII block of the Regional Agricultural Research Station, Bijapur situated in Northern Dry Zone of Karnataka state at 16°49’N latitude, 75 ° 43’ E longitudes and at an altitude of 593.8 m above mean sea level.

### 3.2 WEATHER CONDITIONS DURING THE CROP GROWTH PERIOD

The agro-meteorological data recorded during the crop season of the present experiment (16-09-2011 to 30-12-2011) at the Agro-meteorological observatory, Regional Agricultural Research Station, Bijapur were presented as weekly average temperatures, relative humidity, rainfall and evaporation and bright sunshine hours and wind speed in Appendix I and graphically presented in Figures 3.1, 3.2, 3.3 and 3.4.

The total rainfall received during the crop season was 120.4 mm and total weekly evaporation was 70.2 mm. Weekly mean maximum temperatures recorded during crop season ranged from 29.3°C to 33.2°C. Similarly, weekly mean minimum temperatures noted during crop season varied from 11.5°C to 21.5° C. While the mean RH (I)(07.30 hrs) during the crop growing period varied from 64.9% to 89.4% with an average of 79.31% and the mean RH (II)(14.30 hrs) being 27.8% to 56.3% with an average of 42.84%.

The mean weekly bright sunshine hours varied from 3 to 9.9 hours day<sup>-1</sup> with an average of 7.33 hours day<sup>-1</sup>. Likewise the mean weekly wind speed ranged from 3.1 to 11.7 Km hour<sup>-1</sup> with an average of 5.58 Km hour<sup>-1</sup>.

The mean weekly pan evaporation during the cropping period ranged from 3.4 to 5.2 mm day<sup>-1</sup> with an average of 4.38 mm day<sup>-1</sup>.

### 3.3 SOIL CHARACTERISTICS OF THE EXPERIMENTAL SITE

Soil samples were drawn at random from 0–30 cm soil depth in the experimental field and were analyzed for their physical and chemical properties by adopting standard procedures (Jackson, 1979 and Piper, 1966) and the results are summarized in Table 3.1.

**Table 3.1. Physico-chemical properties of soil of the experimental field**

Particulars	Value	Method adopted
<b>Physical properties</b>		
<b>Mechanical analysis</b>		
a) Coarse sand (%)	15.9	Bouyoucos Hydrometer method ( Piper, 1966)
b) Sand (%)	9.0	
c) Silt (%)	14.9	
d) Clay (%)	60.0	
Textural class	Clayey	
<b>Chemical properties</b>		
P <sup>H</sup> (1:2.5 soil : water)	8.6	Glass electrode pH meter (Jackson,1979)
Electrical conductivity (dS m <sup>-1</sup> ) (1:2.5 soil : water)	0.2	Conductivity meter (Jackson,1979)
Organic carbon (%)	0.37	Walkley and Black's rapid titration method(Walkley and Black,1934)
Available nitrogen (kg ha <sup>-1</sup> )	163	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	22	Olsen's method using colorimeter (Olsen <i>et al.</i> , 1954)
Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	330	Neutral Normal Ammonium Acetate method (Jackson, 1973)

A perusal of the data in Table 3.1 revealed that the soil was clayey in texture, with strongly alkaline in reaction and belonged to S<sub>1</sub> salinity class. The chemical properties of soil revealed that the soil was low in organic carbon, nitrogen, phosphorus and medium in potassium.

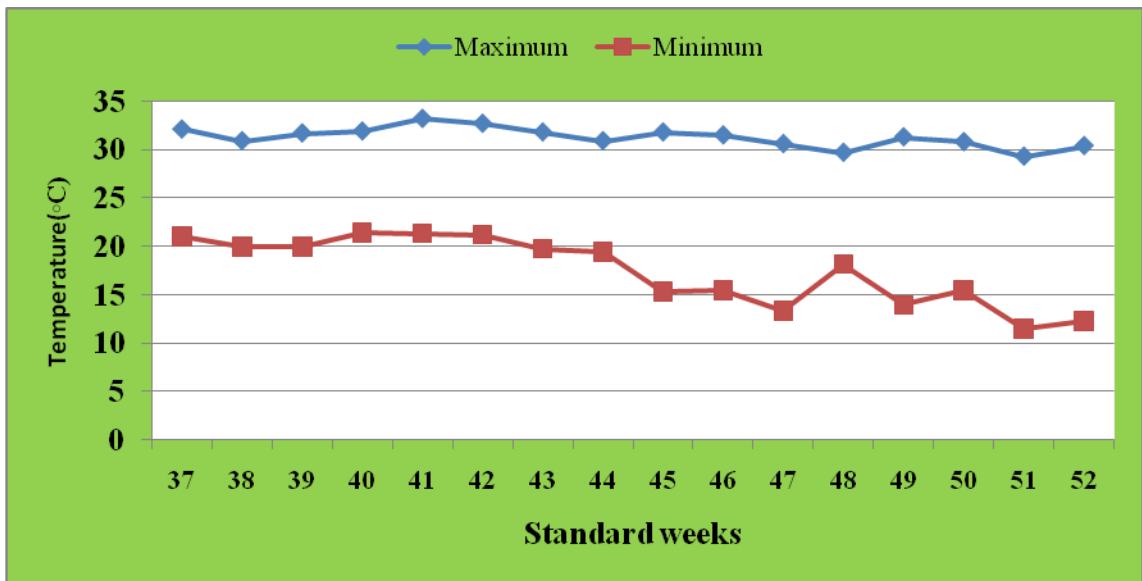


Figure 3.1 Weekly maximum and minimum air temperature during crop growth period of sunflower ( *Rabi* 2011-12).

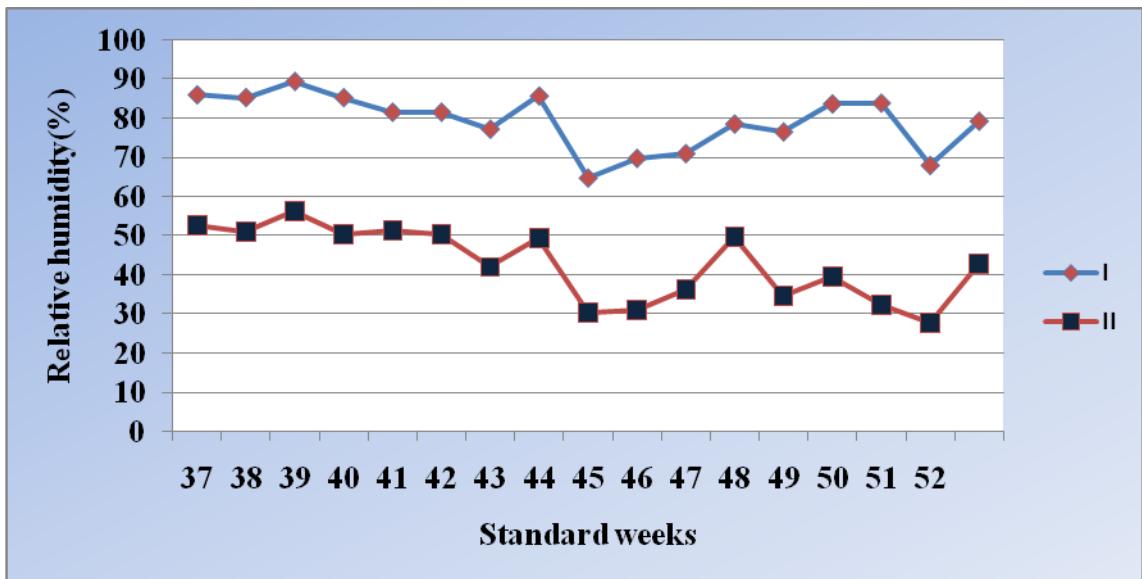


Figure 3.2 Weekly relative humidity (at 7.30 hrs (I) and 14.30 hrs (II)) during crop growth period of sunflower ( *Rabi* 2011-12).

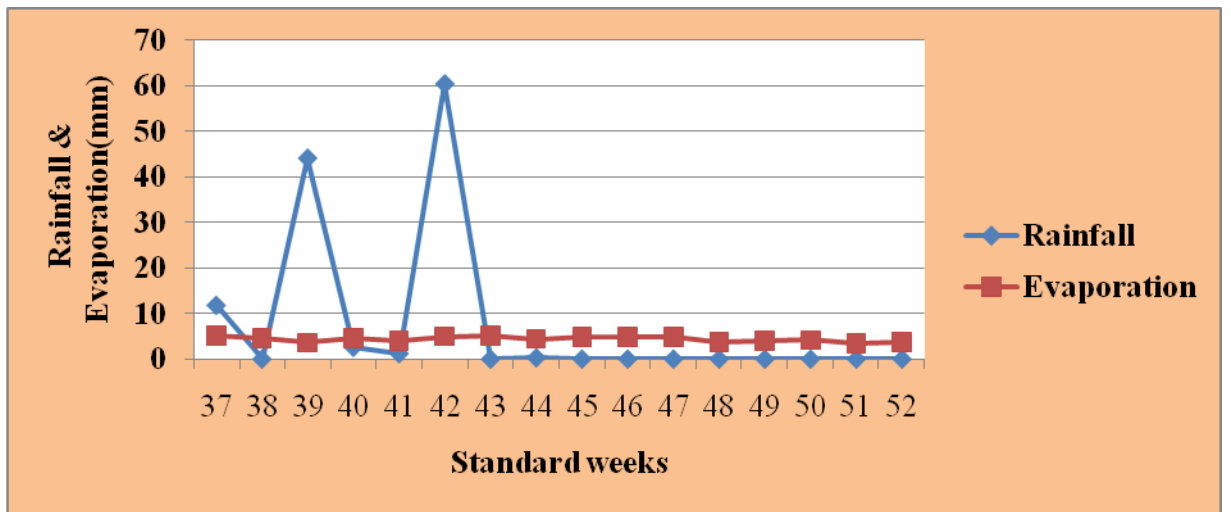


Figure 3.3 Weekly rainfall and evaporation during crop growth period of sunflower (*Rabi 2011-12*).

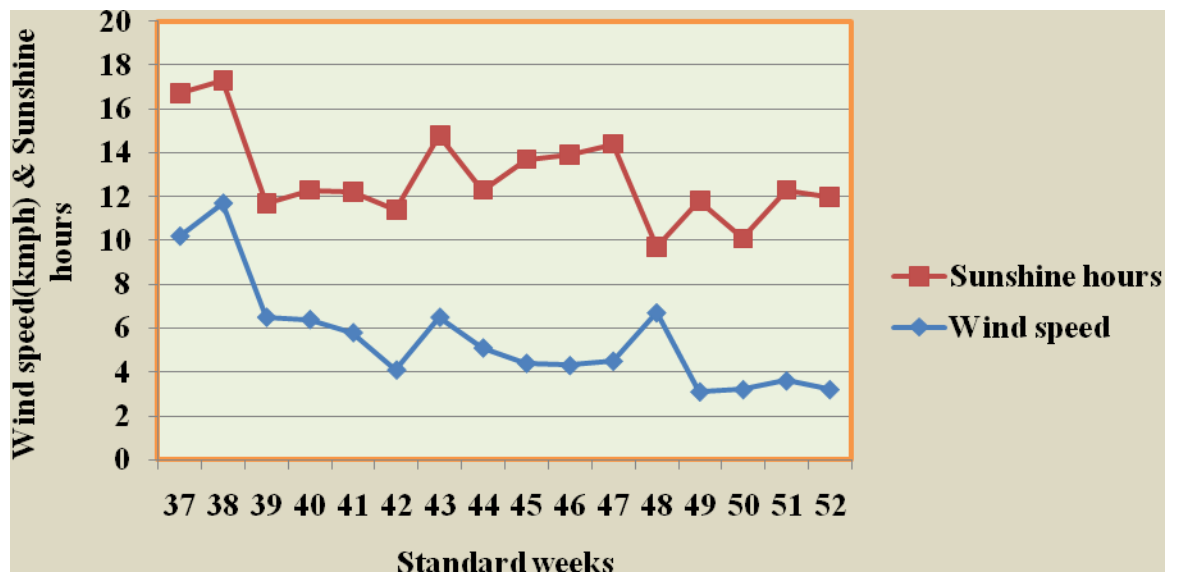


Figure 3.4 Weekly bright sunshine hours and wind speed during crop growth period of sunflower (*Rabi 2011-12*).

### 3.4 CROPPING HISTORY

The cropping history of the experimental field is presented in Table 3.2.

**Table 3.2. Cropping History of Experimental location**

S. No.	Year	Season	Crop
1	2008-09	<i>Kharif</i> <i>Rabi</i>	Fallow Sunflower
2	2009-10	<i>Kharif</i> <i>Rabi</i>	Fallow Sorghum
3	2010-11	<i>Kharif</i> <i>Rabi</i>	Sunnhemp Present investigation(Sunflower)

### 3.5 EXPERIMENTAL DETAILS

#### 3.5.1 Design and layout of experiment

The experiment entitled “**Nutrient management in *Rabi* sunflower (*Helianthus annuus. L*) in relation to different tillage practices imposed during *Kharif*” was conducted during *rabi* season 2011. The treatments were laid in a split plot design with three replications.**

#### 3.5.2 Plot size

Gross : 6.6 m x 6.4 m  
Net : 5.8 m x 5.4 m  
Spacing : 60 cm x 20 cm

#### 3.5.3 Design : Split plot design

Treatments

Main plots	: Three (Tillage treatments)
Sub plots	: Five(Nutrient management)
Total treatments	: Fifteen

Replications : 3  
Total number of plots : 3 x15= 45

### 3.5.4 Treatment Details:

#### Main plot – Tillage practices

T<sub>1</sub> – Conventional Tillage – 1 summer ploughing and 2 harrowings before sowing

T<sub>2</sub>– Reduced Tillage – Harrowing twice before sowing

T<sub>3</sub>– Minimum Tillage– Harrowing once before sowing

#### Sub plot – Nutrient management

N<sub>1</sub> – In- situ Sunn hemp green manure incorporation @ 5 t biomass ha<sup>-1</sup>  
(23 :55 :53 N: P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O kg ha<sup>-1</sup> )

N<sub>2</sub> – In- situ Sunn hemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN  
through urea (29:52.5:44 N: P<sub>2</sub>O<sub>5</sub> :K<sub>2</sub>O kg ha<sup>-1</sup> )

N<sub>3</sub> –100% RDF through fertilizer (35:50:35 N: P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O kg ha<sup>-1</sup> )

N<sub>4</sub> – Farmers’ practice (24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>)

N<sub>5</sub> – Farmers’ practice + In situ Sunn hemp green manure incorporation @ 2.5 t ha<sup>-1</sup>  
( 35.5: 32.5: 9 N: P<sub>2</sub>O<sub>5</sub> :K<sub>2</sub>O kg ha<sup>-1</sup> )

- **Note:** Main plot treatments were imposed in *Kharif* season and Sunflower was sown in *Rabi* season.
- Sunnhemp grown and incorporated after imposing main treatments.
- Nutrient content of sunnhemp- 2.3%N, 0.5%P and 1.8%K.
- P and K were applied through inorganic fertilisers as per the treatment.
- The values in the parenthesis indicate total nutrient supplied by the treatment.

### 3.6 AGRONOMIC CHARACTERS OF SUNFLOWER HYBRID

**KBSH-1:** It has been released in 1992 for cultivation all over India because of its wider adaptability to varying soil and climatic conditions. It matures in 90-95 days. It grows tall up to 150-180 cm with a head size of 15-20 cm diameter and yields about 19-20 q ha<sup>-1</sup> but under good agronomic practices it yields as high as 39 q ha<sup>-1</sup> with an oil content of 43-45 per cent.

## **3.7 CULTIVATION DETAILS**

### **3.7.1 Preparatory cultivation**

The experimental field was prepared by ploughing with tractor drawn plough in conventional tillage block with the receipt of showers. Two harrowings were done for conventional and reduced tillage blocks and one harrowing in minimum tillage block with bullock drawn blade harrows and finally the land was levelled with a wooden plank and demarketed in to individual plots.

### **3.7.2 Growing and incorporation of of Sunnhemp**

Local variety of sunnhemp was broadcasted in the green manure plots at the seed rate of 10 kg ha<sup>-1</sup> and 5 kg ha<sup>-1</sup> as per the treatments. Sunnhemp was incorporated into the soil 47 days after sowing. The nutrients supplied through sunnhemp on 20% dry weight basis( as 80% is water) was (23:5:18 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg ha<sup>-1</sup>) for 5 t ha<sup>-1</sup> and (11.5:2.5:9 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg ha<sup>-1</sup>) for 2.5 t ha<sup>-1</sup> respectively. (Nutrient content of sunnhemp- 2.3%N, 0.5%P and 1.8%K).

### **3.7.3 Fertilizer application**

A uniform dose of 50 kg P<sub>2</sub>O<sub>5</sub> and 35 kg K<sub>2</sub>O kg ha<sup>-1</sup> were applied through single super phosphate, muriate of potash respectively and nitrogen was applied through urea as per the treatments as basal dose according to the treatments. In case of farmer's practice, 24 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> were applied. The fertilizers were band placed from the crop row.

### **3.7.4 Seeds and Sowing**

Healthy and matured seeds with good germination (96%) of KBSH-1 Hybrid were used. Sowing was done on 16-09-2011 as *rabi* crop. Seeds were sown by dibbling method using two seeds per hill with a recommended spacing of 60 x 20 cm at a depth of 3 to 4 cm with a seed rate of 12.5 kg ha<sup>-1</sup>.

### **3.7.5 Herbicide spray**

The minimum tillage block was sprayed with Pendimethalin @ 1 kg a.i ha<sup>-1</sup> with the help of knapsack sprayer on the next day after sowing.

### **3.7.6 Intercultivation**

Thinning was done 15 days after sowing. Hoeing was done at 25 days after sowing in all plots and one hoeing at 45 days after sowing only in conventional tillage block. Hand weeding was done at 45 days after sowing in reduced tillage block.

### **3.7.7 Plant Protection**

Crop was free of pests and diseases; however, prophylactic spray of Monocrotophos @ 1.6 ml lit<sup>-1</sup> was sprayed at pre- flowering stage.

### **3.7.8 Water Management**

The crop was grown purely as a rainfed crop. Therefore no irrigation was given during the entire crop period.

### **3.7.9 Bird scaring**

Suitable measures were taken to avoid bird damage to the crop by making noises in mornings and evenings.

### **3.7.10 Harvesting**

The crop was harvested when the outer bracts of the flower heads turned to brown, backs of the heads turned to lemon yellow and the seeds were easily detachable. The harvested heads were dried for two weeks under the sun and seeds were separated by beating with sticks and the seed yield of the individual treatment plots was recorded. The stalks after cutting to the ground level were left in the field for drying until they attained a constant weight and later the dry weights were recorded.

## **3.8 BIO-METRIC OBSERVATIONS**

Bio-metric observations were recorded on five plants selected at random from each net plot treatment and mean per plant were worked out.

### **3.8.1 Pre-harvest observations**

#### **3.8.1.1 Plant height**

The height of the five plants were measured with meter scale from ground level to tip of the growing point of stem at 20, 40 and 60 DAS and mean value was computed.

### **3.8.1.2 Number of leaves per plant**

The number of effective leaves from five plants was counted at 20, 40 and 60 DAS and the average number was worked out.

### **3.8.1.3 Leaf Area Index**

Leaf Area of sunflower from each plot was measured by using LI-3100 leaf area meter at 20, 40 and 60 DAS and the following formula was used to obtain leaf area index (LAI)

$$\text{LAI} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Land area occupied by the plants (cm}^2\text{)}}$$

### **3.8.1.4 Dry matter accumulation**

Dry matter was recorded at 20, 40, 60 DAS and at harvest. Five plants from each plot were uprooted, shade dried and later oven dried at 65<sup>0</sup>C for 24 hrs and the final dry weight was recorded. The average dry matter weight per plant were was worked out.

### **3.8.1.5 Days to 50% flowering**

Days to 50% flowering were counted from the date of sowing when 50% plants in each plot produced their flowers.

## **3.9 YIELD ATTRIBUTES AND YIELD**

### **3.9.1 Flower head diameter (cm)**

In each treatment plot diameter of flower head from five marked plants was recorded at maturity stage and the mean value was computed.

### **3.9.2 Total number of seeds per head**

Total number of seeds from each of the five flower heads was counted and the average seeds per head were calculated.

### 3.9.3 Number of filled seeds per head

Number of filled seeds from each of five flower heads was counted and the average filled seed per hectare was recorded.

### 3.9.4 Seed filling percentage (%)

The seed filling percentage for each treatment was calculated by using the formula.

$$\text{Seed filling percentage (\%)} = \frac{\text{No. of filled seeds per head}}{\text{Total no. of seeds per head}} \times 100$$

### 3.9.5 Test weight (1000-seed weight in grams)

1000 seeds were drawn at random from each treatment plot produce and their weights were recorded.

### 3.9.6 Seed yield (kg ha<sup>-1</sup>)

The seed weight of the five sample plants was added to the net plot seed weight and later the seed yield was converted to kg ha<sup>-1</sup> and expressed as seed yield in kg ha<sup>-1</sup>.

### 3.9.7 Stalk yield (kg ha<sup>-1</sup>)

Stalk yield obtained from five sample plants was added to the net plot stalk yield and then stalk yield was recorded in kg ha<sup>-1</sup>.

### 3.9.8 Harvest index (%)

Harvest index for each treatment was calculated by using the formula.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Seed yield + stalk yield (kg ha}^{-1}\text{)}} \times 100$$

### 3.9.9 Oil content (%)

Seed samples were drawn from each treatment produce for oil estimation. The oil content of seed for each treatment was estimated by NMR (Nuclear Magnetic Resonance Spectrometer) method and thereby per cent of oil content in the seeds was recorded directly.

### 3.9.10 Oil yield (kg ha<sup>-1</sup>)

The oil yield (kg ha<sup>-1</sup>) was calculated based on seed yield and corresponding oil content recorded from each treatment.

## 3.10 ANALYSIS OF SOIL SAMPLES

Soil samples collected from 0-30 cm depth were analyzed for available nitrogen, phosphorus and potassium before initiation of the experimentation and after harvest of the crop. The available nitrogen was determined by Alkaline Permanganate method (Subbaiah and Asija, 1956). Available phosphorus was determined by Olsen's (Olsen *et al.*, 1954) method and potassium was determined by Flame Photometer (Jackson, 1973).

## 3.11 ANALYSIS OF PLANT SAMPLES

Plant samples collected from the destructive sampling at harvest in all the experimental plots were used for estimation of nitrogen, phosphorus and potassium contents after recording their dry weight. Nitrogen was estimated by Microkjeldal method (Piper, 1950) after digesting the sample in concentrated H<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>O<sub>2</sub>. Phosphorus and potassium contents were determined in the extracts after digesting the plant material with triacid mixture of 9:4:1 (HNO<sub>3</sub>: H<sub>2</sub>SO<sub>4</sub>: HClO<sub>4</sub>) (Piper, 1966).

Phosphorus content in plant digest was estimated by Vando-Molybdo phosphoric yellow colour method on Klett Summerson photo electric calorimeter and potassium content was determined on ELICO Flame Photometer (Piper, 1966)

The nitrogen, phosphorus and potassium contents were expressed as percentage.

### 3.11.1 Uptake of nutrients at harvest (N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O)

Uptake of total nitrogen, phosphorus and potassium in each treatment plot was worked out by multiplying their concentration with corresponding dry matter yield and expressed in kg ha<sup>-1</sup>.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{Total dry matter (kg ha}^{-1}\text{)}$$

### 3.12 ECONOMICS

The cost of cultivation ha<sup>-1</sup> was calculated for the individual treatments on the basis of prevailing market price of the inputs used.

Gross monetary returns were calculated by multiplying the economic yield with prevailing market price of sunflower seed.

Net monetary returns were calculated by deducting the cost of cultivation from gross monetary returns for each treatment.

Benefit-cost (B : C) ratio was calculated by using the formula

$$\text{Benefit -cost ratio} = \frac{\text{Net returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

### 3.13 Statistical analysis

The data recorded on various parameters were subjected to statistical analysis using split plot design as suggested by Fisher's method of analysis of variance. Statistical significance was tested with the help of F-test at 5 percent level of significance. The difference among treatmental means was tested by the critical difference (CD) value, where the F-test was significant (Panse and Sukhatme, 1967).

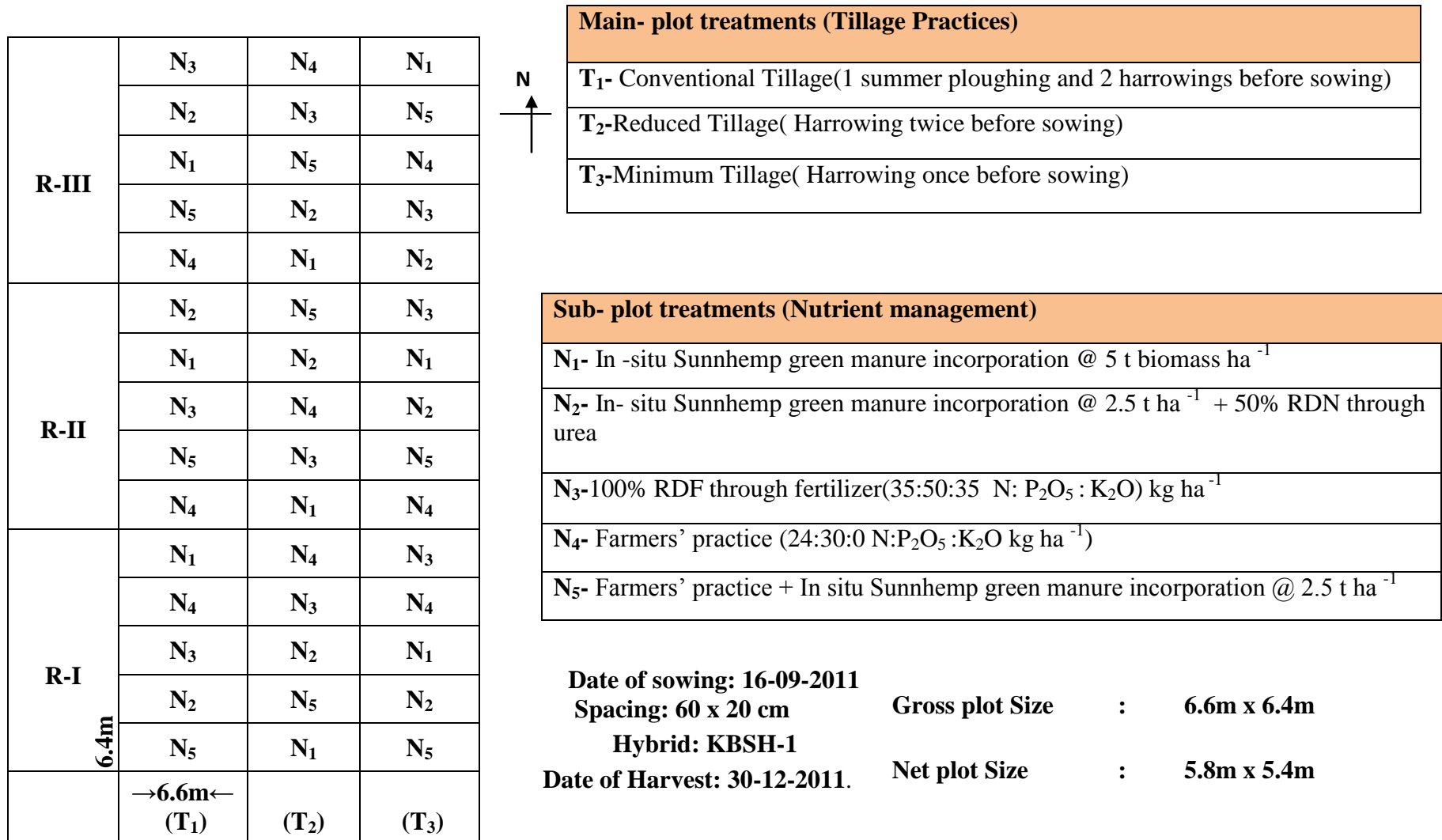


**6.6m**

**Conventional Tillage (A)**

**Reduced Tillage(B)**

**Minimum Tillage(C)**



**Figure 3.5 Layout of the Experimental Field**

## Chapter IV

# RESULTS AND DISCUSSION

The results of the field experiment entitled “Nutrient management in *Rabi* sunflower (*Helianthus annuus*. L) in relation to different tillage practices imposed during *Kharif*” conducted during *rabi* 2011 at RARS, Bijapur are presented in this chapter. Experimental data were statistically analyzed, apportioned under various heads and subheads, furnished in tables and illustrated through figures wherever necessary. Interaction tables were also appended for characters which are found significant. The results found were discussed critically with cause and effect relationship under following headings.

1. Growth parameters
2. Yield attributes and yield
3. Physical and chemical properties of soil
4. NPK content and uptake by crop
5. Economics

## 4.1 GROWTH PARAMETERS

### 4.1.1 Germination percentage (%)

Data pertaining to germination percentage of sunflower as influenced by tillage practices and nutrient management is presented in Table 4.1.

Tillage practices imposed during *kharif* season did not influence the germination percentage of sunflower significantly, but germination was significantly influenced due to nutrient management. Among different nutrient management treatments, 100 % RDF (N<sub>3</sub>) through inorganic fertilizers recorded higher germination percentage and differed significantly from rest of the treatments but on par with N<sub>5</sub>. The per cent increase in germination of N<sub>3</sub> over N<sub>1</sub>, N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub> is 6.0, 8.0, 4.5 and 2.0 respectively. However, the interaction effect due to tillage practices and nutrient management was not significant. The stimulus for germination of a crop variety generally depends upon seed viability under adequate soil moisture supply. The seed reserves of cotyledons may be sufficient for a

short time but adequate quantities of nutrients especially NPK in the soil are required for full growth and establishment of seedling. In the present investigation, N<sub>3</sub> treatment besides N<sub>5</sub>, supplied required amounts of NPK for proper growth of seedlings of sunflower. Rest of the treatments *viz.*, N<sub>4</sub> (Farmer's practice), N<sub>1</sub>, N<sub>2</sub> have failed to put up even 90 % germination which is generally required for non tillering field crops like sunflower. In Farmer's practice (N<sub>4</sub>), potassium was completely ignored and exclusively organic sources to supply NPK(N<sub>1</sub>) or combination of organic plus inorganic (N<sub>2</sub>) have failed to obtain good response as these treatments could not meet the required nutrients as was observed in N<sub>3</sub>(100 % RDF). These findings are in conformity with Byrareddy *et al.* (2008) and Nanjundappa *et al.* (2001).

#### **4.1.2 Plant Height (cm)**

Data pertaining to plant height of sunflower as influenced by tillage practices and nutrient management is given in Table 4.2.

Perusal of the data indicated that tillage practices failed to show any significant effect on plant height of sunflower at various growth stages. These findings are in conformity with Sharma *et al.* (2010). The plant height of sunflower was highly influenced due to nutrient management at different growth stages. Plant height at 20 DAS was significantly higher with 100 % RDF (N<sub>3</sub>) than farmer's practice (N<sub>4</sub>) and In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> plus 50 % RDN through urea(N<sub>2</sub>) but was at par with the treatments N<sub>1</sub> and N<sub>5</sub>. Plant height at 40 and 60 DAS was higher with N<sub>3</sub> (100 % RDF) and significantly differed from N<sub>1</sub>, N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub> but N<sub>1</sub> was on par with N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub>. However, the interaction effect due to tillage practices and nutrient management on plant height was not significant. Present study revealed that inorganic fertilizers at recommended dose have improved the plant height from 20 DAS to 60 DAS showing a sigmoid response. The increase in plant height due to N<sub>3</sub> (100 % RDF) over N<sub>1</sub>, N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub> at 60 DAS was 11.0, 14.0, 13.0 and 10.5 respectively. Instant availability of adequate N, P, and K under N<sub>3</sub> treatment resulted in higher plant height compared to other treatments. The slow release of nutrients from organic sources might be the reason for slight response in combined sources of nutrients of the concerned treatments (N<sub>1</sub>, N<sub>2</sub> and N<sub>5</sub>). Similar results were reported by Chinnamuthu *et al.* (2004), Aruna and Mohammad (2005), Sumathi and Rao (2007), Byrareddy *et al.* (2008) and Gogoi *et al.* (2010).

### **4.1.3 Number of leaves per plant**

Data relating to number of leaves in sunflower as influenced by tillage practices and nutrient management is presented in Table 4.3.

Data indicated that tillage practices did not show any significant difference in number of leaves per plant of sunflower at various growth stages. Nutrient management at 40 and 60 DAS influenced the leaf number significantly but not at 20DAS. N<sub>3</sub> (100 % RDF) produced more number of leaves at 40DAS and differed significantly from rest of the treatments, but N<sub>2</sub> and N<sub>5</sub> were on par and differed significantly from N<sub>1</sub>, N<sub>4</sub> which are on par again. This trend has skewed at 60 DAS, where N<sub>3</sub> proved superior again but on par with N<sub>2</sub> and both of these differed significantly from N<sub>1</sub>, N<sub>4</sub> and N<sub>5</sub>. However, the interaction effect due to tillage practices and nutrient management was not significant. Present study revealed that though inorganic source N<sub>3</sub> (100 % RDF) gave good response, combined sources (N<sub>2</sub>) are not inferior in influencing characters like leaf number. The positive relationship of substitution of nitrogen through organic sources was reported by Byrareddy *et al.* (2008).

### **4.1.4 LAI**

The observation on LAI of sunflower as influenced by tillage practices and nutrient management is given in Table 4.4 and graphically shown in Fig.4.1.

Data revealed that tillage practices have failed to show any significant effect on LAI of sunflower at various growth stages but LAI was highly influenced due to nutrient management at different growth stages. LAI of sunflower at 20 DAS was significantly higher with 100% RDF through fertilizers (N<sub>3</sub>) which is on par with N<sub>5</sub>. Both of these treatments differed significantly from N<sub>1</sub>, N<sub>2</sub>, and N<sub>4</sub>. At 40 and 60 DAS, N<sub>3</sub> proved superior compared to remaining treatments. The interaction effect due to tillage practices and nutrient management was not significant. More plant height in N<sub>3</sub> has helped to initiate more nodes in turn more leaves and higher number of leaves bolstered higher LAI. Similar results were reported by Sumathi and Rao (2007).

### **4.1.5 Dry Matter Production**

Data pertaining to dry matter production of sunflower as influenced by tillage practices and nutrient management at various growth stages is given in Table 4.5 and graphically depicted in Fig. 4.2.

Dry matter production was not significantly influenced by tillage practices at all growth stages except at 20 DAS where reduced tillage proved its superiority in black soil which could be due to favourable physical condition of soil. This finding was in conformity with Basavarajappa *et al.* (2002). At the remaining stages, different types of tillages behaved similarly and there was no significant variation, though conventional tillage produced higher dry matter.

Nutrient management practices influenced the dry matter production at various growth stages significantly. 100% Recommended dose of fertilizer (N<sub>3</sub>) produced greater quantities of dry matter but was on par with N<sub>2</sub> and both of these treatments differed significantly from rest of the treatments at all growth stages. However, N<sub>2</sub> was on par with N<sub>5</sub>. Though N, P and K in inorganic form recorded highest dry matter, application of these nutrients, atleast 50 % through organic form (N<sub>2</sub>) produced the same quantity of dry matter. This once again proved the prevailing trend generally observed in the field crops response to various sources of nitrogen. The per cent increase in dry matter production of sunflower at harvest with N<sub>3</sub> over N<sub>1</sub>, N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub> is 15.0, 6.0, 25.0 and 9.0 respectively. The reason could be better synthesis of chlorophyll and proteins and other compounds of physiological importance which supported in enhancing photosynthetic activity due to higher leaf area. Availability of inorganic nitrogen during the early stages of crop growth contributed positively towards taller plants with more number of leaves and higher LAI which was reflected in higher dry matter production in this particular treatment. These findings corroborate the results of Shylaja *et al.* (2003), Kumar *et al.* (2007) and Sumathi and Rao (2007).

The interaction effect due to tillage practices and nutrient management on dry matter production was significant only at 20 DAS (Table 4.6).

Treatment combination T<sub>2</sub>N<sub>3</sub>(reduced tillage with inorganic source of nutrients) proved better but on par with T<sub>1</sub>N<sub>3</sub>, T<sub>3</sub>N<sub>3</sub>, T<sub>1</sub>N<sub>2</sub> and T<sub>2</sub>N<sub>2</sub>.

#### **4.1.6 Days to 50 per cent flowering**

Data pertaining to Days to 50 % flowering of sunflower as influenced by tillage practices and nutrient management is given in Table 4.7.

Perusal of the data indicated that neither tillage practices nor nutrient management influenced days to 50 per cent flowering significantly in sunflower as it is generally a genetically dependent character.

The interaction effect was also non significant.

## **4.2 YIELD ATTRIBUTES AND YIELD**

### **4.2.1 Flower head diameter**

Data pertaining to flower head diameter of sunflower as influenced by tillage practices and nutrient management is presented in Table 4.8 and graphically depicted in Fig. 4.3.

Perusal of the data indicated that reducing the tillage intensity did not have any significant effect on head diameter of sunflower, but nutrient management strategies highly influenced it. Among different nutrient management treatments, N<sub>3</sub> recorded maximum diameter and differed significantly from N<sub>4</sub> and N<sub>5</sub> but was on par with N<sub>2</sub>, and N<sub>1</sub>. However, the interaction effect due to tillage practices and nutrient management on head diameter was not significant.

Present study revealed that farmer's practice of using lower dose of N and P without K resulted in smaller size heads pronouncing the importance of recommended dose of N, P and K. It is also clear that the impact on head diameter was same irrespective of sources of nitrogen, whether entire organic, inorganic or combination of these two. Higher plant height, LAI and dry matter production and greater translocation of photosynthates to the developing head resulted in larger flower size. These findings corroborate the results of Chinnamuthu *et al.* (2004), Aruna and Mohammad (2005), Mahavishnan *et al.* (2006), Sumathi and Rao (2007) and Byrareddy *et al.* (2008).

### **4.2.2 Number of seeds per head**

Data on number of seeds per head of sunflower as influenced by tillage practices and nutrient management is given in Table 4.8 and illustrated in Fig. 4.4.

The results revealed that tillage practices as well as nutrient management practices significantly influenced the seed number per head in sunflower. Significantly higher number of seeds per head in sunflower was recorded with minimum tillage (T<sub>3</sub>) over reduced tillage (T<sub>2</sub>) but was on par with conventional tillage (T<sub>1</sub>). The higher number of seeds in minimum tillage could be due to more conservation of nutrients and improvement in soil properties *viz.*, physical, chemical and biological properties. (Meena, 2010).

The number of seeds per head of sunflower was influenced due to nutrient management. Significantly higher number of seeds per head was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than the rest of the treatments, but was on par with N<sub>2</sub>. The increased

head diameter in N<sub>3</sub> and N<sub>2</sub> might have accommodated more number of florets resulting in more number of seeds. These findings corroborate with the results of Sumathi and Rao (2007).

The interaction effect due to tillage practices and nutrient management on number of seeds per head was not significant.

#### **4.2.3 Number of filled seeds per head**

Data pertaining to number of filled seeds per head of sunflower as influenced by tillage practices and nutrient management is given in Table 4.8 and graphically depicted in Fig. 4.5.

Perusal of the data indicated that tillage practices did not show any significant impact on number of filled seeds per head. Nutrient management practices have significantly influenced number of filled seeds per head. Among the different nutrient management practices, 100% RDF through fertilizer (N<sub>3</sub>) gave more filled seeds per head and it differed significantly from the rest of the treatments. But, N<sub>1</sub>, N<sub>2</sub>, and N<sub>5</sub> were on par. The percent increase of filled seeds in N<sub>3</sub> over N<sub>1</sub>, N<sub>2</sub>, N<sub>4</sub> and N<sub>5</sub> was 26.0, 16.0, 41.0 and 20.0 respectively. Application of nitrogen through inorganic source again proved its superiority. More number of leaves, LAI and dry matter production contributed for larger size flower heads that accommodated more number of florets, seeds, manifesting in more number of filled seeds in N<sub>3</sub>. Efficient translocation of photosynthates due to adequate nutrition favoured better seed filling. These findings corroborate with the results of Sumathi and Rao (2007).

The interaction effect due to tillage practices and nutrient management on number of filled seeds per head was not significant.

#### **4.2.4 Seed filling percentage**

Data pertaining to seed filling percentage of sunflower as influenced by tillage practices and nutrient management is given in Table 4.9 and graphically depicted in Fig. 4.6.

Perusal of the data indicated that neither tillage practices nor nutrient management significantly influenced seed filling percentage of sunflower.

The interaction effect was also not significant.

#### **4.2.5 Seed weight per head**

Data pertaining to seed weight per head of sunflower as influenced by tillage practices and nutrient management is presented in Table 4.9 and illustrated in Fig. 4.7.

Tillage practices and nutrient management significantly affected the seed weight per head of sunflower. Minimum tillage recorded more seed weight per head and differed significantly from T<sub>1</sub>, and T<sub>2</sub> which were on par. Conserved nutrients, moisture as well as improved soil properties supported good plant growth that maintained more number of seeds per head and better seed filling and because of this, the seed weight per head was also enhanced (Meena, 2010).

The seed weight per head of sunflower was influenced due to nutrient management. Significantly higher seed weight per head of sunflower was seen with 100% RDF through fertilizer (N<sub>3</sub>) than that of farmer's practice (N<sub>4</sub>) but was at par with rest of the treatments. Efficient translocation of photosynthates maintained more number of seeds that resulted in higher seed weight per head. These findings corroborate the results of Mahavishnan *et al.* (2006).

The interaction effect due to tillage practices and nutrient management on seed weight per head was not significant.

#### **4.2.6 Test weight (1000 seed weight)**

Data on test weight of sunflower as influenced by tillage practices and nutrient management is given in Table 4.9 and illustrated in Fig. 4.8.

Data indicated that different tillage practices did not influence the test weight of sunflower significantly. This finding corroborates the results of Sharma *et al.* (2010).

Nutrient management practices have highly influenced the test weight in sunflower. Significantly higher test weight of sunflower was seen with 100% RDF through fertilizer (N<sub>3</sub>) than farmer's practice (N<sub>4</sub>) and farmer's practice + In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> (N<sub>5</sub>) but was on par with In -situ sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup> (N<sub>1</sub>) and In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through urea (N<sub>2</sub>). N<sub>1</sub>, N<sub>4</sub> and N<sub>5</sub> were also on par. The test weight of a cultivar is a genetic character and is not much influenced due to change in management practices in a defined environment. But in the present investigation, nitrogen nutrition irrespective of source, influenced test weight. Better seed filling might have contributed for more test weight in the above treatments. These findings corroborate the results of Bellaki *et al.* (1997), Aruna and Mohammad (2005), Sumathi and Rao (2007), Gogoi *et al.* (2010) and Dhoke *et al.* (2010).

The interaction effect due to tillage practices and nutrient management on test weight of sunflower was not significant.

#### 4.2.7 Seed and stalk yield (kg ha<sup>-1</sup>)

Data pertaining to seed and stalk yield of sunflower as influenced by different tillage practices and nutrient management is given in Table 4.10 and graphically depicted in Fig. 4.9 and 4.10 respectively.

Perusal of the data indicated that tillage practices could not influence both the seed yield and stalk yield of sunflower significantly during the *rabi* season. This finding corroborates the results of Murillo *et al.* (1998), Bellido *et al.* (2003), Nimbole *et al.* (2005), Sharma *et al.* (2009), Meena (2010) and Gupta *et al.* (2011).

The seed yield of sunflower was significantly influenced due to nutrient management treatments. Among different nutrient management treatments, 100% RDF through fertilizer (N<sub>3</sub>) produced significantly higher seed yield of 1187 kg ha<sup>-1</sup> than that of farmer's practice (24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup>-N<sub>4</sub>) which recorded lowest yield of 872 kg ha<sup>-1</sup>. However, seed yield of sunflower with 100% RDF through fertilizer (N<sub>3</sub>) was on par with rest of the treatments *viz.*, N<sub>2</sub>, N<sub>1</sub> and N<sub>5</sub>. Same trend was reflected as far stalk yield was concerned where N<sub>1</sub> besides N<sub>4</sub>, differed significantly from rest of the treatments (N<sub>2</sub>, N<sub>3</sub> and N<sub>5</sub>). Seed yield with 100% RDF through fertilizer (N<sub>3</sub>) was 2.0, 15.5, 16.0 and 36.0 per cent more compared to In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through urea (N<sub>2</sub>), In -situ sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup> (N<sub>1</sub>), farmer's practice + In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> (N<sub>5</sub>) and farmer's practice (24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup> -(N<sub>4</sub>) respectively. Increased seed yield of sunflower was due to increase in yield attributes like number of seeds per head, filled seeds per head, seed weight per head and test weight as observed in the present investigation. Increased nitrogen availability due to adequacy of instant NO<sub>3</sub><sup>-</sup> ions from inorganic source during seedling and grand vegetative stage might have increased dry matter production and its better partitioning resulted in improvement of yield contributing characters, culminating in higher seed yield and stalk yield which was clearly observed in case of N<sub>3</sub>. Increase in seed yield was also due to addition of organic matter (green manure) which upon decomposition (mineralisation), released nutrients in available form for crop absorption slowly during subsequent stages of growth and development in

sunflower in N<sub>2</sub> treatment which performed on par with N<sub>3</sub> as far growth contributing and yield attributing characters are concerned. N<sub>1</sub> and N<sub>5</sub> also recorded on par seed yield compared to N<sub>3</sub> and N<sub>2</sub> but only improvements in yield attributes supported rather than their growth contribution. Similar results were reported by Khatik and Dikshit (2001) Kavitha and Lakshmi (2002), Sharma *et al.* (2002), Aruna and Mohammad (2005), Nimbole *et al.* (2005), Paneer Selvam and Bheemaiah (2005), Byrareddy *et al.* (2008), Maheswari *et al.* (2008), Bombale *et al.* (2009), Deshmukh *et al.* (2009), Paulpandi *et al.* (2009), Tolanur (2009) Gogoi *et al.* (2010) and Prasad *et al.* (2010).

In stalk yield also more or less same trend was reflected. Similar results were reported by Khatik and Dikshit (2001), Sumathi and Rao (2007), Paulpandi *et al.* (2009), Tolanur (2009), Gogoi *et al.* (2010) and Dhoke *et al.* (2010).

The interaction effect due to tillage practices and nutrient management on seed and stalk yield of sunflower was not significant.

#### **4.2.8 Harvest Index**

Data pertaining to harvest index of sunflower as influenced by tillage practices and nutrient management is given in Table 4.10.

Perusal of the data indicated that tillage practices and nutrient management could not influence the harvest index of sunflower significantly. This finding corroborates the results of Meena (2010), Kumar *et al.* (2007) and Mahavishnan *et al.* (2006).

The interaction effect due to tillage practices and nutrient management on harvest index of sunflower was not significant.

#### **4.2.9 Oil content (%)**

Data pertaining to oil content of sunflower as influenced by tillage practices and nutrient management is given in Table 4.11.

Perusal of the data indicated that neither tillage practices nor nutrient management treatments could influence the oil content of sunflower significantly. This finding corroborates the results of Murillo *et al.* (1998) and Bombale *et al.* (2009).

The interaction effect due to tillage practices and nutrient management on oil content of sunflower was not significant.

#### **4.2.10 Oil yield (kg ha<sup>-1</sup>)**

Data pertaining to oil yield of sunflower as influenced by tillage practices and nutrient management is given in Table 4.11.

Perusal of the data indicated that tillage practices could not influence the oil yield of sunflower significantly.

The oil yield of sunflower was significantly influenced due to nutrient management treatments. Significantly higher oil yield of sunflower was seen with In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through urea (N<sub>2</sub>) than N<sub>4</sub> but was on par with rest of the treatments.

The interaction effect due to tillage practices and nutrient management on oil yield of sunflower was not significant.

### **4.3 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL**

#### **4.3.1 Soil moisture content (%)**

Data pertaining to soil moisture content after harvest of sunflower as influenced by tillage practices and nutrient management is given in Table 4.12.

Perusal of the data indicated that soil moisture after harvest of sunflower was significantly influenced by tillage practices. Significantly higher soil moisture was recorded with minimum tillage than reduced and conventional tillage. This might be due to less disturbance of soil due to reduced number of tillage operations resulting in increased water availability. This is in conformity with the findings of Aase and Schaefer (1996), Peterson *et al.* (1996), Halvorson (1999), McGee *et al.* (1997), Tanaka and Anderson (1997) and Sharma *et al.* (2009).

Nutrient management practices failed to show significant influence on soil moisture content after harvest of sunflower.

The interaction effect due to tillage practices and nutrient management on soil moisture content was not significant.

#### **4.3.2 Bulk density (g cc<sup>-1</sup>)**

Data pertaining to bulk density of soil as influenced by tillage practices and nutrient management is given in Table 4.13.

Perusal of the data indicated that bulk density was not significantly influenced by tillage practices and nutrient management both at 60DAS and at harvest. Similar results were reported by Meena (2010), Sujatha *et al.* (2008) and Laddha *et al.* (2006).

The interaction effect due to tillage practices and nutrient management on bulk density of soil was not significant at 60 DAS and at harvest.

#### **4.3.3 Organic carbon (%)**

Data pertaining to soil organic carbon as influenced by tillage practices and nutrient management is given in Table 4.14.

Perusal of the data indicated that tillage practices could not influence the soil organic carbon significantly. The soil organic carbon was significantly influenced due to nutrient management treatments. Significantly higher soil organic carbon was seen with In-situ sunnhemp green manure incorporation @  $2.5 \text{ t ha}^{-1}$  + 50% RDN through urea ( $\text{N}_2$ ) than farmer's practice ( $\text{N}_4$ ) but was at par with rest of the treatments. This could be due to increase in formation of humic acid stimulating activity of microbes due to integrated treatments with both organic and inorganic sources.(Bajpai *et al.* 2006). Similar results were reported by Sharma *et al.* (2002), Gogoi *et al.* (2010) and Prasad *et al.* (2010).

The interaction effect due to tillage practices and nutrient management on soil organic carbon was not significant.

#### **4.3.4 pH**

Data pertaining to soil pH as influenced by tillage practices and nutrient management is given in Table 4.14.

Perusal of the data indicated that tillage practices and nutrient management could not influence the pH of soil significantly.

#### **4.3.5 EC ( $\text{d Sm}^{-1}$ )**

Data pertaining to soil EC as influenced by tillage practices and nutrient management is given in Table 4.14.

Perusal of the data indicated that tillage practices and nutrient management could not influence the EC of soil significantly.

#### **4.3.6 Available nitrogen ( $\text{kg ha}^{-1}$ )**

Data pertaining to available soil nitrogen after harvest of sunflower as influenced by tillage practices and nutrient management is given in Table 4.15.

Perusal of the data indicated that tillage practices did not influence the available nitrogen of soil significantly. Similar results were reported by Murillo *et al.* (1998) and Gupta *et al.* (2011).

Available soil nitrogen was significantly influenced due to nutrient management treatments. Significantly higher available soil nitrogen was seen with In-situ sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup> (N<sub>1</sub>) over 100% RDF through fertilizer (N<sub>3</sub>) and farmer's practice (N<sub>4</sub>) but was at par with rest of the treatments. It might be due to mineralisation of organic nitrogen over a suspended period of time. Similar results were reported by Khatik and Dikshit (2001), Shylaja *et al.* (2003), Sawale *et al.* (2004), Aruna and Mohammad (2005), Bombale *et al.* (2009) and Gogoi *et al.* (2010).

The interaction effect due to tillage practices and nutrient management on available nitrogen was not significant.

#### **4.3.7 Available phosphorous (kg ha<sup>-1</sup>)**

Data pertaining to available soil phosphorus after harvest of sunflower as influenced by tillage practices and nutrient management is given in Table 4.15.

Neither tillage practices nor nutrient management practices have shown any significant impact on available phosphorus in the soil. But there was a slight increase in availability of the phosphorus as compared to initial soil values. Similar results were reported by Murillo *et al.* (1998) and Gupta *et al.* (2011).

The interaction effect was also not significant.

#### **4.3.8 Available potassium (kg ha<sup>-1</sup>)**

Data pertaining to available soil potassium after harvest of sunflower as influenced by tillage practices and nutrient management is given in Table 4.15.

Perusal of the data indicated that tillage practices could not influence the available potassium of soil significantly. Similar results were reported by Murillo *et al.* (1998) and Gupta *et al.* (2011).

Available potassium was significantly influenced due to nutrient management treatments. Significantly higher available soil potassium was seen with 100% RDF through fertilizer (N<sub>3</sub>) than Farmer's practice (N<sub>4</sub>) and Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup>(N<sub>5</sub>) but was at par with rest of the treatments (N<sub>1</sub> and N<sub>2</sub>). In general, there was increase in available potassium compared to initial soil values. This might be due to more availability of potassium with inorganic and organic source in

N<sub>1</sub>, N<sub>2</sub> and N<sub>3</sub> whereas potassium application was completely ignored in treatments N<sub>4</sub> and N<sub>5</sub>. N<sub>5</sub> though, received little dose from organic source maintained good content of K. Similar results were reported by Khatik and Dikshit (2001), Shylaja *et al.* (2003), Sawale *et al.* (2004), Bombale *et al.* (2009) and Gogoi *et al.* (2010).

#### **4.4 NPK CONTENT AND UPTAKE BY THE CROP**

##### **4.4.1 NPK Content (%)**

Perusal of the data in Table 4.16. indicated that N and P content in sunflower was significantly influenced by tillage practices and nutrient management, while no significant effect was seen on K content. Significantly higher N and P content was seen with conventional tillage over minimum tillage, but both of these were on par with reduced tillage indicating irrespective of method and number of tillage, sunflower absorbed nutrients efficiently to maintain optimum N and P content for good growth and development.

Among nutrient management treatments, significantly higher N content of sunflower was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than rest of the treatments which might be due to ready availability of nitrogen through inorganic source. Significantly higher P content was seen with 100% RDF through fertilizer (N<sub>3</sub>) and In- situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup>(N<sub>5</sub>) and both of these differed significantly from rest of the treatments ( N<sub>1</sub>, N<sub>2</sub> and N<sub>4</sub> )

The interaction effect due to tillage practices and nutrient management on NPK content was not significant.

##### **4.4.2 NPK uptake at harvest (kg ha<sup>-1</sup>)**

Data pertaining to NPK uptake of sunflower at harvest as influenced by tillage practices and nutrient management is given in Table 4.17 and graphically depicted in Fig. 4.11, 4.12 and 4.13.

Perusal of the data indicated that N uptake by sunflower at harvest was significantly influenced by tillage practices and nutrient management. Significantly higher N uptake was seen with conventional tillage over minimum tillage but was on par with reduced tillage. More N content and corresponding dry matter contributed for higher nitrogen uptake in T<sub>1</sub> and T<sub>2</sub>. Similar results were reported by Sharma *et al.* (2010) and Singh *et al.* (2011), Murillo *et al.* (1998), Bellido *et al.* (2003). Neither P nor K uptake was significantly influenced due to tillage practices in sunflower during *rabi* season.

Significantly higher N uptake in sunflower was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than rest of the treatments. But N<sub>2</sub> and N<sub>5</sub> differed from N<sub>4</sub> and N<sub>1</sub>. Ready availability of nitrogen through inorganic source in N<sub>3</sub> was the reason for higher N uptake. Similar results were reported by Paneer Selvam and Bheemaiah (2005) and Sumathi and Rao (2007), Murillo *et al.* (1998) and Bellido *et al.* (2003).

Significantly higher phosphorus uptake of sunflower was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than rest of the treatments except farmer's practice +In- situ Sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup>(N<sub>5</sub>), due to more P content and dry matter production. Similar results were reported by Guled *et al.* (2003)..

Potassium uptake by sunflower was also significantly influenced by nutrient management treatments. Significantly higher potassium uptake of sunflower was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than farmer's practice (N<sub>4</sub>) but was on par with rest of the treatments (N<sub>1</sub>, N<sub>2</sub> and N<sub>5</sub>), but N<sub>1</sub> and N<sub>4</sub> were on par. This might be due to more availability of potassium with inorganic and organic source in N<sub>1</sub>, N<sub>2</sub> and N<sub>3</sub> whereas potassium application was completely ignored in treatment N<sub>4</sub>. Similar results were reported by Khatik and Dikshit (2001), Shylaja *et al.* (2003), Sawale *et al.* (2004), Bombale *et al.* (2009) and Gogoi *et al.* (2010).

The interaction effect due to tillage practices and nutrient management on NPK uptake of sunflower was not significant.

#### **4.4.3 Weed density (Number m<sup>-2</sup>)**

Data pertaining to weed density in sunflower at different stages as influenced by tillage practices and nutrient management is given in Table 4.18.

Perusal of the data indicated that weed density in sunflower was significantly influenced by tillage practices at 20 and 40 DAS but not at 60 DAS.

At 20 DAS, significantly higher weed density in sunflower was recorded with reduced tillage (T<sub>2</sub>) over minimum tillage (T<sub>3</sub>). This could be due to residual effect of herbicide sprayed immediately after sowing in minimum tillage during initial stages. However, weed density though higher in reduced tillage was on par with conventional tillage. At 40 DAS, significantly higher weed density was recorded with minimum tillage (T<sub>3</sub>) over conventional (T<sub>1</sub>) and reduced tillage (T<sub>2</sub>) because of re-growth of weeds with the loss of residual effect of herbicide. At 60 DAS tillage practices failed to show any significant effect on weed density.

Nutrient management practices failed to show any significant effect on weed density at all growth stages of sunflower.

The interaction effect due to tillage practices and nutrient management on weed density in sunflower was not significant.

#### **4.5 ECONOMICS**

Data pertaining to economics of sunflower as influenced by tillage practices and nutrient management is given in Table 4.19.

Maximum gross returns (38061Rs ha<sup>-1</sup>) was realized for the treatment combination T<sub>3</sub>N<sub>3</sub> (Minimum tillage with 100% recommended dose of fertilizer) followed by T<sub>3</sub>N<sub>2</sub> (35142 Rs ha<sup>-1</sup>). The same trend was reflected in net returns. The benefit cost ratio of T<sub>3</sub>N<sub>3</sub> was highest followed by T<sub>3</sub>N<sub>2</sub>. Application of recommended dose of fertilizer contributed to higher seed yield and minimum tillage had less cost of cultivation which in turn increased the gross returns, net returns and Bbenefit-cost ratio. Similar results were reported by Sharma *et al.* (2009) and Deshmukh *et al.* (2002)

**Table 4.1. Germination percentage of sunflower as influenced by tillage practices and nutrient management.**

<b>Treatments</b>	<b>Germination (%)</b>
<b>Main- plot treatments (Tillage Practices)</b>	
<b>T<sub>1</sub></b> - Conventional Tillage ( 1 summer ploughing and 2 harrowings before sowing)	91
<b>T<sub>2</sub></b> -Reduced Tillage ( Harrowing twice before sowing)	90
<b>T<sub>3</sub></b> -Minimum Tillage ( Harrowing once before sowing)	87
<b>SEd ±</b>	1.71
<b>CD (P=0.05)</b>	NS
<b>Sub -plot treatments (Nutrient management)</b>	
<b>N<sub>1</sub></b> - In-situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	88
<b>N<sub>2</sub></b> - In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	86
<b>N<sub>3</sub></b> -100% RDF through fertilizer (35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O kg ha <sup>-1</sup> )	93
<b>N<sub>4</sub></b> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O kg ha <sup>-1</sup> )	89
<b>N<sub>5</sub></b> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	91
<b>SEd ±</b>	1.96
<b>CD (P=0.05)</b>	4.0
<b>Interaction (T × N)</b>	
<b>Main at same level of sub</b>	
<b>SEd ±</b>	3.48
<b>CD (P=0.05)</b>	NS
<b>Sub at same level of main</b>	
<b>SEd ±</b>	3.39
<b>CD (P=0.05)</b>	NS

**Table 4.2. Plant height (cm) of sunflower as influenced by tillage practices and nutrient management at different crop growth stages.**

Treatments	Plant height(cm)		
	20 DAS	40 DAS	60 DAS
<b>Main- plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	30	57	144
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	30	47	144
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	29	50	145
<b>SEd ±</b>	0.63	3.27	3.72
<b>CD (P=0.05)</b>	NS	NS	NS
<b>Sub- plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	30	49	142
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	28	46	139
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	31	60	158
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	28	52	140
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	30	51	143
<b>SEd ±</b>	0.53	3.14	4.79
<b>CD (P=0.05)</b>	1.1	6.4	9.8
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
<b>SEd ±</b>	1.04	5.86	8.30
<b>CD (P=0.05)</b>	NS	NS	NS
<b>Sub at same level of main</b>			
<b>SEd ±</b>	0.93	5.44	8.30
<b>CD (P=0.05)</b>	NS	NS	NS

**Table 4.3. Number of leaves of sunflower as influenced by tillage practices and nutrient management at different crop growth stages.**

Treatments	Number of leaves		
	20 DAS	40 DAS	60 DAS
<b>Main- plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	6	16	25
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	6	16	24
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	6	15	22
SEd ±	0.26	0.49	1.20
CD (P=0.05)	NS	NS	NS
<b>Sub- plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	6	15	23
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	6	16	25
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	7	17	26
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	6	15	23
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	6	16	23
SEd ±	0.30	0.45	0.99
CD (P=0.05)	NS	0.94	2.06
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	0.54	0.86	1.95
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	0.52	0.79	1.72
CD (P=0.05)	NS	NS	NS

**Table 4.4. LAI of sunflower as influenced by tillage practices and nitrogen management at different crop growth stages.**

Treatments	LAI		
	20 DAS	40 DAS	60 DAS
<b>Main- plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	0.46	1.54	1.93
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	0.41	1.48	1.91
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	0.44	1.56	1.90
SEd ±	0.01	0.13	0.12
CD (P=0.05)	NS	NS	NS
<b>Sub- plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	0.39	1.32	1.76
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	0.44	1.61	1.84
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	0.55	1.97	2.52
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	0.37	1.24	1.64
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	0.48	1.45	1.81
SEd ±	0.03	0.17	0.18
CD (P=0.05)	0.07	0.35	0.37
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	0.05	0.29	0.30
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	0.06	0.29	0.31
CD (P=0.05)	NS	NS	NS

**Table 4.5. Dry matter production (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nutrient management at different crop growth stages.**

Treatments	20 DAS	40 DAS	60 DAS	Harvest
<b>Main - plot treatments (Tillage Practices)</b>				
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	119	654	2638	4666
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	123	645	2597	4622
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	121	640	2569	4366
<b>SEd ±</b>	0.75	4.13	63.30	155.31
<b>CD (P=0.05)</b>	2.0	NS	NS	NS
<b>Sub- plot treatments (Nutrient management)</b>				
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	119	634	2491	4378
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	124	662	2677	4748
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	126	671	2776	5023
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	113	617	2421	4010
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	122	648	2642	4598
<b>SEd ±</b>	1.12	6.99	76.74	128.52
<b>CD (P=0.05)</b>	2.3	14.4	158.4	265.3
<b>Interaction (T × N)</b>				
<b>Main at same level of sub</b>				
<b>SEd ±</b>	1.89	11.59	134.69	252.51
<b>CD (P=0.05)</b>	4.1	NS	NS	NS
<b>Sub at same level of main</b>				
<b>SEd ±</b>	1.94	12.11	132.91	222.60
<b>CD (P=0.05)</b>	Sig	NS	NS	NS

**Table 4.6. Interaction effect at 20 DAS on dry matter production (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nutrient management**

Tillage (T)	Nutrient management(N)					Mean
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>	
<b>T<sub>1</sub>- Conventional</b>	118	125	126	106	120	119
<b>T<sub>2</sub>- Reduced</b>	121	125	127	118	123	123
<b>T<sub>3</sub>- Minimum</b>	118	123	125	116	122	121
<b>Mean</b>	119	124	126	113	122	
<b>Interaction (T×N)</b>	<b>SEd ±</b>			<b>CD (P=0.05)</b>		
<b>Main at same level of sub</b>	<b>1.89</b>			<b>4.1</b>		
<b>Sub at same or different level of main</b>	<b>1.94</b>			<b>4.2</b>		

**Table 4.7. Days to 50 percent flowering in sunflower as influenced by tillage practices and nutrient management**

<b>Treatments</b>	<b>Days to 50% flowering</b>
<b>Main- plot treatments (Tillage Practices)</b>	
<b>T<sub>1</sub></b> - Conventional Tillage ( 1 summer ploughing and 2 harrowings before sowing)	56
<b>T<sub>2</sub></b> -Reduced Tillage ( Harrowing twice before sowing)	55
<b>T<sub>3</sub></b> -Minimum Tillage ( Harrowing once before sowing)	56
<b>SEd ±</b>	0.75
<b>CD (P=0.05)</b>	NS
<b>Sub -plot treatments (Nutrient management)</b>	
<b>N<sub>1</sub></b> - In-situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	56
<b>N<sub>2</sub></b> - In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	55
<b>N<sub>3</sub></b> -100% RDF through fertilizer (35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O kg ha <sup>-1</sup> )	58
<b>N<sub>4</sub></b> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	54
<b>N<sub>5</sub></b> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	56
<b>SEd ±</b>	1.56
<b>CD (P=0.05)</b>	NS
<b>Interaction (T × N)</b>	
<b>Main at same level of sub</b>	
<b>SEd ±</b>	2.54
<b>CD (P=0.05)</b>	NS
<b>Sub at same level of main</b>	
<b>SEd ±</b>	2.71
<b>CD (P=0.05)</b>	NS

**Table 4.8. Head diameter (cm), No. of seeds per head and No. of filled seeds per head of sunflower as influenced by tillage practices and nitrogen management.**

Treatments	Head diameter	No. of seeds /head	No. of filled seeds/ Head
<b>Main- plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	9.5	1008.7	878.9
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	9.7	963.2	827.6
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	10.3	1068.6	914.1
SEd ±	0.23	22.73	23.44
CD (P=0.05)	NS	62.7	NS
<b>Sub- plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	9.8	941.2	824.1
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	10	1060.6	896.5
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O) kg ha <sup>-1</sup>	10.6	1174.8	1040.5
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	9.0	902.0	738.3
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	9.4	989.0	868.3
SEd ±	0.43	71.90	48.88
CD (P=0.05)	0.8	148.4	100.9
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	0.70	113.69	79.28
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	0.74	124.54	84.67
CD (P=0.05)	NS	NS	NS

**Table 4.9. Seed filling percentage (%), seed weight per head (g) and test weight (g) of sunflower as influenced by tillage practices and nutrient management**

Treatments	Seed filling %	Seed weight /head	Test weight (1000 seeds)
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	87	48.8	43.19
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	86	46.0	43.66
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	85	55.1	42.72
SEd ±	1.44	1.41	1.10
CD (P=0.05)	NS	3.94	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	88	47.6	43.1
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	85	56.0	45.6
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	87	57.0	45.9
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	82	40.6	40.4
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	87	48.7	40.8
SEd ±	4.28	4.86	1.86
CD (P=0.05)	NS	10.0	3.6
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	6.79	7.77	3.10
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	7.41	8.43	3.23
CD (P=0.05)	NS	NS	NS

**Table 4.10. Seed yield (kg ha<sup>-1</sup>), stalk yield (kg ha<sup>-1</sup>) and harvest index (%) of sunflower as influenced by tillage practices and nutrient management.**

Treatments	Seed yield	Stalk yield	Harvest index
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	1017.3	2265.3	31.38
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	999.9	2206.1	31.72
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	1148.6	1940.9	37.11
<b>SEd ±</b>	48.40	219.12	2.24
<b>CD (P=0.05)</b>	NS	NS	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	1028.2	1993.6	34.42
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	1167.8	2182.2	35.15
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	1187.5	2483.8	32.46
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	872.9	1674.9	34.03
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	1020.0	2352.8	30.96
<b>SEd ±</b>	99.30	200.25	3.10
<b>CD (P=0.05)</b>	205.0	413.4	NS
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
<b>SEd ±</b>	161.27	379.81	5.30
<b>CD (P=0.05)</b>	NS	NS	NS
<b>Sub at same level of main</b>			
<b>SEd ±</b>	171.99	346.84	5.37
<b>CD (P=0.05)</b>	NS	NS	NS

**Table 4.11. Oil content (%) and oil yield (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nutrient management.**

Treatments	Oil content	Oil yield
<b>Main plot treatments (Tillage Practices)</b>		
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	32.37	329.89
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	32.49	324.95
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	32.24	370.21
<b>SEd ±</b>	0.43	15.76
<b>CD (P=0.05)</b>	NS	NS
<b>Sub plot treatments (Nutrient management)</b>		
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	32.40	332.72
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	33.03	384.83
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	31.77	376.47
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	32.24	281.33
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	32.39	331.72
<b>SEd ±</b>	0.71	32.68
<b>CD (P=0.05)</b>	NS	67.47
<b>Interaction (T × N)</b>		
<b>Main at same level of sub</b>		
<b>SEd ±</b>	1.18	53.02
<b>CD (P=0.05)</b>	NS	NS
<b>Sub at same level of main</b>		
<b>SEd ±</b>	1.23	56.60
<b>CD (P=0.05)</b>	NS	NS

**Table 4.16. NPK content (%) of sunflower at harvest as influenced by tillage practices and nutrient management**

Treatments	N	P	K
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	1.22	0.34	4.03
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	1.18	0.32	3.84
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	1.05	0.29	3.67
SEd ±	0.04	0.01	0.81
CD (P=0.05)	0.12	0.03	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	1.08	0.29	3.78
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	1.08	0.29	4.16
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	1.36	0.35	4.28
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	1.10	0.30	3.00
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	1.14	0.35	4.01
SEd ±	0.06	0.01	0.61
CD (P=0.05)	0.13	0.03	NS
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	0.11	0.02	1.25
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	0.11	0.02	1.06
CD (P=0.05)	NS	NS	NS

**Table 4.17. N P K uptake (kg ha<sup>-1</sup>) of sunflower at harvest as influenced by tillage practices and nutrient management**

Treatments	N	P	K
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	57.35	15.81	188.34
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	54.74	13.61	179.85
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	46.53	13.90	161.96
SEd ±	2.51	0.70	35.43
CD (P=0.05)	6.93	NS	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	47.54	12.85	166.46
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	51.58	13.59	197.25
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	68.28	17.41	212.79
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	44.23	12.21	121.65
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	52.74	16.15	185.69
SEd ±	3.50	0.73	26.67
CD (P=0.05)	7.23	1.52	55.06
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	5.98	1.33	54.43
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	6.07	1.27	46.20
CD (P=0.05)	NS	NS	NS

**Table 4.15. Available NPK of soil at harvest ( $\text{kg ha}^{-1}$ ) as influenced by tillage practices and nutrient management**

Treatments	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	173.93	28.85	392.64
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	186.0	28.95	374.16
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	184.38	28.02	371.12
SEd ±	8.14	0.47	10.80
CD (P=0.05)	NS	NS	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	196.80	28.68	385.86
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	186.0	28.82	402.13
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	175.93	29.02	408.13
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	163.03	28.15	331.60
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	185.43	28.36	368.80
SEd ±	9.79	0.29	9.12
CD (P=0.05)	20.23	NS	26.64
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	17.23	0.65	17.79
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	16.97	1.06	24.15
CD (P=0.05)	NS	NS	NS
Initial value	163	24	330

**Table 4.14. Organic carbon (%), pH and electrical conductivity (ds m<sup>-1</sup>) of soil as influenced by tillage practices and nutrient management.**

Treatments	OC	pH	EC
<b>Main plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)	0.36	8.64	0.23
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)	0.37	8.55	0.24
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)	0.38	8.62	0.16
SEd ±	0.04	0.12	0.06
CD (P=0.05)	NS	NS	NS
<b>Sub plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	0.39	8.66	0.24
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	0.40	8.41	0.26
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>	0.39	8.71	0.19
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	0.36	8.73	0.16
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	0.38	8.51	0.21
SEd ±	0.01	0.12	0.04
CD (P=0.05)	0.03	NS	NS
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	0.01	0.23	0.09
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	0.01	0.22	0.08
CD (P=0.05)	NS	NS	NS
Initial value	0.37	8.6	0.20

**Table 4.12. Soil moisture content (%) after harvest of sunflower as influenced by tillage practices and nutrient management.**

<b>Treatments</b>	<b>Soil moisture %</b>
<b>Main- plot treatments (Tillage Practices)</b>	
<b>T<sub>1</sub></b> - Conventional Tillage ( 1 summer ploughing and 2 harrowings before sowing)	8.21
<b>T<sub>2</sub></b> -Reduced Tillage ( Harrowing twice before sowing)	9.24
<b>T<sub>3</sub></b> -Minimum Tillage ( Harrowing once before sowing)	10.37
<b>SEd ±</b>	0.30
<b>CD (P=0.05)</b>	0.84
<b>Sub -plot treatments (Nutrient management)</b>	
<b>N<sub>1</sub></b> - In-situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	9.45
<b>N<sub>2</sub></b> - In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	9.91
<b>N<sub>3</sub></b> -100% RDF through fertilizer (35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O kg ha <sup>-1</sup> )	9.36
<b>N<sub>4</sub></b> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	9.44
<b>N<sub>5</sub></b> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	9.42
<b>SEd ±</b>	0.41
<b>CD (P=0.05)</b>	NS
<b>Interaction (T × N)</b>	
<b>Main at same level of sub</b>	
<b>SEd ±</b>	0.70
<b>CD (P=0.05)</b>	NS
<b>Sub at same level of main</b>	
<b>SEd ±</b>	0.71
<b>CD (P=0.05)</b>	NS

**Table 4.13. Bulk density ( $\text{g cc}^{-1}$ ) of soil at 60DAS and harvest of sunflower as influenced by tillage practices and nutrient management**

Treatments	At peak vegetative stage(60DAS)	At harvest
<b>Main plot treatments (Tillage Practices)</b>		
T <sub>1</sub> - Conventional Tillage(1 summer ploughing and 2 harrowings before sowing)	1.19	1.20
T <sub>2</sub> -Reduced Tillage( Harrowing twice before sowing)	1.20	1.21
T <sub>3</sub> -Minimum Tillage( Harrowing once before sowing)	1.20	1.21
<b>SEd ±</b>	0.004	0.006
<b>CD (P=0.05)</b>	NS	NS
<b>Sub plot treatments (Nutrient management)</b>		
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	1.19	1.20
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	1.19	1.21
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O) kg ha <sup>-1</sup>	1.20	1.20
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	1.20	1.21
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	1.20	1.21
<b>SEd ±</b>	0.008	0.006
<b>CD (P=0.05)</b>	NS	NS
<b>Interaction (T × N)</b>		
<b>Main at same level of sub</b>		
<b>SEd ±</b>	0.01	0.01
<b>CD (P=0.05)</b>	NS	0.16
<b>Sub at same level of main</b>		
<b>SEd ±</b>	0.01	0.01
<b>CD (P=0.05)</b>	NS	NS

**Table 4.18. Weed density (number m<sup>-2</sup>) in sunflower as influenced by tillage practices and nutrient management at different crop growth stages.**

Treatments	Weed density (number m <sup>-2</sup> )		
	20 DAS	40 DAS	60 DAS
<b>Main- plot treatments (Tillage Practices)</b>			
T <sub>1</sub> - Conventional Tillage(1 summer ploughing and 2 harrowings before sowing)	11.93	23.53	21.93
T <sub>2</sub> -Reduced Tillage( Harrowing twice before sowing)	14.13	23.40	20.06
T <sub>3</sub> -Minimum Tillage( Harrowing once before sowing)	10.20	26.33	25.26
SEd ±	0.99	0.64	2.14
CD (P=0.05)	2.74	1.78	NS
<b>Sub- plot treatments (Nutrient management)</b>			
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>	12.66	24.00	21.55
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea	11.88	24.22	22.00
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O) kg ha <sup>-1</sup>	12.33	25.44	24.33
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )	11.00	23.77	22.11
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>	12.55	24.66	22.11
SEd ±	0.74	1.60	1.24
CD (P=0.05)	NS	NS	NS
<b>Interaction (T × N)</b>			
<b>Main at same level of sub</b>			
SEd ±	1.51	2.56	2.88
CD (P=0.05)	NS	NS	NS
<b>Sub at same level of main</b>			
SEd ±	1.28	2.77	2.15
CD (P=0.05)	NS	NS	NS

**Table 4.19. Economics of sunflower as influenced by tillage practices and nutrient management.**

Treatments	Gross returns (Rs ha <sup>-1</sup> )	Net returns (Rs ha <sup>-1</sup> )	Cost of cultivation (Rs ha <sup>-1</sup> )	B:C ratio
T <sub>1</sub> N <sub>1</sub>	28295	15976	12319	1.30
T <sub>1</sub> N <sub>2</sub>	29201	16473	12728	1.29
T <sub>1</sub> N <sub>3</sub>	30813	18331	12482	1.47
T <sub>1</sub> N <sub>4</sub>	28899	16990	11909	1.43
T <sub>1</sub> N <sub>5</sub>	30309	18056	12253	1.47
T <sub>2</sub> N <sub>1</sub>	26726	16557	10169	1.63
T <sub>2</sub> N <sub>2</sub>	34898	24320	10578	2.30
T <sub>2</sub> N <sub>3</sub>	29604	19272	10332	1.87
T <sub>2</sub> N <sub>4</sub>	24489	14730	9759	1.51
T <sub>2</sub> N <sub>5</sub>	26918	16815	10103	1.66
T <sub>3</sub> N <sub>1</sub>	34438	25269	9169	2.76
T <sub>3</sub> N <sub>2</sub>	36142	26564	9578	2.77
T <sub>3</sub> N <sub>3</sub>	38061	28729	9332	<b>3.08</b>
T <sub>3</sub> N <sub>4</sub>	22556	13797	8759	1.58
T <sub>3</sub> N <sub>5</sub>	31517	22414	9103	2.46

Sale price of seed- 29 Rs kg<sup>-1</sup>

<b>Main- plot treatments (Tillage Practices)</b>
T <sub>1</sub> - Conventional Tillage (1 summer ploughing and 2 harrowings before sowing)
T <sub>2</sub> -Reduced Tillage ( Harrowing twice before sowing)
T <sub>3</sub> -Minimum Tillage ( Harrowing once before sowing)
<b>Sub- plot treatments (Nutrient management)</b>
N <sub>1</sub> - In -situ Sunnhemp green manure incorporation @ 5 t biomass ha <sup>-1</sup>
N <sub>2</sub> - In- situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup> + 50% RDN through urea
N <sub>3</sub> -100% RDF through fertilizer(35:50:35 N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O) kg ha <sup>-1</sup>
N <sub>4</sub> - Farmer's practice (24:30:0 N:P <sub>2</sub> O <sub>5</sub> :K <sub>2</sub> O kg ha <sup>-1</sup> )
N <sub>5</sub> - Farmer's practice + In-situ Sunnhemp green manure incorporation @ 2.5 t ha <sup>-1</sup>



**Plate 4.1. View of Sunnhemp sown at 10 kg ha<sup>-1</sup> for In-situ incorporation @ 5 t ha<sup>-1</sup>.**



**Plate 4.2. View of Sunnhemp sown at 5 kg ha<sup>-1</sup> for In-situ incorporation @ 2.5 t ha<sup>-1</sup>.**



**Plate 4.3. An over view of Sunflower experimental field at 40 DAS.**



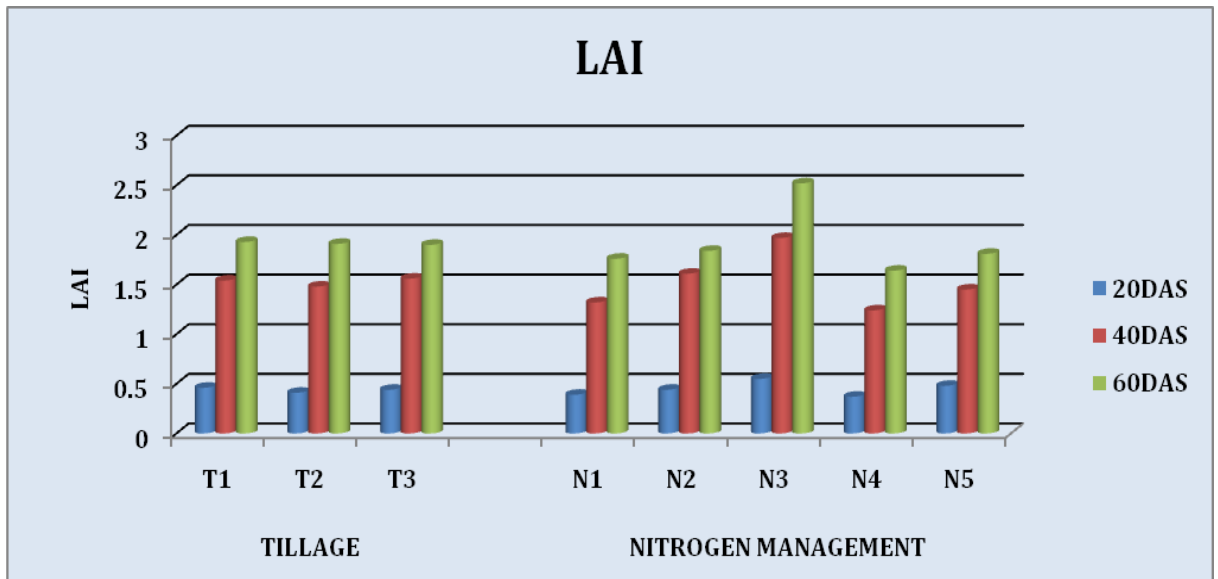
**Plate 4.4. An over view of Sunflower experimental field at 60 DAS.**



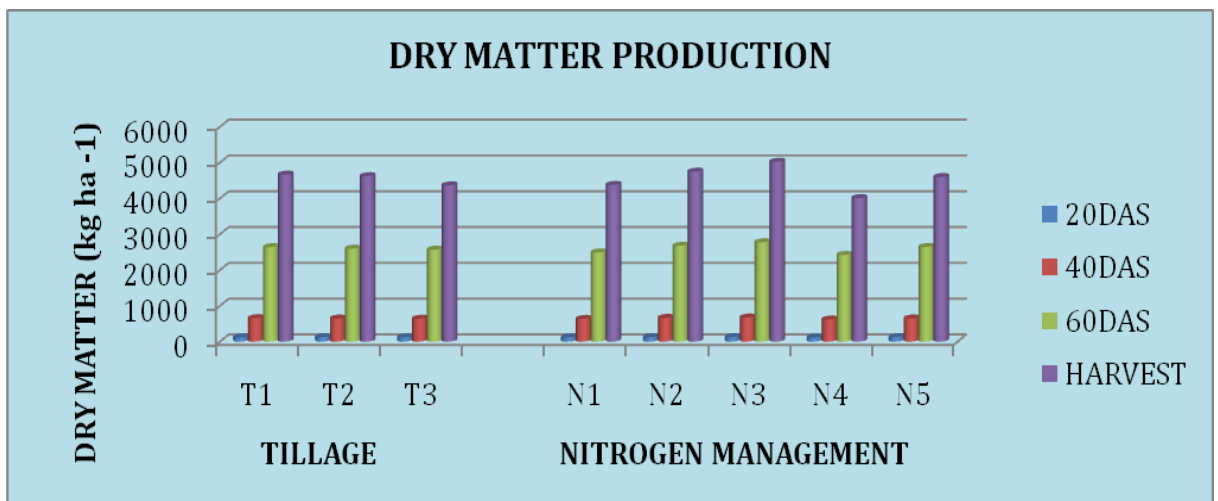
**Plate 4.5. An over view of Sunflower experimental field at 50 percent flowering stage.**



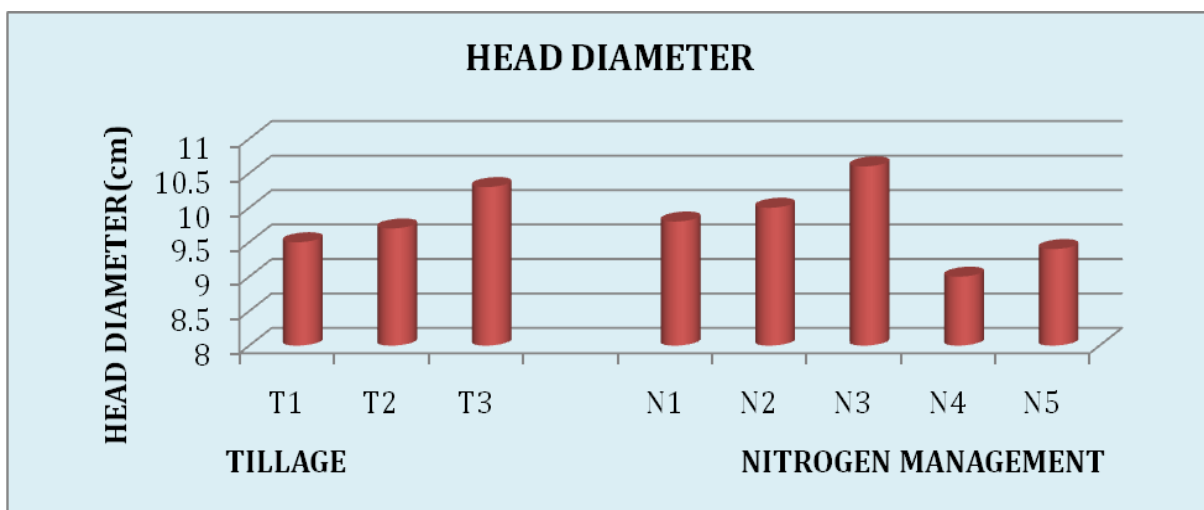
**Plate 4.6. An over view of Sunflower experimental field at harvest.**



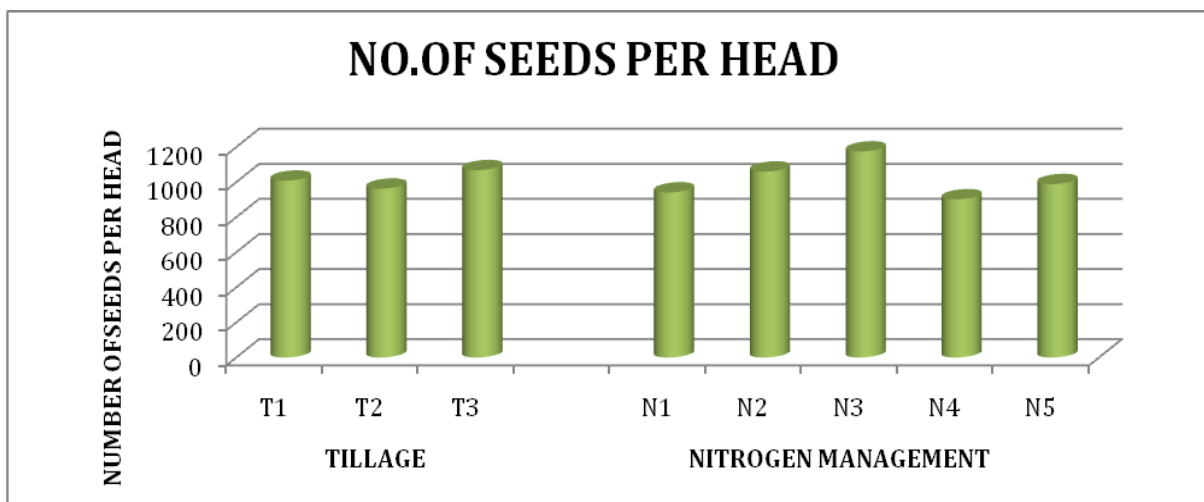
**Figure 4.1.** LAI of sunflower as influenced by tillage practices and nitrogen management at different crop growth stages.



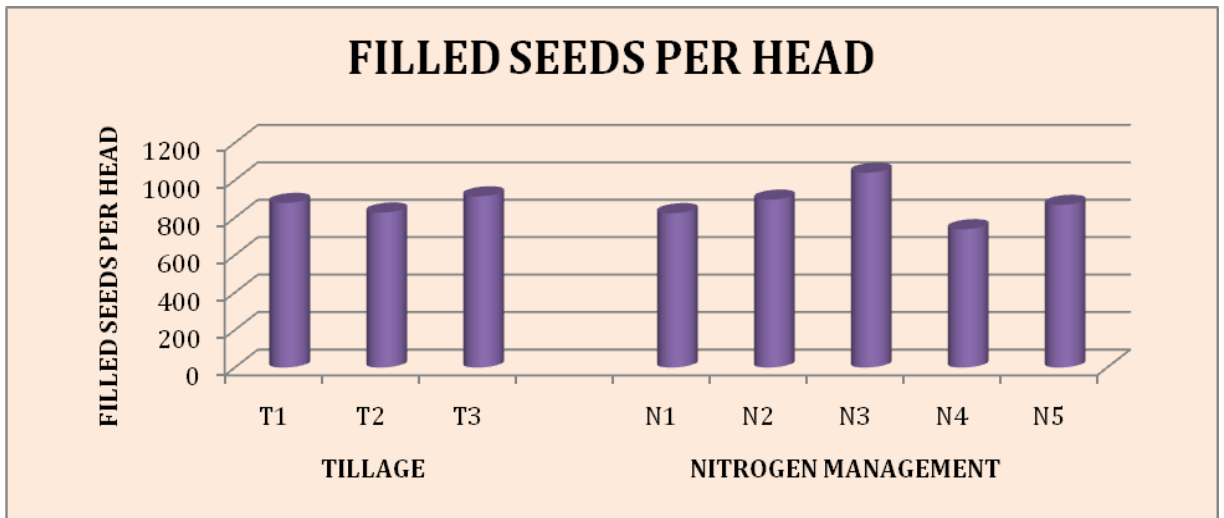
**Figure 4.2.** Dry matter production (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nitrogen management at different crop growth stages.



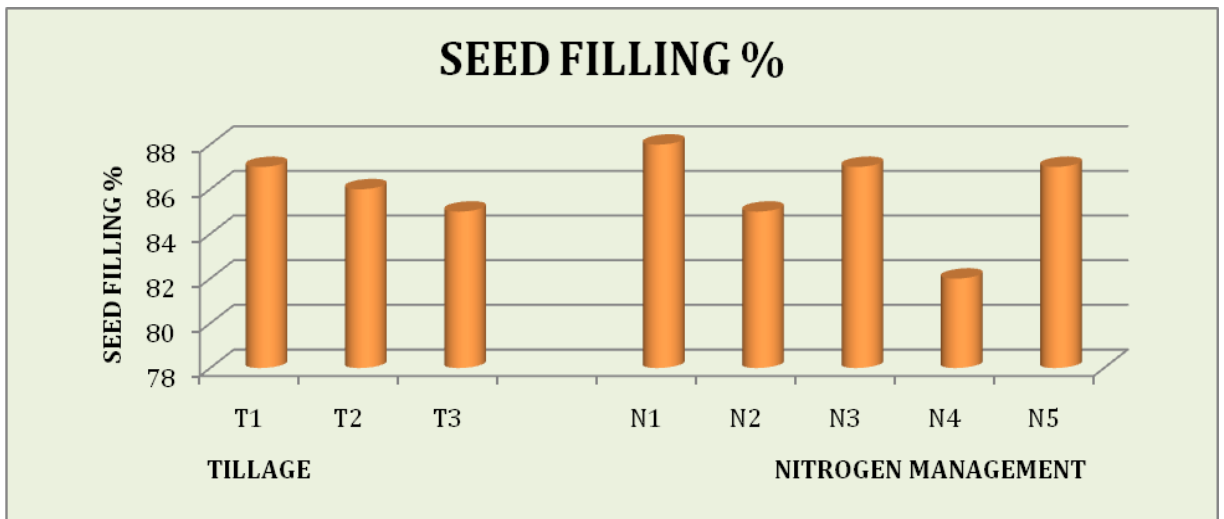
**Figure 4.3. Head diameter (cm) of sunflower as influenced by tillage practices and nitrogen management.**



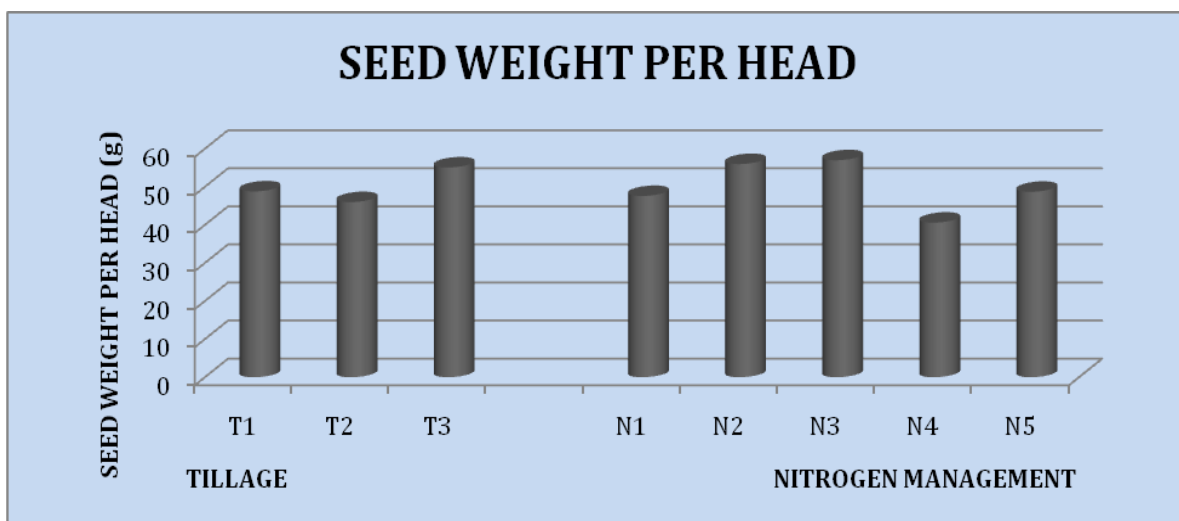
**Figure 4.4. Number of seeds per head of sunflower as influenced by tillage practices and nitrogen management.**



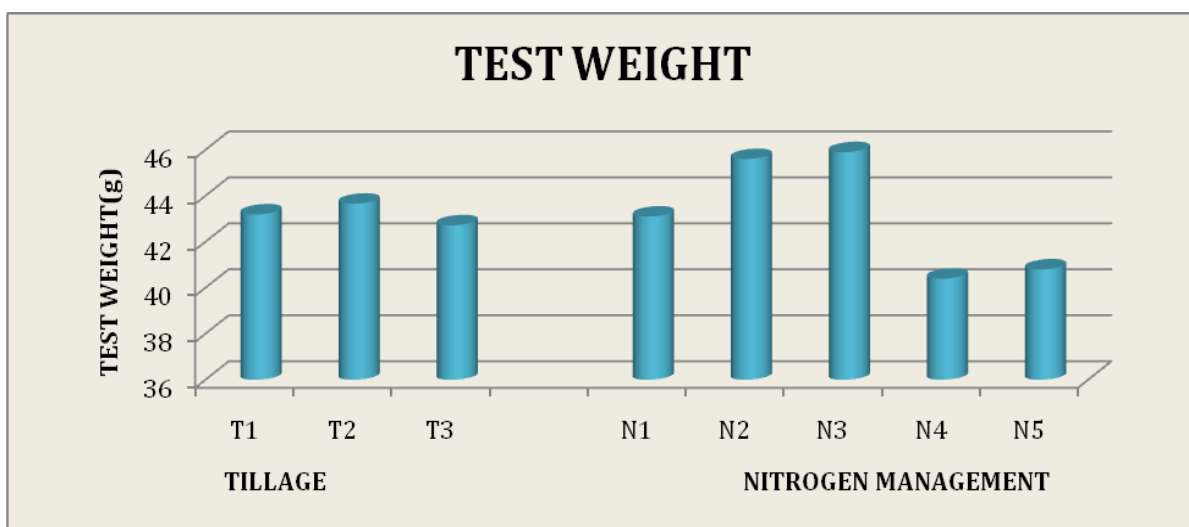
**Figure 4.5.** Number of filled seeds per head of sunflower as influenced by tillage practices and nitrogen management.



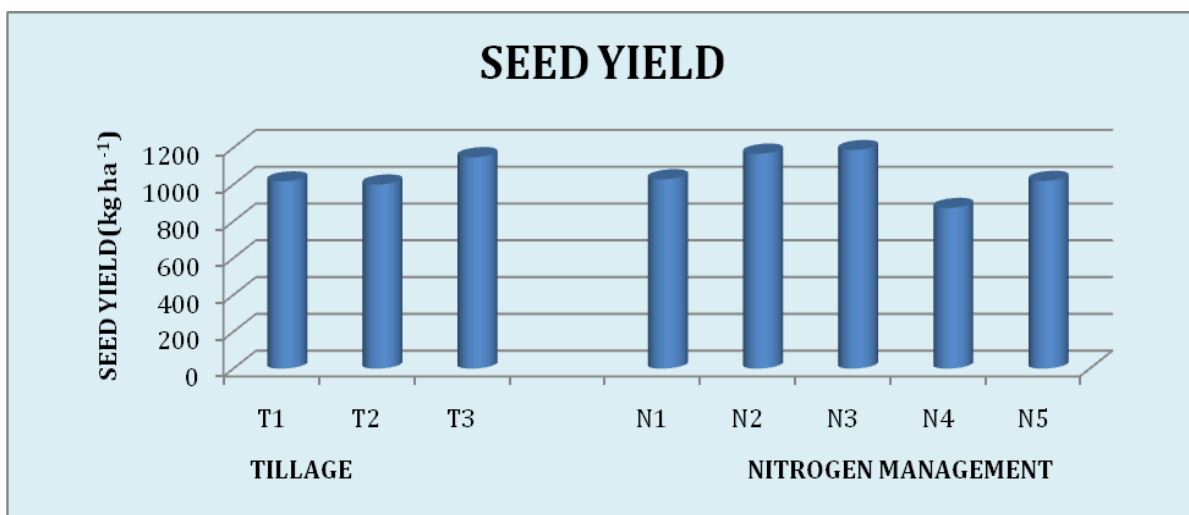
**Figure 4.6.** Seed filling percentage(%) of sunflower as influenced by tillage practices and nitrogen management.



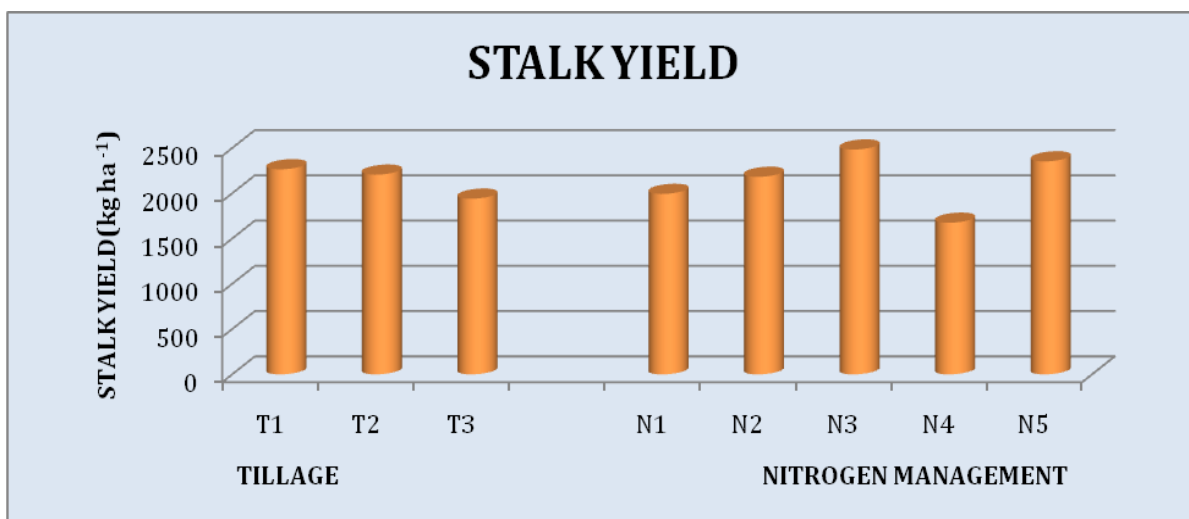
**Figure 4.7. Seed weight per head (g) of sunflower as influenced by tillage practices and nitrogen management**



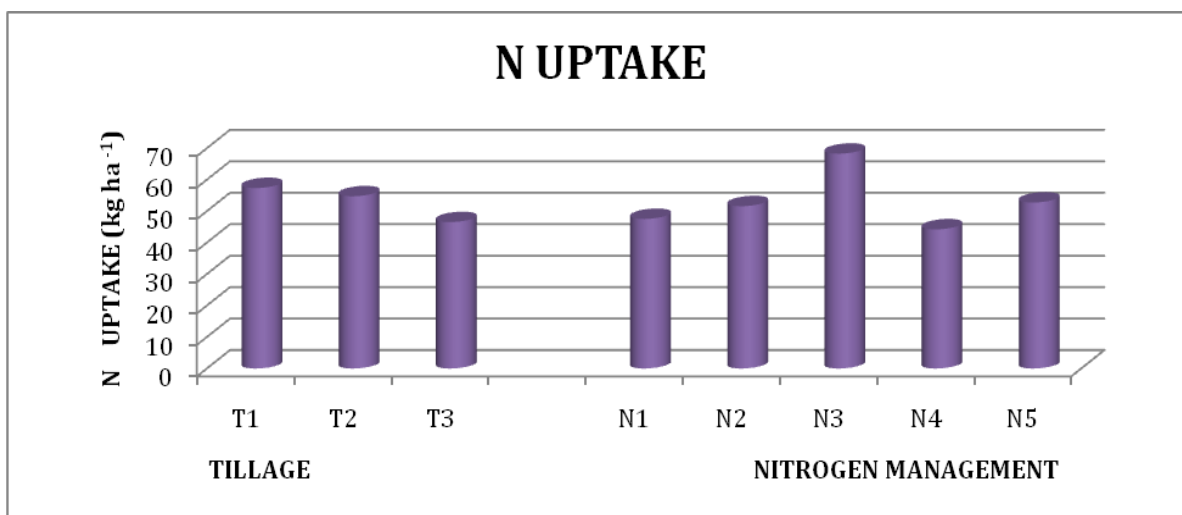
**Figure 4.8. Test weight (1000 seeds) (g) of sunflower as influenced by tillage practices and nitrogen management.**



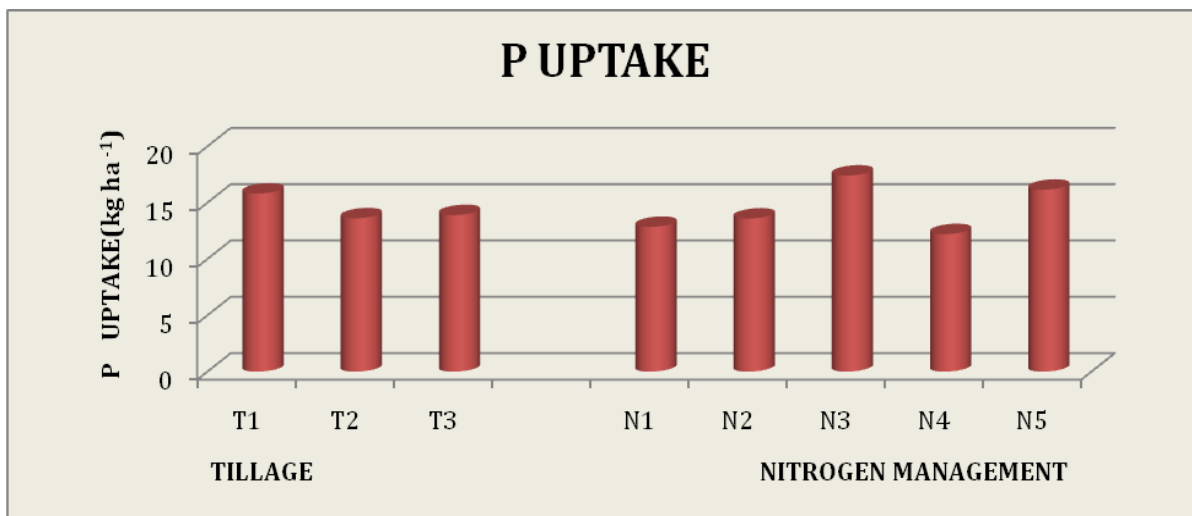
**Figure 4.9.** Seed yield (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nitrogen management.



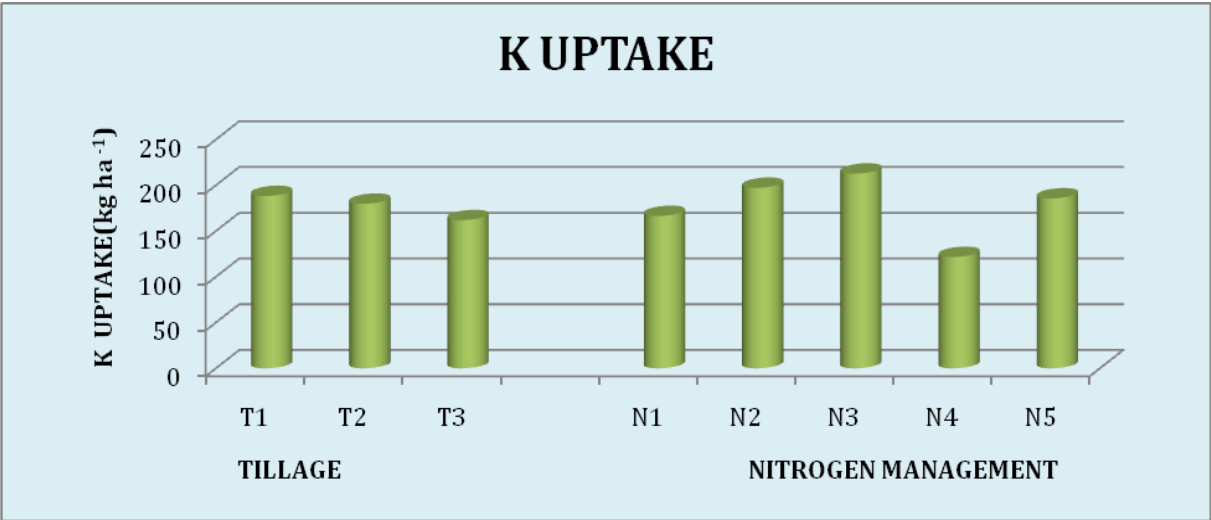
**Figure 4.10.** Stalk yield (kg ha<sup>-1</sup>) of sunflower as influenced by tillage practices and nitrogen management.



**Figure 4.11.** Nitrogen uptake ( $\text{kg ha}^{-1}$ ) of sunflower at harvest as influenced by tillage practices and nitrogen management.



**Figure 4.12.** Phosphorus uptake ( $\text{kg ha}^{-1}$ ) of sunflower at harvest as influenced by tillage practices and nitrogen management.



**Figure 4.13.** Potassium uptake (kg ha<sup>-1</sup>) of sunflower at harvest as influenced by tillage practices and nitrogen management.

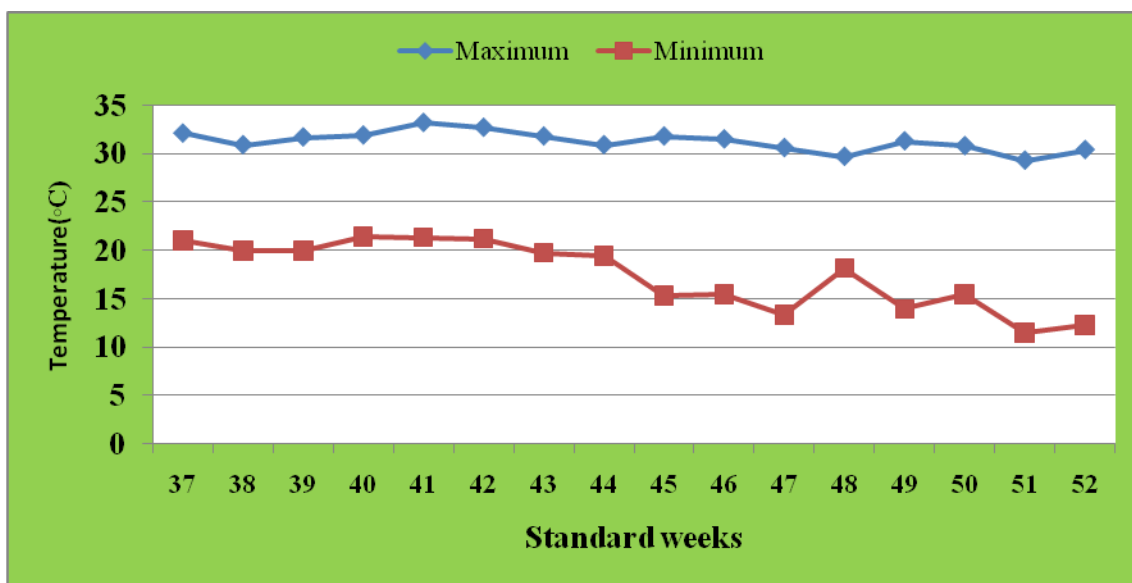


Figure 3.1 Weekly maximum and minimum air temperature during crop growth period of sunflower ( *Rabi* 2011-12).

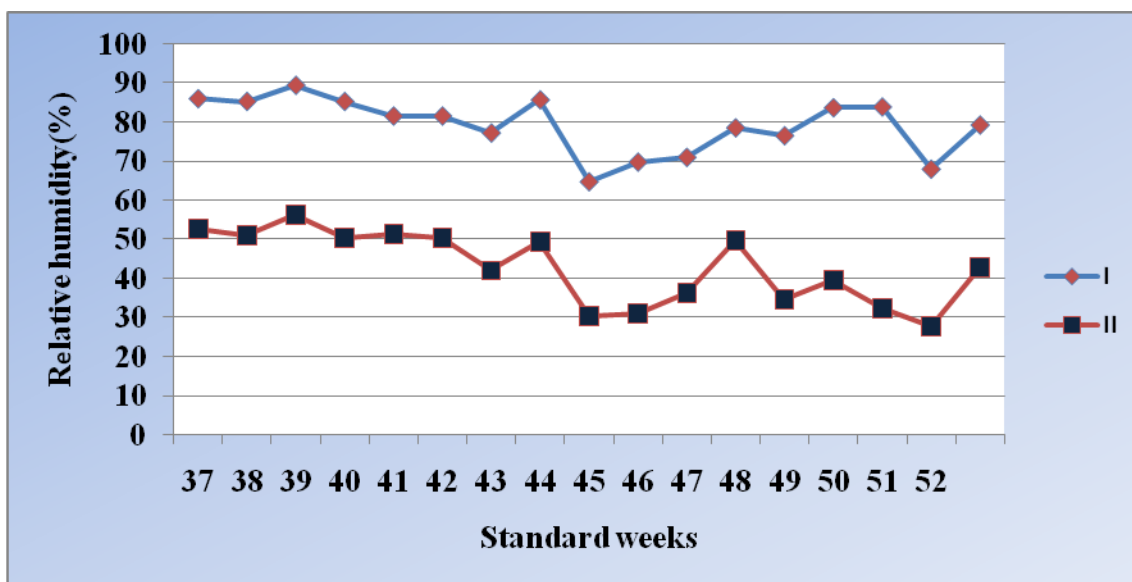


Figure 3.2 Weekly relative humidity (at 7.30 hrs (I) and 14.30 hrs (II)) during crop growth period of sunflower ( *Rabi* 2011-12).

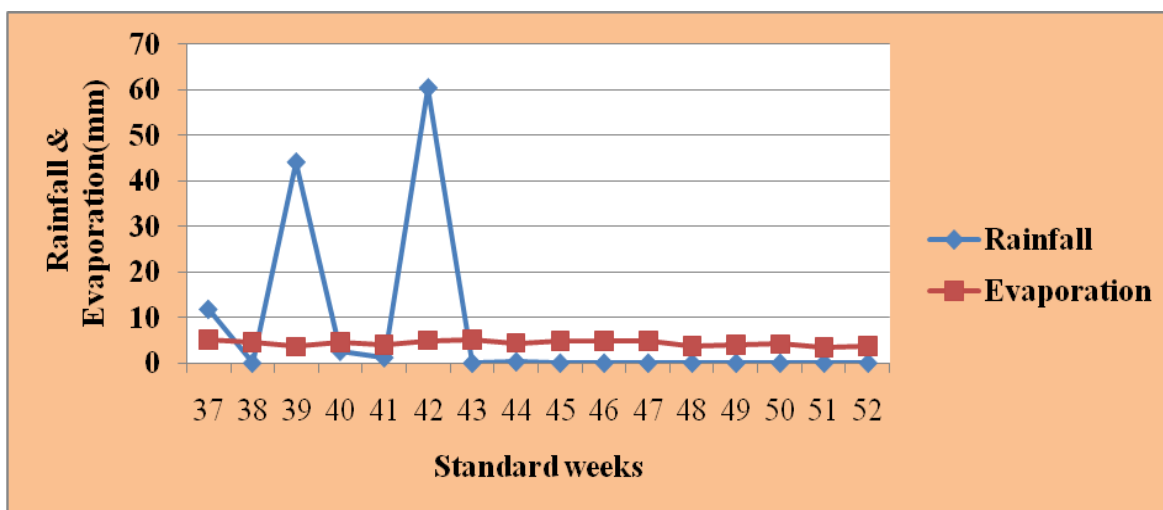


Figure 3.3 Weekly rainfall and evaporation during crop growth period of sunflower (Rabi 2011-12).

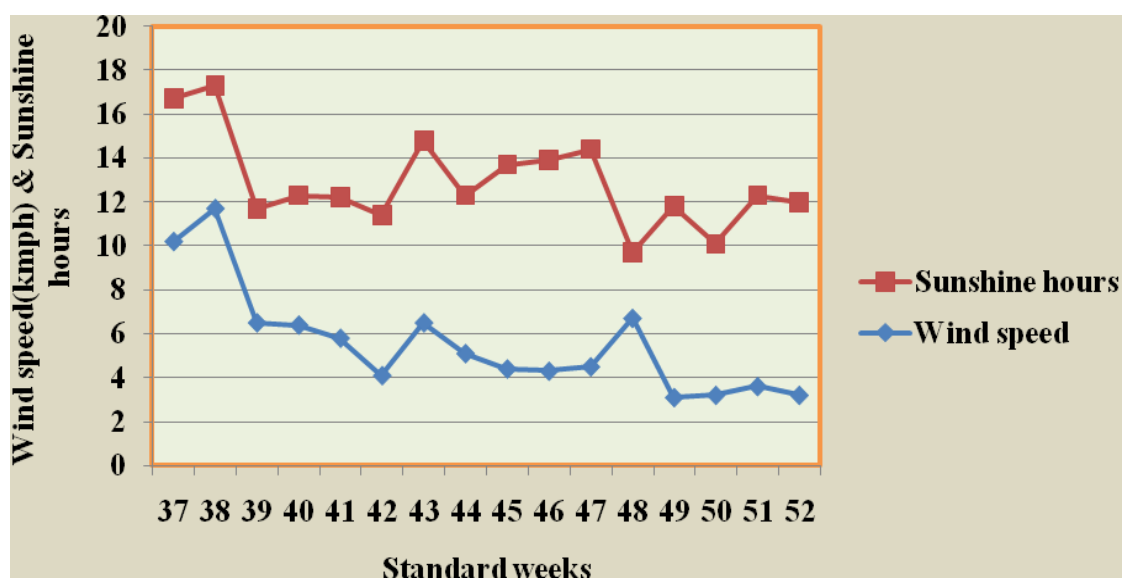


Figure 3.4 Weekly bright sunshine hours and wind speed during crop growth period of sunflower (Rabi 2011-12).

## Chapter V

# SUMMARY AND CONCLUSIONS

A field experiment entitled “Nutrient management in *Rabi* sunflower (*Helianthus annuus*. L) in relation to different tillage practices imposed during *Kharif*.” was conducted on a deep black clay soil that was low in organic carbon, available nitrogen and available phosphorus and medium in available potassium at Regional Agricultural Research Station, Bijapur in Northern Dry Zone of Karnataka to know the effect of tillage practices (**T<sub>1</sub>**- Conventional Tillage- 1 summer ploughing and 2 harrowings before sowing, **T<sub>2</sub>**-Reduced Tillage- Harrowing twice before sowing and **T<sub>3</sub>**-Minimum Tillage- Harrowing once before sowing) and nutrient management (**N<sub>1</sub>**- In situ sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup>, **N<sub>2</sub>**- In situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through fertilizer, **N<sub>3</sub>**- 100% RDF through fertilizer-35:50:35 N: P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O kg ha<sup>-1</sup>, **N<sub>4</sub>**- Farmers’ practice - 24:30:0 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup> and **N<sub>5</sub>**- Farmers’ practice + In situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup>) on growth, yield, NPK uptake and economics of sunflower during *rabi* season. The experiment was laid out in split-plot design with three replications. Tillage practices were taken as main plot treatments while nutrient management was taken as sub plot treatments. In general, the climatic conditions were congenial during the crop growth period and incidence of pest and disease attack was not noticed.

The results indicated that tillage practices could not significantly influence the growth and yield attributes of sunflower. However, dry matter during the initial stages was significantly higher with reduced tillage (**T<sub>2</sub>**) over conventional (**T<sub>1</sub>**) and minimum tillage (**T<sub>3</sub>**).

Yield components like number of seeds per head and seed weight per head was significantly higher with minimum tillage (**T<sub>3</sub>**), while tillage did not show significant influence on rest of the yield attributes, seed yield and stalk yield. Tillage had a significant effect on soil physical properties. Soil moisture content after harvest of sunflower was significantly higher with minimum tillage (**T<sub>3</sub>**) over conventional (**T<sub>1</sub>**) and reduced tillage (**T<sub>2</sub>**). Bulk density of soil was not influenced by tillage practices at peak vegetative stage and at harvest. Significantly higher N uptake of sunflower was

recorded with conventional tillage (**T<sub>1</sub>**) over minimum tillage (**T<sub>3</sub>**) but was at par with reduced tillage (**T<sub>2</sub>**). Weed density in sunflower was significantly higher with reduced tillage over minimum tillage during initial stages and thereafter minimum tillage recorded higher weed density till flowering and no significant effect was seen after flowering.

Plant height, leaf number and LAI were significantly higher with 100% RDF through fertilizer (**N<sub>3</sub>**) than rest of the treatments. Dry matter production at harvest was significantly higher with 100% RDF through fertilizer (**N<sub>3</sub>**) than rest of the treatments. Interaction effect on dry matter production at 20 DAS was significantly higher with **T<sub>2</sub>N<sub>3</sub>** (Reduced tillage and 100% RDF through fertilizer) but on par with **T<sub>1</sub>N<sub>3</sub>**, **T<sub>3</sub>N<sub>3</sub>**, **T<sub>1</sub>N<sub>2</sub>** and **T<sub>2</sub>N<sub>2</sub>**.

100% RDF through fertilizer (**N<sub>3</sub>**) recorded maximum head diameter and differed significantly from **N<sub>4</sub>** and **N<sub>5</sub>** but was on par with **N<sub>2</sub>**, and **N<sub>1</sub>**. Significantly higher number of seeds per head was recorded with 100% RDF through fertilizer (**N<sub>3</sub>**) than the rest of the treatments but was on par with **N<sub>2</sub>**. 100% RDF through fertilizers (**N<sub>3</sub>**) recorded more filled seeds per head and it differed significantly from rest of the treatments. Significantly higher test weight of sunflower was seen with 100% RDF through fertilizer (**N<sub>3</sub>**) but was on par with **N<sub>1</sub>** and **N<sub>2</sub>**.

100% RDF through fertilizer (**N<sub>3</sub>**) produced significantly higher seed yield over **N<sub>4</sub>** and was on par with rest of the treatments *viz.*, **N<sub>2</sub>**, **N<sub>1</sub>** and **N<sub>5</sub>**. Same trend was reflected as far stalk yield was concerned, where **N<sub>1</sub>** besides **N<sub>4</sub>** differed significantly from rest of the treatments (**N<sub>2</sub>**, **N<sub>3</sub>** and **N<sub>5</sub>**). Significantly higher oil yield of sunflower was seen with In-situ sunnhemp incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through fertilizer (**N<sub>2</sub>**) than **N<sub>4</sub>** but was on par with rest of the treatments.

Significantly higher soil organic carbon was seen with In-situ sunnhemp green manure incorporation @ 2.5 t ha<sup>-1</sup> + 50% RDN through fertilizer (**N<sub>2</sub>**) than **N<sub>4</sub>**, but was at par with rest of the treatments. Soil pH and EC were not influenced due to nutrient management. Significantly higher available nitrogen was seen with In -situ sunnhemp green manure incorporation @ 5 t biomass ha<sup>-1</sup> (**N<sub>1</sub>**) over 100% RDF through fertilizer (**N<sub>3</sub>**) and farmers' practice (**N<sub>4</sub>**) but was at par with rest of the treatments. Significantly higher available potassium was seen with 100% RDF through fertilizer (**N<sub>3</sub>**) than farmers' practice (**N<sub>4</sub>**) and farmers' practice + In situ sunnhemp green manure

incorporation @ 2.5 t ha<sup>-1</sup>(N<sub>5</sub>) but was at par with rest of the treatments(N<sub>1</sub> and N<sub>2</sub>). Significantly higher N and P content of sunflower were recorded with 100% RDF through fertilizer (N<sub>3</sub>) than rest of the treatments. Significantly higher NPK uptake in sunflower was recorded with 100% RDF through fertilizer (N<sub>3</sub>) than rest of the treatments. The minimum tillage with 100% RDF through fertilizer (T<sub>3</sub>N<sub>3</sub>) produced the highest gross monetary returns (Rs ha<sup>-1</sup>), net monetary returns (Rs ha<sup>-1</sup>) and benefit-cost ratio over other treatments.

From the results of the present investigation, it is concluded that minimum tillage (harrowing once before sowing) with 100 % RDF through fertilizer (N<sub>3</sub>) was found to be optimum for getting higher productivity of sunflower during *rabi* season under dry conditions. A few more years of field testing, however is necessary before making it a general recommendation.

### **Conclusions:**

1. Minimum tillage (T<sub>3</sub>) with one harrowing was found to be the optimum tillage practice for good growth and development and for higher productivity of sunflower on clay soil under dry conditions of Bijapur.
2. Application of 100% recommended dose of fertilizer through inorganic source (N<sub>3</sub>) realized higher growth and development and seed yield in sunflower.
3. Maximum gross returns, net returns and Benefit-cost ratio were realized for T<sub>3</sub>N<sub>3</sub> ( Minimum tillage with 100 % recommended dose of fertilizer) followed by T<sub>3</sub>N<sub>2</sub>.

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