

**EFFECT OF TILLAGE AND IPNS ON SOIL
PROPERTIES, UPTAKE OF NUTRIENTS AND
PRODUCTIVITY OF SOYBEAN – COTTON
ROTATION IN VERTISOL**

THESIS

**Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of**

**DOCTORATE OF PHILOSOPHY
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL
CHEMISTRY)**

**By
ASHOK BHAGWAN AGE**

**DEPARTMENT OF SOIL SCIENCE AND
AGRICULTURAL CHEMISTRY
POST GRADUATE INSTITUTE, AKOLA**

**DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
KRISHINAGAR PO, AKOLA (MS) 444104**

Enrolment Number – NN/3271

2019

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **“EFFECT OF TILLAGE AND IPNS ON SOIL PROPERTIES, UPTAKE OF NUTRIENTS AND PRODUCTIVITY OF SOYBEAN-COTTON ROTATION IN VERTISOL”** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola

(Ashok Bhagwan Age)

Date: 22 /02/2019

Enrolment No.NN-3271

CERTIFICATE

This is to certify that thesis entitled **“EFFECT OF TILLAGE AND IPNS ON SOIL PROPERTIES, UPTAKE OF NUTRIENTS AND PRODUCTIVITY OF SOYBEAN-COTTON ROTATION IN VERTISOL”** submitted in partial fulfilment of the requirements for the degree of **“Doctor of Philosophy in Agriculture (Soil Science and Agricultural Chemistry)”** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Ashok Bhagwan Age** under my guidance and supervision.

The subject of the thesis has been approved by the students Advisory Committee.

Place : Akola
Date : 22/02/2019

(P.R. Kadu)
Chairman
Advisory Committee

Countersigned

Associate Dean
Post Graduate Institute

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE
INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

1	Chairman	Dr. P. R. Kadu	_____
2	Member	Dr. V.V. Gabhane	_____
3	Member	Dr. V.K. Kharche	_____
4	Member	Dr. A. N. Paslawar	_____
5	Member	Dr. N.M. Konde	_____
6	External Examiner	(Dr. Muneshwar Singh)	_____

ACKNOWLEDGEMENT

Words are omnipotent and are believed to be mightier than sword. Words are said to be the finest invention by mankind. But words fail to do one thing they can not reveal the true depth of human emotions, happy or sad. But when there is no other means to express our feelings, we have to eventually resort to this medium of expression. This is least we can do. Hence this wordy endeavour.

At this inexplicable moment, words are not in lexicon to express my sincere sense of gratitude, but with full honour and ecstasy of delight I express my heartfelt, sincere thanks to my affectionate teacher as well as honourable and esteemed guide, Dr. P. R. Kadu, Professor, Department of Soil Science and Agricultural Chemistry Dr. PDKV, Akola. Whose judicial supervision, unceasing interest, constant endeavour, incessant encouragement, impeccable guidance, parental affection and constructive criticism throughout the compendious study turned my aspiration into a concrete reality with completion of this endeavour. I am, and shall be for entire life, greatly, thankful to the Chairman of my Advisory Committee Dr. P.R.Kadu, for his support and guidance throughout the course of this work.

I am also indebted to extend my heartfelt thanks to the members of my Advisory Committee Dr. V.V. Gabhane, Professor, AICRP on Dry land Agriculture, Dr. PDKV Akola, Dr. V. K. Kharche, Professor & Director of Research, Dr. PDKV, Akola, Dr. A. N. Paslawar, Professor, In-charge of CORT, Department of Agronomy and Dr. N.M. Konde, Assistant Professor and In-charge, education, Department of Soil Science and Agril. Chemistry, for their constant help, support, constructive criticism and encouragement.

It is my proud privileged to record my heartfelt thanks to Dr. P. R. Kadu, Head, Department of Soil Science and Agril. Chemistry, Dr. PDKV, Akola, Dr. Y. B. Taiade, Associate Dean, Post Graduate Institute, Dr. V.K. Kharche, Dean, Faculty of Agriculture, Dr. PDKV, Akola for

providing necessary facilities during the course work and research investigation.

I am also thankful to Dr. V. D. Guldekar, Professor, Department of Soil Science and Agril. Chemistry, Dr. R. N. Katkar, Professor, Department of Soil Science and Agril. Chemistry, Dr. S. D. Jadhao, Professor, Department of Science and Agril. Chemistry, Dr. P.W. Deshmukh, Associate Professor, , Shri. P.A. Gite, Associate Professor, Dr. S. S. Hadole, Associate Professor, Dr. G.S. Laharia, Assistant Professor, Dr. D.V. Mali, Assistant Professor, Dr. S.M. Jadhav, Assistant Professor, Dr. D. S. Kankal , Assistant Professor, Dr. B.A. Sonune, Assistant Professor, Shri. P. A. Sarap, Assistant Professor, Miss. Neelam Kanse, Assistant Professor and Mr. P.N. Mangare, S.R.A., Shri. D.P. Deshmukh, J.R.A., Miss. Dipti Agarkar, J.R.A., Shri. P.R. Deshmukh, Agril. Assistant, Department of Soil Science and Agricultural Chemistry for their timely help in shaping up my doctoral studies., Special thanks to Dr. S.D. Jadhao, Professor, Department of SSAC, Dr. PDKV, Akola and Dr. S.W. Jahagirdar, Ex Associate Professor, Department of Agril. Economics and Statistics, Dr. PDKV, Akola for their constant help during course of investigation. I will consider myself as a felon, if I fail to wish my thanks to other staff members of Department of Soil Science and Agricultural Chemistry for their valuable help.

The instrument of acknowledgement would remain out of tune if I do not thank to my colleagues and PG juniors for their necessary help throughout the course of this investigation. I am also thankful to Shri. S.R. Lakhe, Research Associate, AICRP on MSPE, Shri. Ramteke, Shri. Kurhe, Shri. Chavan, Shri. Bramhane, Shri. Nage, and all the staff members of the Department of Soil Science and Agricultural Chemistry Dr. PDKV, Akola.

To express my sincere gratitude to my beloved parents in the form of words is rather restrictive both in expression and quantum yet at this juncture it is my esteem duty to pour my heart and to reserve my high regards to my ideal, adorable and thinking baba, Late Shri. Bhagwan Age and aai, Kamal Age who have been a source of encouragement throughout my educational career. I also wish to record my sincere gratitude to my wife

Dr. Jyoti Ashok Age and my daughter ku. Prashika Age and son ku. Adarsha Age who always stood like a lighthouse for illuminating the pathway of my every success and for their sacrifices in moulding me to a learned as a doctorate citizen.

Last but not least, very special thanks for my dear and near friends Sushil Zodge, Samadhan Survase, Miss.Usha Satpute, Miss.PAyal Hadke, Ms. Ashwini Chandel, Shri. Omprakash Rakhonde, Dilip Nalge, Suraj Ransing, Miss. Ingle, Prabhat Patle, Ms.Chetana Kumbhar for their kind co-operation, moral support, emotional support, inspiration, friendship and for all the personal and professional help during my research work and completion of dissertation.

Behind every person who does something that can be hailed as an achievement, there is always a vortex of some people who enable him to do what he does. The completions of my life and the people who have made this possible have been duly acknowledged above.

I pray that I may be blessed enough to have such people to help me sail my boat through the rough waters that may come my way in future.

Place : Akola

Dated : 22 /02/2019

(Ashok Bhagwan Age)

Table of Contents

Sr. No.	Particulars	Page
A	Declaration of student	i
B	Certificate	ii
C	Acknowledgement	iii-v
D	List of Tables	vi-x
E	List of Figures	xi-xiii
F	List of Plates	xiv
G	Abbreviations	xv-xvi
H	Thesis Abstract	xvii-xix
I	Introduction	1-10
II	Review of Literature	11-108
III	Material and Methods	109-132
IV	Results and Discussion	133-291
V	Summary and Conclusions	292-301
VI	Literature Cited	302-337
	Vita	338
	APPENDICES	339-358

(A) List of Tables

Table	Title	Page
1	Rainfall distribution at Akola during 2016-2017	111
2	Rainfall distribution at Akola during 2017-2018	113
3	Physical and chemical properties of experimental soil at start of experiment (Kharif 2010)	115
4	Cropping history of the experimental plot	117
5	Chemical composition of organics added in soil (oven dry basis)	121
6	Sources and quantity of fertilizers and manures added in soybean during 2016-17	123
7	Sources and quantity of fertilizers and manures added in cotton during 2017-18	124
8	Effect of tillage and IPNS on bulk density of soil after harvest of soybean and cotton under soybean-cotton rotation	136
9	Effect of tillage and IPNS on hydraulic conductivity of soil after harvest of soybean and cotton under soybean-cotton rotation	139
10	Effect of tillage and IPNS on mean weight diameter of soil after harvest of soybean and cotton under soybean-cotton rotation	144
11	Effect of tillage and IPNS on pH of soil after harvest of soybean and cotton under soybean-cotton rotation	152
12	Effect of tillage and IPNS on electrical conductivity of soil after harvest of soybean and cotton under soybean-cotton rotation	155
13 a	Effect of tillage and IPNS on organic carbon of soil after harvest of soybean and cotton under soybean-cotton rotation	158

13 b	Interaction effect of tillage and IPNS on organic carbon of soil after harvest of soybean and cotton	159
14 a	Effect of tillage and IPNS on available nitrogen in soil after harvest of soybean and cotton under soybean-cotton rotation	165
14 b	Interaction of tillage and IPNS on Available N of soil after harvest of soybean and cotton	166
15	Effect of tillage and IPNS on available phosphorus in soil after harvest of soybean and cotton under soybean-cotton rotation	171
16	Effect of tillage and IPNS on available potassium in soil after harvest of soybean and cotton under soybean –cotton rotation	176
17	Effect of tillage and IPNS on available sulphur in soil after harvest of soybean and cotton under soybean-cotton rotation	179
18	Effect of tillage and IPNS on available Zn in soil after harvest of soybean and cotton under soybean-cotton rotation	184
19	Effect of tillage and IPNS on available Fe in soil after harvest of soybean and cotton under soybean-cotton rotation	188
20	Effect of tillage and IPNS on available Mn in soil after harvest of soybean and cotton under soybean-cotton rotation	192
21	Effect of tillage and IPNS on available Cu in soil after harvest of soybean and cotton under soybean-cotton rotation	196
22	Effect of tillage and IPNS on inorganic N forms in soil after harvest of soybean under soybean-cotton rotation	200
23	Effect of tillage and IPNS on inorganic N forms in soil after harvest of cotton under soybean-cotton rotation	204

24	Effect of tillage and IPNS on Soil Microbial Biomass Carbon of soil at grand growth period of soybean and cotton under soybean-cotton rotation	209
25	Effect of tillage and IPNS on Dehydrogenase activity of soil at grand growth period of soybean and cotton under soybean-cotton rotation	213
26	Effect of tillage and IPNS on CO ₂ evolution of soil of soybean and cotton under soybean-cotton rotation	217
27	Effect of tillage and IPNS on SOC Stock in soil after harvest of soybean and cotton under soybean–cotton rotation	220
28 a	Effect of tillage and IPNS on seed and straw yield of soybean under soybean-cotton rotation	227
28 b	Interaction effect of tillage and IPNS on soybean seed and straw yield under soybean-cotton rotation	228
29 a	Effect of tillage and IPNS on seed cotton and stalk yield of cotton under soybean-cotton rotation	234
29 b	Interaction effect of tillage and IPNS on seed cotton and stalk yield of cotton under soybean-cotton rotation	235
30	Effect of tillage and IPNS on total uptake of nitrogen by soybean under soybean-cotton rotation	244
31	Effect of tillage and IPNS on total uptake of phosphorus by soybean under soybean-cotton rotation	248
32	Effect of tillage and IPNS on total uptake of potassium by soybean under soybean-cotton rotation	251
33	Effect of tillage and IPNS on total uptake of sulphur by soybean under soybean-cotton rotation	255
34	Effect of tillage and IPNS on total uptake of nitrogen by cotton at harvest stage	264
35	Effect of tillage and IPNS on total uptake of phosphorus by cotton at harvest stage	267

36	Effect of tillage and IPNS on total uptake of potassium by cotton at harvest stage	271
37	Effect of tillage and IPNS on total uptake of sulphur cotton at harvest stage	274
38	Soil Quality Index as influenced by tillage and IPNS under soybean-cotton rotation	281
39	Multiple regressions of total soil parameters and soil indicators	283
40	Per cent contribution of key Soil Quality Indicators in Seed yield and Soil Quality Index under conservation tillage	285

B) List of Figures

Fig.	Title	Page
1a	Rainfall at Akola (2016-17)	111
1b	Weekly rainfall at Akola (2016-17)	112
2a	Rainfall at Akola (2017-18)	114
2b	Weekly rainfall at Akola (2017-18)	114
3	Plan of layout of experimental field	116
4	Effect of tillage and IPNS on hydraulic conductivity of soil after harvest of soybean and cotton	140
5	Effect of tillage and IPNS on Mean weight diameter of soil after harvest of soybean and cotton	145
6	Effect of tillage and IPNS on Soil moisture content of soil at critical growth stages of soybean	147
7	Effect of tillage and IPNS on Soil moisture content of soil at critical growth stages of cotton	149
8	Effect of tillage and IPNS on Organic carbon of soil after harvest of soybean	160
9	Effect of tillage and IPNS on available N of soil after harvest of soybean and cotton	167
10	Effect of tillage and IPNS on available P of soil after harvest of soybean and cotton	172
11	Effect of tillage and IPNS on available K of soil after harvest of soybean and cotton	177
12	Effect of tillage and IPNS on available S of soil after harvest of soybean and cotton	180

13	Effect of tillage and IPNS on available Zn of soil after harvest of soybean and cotton	185
14	Effect of tillage and IPNS on available Fe of soil after harvest of soybean and cotton	189
15	Effect of tillage and IPNS on Available Mn of soil after harvest of soybean and cotton	193
16	Effect of tillage and IPNS on Available Cu of soil after harvest of soybean and cotton	197
17	Effect of tillage and IPNS on In organic N forms of soil after harvest of soybean	201
18	Effect of tillage and IPNS on In organic N forms of soil after harvest of cotton	205
19	Effect of tillage and IPNS on SMBC of soil at grand growth of soybean and cotton	210
20	Effect of tillage and IPNS on DHA of soil at grand growth stage of soybean and cotton	214
21	Effect of tillage and IPNS on CO ₂ evolution of soil at grand growth stage of soybean and cotton	218
22	Effect of tillage and IPNS on SOC Stock of soil after harvest of soybean and cotton	221
23	Effect of tillage and IPNS on seed and straw yield of soybean	229
24	Effect of tillage and IPNS on seed cotton and stalk yield of cotton	236
25	Effect of tillage and IPNS on uptake of nitrogen by soybean	245
26	Effect of tillage and IPNS on uptake of phosphorus by soybean	249

27	Effect of tillage and IPNS on uptake of Potassium by soybean	252
28	Effect of tillage and IPNS on uptake of sulphur by soybean	256
29	Effect of tillage and IPNS on uptake of nitrogen by cotton	265
30	Effect of tillage and IPNS on uptake of phosphorus by cotton	268
31	Effect of tillage and IPNS on uptake of potassium by cotton	272
32	Effect of tillage and IPNS on uptake of sulphur by cotton	275
33	Effect of IPNS on apparent nutrient balance in conservation tillage by soybean and cotton under soybean-cotton rotation	277
34	Effect of IPNS on apparent nutrient balance in conventional tillage by soybean and cotton under soybean-cotton rotation	279
35	Effect of tillage and IPNS on Soil Quality Index	282
36	Per cent contribution of key Soil Quality Indicators in Seed yield and Soil Quality Index under conservation tillage	284
37	Per cent contribution of key Soil Quality Indicators in Seed yield and Soil Quality Index under conventional tillage	284
38	Effect of tillage and IPNS on economics by soybean and cotton under soybean-cotton rotation	290

(C)

List of Plates

Plate	Caption	Page
1	Overview of field experiment	120
2	Compost preparation	122
3	Organics application in soybean	125
4	Organics application in cotton	126
5	Effect of tillage and IPNS under soybean	226
6	Effect of tillage and IPNS under cotton	232

(D)**Abbreviations**

%	- per cent
/	- Per
@	- at the rate of
AICRP	- All India Coordinated Research Project
BD	- Bulk density
°C	- Degree Celsius
CD	- Critical difference
cfu	- colony forming unit
cm	- Centimeter
CNS	- conservation tillage
CNV	- conventional tillage
DAS	- Days after sowing
DHA	dehydrogenase activity
DTPA	- Diethylene Triamine Penta acetic Acid
dS m ⁻¹	- Deci siemens per meter
EC	- Electrical conductivity
<i>et al.</i>	- <i>et alia</i> (and others)
<i>etc.</i>	- <i>Etcetera</i>
Fe	- Iron
Fig.	- Figure
FYM	- Farm yard manure
g	- Gram
ha ⁻¹	- per hectare
<i>i.e.</i>	- <i>id est</i> (that is)
INM	- Integrated nutrient management
J	- Journal
K	- Potassium
kg ha ⁻¹	- Kilogram per hectare
m	- Meter
Mg	- Megagram

mg kg ⁻¹	-	Milligram per kilogram
mm	-	Millimeter
MWD		mean weight diameter
Mn	-	Manganese
MOP	-	Muriate of potash
MW	-	Meteorological week
N	-	Nitrogen
NS	-	Non significant
OC	-	Organic carbon
P	-	Phosphorus
ppm	-	parts per million
q ha ⁻¹	-	Quintal per hectare
RDF	-	Recommended dose of fertilizer
SSP	-	Single super phosphate
SE (m)±	-	Standard error of mean
SMBC	-	soil microbial biomass carbon
SMBN	-	soil microbial biomass nitrogen
t ha ⁻¹	-	tonne per hectare
µg	-	Microgram
<i>viz.</i>	-	<i>videlicet</i> (namely)
VC	-	Vermicompost
yr ⁻¹	-	per year
WSA	-	water stable aggregate
Zn	-	zinc
ZT	-	zero tillage

(F)

THESIS ABSTRACT

- a. Title of the thesis : **EFFECT OF TILAGE AND IPNS ON SOIL PROPERTIES, UPTAKE OF NUTRIENTS AND PRODUCTIVITY OF SOYBEAN-COTTON ROTATION IN VERTISOL.**
- b. Full name of student : **Ashok Bhagwan Age**
- c. Name and address of major advisor : **Dr. P. R. Kadu**
Professor (CAS)
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola-444 104
- d. Degree to be awarded : Ph.D. (Agriculture)
(Soil Science and Agricultural Chemistry)
- e. Year of award of degree : 2019
- f. Major subject : Soil Science and Agricultural Chemistry
- g. Total number of pages in thesis : 296
- h. Number of words in thesis abstract : 570
- i. Signature of the student :
- j. Signature, name and address of forwarding authority :

Head

Department of Soil Science and Agricultural
Chemistry, Dr. PDKV, Akola

ABSTRACT

The present investigation was conducted during *kharif* 2016-17 and 2017-18 with a view to study the “ Effect of tillage and IPNS on soil properties, uptake of nutrients and productivity of soybean-cotton rotation in Vertisol” executed at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with an objectives to study the effect of tillage and IPNS on physical,

chemical and biological properties of soil, to assess the effect of tillage and IPNS on yield and nutrient uptake by soybean. To find out the effect of tillage and IPNS on yield and nutrient uptake by cotton.

The experiment was carried out with main plot comprises two treatments i.e. conservation tillage (one harrowing and two weeding) and conventional tillage (one ploughing , one harrowing, two hoeing and two hand weeding) and eight sub plot treatments of integrated plant nutrient system consisting of control, 100 per cent RDF and use of chemical fertilizer along with organic source of nutrient in which 50 per cent N applied through organic sources (FYM, wheat straw, glyricidia leaf manuring (GLM), composted cotton straw, vermicompost and phosphocompost) and remaining N was applied through chemical fertilizers. The experiment was framed in randomised block design with three replications. The soil and plant samples were analysed after each crop during 2016-17 and 2017-18. Similarly the apparent nutrient balance, soil quality index and cost economics were also computed.

The use of organics viz. FYM, GLM, phosphocompost and vermicompost in conjunction with chemical fertilizers registered improvement in physical properties viz. bulk density, HC, MWD, and soil moisture content after harvest of both crop under conservation tillage. Significantly higher soil organic carbon, available N, P, K, S and micronutrients were recorded with the conjunctive use of organics viz. FYM, GLM, phosphocompost and vermicompost along with chemical fertilizers under conservation tillage during both the year. The biological properties viz. SMBC, SMBN, CO₂ evolution and DHA were improved significantly under various IPNS treatments comprising use of FYM, phosphocompost, GLM, and vermicompost amalgamated with chemical fertilizers under conservation tillage. The significantly highest soybean seed yield and seed cotton yield as well as highest uptake of nutrients were recorded with the application of phosphocompost in conjunction with chemical fertilizers followed by FYM, GLM and vermicompost under conservation tillage.

Among the tillage practices, the conservation tillage was found beneficial in improving physical, chemical and biological properties of soil. Similarly, significantly higher soybean and cotton yield and uptake of nutrients were recorded in conservation tillage as compared to conventional tillage under soybean-cotton rotation.

The apparent nutrient balances of major nutrients were assessed. The lowest negative balance of N and K was observed with application of composted cotton stalk. While the highest P balance was noted with the application of wheat straw.

The soil quality index was assessed based on 24 soil parameters. Principal component analysis (PCA) was run to arrived at component values. The significantly highest SQI was observed with FYM followed by GLM and phosphocompost. However, among the tillage practices, conservation tillage was recorded higher soil quality index as compared to conventional tillage.

The B:C ratio was noted highest in conservation tillage as compared to conventional tillage. Among the various IPNS treatments the use of FYM and Phosphocompost was found equally beneficial for achieving higher B:C ratio. The results obtained will serve as a benchmark database for further monitoring of soil quality and sustainability of crop production under soybean-cotton rotation in Vertisols.

CHAPTER I

INTRODUCTION

1.1 Background Information

Indian agriculture has entered in a new phase of research and development from the green revolution era of enhancing crop productivity to resolving the new challenges emerged out from green revolution. In order to resolve these problems and to meet out emerging needs, the demand of efficient use and conservation of resources is creating the pressure on the researchers. Issues of resource conservation and maintaining their sustainability is important in view of facing problems of resource degradation along with the fundamental principle of reducing costs of crop production and increasing profitability.

Agricultural systems are relying on approaches like sustainable agriculture or conservation agriculture, are not only able to support high productivity, but also preserve biodiversity along with environmental safeguards.

Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes, like nitrogen fixation, nutrient cycling, soil regeneration and protection of natural enemies of pest and diseases as well as the targeted use of inputs. Its increasing concerns have been seen as a positive response to limits both, traditional- low input agriculture and intensive modern- high input in agriculture production systems.

Conservation agriculture has emerged as a new paradigm to achieve the goals of sustainable agricultural production. It involves the new and innovative ways of generating and promoting technologies that focus on resource conservation as a way to enhance productivity in a sustainable manner. Conservation agriculture aims at reversing the process of degradation inherent to the conventional agricultural practices like intensive cultivation and burning or removal of crop residues. Aggressive seed bed preparation with heavy machinery lead to declining soil fertility, biodiversity and erosion. The nutrient needs of the Indian agriculture are so large that

no single plant nutrient source be it fertilizers, organic manures, green manures or biofertilizers are in position to meet the entire plant nutrient demand. Therefore, resource conservation becomes a top priority and restoration of precious soil resource by way of innovative means of management is the need of the day.

Soil is a finite natural resource of the production of different crops. The degradation of soil health has emerged as a major factor responsible for stagnation in agricultural production and is posing a serious threat to our national food security for the last few years. The degradation of soil health in many cultivated areas is manifested in terms of loss of soil organic matter and depletion of native soil fertility due to imbalanced and unscientific use of fertilizer. This has become a major constraint now in improving crop productivity. The escalating population, attenuating good quality land resources for crop production and increasing concern for declining soil quality and environment degradation highlight the urgency for continuously enhancing and sustaining the productivity of land. The high yielding hybrid varieties of many crops are being grown by the farmers in the country which resulted in heavy nutrient mining from the soil. The utility of land to produce yield is limited and limits of production are set by soil and climatic parameters.

Soybean cultivation is continuously increasing due to its dual utility as pulse as well as oil seed crop, besides it has better market price, high protein content (40-42 %) and oil content (20-22 %). It is the cheapest and richest source of high quality protein. It supplies most of the nutritional constituents essential for human health. Hence, soybean is called as "Wonder bean" or "Miracle bean". Soybean occupies an intermediate position between legumes and oilseed. It is grown in the area which receive 800-1200 mm rainfall and on almost all types of soil. Soybean crop contributes 24-30 q ha⁻¹ residues which can be recycled and nutrient content therein be harnessed for the succeeding crop besides improving the soil fertility.

In India, area under soybean cultivation is approximately 9.95 m ha with production of 12.57 MT. Maharashtra ranks 2nd in soybean cultivated area and production in country. The area under soybean crop in Maharashtra is 35.80 lakh ha of total cultivated area of the country with an average productivity of 1102 kg ha⁻¹ and production 39.45 lakh MT. (Anonymous, 2016). Out of total soybean cultivated area in Maharashtra 75 to 80% area is in Vidarbha. The area under soybean cultivation in Vidarbha is 25.50 lakh ha with production of 21.62 lakh MT and average productivity is 1050 kg ha⁻¹.

The soybean has great potential to produce large amount of shaded biomass. Considering the magnitude of the produced biomass and its utilization in enhancement of soil carbon the present study was framed to identify the enormity of soybean in sequestering the carbon in soil.

Cotton (*Gossypium spp.*) is one of the important commercial crops known as “White Gold of Black Soil” in Maharashtra in general and in Vidarbha in particular, is a leading fiber crop and second most important crop in the world (Rajendran *et al.*, 2005). India ranks first in global scenario with 20 per cent of the world’s total cotton area and second in production next to China. Maharashtra is one of the leading cotton growing states in India having 38.27 lakh ha area under cotton cultivation which is one third of country’s area of cotton cultivation with the production of 75 lakh bales. The productivity of cotton in Maharashtra is 333 kg lint per ha (Anonymous, 2016). The economy of agricultural community of *Vidarbha* is mostly dependent on the cotton. The area under cotton in *Vidarbha* is 14.22 lakh ha with production of 23 lakh bales. The reasons for low productivity includes erratic distribution of rainfall, imbalanced fertilizer use, poor quality seed, low adoption of improved agro-techniques and decline in soil health (Anonymous, 2016).

1.2 Importance and need of study

Most of the soils of the cotton growing areas are low in organic carbon, nitrogen and available phosphorus (Rattan *et al.* 1999). As

discussed earlier, considering soil as a only and finite source of crop production, increase in production and productivity can be achieved only through enhanced *vis-a-vis* sustained soil fertility by replenishment of removed nutrients in crop production system. It seems that major population of farmers prefers to supply the entire nutritional requirement of crops through chemical fertilizers alone. The continuous use of chemical fertilizer alone deteriorates the soil fertility and fertilizer use efficiency (Muthuswamy *et al.*, 1990). Intensive cropping and tillage systems have led to substantial decreases in the SOC through enhanced microbial decomposition and through wind and water erosion of inadequately protected soils which is often accompanied by a decline in soil productivity. Carbon loss by tillage is caused by greater oxidation of SOC and it ranges from 20 to 50 per cent in soil dominating the semi-arid regions of India.

Therefore, it is the time now to develop such a crop management system that may sustain the soil and crop productivity in terms of maintenance of physical, chemical and biological properties of soil. This can be achieved with modification in existing tillage practices, integrated plant nutrient management in order to enhance and sustain the overall soil quality. The restoration and maintenance of soil organic carbon (SOC) is of most paramount importance while identifying the appropriate management practices. It is primarily governed by climate; particularly precipitation and temperature and cropping cum tillage systems. Increasing carbon sequestration in agricultural soils and making them a net sink for atmospheric carbon can be achieved by adoption of the best management cum cropping systems involving use of balanced fertilizers, conservation tillage practices, crop residue management, use of organic manures and various soil conservation practices. Thus, it is essential to utilize all available organic resources and to develop crop management system for sustainable cotton and soybean production as well as maintenance of soil health. The organic matter in crop residues serves as a major source for replenishing various fractions of soil organic matter and subsequently influences aggregation, porosity and other soil properties. Use of organics, crop residues, green manures, agricultural wastes, biofertilizers as the

components of integrated nutrient management alleviate soil health by changing rhizosphere environment.

Fertilizers are the costly inputs hence, it is very essential to bring economy in the use of inorganic fertilizer by their judicious use in combination with organic manures. The application of organic manures not only ameliorates the soil properties but also ensure sustainable crop production in long run (Reddy and Reddy, 1998). This also ensure continuous supply of nutrient to crop plants for longer period due to slow release of nutrients thus improve yield potential of crop with secondary and micronutrients in order to maintain high yields.

Tillage of the soil is the mechanical manipulation of soil using implement by loosening it for good germination of seeds, plant growth which also help in soil and water conservation. It facilitates increase in moisture storage capacity of soil profile, provide *in situ* moisture conservation. Tillage is an important agronomic practice essential to create and maintain good soil condition. Preparatory tillage helps to minimize weed problem and also to maintain soil and surface conditions erosion resistant. It also help to incorporate manures, fertilizers, amendment of crop residues into soil, improve soil aeration and control weed, increase soil aeration, soil temperature, create better environment for soil microorganism, ultimately increase the nutrient uptake and crop yield (FAO, 1979).

In view of the above discussion about declining soil fertility and reduction in crop productivity the resource conservation becomes a top priority and restoration of precious soil resource by way of innovative means of management is the need of the day.

In recent years the concept of conservation agriculture through conservation tillage has come in mode, as a means of reducing time, labour and machine operation as well as conserving moisture and reducing soil erosion and nutrient loss. Conservation tillage is more appropriate strategy for rain fed production system. Conservation tillage is generic term encompassing many different soil management practices. It is

generally defined as “any tillage system that reduces loss of soil or water relative to conventional tillage”, mostly a form of non inversion tillage, allows protective amount of residue mulch on the surface. Conservation tillage allows crop residues as surface mulch, is effective in conserving soil and water and maintains good soil structure, organic matter contents and maintains desirably high and economic level of productivity (Lal *et al*, 1989). Conservation tillage can rebuild organic carbon levels in soil and increases the carbon sequestration in soil (Novak *et al.*, 2009). Under such condition integrated plant nutrient supply and management is best future strategy for enhancing soil quality and crop productivity (Swarup, 2010).

The nutrient content of various organic resources having the total nutrient potential of 14.85 million tonnes was estimated in 2000, which would become around 16.34 and 32.41 million tonnes by 2010 and 2025, respectively. Out of these organic resources, considerable tapable potential of nutrients ($N + P_2O_5 + K_2O$) from human excreta, livestock dung and crop residues has been worked out to the order of 5.05 million tonnes in 2000, which would be about 6.24 and 7.75 million tonnes by 2010 and 2025, respectively for the required food grain production of the increased human population (Mahajahan and Gupta, 2009). However, mere use of organics will not sustain the soil productivity for long time; hence, the application of organics needs to be supplemented with chemical fertilizers. Thus, the fertility of the soil needs to be maintained and sustained through organic manure, crop residues incorporation and biological sources with supplemental application of chemical fertilizer along with specific management practices for different crops and cropping systems (Kanwar, 1997).

Vertisols are swell-shrink type soils with high water retentively, low infiltration rate and high cation exchange capacity. Improvement and maintenance of the organic matter in these soils is an essential precondition to sustain reasonable levels of organic cotton production as this would increase water infiltration, reduce erosion, and improve soil structure and aggregate stability, besides enhancing the supply of nutrients, particularly, N, P and S. Hence, a good organic matter

management programme is needed for fertility management under organic production system. Rainfed cotton crop in Central India removes around 5.8 kg N, 2.0 kg P and 6.6 kg K per 100 kg seed cotton produced. With many such alternate uses of FYM, such huge quantities required to meet the crop's nutrient requirement is generally not available. Hence, a combination of sources with different biological properties must be resorted.

Among various sources of organic matter, FYM improves, physical, chemical and biological environment thereby increasing the crop yield. Application of FYM significantly increased the soil organic carbon, infiltration rate, water retention, aggregation and aggregate stability in water (Benbi *et al.*, 1998). The another important source of organic manure is green manuring which is an age old concept of soil fertility management and being practiced to incorporate the succulent green portion of plant such as leaves, twigs and lopping of trees into soil. Green manuring crop are known to fix atmospheric nitrogen, improve soil structure and recycle nutrients and decomposition of organic matter resulting in liberation of CO₂ which influence on weathering of minerals and ultimate release of plant nutrients.

Efficient use of water in nutrient management is also highly critical to sustain agricultural production and will increase the demand in future to meet a projected growing demands matching with rapidly swelling population, more particularly in the context of declining per capita land, water use efficiency in dry land agriculture availability, soil and water pollution and increasing fertilizer cost, etc. (Verma *et al.* 2010).

In this context, the present investigation was planned to study the effect of tillage and integrated plant nutrient management on soil properties, uptake of nutrients and yield of soybean and cotton in Vertisol.

1.3 Objectives of study

It was proposed to undertake the study entitled “Effect of tillage and IPNS on soil properties, uptake of nutrients and productivity of soybean-cotton rotation in Vertisol”, with the following objectives.

1. To assess the effect of tillage and IPNS on physical, chemical & biological properties of soil
2. To study the effect of tillage and IPNS on yield and nutrients uptake by soybean
3. To find out the effect of tillage and IPNS on seed cotton yield and nutrients uptake by cotton

1.4. Hypothesis

Different resource conservation practices enhance the crop productivity and improve the soil physical, chemical as well as biological properties. The physical properties viz. water stable aggregates, mean weight diameter, available water capacity, hydraulic conductivity and infiltration rate increases with the application of crop residues along with fertilizers where as bulk density decreases. The chemical properties namely organic carbon content and available nutrients enhances with the application of crop residues supplemented with chemical fertilizers through conservation practices. The microbial population proliferates after incorporation of organic manures or crop residues which acts as substrate for microbes and helps in decomposition, releases the nutrients for the growth and development of the plants. The microorganisms also release mucilage and enzymes which acts as binding agent of soil particles, leading to improvement in soil aggregation.

Soil aggregation and soil structure improved in conservation tillage due to minimum disturbance along with improvement in biological properties like SMBC, DHA and active carbon. Thus, the soil organic matter status can be built up by using various available organic resources with very minimum disturbance to soil, considering the rate of evolution of CO₂.

Therefore, more logical way to manage and improve the long term soil fertility and productivity of cotton and soybean crops is to use

inorganic and organic sources of plant nutrients in integrated manner and to adopt conservation tillage.

1.5 Scope and limitation

There is a wide scope for utilization of conservation tillage and integrated nutrient management in agriculture. Conservation tillage and integrated nutrient management in various cropping systems is an important way for build-up of soil organic matter and thereby augmenting the soil fertility and soil quality. It reduces time, labour and machine operation as well as conserving moisture and reducing soil erosion and nutrient loss there by sustaining the crop yields as well as soil health.

Combined use of FYM, crop residues, green manure is a better option to build up the soil organic matter pools for sustained high nutrient supply. It has potential for improving soil and water conservation, sustaining soil productivity, soil fertility and soil quality. Though the conservation agriculture practices have been found very useful in the light textured soils, it has a wide scope to be systematically studied in heavy black soils like Vertisols.

Retention of crop residues on the soil surface with minimum or no tillage has three broad objectives to maintain enough plant residues on the soil surface to provide protection against water and wind erosion to increase entry and storage of soil water and to reduce energy use in cultivation.

Conservation tillage entails a systems approach to farming, and involves techniques for management of various multidisciplinary strategies. A change in cultivation type or frequency would be expected to alter the microenvironment in such a way that weeds, diseases and insects would be affected, although the type of response may be determined by the crop, the pest, or the environment. The type and frequency of cultivation would also affect nutrient cycling and nutrient management. There are certain limitations i.e. it needs a thorough understanding of the concept and requires careful farm management practices to be successful. Most soil pests populations are increased. Weeds compete with the main crops. High

tendency of a carryover of the insect pests and diseases from the crop residues. Organic matters are not evenly distributed or are concentrated at the topsoil. It needs patience and waits a longer time to have an excellent soil.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made to review the effect of tillage and integrated plant nutrient system on soil properties and uptake of nutrients and productivity of soybean- cotton rotation in Vertisol which are described under the following appropriate heads.

- 2.1 Effect of tillage and integrated plant nutrient system on soil properties
 - 2.1.1 Physical properties
 - 2.1.2 Chemical properties
 - 2.1.3 Biological properties
- 2.2. Effect of tillage and integrated plant nutrient system on yield of soybean and seed cotton yield.
- 2.3. Effect of tillage and integrated plant nutrient system on nutrient content and uptake by soybean and cotton
- 2.4 Nutrient balance
- 2.5 Soil Quality Index

Conservation tillage is more appropriate strategy for rainfed production system. Conservation tillage (CT) has many advantages, and the system can be applied to many different situations. However, the system must be modified and adapted to meet geographical, environmental, and cultural conditions within a given region. CT is more than just omitting cultivation from crop production. It involves carefully matching the attributes of all components of the tillage system to the crop that is being produced. CT will not always produce yields of the cash crop that equal yields of conventionally tilled crops. The primary purpose of CT is to reduce soil erosion, improve water infiltration, and improve the environment while allowing an acceptable yield of a given crop. CT is sometimes considered to be synonymous with minimum tillage, reduced tillage, low-till, no-till, and sustainable agriculture. All of these systems are

designed to maintain as much vegetative cover on the soil as possible, and to minimize tillage. A cover crop could be maintained continually on the entire soil surface, or covers could be maintained in strips separated by tilled areas.

The importance of organic manure in promoting the soil health and better plant nutrition has started receiving much recognition in recent years. The supplementary and complementary use of organic manures along with inorganic fertilizers improves the physico-chemical properties of soil besides improving the efficiency of applied fertilizers. Application of farm yard manure to the soil is being practiced since ancient times. Besides, it supplies all the major nutrients including micronutrients in available form to the plants through biological decomposition. Indirectly, it improves physical properties of soil such as aggregation, aeration, permeability and water holding capacity resulted in increasing crop yields either by acceleration of respiratory process by increasing cell permeability by growth hormone action or by combination of all these processes.

To minimize existing current annual negative nutrient balance of NPK, increased use of fertilizers along with possible use of organic manures would be essential and inevitable. Organics, which can supply a portion of the P and K along with the secondary and micronutrients helps offset the negative nutrient balance and slow down nutrient depletion processes. The importance of organics in improving soil physical and biological properties cannot be denied, their efficient use to the extent possible should, therefore, be promoted and integrated nutrient management be practiced.

2.1 Physical properties

2.1.1 Effect of tillage and IPNS on Physical properties

Verma and Singh (1974) reported that wheat straw was proved to be best aggregating agent, whereas addition of nitrogen and incubation under saturation caused significant reduction in soil aggregation. Further, it was also reported that the incorporation of wheat straw was

found beneficial in improving the soil moisture retention capacity with special significance in Punjab soils, which crust badly.

Bhatia and Shukla (1982) reported that use of FYM either alone or in combination with fertilizers increased significantly mean weight diameter, the water holding capacity and retention of moisture at field capacity. Whereas, regular application of only chemical fertilizers had an adverse effect on the retention of soil moisture.

Blavins *et al.* (1983) observed that bulk density of Maury silt loam soil was 1.25 Mg m^{-3} and 1.28 Mg m^{-3} due to the effect of 10 years of no tillage while it was 1.29 Mg m^{-3} and 1.31 Mg m^{-3} under the conventional tillage in 0-8 and 8-15 cm depth respectively.

Magar *et al.* (1983) found that FYM was most effective in increasing basic infiltration rate of black soil by about four folds. With incorporation of press mud cake and wheat straw, the infiltration rate was doubled over control at 120 minutes elapsed time.

Venkateshwaralu (1984) observed that in Alfisols of Hyderabad, bulk density decreased with incorporation of 20 kg N through crop residues. The incorporation of organic residues and straw manures also decreased the bulk density significantly (1.17 g/cc) from initial bulk density (1.31 g/cc).

Khiani and More (1984) conducted a field experiment on medium black and clay loam soil to find the long term effect of tillage operation and farm yard manure application on soil properties and crop yield and observed that physical properties like maximum water holding capacity and moisture retention were significantly influenced by application of FYM and tillage operation.

Acharya *et al.* (1988) reported that the beneficial effect of the long term application of balanced rates of fertilizers alone or in combination with organic manure on the improvement of the soil aggregation. Continuous application of N through chemical fertilizers alone decreased the soil moisture retention characteristics as a result of reduced field capacity and permanent wilting point, whereas, application of FYM along

with NPK recorded higher soil moisture retention and also there was increase in water holding capacity of soil due to addition of wheat straw and cattle manure.

Lal and Mathur (1989) also reported removal of micronutrients by the crop for 30 years did not bring their level below critical limit, though they were not supplied from outside sources. Constant supply through native minerals (feldspar, hornblende, biotite, tourmaline, etc.) and fertilizer carrying these nutrients as impurities was the probable reason for the same. They further observed higher amount of available Zn, Cu and Mn in plots supplied with only organics than those in inorganic or half organic + inorganic applied plots. The mean weight diameter (MWD) value varied from 0.3 to 1.3 mm and had lower values in the treatments receiving nitrogenous fertilizers without K while appreciably higher values of MWD and reduced bulk density was observed where organic manure was incorporated.

Badanur *et al.* (1990) reported significant reduction in bulk density of Vertisol with crop residue incorporation over fertilizer application.

The supplementary and complementary use of organic residues besides improving physico-chemical properties also improves the use efficiency of applied fertilizers. With escalating cost of energy based fertilizer materials, integrated nutrient supply approach combining organic and biological source along with chemical fertilizers would be more remunerative for getting higher returns with considerable fertilizer economy. Incorporation of crop residues into the soil can help to maintain soil fertility (Prasad and Power, 1991).

Bharadwaj and Omanwar (1992) studied the impact of the long-term fertility treatments on bulk density, water contents and microbial population after nine years of continuous cropping (rice-wheat-cowpea) on Aquic Hapludoll at Pantnagar. The increasing graded doses of NPK fertilizers showed lesser bulk density than control. Similarly, 100% NPK + FYM showed lower bulk density (1.31) than those under fallow plots (1.32) and soil water retention at 33 and 1500 kPa and available water in the

surface soil (0-15 cm) varied from 28.8 to 37.7 per cent, 14.5 to 20.2 per cent and 14.3 to 19.6 per cent respectively. Water content in fallow soil was more than that in control. The fallow soils and FYM treated plots (100% NPK + FYM) showed higher available water content than those of fertilizer treated plots. Application of NPK + FYM also showed increase in microbial counts over NPK treated plots.

Pawar and Jadhav (1996) studied physico-chemical properties under different cropping sequences and reported that bulk density after *kharif* crops was significantly decreased under groundnut-sorghum (1.29 Mg m^{-3}) and under greengram-sorghum (1.30 Mg m^{-3}) than soybean-sorghum and fallow-sorghum (1.31 Mg m^{-3}) during both the years.

Laddha and Totawat (1997) reported that disc and chisel ploughing significantly reduced bulk density, increased hydraulic conductivity than minimum tillage. The average value of these parameter in the top 15 cm of soil for minimum tillage compared with deep tillage (1.41 and 1.37 Mg m^{-3} , 1.51 and 1.78 cm hr^{-1})

Reddy (1997) reported improvement in moisture content, porosity, hydraulic conductivity and infiltration rate of swell-shrink soil due to incorporation of wheat straw @ 5 t ha^{-1} followed by press mud cake, FYM, *Glyricidia maculata* over control.

Bellaki and Badanur (1997) conducted a field experiment at Regional Research Station, Bijapur for four years (1984-94) study and observed that in situ incorporation of sunhemp reduced the bulk density as compared with fertilizer application. Application of sunhemp in combination with fertilizers improved infiltration rate, water stable aggregates, porosity, field capacity, maximum water holding capacity under dryland.

Salinas-Garcia *et al.* (1997) reported that the soil bulk density increased with depth and was significantly influenced by tillage treatment at all sampling depth; deeper tillage system (mould bould plough and chisel plough) generally exhibited lower bulk densities as compared to the shallower tillage (minimum tillage) and no tillage treatments.

Sharma and Gupta (1998) reported that the bulk density reduced significantly with increase in water holding capacity under application of N through organic sources in soybean-safflower cropping sequence.

Bellakki *et al.* (1998) studied long-term field experiment at the Agricultural Research Station, Siruguppa (Karnataka) under irrigation from 1984 to 1994 on rice (two crops in year) continuously on Typic Haplusterts. They revealed that the application of various organic materials to meet 50 per cent N along with 50 per cent NPK (60:30:30 kg ha⁻¹) recorded significantly lower bulk density. Rice straw incorporation either to meet 50 per cent or 25 per cent N along with fertilizers increased the hydraulic conductivity, soil water retention characteristics and maximum water holding capacity.

Malewar *et al.* (1998) reported significant improvement in bulk density, hydraulic conductivity and water holding capacity and porosity of Vertisol with the application of FYM alone as a source of nitrogen as compared to application of N through urea or combination of both.

Ismail *et al.* (1998) observed significant decrease (1.21 to 1.15 Mg m⁻³) in bulk density and increase in hydraulic conductivity (9.7 to 11.3 m s⁻¹ x 10⁻⁶) in Vertisol with the application of FYM @ 30 Mg ha⁻¹ over control.

Bharambe *et al.* (1999) observed that the decrease in bulk density with incorporation of cowpea at flowering + sorghum stubbles with irrigations (S₃ and S₄). Highest mean weight diameter (0.66 mm) was observed with incorporation of cowpea at flowering + sorghum stubbles under rainfed (S₄) followed by cowpea at flowering + sorghum stubbles with irrigations (S₃).

Solaiappan *et al.* (1999) conducted a field experiment on cotton in heavy black soil and observed that among legume, sunhemp biomulch registered higher soil moisture content (22.8 % and 20.3 % at 30 cm and 45 cm depth).

Babhulkar *et al.* (2000) reported that application of 7.5 Mg ha⁻¹ FYM with 50 % of N and P resulted in significant decrease in bulk density (1.68 to 1.56 Mg m⁻³) and increase in hydraulic conductivity (0.31 to 0.67 cm h⁻¹) of Vertisol as compared to control.

Prasad and Sinha, (2000) studied a long-term fertilizer experiment initiated during 1988-89 with wheat-rice at Pusa in Bihar on sandy loam soil. The conjunctive use of 100% NPK with organics continuously for 8 years influenced grain yield of rice and wheat in calcareous soil in the order of farmyard manure (FYM) + crop residues > FYM > crop residues > no FYM or crop residues. The FYM or FYM + crop residues could substitute 50% NPK for wheat production and their residual effect was equivalent to 50% of the recommended dose of NPK as chemical fertilizer on the yield of succeeding rice crop. Economic analysis indicated that recycling of crop residues is economical, profitable and healthy for sustainable rice and wheat production. Available N, P, K and S increased in soil when different levels of fertilizers were applied along with crop residues and organic manure. The highest soil aggregation was observed under balanced use of fertilizer with organic manure and crop residues. Improvement in soil aggregation with the application of crop residues and organic manure resulted in increase in hydraulic conductivity, water-storage capacity and decrease in bulk density.

Gupta *et al.* (2000) reported that after two cycles of rice-wheat rotation in sandy loam soil, the highest available zinc in surface layer of the profile was recorded under use of 100% NPK + ZnSO₄ @ 62.5 kg ha⁻¹ applied to each crop which was at par with 100% NPK + FYM and significantly higher as compare to control.

Sharma *et al.* (2000) found decrease in bulk density in crop residue and FYM incorporated treatment.

Kumar and Gosh (2000) reported a decreasing trend of bulk density with increasing passes of harrowing. The lowest value (1.22 Mg m⁻³) of bulk density was obtained where six passes of harrowing was done and highest (1.49 Mg m⁻³) under zero-tillage.

Rajkanan *et al.* (2001) revealed that the lowest bulk density (1.54 Mg m^{-3}) was registered in the chiseled plot which was significantly lower than other treatment and highest (1.67 Mg m^{-3}) in country ploughing treatment and chiseling increased the hydraulic conductivity (2.189 cm h^{-1}) than other tillage treatment and also reduction in bulk density and increased hydraulic conductivity with application of composted coir pith and FYM @ 12.5 t ha^{-1} .

Wankhade *et al.* (2001) conducted experiment on cotton in medium deep clay soil at cotton research unit, Dr. PDKV, Akola (M.S) and indicated that bio-mulching with cowpea, green gram and sunhemp conserved soil moisture to the extent of 12.8, 10.6 and 11.3% at flowering stage and 7.72, 10.10 and 8.71 % respectively at harvesting stage.

Ray *et al.* (2001) reported that incorporation of green manure and disc ploughing and chiseling before puddling for rice improved the soil aggregation and decreased bulk density and increased the saturated hydraulic conductivity.

Bharambe *et al.* (2002) stated that the effect of crop residue management in improving the soil characteristics persist even after the harvest of second crop in a soybean-sorghum cropping sequence. Soybean considerably improved the physical properties of soil such as increase in soil aggregation decrease in bulk density and increase infiltration rate.

Katkar *et al.* (2002) indicated that the bulk density decreases with the application of organics such as FYM, greengram mulching, glyricidia and sunhemp *In situ* green manuring from 1.56 to 4.83 per cent and their combination with inorganic fertilizers from 0.77 to 3.96 per cent.

Prakash *et al.* (2002) found that in Alfisol, bulk density decreased with the treatments of organic nutrient sources as compared to application through chemical fertilizers and control.

Reddy *et al.* (2002) reported that application of wheat straw (5 t ha^{-1}) and deep tillage up to 20 cm by iron plough reduced bulk density (1.26 Mg m^{-3}) significantly and increased hydraulic conductivity.

Kadu *et al.* (2003) studied the Vertisols of Nagpur, Amravati and Akola districts of Maharashtra State and reported that the hydraulic conductivity of Nagpur soils ranged from 4 to 20 mm hr⁻¹ and rapidly decreased with depth, even though the clay content was almost uniform. The hydraulic conductivity of Amravati and Akola soils ranged from 1 to 12 mm hr⁻¹. They further reported that B_{ss} horizon of soils of Amravati and Akola with ESP and hydraulic conductivity values of about 6 and 1.0 mm hr⁻¹ respectively, indicated the very poor internal drainage condition.

Mohanty and Painuli (2003) reported that the tillage practices decreases the mean weight diameter of the soil.

Selvi *et al.* (2003) studied a long- term experiment conducted since 1972 on Vertic Ustropept which indicated that application of 10 t ha⁻¹ of FYM along with 100 per cent NPK recorded significantly lower bulk density, increased the hydraulic conductivity, water stable aggregates, porosity and water holding capacity. There was increase in CEC, organic carbon and total N content of soil due to incorporation of organics with inorganics. There was no marked changes in soil pH and EC due to various treatments. Available micronutrients and major nutrients increased significantly when organics were incorporated along with inorganic sources of nutrients.

More and Hangarge (2003) reported that bulk density declined and water holding capacity increased with application of crop residue.

Bhattacharyya *et al.* (2004) studied effect of long term manuring on soil physicochemical properties under soybean-wheat cropping sequence and reported that soil organic carbon content of soil were higher in FYM treated plots. Bulk density was minimum (1.24, 1.24, and 1.25 Mg m⁻³) under application of NPK +FYM in all depth 0 -15, 15- 30, 30-45 cm, respectively and shows negative correlation with organic carbon content. Soil water retention and available water capacity were highest under use of N+FYM and NPK+FYM.

Abu-Hamdeh (2004) studied the effect of tillage treatments (mouldboard plowing, chisel plowing, and disk plowing) on soil water holding capacity and on soil physical properties was investigated. The results showed that infiltration rate was strongly affected by tillage treatments in the top soil. Dry bulk density from 0 to 20 cm was affected by tillage treatments and from 20 to 40 cm by axle load. Tillage systems generally affected the ability of the soils to hold moisture and the available water capacity.

Mikha and Rice (2004) observed that aggregate size distribution was significantly influenced by the interaction with tillage and nitrogen sources. Significantly greater amount of macro aggregates (>200 and 250-200 mm) were present in conventional tillage compared with minimum tillage.

Surekha et al. (2004) noticed significant decrease in bulk density with straw application ($1.21 - 1.29 \text{ Mg m}^{-3}$) over straw burning (1.42 Mg m^{-3}) and control (1.41 Mg m^{-3}) implying improvement in soil structure due to crop residue incorporation.

While studying the effect of FYM application Marathe and Bharmbe (2005) revealed that highest aggregation of soil particles recorded with the application of FYM followed by application of wheat straw over inorganic fertilizers and control. They also reported highest decrease in bulk density in FYM treated plot followed by application of vermicompost and also observed the beneficial effect on hydraulic conductivity, available water capacity and maximum water holding capacity with the incorporation of FYM, Wheat straw, green manuring with sunhemp and vermicompost.

Dam et al., (2005) studied and reported that Different tillage and residue practices could potentially lead to significant differences in both crop production and soil properties, especially if both practices are implemented over a long time period and on continuous monoculture corn (*Zea mays L.*). The objective of this research was to determine how different tillage practices and corn residues affected soil bulk density over an 11-year period. The experimental site consisted of three tillage practices

(no-till, NT; reduced tillage, RT; and conventional tillage, CT). Bulk density was 10 % higher in NT (1.37 Mg m^{-3}) than in CT (1.23 Mg m^{-3}), particularly at the 0–0.10 m depth and the long-term cropping of corn under different tillage and residue practices can change bulk density in the surface soil layer.

Selvi et al. (2005) studied a long- term experiment conducted since 1972 on Vertic Ustropept which indicated that application of 10 t ha^{-1} of FYM along with 100 per cent NPK recorded significantly lower bulk density, increased the hydraulic conductivity.

Kumar and Yadav (2005) observed lower bulk density under conventional tillage than no tillage. In conventional tillage, the bulk density reduced to 1.42 g cm^{-3} from the initial value due to ploughing repeatedly and pulverization due to planking, while it is increased when no tillage (1.45 g cm^{-3}) was used.

Gurav et al. (2006) reported that application of 50% RDF + 50% N through FYM alone or along with 2% urea spray at flowering and 2% DAP at boll development stage recorded maximum moisture content at flowering and boll development stages. Whereas, application of RDF alone or along with foliar spray of 2% urea at flowering + spray of 2% DAP at boll development stage recorded minimum moisture percentage.

Sharma (2006) observed that among different tillage practices the conventional tillage and bed planting had shown favorable effect in lowering the bulk density of surface layer (0-0.07m). At CRI stage and harvest, zero tillage and strip tillage showed significant higher values than conventional tillage.

Hati et al. (2007) reported that balanced application of inorganic fertilizers and organic amendments greatly influence the accumulation of organic matter in soil and also influence the soil physical environment. An investigation was carried out to study the long-term impact of fertilizer and manure application in a soybean-wheat-maize (fodder) crop rotation on soil organic carbon status and physical properties of a vertisol (Typic Haplustert or Pellic Vertisols) in sub-humid sub-tropical India. The

results showed that the soil organic carbon (SOC) content in 100% NPK and 100% NPK + FYM treatments increased, respectively, by 22.5 and 56.3% over the initial level. The electrical conductivity, SOC, aggregation, water retention and available water capacity of the soil were increased while the bulk density was reduced significantly with the 100% NPK + FYM. However, the use of imbalanced (100% N) and suboptimal rate of inorganic fertilizer (50% NPK) as compared to the unfertilized control showed no significant effect on the physical properties. The study indicates that application of balanced rate of fertilizer in combination with organic manure could sequester soil organic carbon in the surface layer, which improve the soil physical environment and sustain higher crop productivity under this intensive cropping system.

Zibiske and Bradford (2007) reported that tillage treatments significantly affect distribution of soil water stable aggregates. However, conventional tillage increases the percent water stable aggregates than rotary tillage and no-tillage.

Tripathi and Sawarkar (2007) reported that the lower bulk density in surface horizons may be due to comparatively higher organic matter.

Rashidi and Keshavarzpour (2007) conducted field experiment and were observed effect of different tillage method on bulk density of soil. They were studied two year experiment and reported that different tillage treatments affected soil bulk density during both the years of study. The highest soil bulk density of 1.52 g cm^{-3} was obtained for no-tillage treatment and lowest soil bulk density of 1.41 g cm^{-3} for conventional tillage.

Nalge *et al.* (2007) reported that the hydraulic conductivity decreased with increase in depth of soil which was 0.492 and 0.412 cm hr^{-1} to the depth of 0-15 and 15-30 cm respectively.

Jadhao and Bharambe (2007) were conducted experiment on incorporation of crop residue alone and in combination with 50 and 100% RDF under soybean-chickpea cropping sequence and reported significant

increase in hydraulic conductivity of the soil (1.25 cm ha^{-1}) than initial (1.13 cm h^{-1}) after completion of 2 years.

Deshmukh *et al.* (2007) observed that the hydraulic conductivity was significantly varied from 0.30 cm h^{-1} to 1.79 cm h^{-1} with highest values of 1.79 cm h^{-1} under FYM combination with fertilizers application.

Gupta *et al.* (1998) carried out a field study for two years at the research farm, CCS HAU, Hisar, pearl millet and wheat were grown in rotation resulted that DTPA extractable Zn reduced from initial 0.97 mg kg^{-1} to 0.74 , 0.68 , 0.64 and 0.59 mg kg^{-1} soil, in control, low, medium and high fertility treatments respectively. Similarly, DTPA extractable Cu also reduced from initial 0.8 mg kg^{-1} to 0.68 , 0.65 , 0.59 and 0.54 mg kg^{-1} , respectively in control, low, medium and high fertility levels. Post harvest Mn and Fe increased from 12.1 mg kg^{-1} to 15.3 mg kg^{-1} soil and 4.0 to 6.1 gm kg^{-1} soil with increasing fertility levels. There was no change in the DTPA Mn and Fe at initial stages and the control.

Katkar *et al.* (2007) reported that bulk density was significantly decreased with application of FYM @ 10 t ha^{-1} , followed by FYM @ 10 t ha^{-1} + 100% RDF and FYM @ 10 t ha^{-1} + 50% RDF + spraying of 2 % urea and DAP and slightly increase in the bulk density in treatment where only chemical fertilizers were used.

Gulser and Candemir (2008) determined saturated hydraulic conductivity in soils by pedotransfer models derived using some moisture constant and soil physical properties. Saturated hydraulic conductivity values were determined in 30 different soil samples using constant head permeability method. According to path analysis results, direct effect of some soil properties on hydraulic conductivity were in following order, permanent wilting point (PWP) > bulk density (BD) > clay (C) > silt (si) > field capacity. Soil physical properties generally had the highest effect on hydraulic conductivity though PWP. Saturated hydraulic conductivity predicted by the second order PTF models was highly significant using only

C, si. And BD ($r=0.868$) and using only moisture constants, FC and PWP ($r=0.796$) in the models.

Borghei *et al.* (2008) observed that prior to tillage practices, the average bulk density values at soil layers of 0-20, 20-40, and 40-60 cm were 1.24, 1.48 and 1.65 g cm⁻³ respectively. The highest decrease in bulk density was observed in subsoiling treatments, while the least one was in conventional tillage. Working depth did not create significant effect on soil bulk density. Bulk density decreased in subsoiling treatments compared to conventional tillage in 20-40 cm depth range showing compacted soil layer in this depth range. This observation is in close agreement with the results obtained on penetration resistance.

Abdullah *et al.* (2008) reported that soils under conventional tillage (CT) generally have lower bulk density and associated higher total porosity within the plough layer than under no tillage (NT). No-till farming can reduce soil erosion, conserve soil moisture and minimize labor and fuel consumption. Six tillage methods for the second crop sunflower were tested and compared each other within after lentil harvesting at 2003 and 2004 years in a clay loam soil. According to results, the first year, the bulk density had decreased from 1.29 to 1.09 g cm⁻³, the second year the bulk density had decreased from 1.41 to 1.23 g cm⁻³.

Rasool *et al.* (2008) studied experiment at Ludhiana on sandy loam soil (TypicUstipsament) to characterize the soil physical quality in relation to the long-term (32 years) application of farmyard manure (FYM) and inorganic fertilizers in maize (*Zea mays L.*) wheat (*Triticum aestivum L.*) cropping system. The application of FYM to maize increased the organic carbon by 16% whereas N₁₀₀P₅₀ K₅₀ increased it by 21%. The increased organic matter with both FYM and N₁₀₀P₅₀ K₅₀ decreased soil bulk density from that in control plots. The mean weight diameter (MWD) was highest in FYM plots of both maize (0.160 mm) and wheat (0.172mm) closely followed by that in N₁₀₀P₅₀ K₅₀ plots. The grain yield and uptake of N, P and K by both maize and wheat were higher with the application of FYM and inorganic fertilizers than in control plots. The uptake of N, P and K increased with the application of FYM and N₁₀₀P₅₀ K₅₀.

He *et al.* (2009) reported that conservation tillage contained more macro-aggregates (13-37 %) and micro-aggregates (25-59 %) and increases water storage than traditional tillage.

Rao and Janawade (2009) reported that green manuring with sunhemp decreased the bulk density (1.29 Mg m^{-3}) at 0-15 cm depth.

Surekha and Rao (2009) reported decrease in bulk density (1.16 to 1.20 Mg m^{-3}) under application of organic source as nutrient management as compared to control (1.30 Mg m^{-3}).

Alvarez and Steinbach (2009) reported that increase in the bulk density under no-till in comparison to plow tillage were generally small, averaging 4%, but cone penetration increased by 50% in many soils. The increase of bulk density was greater in soils of initial low bulk density. Neither bulk density increases nor cone penetration changes reached critical threshold for roots development. Aggregate stability and water infiltration rate were higher in soils subjected to limited tillage systems than under plow tillage. The improvement of aggregate stability was higher in poorer structured soils, with an average increase of 70% under no-till in relation to plow tillage. Under no-till infiltration rate doubled in average that of plow tillage. Soil water content during the critical periods of sowing and flowering was generally greater under limited tillage but, conversely, nitrate nitrogen levels were greater in plow tillage. Higher soil water content under no-till in relation to plow tillage may satisfied the evapotranspiration demand of 1–3 days of crops during the critical flowering period, being nitrate nitrogen in average 21 kg ha^{-1} lower under no-till.

Khan *et al.* (2010) studied a field experiment was conducted at Research Area of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad during year 2004 with the objective to determine the effect of tillage and Farm Yard Manure on soil tilth at sandy clay loam soil. The experiment was laid out in Randomized Complete Blocked Design with four replications having split plot arrangement. Three tillage aspects (Deep tillage (DP), Conventional tillage (CT) and Minimum tillage (MT) and three Farm Yard Manure levels (20 t ha^{-1} , 40 t ha^{-1} and

control) were used as media of research. The tillage methods were kept in the main plots and FYM levels in subplots. The results revealed that tillage methods significantly increases the soil physical properties as increase in saturated hydraulic conductivity in deep tillage method and decrease in bulk density of soil was noted. The farm yard manure (FYM) also affected the physical properties as it increased saturated hydraulic conductivity. The maximum supply of nitrogen contents (0.079%) was recorded in case of application of FYM (40 t ha⁻¹) during minimum tillage

Kharche *et al.* (2010) reported that conjunctive use of organics like FYM, wheat cut straw and green manure have strongly influenced dynamic soil properties and were found beneficial for restoring soil quality. The decline in soil quality in Vertisol under long term experimentation revealed causes of soil quality degradation especially in reduction of SOC, MWD, water retention and depletion of available nutrient status due to lack of organic mater addition of crop residue incorporation in soil observed at only chemical fertilizer treatment.

Parvin *et al.* (2014) conducted a long-term field experiment with the objective of assessing the effect of shallow tillage (ST) and mouldboard ploughing (MP) on important soil physical properties and crop performance. Results revealed that, the higher hydraulic conductivity and lower water content at the 1 m water column showed better drainage possibilities in shallow tillage (ST) than mouldboard ploughing (MP).

Ogundare *et al.* (2015) conducted a field experiment in a randomized complete block design (RCBD) with three replicates to randomize the tillage methods (main plots) and foliar fertilizer application (sub-plots), respectively. The experiment comprised of three tillage methods: No Tillage (NT), Manual Tillage (MT) and convectional tillage (Ploughing, Harrowing and Ridging, PHR) and three foliar fertilizer rates : 0, 2 and 4 liters of foliar fertilizer per hectare. The different tillage practices significantly affected soil dry bulk density in the 0 - 15 cm soil depth. The No Tillage treatment recorded the highest bulk density at 30, 60 and 90 DAP (1.54, 1.60 and 1.62 g cm³ respectively) significantly higher than that of the PHR followed by MT treatments.

Qamar *et al.* (2015) conducted an experiment with a randomized complete block design in a split plot arrangement with four tillage methods [conventional tillage, (CT); deep tillage, (DT); zero tillage with zone disc tiller, (ZDT); and happy seeder, (HS)] during 2009-10 and 2010-11. Result indicated that, deep tillage, (DT) significantly decreased volumetric moisture content when compared with conventional tillage, (CT); zero tillage with zone disc tiller, (ZDT); and happy seeder, (HS).

Moraes *et al.* (2016) carried out an experiment on soil physical quality on tillage and cropping systems after two decades in the subtropical region of Brazil and observed the conventional tillage (CT) resulted in soil pulverization at 0–0.10 m depth, leading to lower BD and higher macroporosity compared to the other soil tillage systems. At layers below 0.10 m, CT increased the BD and reduced the macroporosity to critical levels for crop growth. Continuous use of no-tillage improved soil physical quality mainly at deeper layers.

Parihar *et al.* (2016) carried out an experiment on long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains and analyzed the SOC, physical and biological properties of soil at various depths after 7 years of continuous zero tillage (ZT), permanent raised beds (PB) and conventional tillage (CT) indiversified maize rotations, the results revealed that as compared to CT plots, the soil physical properties like water stable aggregates (WSA) > 250 μm were 16.1-32.5% higher, and bulk density (BD) and penetration resistance (PR) showed significant ($P < 0.05$) decline (11.0–14.3 and 11.2–12.0%) in ZT and PB plots at 0–15 and 15–30 cm soil layers.

Gandura *et al.* (2017) conducted field experiment in a completely randomized block design using three tillage practices (conventional tillage (CT), ridge tillage (RT) and zero tillage (ZT)) the bulk density for the soil surface (0 - 20 cm) were the highest for ZT followed by RT, and the least was for CT. And for 20 - 40 cm and 40 - 60 cm depths, the lowest bulk density were under ZT followed by RT and CT due to machinery weights used in CT. Total porosity was influenced by the

different tillage practices. At 0 - 20 cm soil depth, the highest Total Porosity was recorded under CT, and the lowest under ZT and the RT was intermediate between both ZT and CT.

Salahin et al. (2017) conducted an experiment at Bangladesh to assess the effects of tillage practices and crop residue retention on soil physical properties, soil organic carbon (SOC) and crop yields in a wheat - mung-bean - rice system. Treatments consisted of three tillage practices (MT: minimum tillage; CT: conventional tillage and DT: deep tillage). The soil moisture measured at 0 - 15 cm depth significantly changed due to different tillage practices. MT practice gave the highest soil moisture content in all sampling dates from initial to harvest compared to other tillage practices, whereas the lowest moisture was found in DT practice.

Kumar et al., (2018) conducted experiment to study Effect of various tillage methods on soil compaction during Rabi season of year 2013-14 at village Ladwa, Hisar, Haryana (In with six tillage treatments no-tillage (T1), rotavator (T2), disc harrow (T3), Rotavator + subsoiler (T4), disc harrow + subsoiler (T5), power harrow (T6). Bulk density (g cc^{-1}) of soil was recorded at two depths of soil 10 cm and 20 cm before and after the tillage treatments. At 10 cm soil depth bulk density was 1.48 g cc^{-1} before treatments and after treatment ranged between 1.43 to 1.48 g cc^{-1} . Higher reduction in bulk density was observed in treatment T4 (rotavator + subsoiler) and treatment T5 (disc harrow + subsoiler). Minimum change was recorded in the treatment T1 (no tillage). Almost similar trend was found at 20 cm soil depth. At 20 cm soil depth the soil bulk density before the treatment was 1.51 g cc^{-1} and after the treatment it ranged between 1.40 to 1.51 g cc^{-1} . Maximum reduction in soil bulk density was found in treatment T4 (rotavator + subsoiler) and minimum reduction was registered in treatment T1 (no tillage).

2.1.2 Chemical properties

Long term application of organic manures as well as inorganic fertilizers is likely to influence the soil reaction. Organic manures after their addition to soil undergo decomposition by the action of soil

microorganisms. During such biological degradation, organic acids are formed which help to lower down the soil pH. Large number of investigators have recorded contrasting views about the effect of manures and fertilizers on soil reaction.

Gaikwad and Khupse (1976) observed that the available potassium percent was more due to ploughing (0.0135 and 0.0151) than harrowing (0.0112 and 0.0134) at 0-15 and 15-30 cm depth of black soil respectively.

Lohakare (1980) studied the effect of various levels of FYM and NPK fertilizers alone and in combination for 15 years on black soils. He found that the long term use of FYM and fertilizers did not affect the pH, EC and the CaCO_3 content to a noticeable level. Slight decrease in pH and EC of soil was noticed due to FYM and fertilizers while no specific trend was observed due to various treatments.

Chaudhary *et al.* (1981) studied the effect of application of 0, 30 and 60 kg P_2O_5 , 30 kg K_2O and 0, 15t FYM ha^{-1} in different combinations in three phases of manuring to Bajara-Wheat crop rotation and observed that pH and EC of soil remained more or less unaffected under various treatments. The pH of soil was slightly affected due to application of FYM and phosphorus. Also, reported that organic carbon of the soil increased by 0.033, 0.042 and 0.14 per cent with 30 and 60 kg P_2O_5 and 15 t FYM ha^{-1} , respectively.

Dick (1983) reported that there was greater amount of nitrogen, phosphorus and potassium under no-till surface (0-30 cm) soil compared to minimum and conventional tillage.

Bhriguvanshi (1988) observed significant improvement in organic carbon status of sandy loam and clay loam soils with the application of FYM alone or in combination with the nitrogenous fertilizers.

Badanur *et al.* (1990) reported that in Vertisol, soil reaction decreased (8.5 to 8.2) significantly subabul and sunhemp with incorporation while electrical conductivity did not vary much (0.18 to 0.10 dS m^{-1}) with the incorporation of crop residue and green manures over

fertilizer application. Organic carbon content of Vertisol found significant increase (0.55 to 0.68 %) with subabul, sunhemp and farm yard manure application for three years as compared to stubbles, stalks and fertilizer application. Available N content increased with subabul, sunhemp and farmyard manure over fertilizer application but decreased significantly with crop residues incorporation. Available P content of soil increased significantly with crop residue and green manures over fertilizer application, while available K content was highest with incorporation of sorghum stubbles and safflower stalks.

Patil *et al.* (1993) conducted incubation study with different organic materials (FYM, sunflower heads and wheat straw) and reported that, due to the decomposition of organic material the soil nutrient status were changed over the initial status of the soil. The availability of the potassium was increased with the incorporation of organic materials. Wheat straw was found to be the most superior in increasing potassium availability in soil followed by sunflower heads and FYM.

Bharadwaj and Omanwar (1994) observed that maximum available nitrogen was observed in 150 percent RDF of NPK (580 kg ha⁻¹) FYM treated plots with 100 percent NPK recorded significant increase in available N (50 g kg ha⁻¹) over control (250 kg ha⁻¹). Increase in available nitrogen may be due to direct addition of NPK through FYM and inorganic fertilizers to the available pool of soil.

Indulkar and Malewar (1994) observed that the DTPA-Zinc in the control treatment after the crop rotation (sorghum-wheat) was 0.54 to 0.51 ppm compared with initial zinc (0.68 and 0.70 ppm) during two years of study. They reported varying levels of nitrogen i.e., 0, 30, 60 and 90 kg N ha⁻¹ to cotton and observed that the increase in levels of N increased the dry matter production at all the growth stages, consequently N, P and K uptake was also increased.

Malewar and Hasnabade (1995) reported significant increase in available N with continuous application of organics and inorganics particularly FYM+NPK.

Chaudhary and Das (1996) reported that application of P, S and Mo to blackgram had significant residual effect on the grain and stover yield of safflower. The increase in yield may be attributed to improved soil fertility (organic carbon, available N, P, K, S and Mo) compared with higher availability of moisture to safflower after the harvest of blackgram.

Hegde (1996) suggested that integrated nutrient supply of inorganic and organic sources is of great importance for maintenance of productivity in intensive cropping systems and evaluated the integrated use of chemical fertilizers and the organic sources of farm yard manure (FYM), wheat straw, and green manure on the long-term productivity of an irrigated sorghum (*Sorghum-bicolor* (L.) Moench)- wheat (*Triticum aestivum* (L.)) system in permanent plots under the AICRP on Cropping systems at Akola, Parbhani and Rahuri in Maharashtra, India in semiarid region. The results showed the integrated nutrient supply increased soil organic carbon and available N compared to application of all nutrients through fertilizers. It had a variable effect on a available P status and reduced the decline in available K.

The agriculturally important and widespread vertisol and Alfisol soil series of Western Maharashtra were assessed by Pharande *et al.* (1996) for their depth wise distribution of total and DTPA extractable micronutrient contents during the year 1992-1993. The DTPA extractable Fe, Mn, Zn and Cu content in vertisol were in the range of 3.5 to 19.4, 7.3 to 40.1, 0.2 to 3.9 and 1.3 to 6.3 mg kg⁻¹ while in Alfisols the range was from 3.6 to 63.0, 2.0 to 147.7, 0.08 to 4.4 and 0.4 to 0.7 mg kg⁻¹, respectively.

Aggarwal *et al.* (1997) reported that short term addition of crop residues or organic manures in hot climates promotes rapid decomposition, may lead to only slight or no increase in organic carbon, but long term addition increased both carbon and nitrogen.

Bellakki and Badanur (1997) conducted long-term experiment on effect of INM on the properties of Vertisol under dryland agriculture and reported highest available N (235 kg ha⁻¹) in surface soil with the

incorporation of sunhemp along with fertilizers, which was at par with RDF and other fertilizer treatments. Continuous use of FYM and sunhemp either alone or in combination with chemical fertilizers recorded significantly higher available P and K than the others.

Ghuman *et al.* (1997) reported that green manuring with sunhemp in sandy loam soil increased $\text{NO}_3\text{-N}$ by 7.0 and 6.4 kg ha^{-1} in 0-10 and 10-20 cm soil layers respectively over control. Ans also reported that decrease in pH by 0.3 units with sunhemp green manuring for four years under rainfed condition on sandy loamy soil. However, in subsoil layers, the effect was non-significant.

Mathur (1997) reported that incorporation of full dose of FYM@16 t ha^{-1} recorded significantly highest organic carbon (4.1 g kg^{-1}) content in soil which was on par with $1/2 \text{ FYM} + 1/2 \text{ NPK}$ (3.7 g kg^{-1}).

Bellakki *et al.* (1998) studied long-term field experiment at the Agricultural Research Station, Siruguppa (Karnataka) under irrigation from 1984 to 1994 on rice (two crops in year) continuously on Typic Haplusterts. The highest organic carbon content (5.6 g kg^{-1}) was observed with incorporation of glyricidia along with 50 per cent NPK ($60:30:30 \text{ kg ha}^{-1}$) which was significantly higher than various other fertilizer levels. The highest available nitrogen content of the soil (389 kg ha^{-1}) was recorded under application of 50 per cent RDF through chemical fertilizers along with glyricidia to meet 50 per cent recommended nitrogen. Long-term incorporation of organic materials to meet 25 per cent N along with 75 per cent NPK through chemical fertilizers resulted in significantly higher available phosphorus of the soil over different levels of fertilizers. The available potassium content of the soil was significantly increased in soil with combined application of various levels of organic and inorganic sources of nutrients over period of time.

Basumatary and Talukdar, (1998) reported that, ammonium N content of the soil increased significantly with increase in level of NPK fertilizers up to 100 per cent of recommended dose. However, a much higher content was observed under integrated treatments where NPK

fertilizers were combined with 25% or 50% N through different organic sources. They also reported that, continuous integrated treatments resulted in higher accumulation of organic matter and its subsequent decomposition and mineralization might have contributed in accumulating higher ammonium N over other treatments.

Ismail *et al.* (1998) reported significant increase in soil available N (316.6 to 360.8 kg ha⁻¹) and available P (15.9 to 19.5 kg ha⁻¹) in Vertisol with the application of FYM @ 30 Mg ha⁻¹ over control, while increase in available K was non-significant. Also reported a significant reduction (8.07 to 7.99) in pH value of Vertisol with application of FYM @ 30 Mg ha⁻¹ over control within one year.

Reddy and Reddy (1998) concluded the experiment for two consecutive years during kharif and rabi season on sandy loam soil to study the effect of organic manures and nitrogen levels on soil available nutrient status in maize-soybean cropping system and observed the higher availability Fe, Cu, Zn, Mn nutrient in order vermicompost>poultry manure>bio gas slurry >farm yard manure.

Santhy *et al.* (1999) reported that continuous cropping and fertilization had significantly increased available N content of soil over initial status but with 100% NPK+FYM, available N content was higher due to higher organic carbon content of soil. And also noticed the highest NH₄-N and NO₃-N with combined application of NPK and FYM, which was ascribed due to increased microbial activity and resultant enhanced nitrification process with a reduction in leaching losses.

Sheeba and Chellamuthu (1999) conducted a long term fertilizer experiment at Tamil Nadu Agricultural University, Coimbatore on a clay loam soil and reported that long term application of organic manures (FYM) with 100 per cent NPK increased the K content of the soil which could be attributed to the greater capacity of organic colloids to hold K ions on the exchange sites. Among the inorganic fertilizers, continuous addition of nitrogen or NP had a depressive effect of the exchangeable K content of

soil which might be due to nutrient imbalance in soil and higher K removal by the crops

Vasanthi and Kumaraswamy (1999) reported that organic carbon content was considerably increased with the application of vermicompost in combination with N, P and K over the application of N, P and K alone.

Babhulkar *et al.* (2000) reported a significant increase in organic carbon of Vertisols with the application of 7.5 Mg FYM ha⁻¹ with half dose of N and P fertilizers and significant increased in available Zinc content (0.95 to 1.16 mg kg⁻¹) in Vertisol with combined application of FYM and inorganic fertilizer.

Bellakki and Badanur (2000) noticed highest available N, P and K in sorghum stubbles @ 5 t ha⁻¹ + 30 kg N and sorghum stubbles @ 5 t ha⁻¹ + cellulolytic organisms. Other treatments showed intermediate available nutrients. Lowest nutrient content was observed in control.

Surya *et al.* (2000) reported significant increase in organic carbon (15-27 %), total N (13-23%) and available P and K content in black soil with the combined application of wheat straw and inorganic fertilizers.

Sharma *et al.* (2000) also found that the organic carbon content increased significantly in the treatments receiving combined application of crop residue, FYM and fertilizer as compared to fertilizer alone.

Srikanth *et al.* (2000) conducted a micro plot (2x2 m²) field experiment at Gandhi Krishi vigyan Kendra, UAS, Bangalore to evaluate the direct and residual effect of compost on soil properties as against use of FYM, Vermicompost and Chemical fertilisers. The lowest pH 6.66 was recorded with enriched compost of industrial wastes.

Nehra and Hooda (2002) found that soil pH and electrical conductivity did not alter under the influence of organic manure as well as fertilizer levels while increasing levels of NPK increased the pH and electrical conductivity of sandy loam soils.

Prakash *et al.* (2002) reported an increase in pH from 5.5 to 6.2 in acid laterite soil through treatment with farmyard manure. They also observed that soil available Fe, Cu and Zn content was significantly higher in FYM treatment plots as compared to all commercial manures (vermicompost and oil cake pellets), chemical fertilizers and control. The trend was similar in the second year, except that the availability of Fe, which was similar with FYM and processed city waste application.

Tiwari *et al.* (2002) studied on long term influence of organic and inorganic fertilization on soil fertility and reported that the inclusion of FYM in the treatment schedule improves the organic carbon status and available N, P, K and S in soil. The omission of S in the fertilizer application has caused a continuous depletion in the available K in all treatments but the decrease was of lower magnitude in 100 % NPK + FYM and 100 % NPK treatments indicating the need to raise the level of K fertilizer application to meet the demand of crops.

Reddy and Malewar (2002) observed that the significantly higher available nitrogen (221.2 kg ha^{-1}), phosphorus (21.2 kg ha^{-1}) and potassium (429.8 kg ha^{-1}) content of soil was obtained with incorporation of crop residue like wheat straw (5 t ha^{-1}) with deep ploughing up to 20 cm.

Singh *et al.* (2002) observed that application of wheat residue @ 4 t ha^{-1} along with recommended N and P enhanced the availability of nutrients in soil.

Katkar *et al.* (2002) used the FYM, glyricidia foliage loppings, greengram mulching either alone or in combination with chemical fertilizers recorded higher available nitrogen, phosphorus and potassium. Significantly higher quantity of nitrogen was observed in glyricidia foliage loppings in 50 per cent combination of RDF.

Guled *et al.* (2002) in a field experiment conducted at Madabhavi watershed on Typic Chropmustert observed that greengram residue incorporation or sunhemp green manure integrated with chemical fertilizers improve chemical property i.e. micronutrients content.

More and Hangarge (2003) reported decrease in pH from 8.00 to 7.85 with application crop residue under cotton-sorghum rotation. The application of crop residue as source of nutrient increases the organic carbon (0.75 %) in soil as compared to other nutrient sources. And also reported that combined application of organic and inorganic source recorded maximum availability of nitrogen, phosphorus and potassium under cotton-groundnut cropping system.

Poongothai and Chitdeshwari (2003) conducted field experiment with blackgram in red sandy loam soil for assessing the efficiency of soil application and seed treatment of Zn, B, S and Mg during 2000 and 2001. The results indicated that the available nutrient status of the post harvest soil ranged from 0.72 to 1.29 mg kg⁻¹ for Zn, 0.37 to 0.53 mg kg⁻¹ for HWS-B and 11.2 to 15.6 mg kg⁻¹ for 0.15% CaCl₂-S. Application of 5 kg Zn + 1.5 kg B + 0.5 kg Mo + 40 kg S ha⁻¹ significantly enhanced the availability of Zn (1.29 mg kg⁻¹), B (0.53 mg kg⁻¹) and sulphur status (15.6 mg kg⁻¹). Similarly, application of 5 kg Zn enriched with 50 kg FYM to clay loam soil enhanced the availability of Zn and Boron in soil by (Chitdeshwari and Duraisami, 2005).

Selvi *et al.* (2003) studied a long term experiment conducted since 1972 on Vertic Ustropept which indicated that application of 10 t FYM ha⁻¹ along with 100 per cent NPK recorded incorporation of organics with inorganics whereas there was no marked change in soil. However the available micronutrient increased significantly when organics were incorporated along with inorganic sources of nutrients.

Halemani *et al.* (2004) observed more reduction in pH with the application of FYM alone @ 10 t ha⁻¹ followed by FYM+ in situ green manuring and FYM + crop residues when compared with fertilizer application and control. However, organics alone and their combinations had no significant influence on EC. They recorded significantly higher available nitrogen, phosphorus and potassium with application of FYM alone @ 10 t ha⁻¹ followed by FYM + crop residues and FYM + in situ green manuring compared to fertilizer application and control. They also found that residual nutrient availability was less due to application of RDF as compared to

organics, because of easy and quick solubility of inorganic sources of nutrients and higher nutrient uptake during crop growth period. These nutrients found increased over the years with application of organics and fertilizers.

Praharaj *et al.* (2004) studied various crop residue application alone and in combination with FYM in cotton and recorded higher availability of nitrogen with the application of FYM @ 10 t ha⁻¹ followed by FYM @ 5 t ha⁻¹ + crop residue @ 5 t ha⁻¹ and FYM+GM as compared to chemical fertilizers as well as control.

Surekha *et al.* (2004) found higher soil organic carbon in all the straw residue treated plots with maximum value recorded in straw + green manuring plot.

Chaturvedi and Chandel (2005) studied on influence of organic and inorganic fertilization on soil fertility and productivity of soybean and reported that, use of organic sources helped in maintaining soil fertility in respect of available nutrients. The higher nitrogen, phosphorus and potassium were recorded with the application of recommended dose of NPK with FYM @ 10 t ha⁻¹ showing 10.3, 24.0 and 4.3 per cent increased over the control respectively. Integrated nutrient management significantly increase the available nitrogen and phosphorus in soil compared to initial values.

The inorganic fertilization also recorded higher organic carbon as compared to unfertilized control, which is due to the use of fertilizer, which helped in higher contribution of biomass to soil in the form of greater root biomass through crop stubbles and residues. The subsequent decomposition of these materials might have resulted in to enhanced organic carbon content of soil reported by Ravankar *et al.* (2005).

In a study on cumulative impact of organic sources (FYM, rice straw and green *karanj* leaves) substituting inorganic fertilizers in recommended fertilizer dose (RDF) once each by 25% and 50% during rainy season in maize-wheat cropping system it was revealed that all the organic sources were instrumental in improving pH and aggregation of

soils. Only rice straw in its higher substitution (50%) could induce significant improvement in bulk density and water-holding capacity of soils but a constant trend of improvement was observed under application of all the sources. All the 3 sources both in their higher and lower substitutions enriched the soils in organic carbon contents. Farmyard manure (FYM) and green *karanj* leaves in their higher substitution improved NPK levels of soils. Rice straw at this level (50% substitution) could bring about significant improvement only in available K content of soils. At lower level of substitution (25%) green manuring with *karanj* leaves induced higher available P and K in soils, but FYM at the level could bring about significant improvement only in available P level. Application of rice straw at this level of substitution (25%) could not alter status of any of the NPK significantly. Substitution of inorganic fertilizers by FYM either (50%) or lower (25%) level was helpful in increasing grain yield and uptake of NPK observed by Pathak *et al.* (2005).

Jain *et al.* (2005) studied on soil properties and maximization of productivity of soybean-wheat system in hill zone of Madhya Pradesh. They reported that, the application of FYM @ 10 tonnes ha⁻¹ to soybean improved the organic carbon and N content of soil (285 kg ha⁻¹) besides unchanged P and K status of the soil and also reported that the soil properties *viz.*, soil pH, organic carbon and N, P, K contents did not deviate much from their initial status due to varying rates of fertilizer application.

After two years of experimentation Verma *et al.* (2005) reported that the application of 100% NPK through FYM 10 t ha⁻¹ and fertilizers, 100% NPK + FYM 10 t ha⁻¹ and FYM 20 t ha⁻¹ significantly improved the organic carbon content of soil. A marked build up of available P content of soil was recorded by applying 100% NPK + FYM @ 10 t ha⁻¹, 100% NPK through FYM @ 10 t ha⁻¹ and fertilizers, FYM @ 20 t ha⁻¹ and 150% NPK, while available K content was not significantly affected by the treatments. The available soil Zn and S also declined over the year of experiments except when these elements were added to the soil with 100% NPK.

Bajpai *et al.* (2006) studied a long term permanent field plot experiment from 1991-92 to 2002-03 to develop suitable integrated nutrient supply system for rice-wheat cropping system and reported that, incorporation of organic sources considerably improved the soil properties i.e. available N, P and K status of soil. The application of organic manure with inorganic fertilizers had the beneficial effect on increasing the phosphate availability. The results also suggest that in spite of phosphorus fixation in swell-shrink soil the conjunctive use of organics with chemical fertilizers is beneficial for improving available phosphorus which is also evidenced by the reduced calcium carbonate contents of the soil there by reducing phosphorus fixation.

Sujata Pothere *et al.* (2007) studied the long term fertilizer experiment started since 1988 at Dr. PDKV, Akola and reported that all the soil chemical properties such as pH, EC, organic matter, total and available NPK and S were favorably influenced with the conjunctive use of organic and inorganic. Highest improvements were observed in the treatment of 100% NPK + 10 t FYM ha⁻¹.

Katkar *et al.* (2007) reported that pH and electrical conductivity was decreased with application of FYM (10 t ha⁻¹) than chemical fertilizer. He also observed highest organic carbon was recorded in FYM @ 10 t ha⁻¹ (4.41 g kg⁻¹) which at par with the treatment FYM @ 10 t ha⁻¹+ 100% RDF (4.41 g kg⁻¹) and FYM @ 10 t ha⁻¹+ 50% RDF (4.41 g kg⁻¹). He also reported that highest available nitrogen, phosphorus and potassium was recorded in application of FYM @ 10 t ha⁻¹+ 100% RDF and which is at par with FYM @ 10 t ha⁻¹+ 50% RDF.

Yaduvanshi and Sharma (2007) The result suggested that incorporation of wheat residue 50 days before rice transplanting with green manuring or with sulphitation pressmud along with recommended dose of fertilizer improve the Zn status

Shivakumar and Ahlawat (2008) reported that the application of 50% and 100% RDF to soybean recorded significantly higher available Zn in soil over control.

Mishra *et al.* (2008) studied the changes in chemical, microbial and enzymatic activities of on acid soil in a long term fertilizer experiment continued since 1956, in an Alfisol at Ranchi continuous organic manure application or in combination with inorganic fertilizer significantly influenced the grain yield, uptake of nutrients, organic carbon, available N,P K and soil, Co₂ evolution, Urease and phosphates over 100% NPK. Grain yield, uptake of nutrients, Co₂ evolution and urease were significantly higher than 100% NPK. The Co₂ evolution, SMBC, urease and phosphates were significantly higher in treatment receiving 100% NP over treatment receiving only 100% N or control. The 100% NPK treatment did not show significant changes in microbial and enzyme activity over 100% NP treatment. The PH, organic carbon, CO₂ evolution, SMBC, urease and phosphates enzyme were found highly significantly correlated with grain yield and nutrient uptake.

Kaur and Brar (2008) observed that 65.1 per cent more soil microbial biomass carbon in 100% NPK + FYM treated plot as compared to control. They reported that the supply and availability of additional mineralizable and readily hydrolysable carbon due to manure application might be responsible for higher microbial carbon in soil.

Vineela *et al.* (2008) studied the effects of long-term cropping, fertilization, manuring and their integration on microbial community in soil samples from five long-term fertilizer experiments being conducted since 1970 at Anantapur, Bangalore, Bellary, Coimbatore and Solapur centres of various rainfed production systems in the semi-arid tropics of India. The counts were high in treatments where combinations of organic and inorganic fertilizers were applied compared to control. Vertisols showed larger organic carbon levels than Alfisols. Fungal population was higher in acidic soils and in treatments under continuous inorganic fertilization whereas a high number of bacteria were found in integrated use of organic and inorganic fertilizers. At most of the locations soil organic C and microbial biomass C showed significant positive correlation with microbial populations. It has been further suggested that even under arid and semi-

arid tropical conditions, regular addition of nutrients in an integrated manner could improve soil organic carbon and microbial population.

Kumar et al. (2008) conducted a long-term field experiment on integrated management of FYM, green manure and crop residues with inorganic fertilizers in rice-wheat system at Ludhiana, since 1993 observed that incorporation of crop residue and organic manure significantly reduced the soil pH and EC. They reported that the incorporation of crop residues along with 50 per cent NPK and FYM or GM contributed towards meeting 50 per cent NPK requirement of rice. Long-term application of crop residues and organic manures increased the soil organic carbon content of the soil. Application of crop residues along with FYM and GM significantly increased the available N content of soil over 100 per cent NPK alone treatment. The available P and K status of soil was highest under 100 per cent NPK + FYM, which was on par with 100 per cent NPK + GM and 50 per cent NPK + FYM. The combined use of crop residue, organic amendments and chemical fertilizers significantly increased the availability of N, P, K in soil over chemical fertilizers alone.

Verma and Mathur (2009) studied the effect of integrated nutrient management on active pools of soil organic matter (SOM) viz., soil microbial biomass carbon, nitrogen, phosphorus and dehydrogenase activity after 9 years of the maize-wheat crop rotation on a Typic Haplustept in a long-term field experiment initiated during kharif 1997 at Rajasthan College of Agriculture, Udaipur. Application of FYM @ 20 t ha⁻¹ significantly increased the microbial biomass carbon, whereas dehydrogenase activity was found in 100% NPK + 10 t FYM ha⁻¹ treatment compared to sole use of chemical fertilizers. Integrated use of FYM with chemical fertilizers or use of FYM alone exerted significant effect on the active pools of soil carbon. The C/N ratio was highly and significantly correlated with soil microbial biomass carbon and dehydrogenase activity under maize crop.

Ramesh et al. (2009) based on four years pooled data reported that among the cropping systems soybean-durum wheat recorded the highest soil organic carbon (0.71%) followed by soybean-mustard (0.68%), soybean-chickpea (0.62%) and soybean-isabgol (0.57%) cropping

system. He also reported that among the cropping systems, soybean-durum wheat recorded the highest soil available N (193.2 kg ha^{-1}) followed by soybean-chickpea (187.4 kg ha^{-1}), soybean-mustard (184.3 kg ha^{-1}) and soybean-isabgol (169.3 kg ha^{-1}) cropping systems at the end of four cropping cycles and soil available P (33.45 kg ha^{-1}) followed by soybean-mustard (25.66 kg ha^{-1}), soybean-chickpea (20.78 kg ha^{-1}) and soybean-isabgol (17.77 kg ha^{-1}) cropping systems.

Novak *et al.* (2009) reported that conservation tillage increases the soil organic carbon as compared to disc tillage system.

Sainju *et al.* (2009) reported that no tillage increases organic carbon in soil as compared to tilled plot.

Rao and Janawade (2009) reported that organic carbon of the soil increased from 3.3 to 28.1 percent in organic manure alone or in combination with fertilizer. Also observed that pH of soil decreased with green manures and organic manure.

Verma and Mathur (2009) reported that higher values of organic carbon content of the soil were found in the treatment receiving farm yard manure alone or in combination with chemical fertilizers (100 % NPK + 10 t FYM) as compared to those treatment receiving chemical fertilizer alone.

Zang *et al.* (2009) were measured net N mineralization rate (NMR), potentially mineralizable N (PMN) and mineral N ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$) in paddy soil at various growth stages of rice to determine the effect of long-term fertilization in subtropical China. They studied long-term treatments included CK (no fertilization), N, NP, NPK and NPK + OM (NPK plus organic manure). The NPK + OM treatment gave the highest values of the measured variables among all treatments. There was no significant difference in other treatments except for mineral N and potentially mineralizable N at early growth stages. All these variables were generally highest at transplanting stage as two thirds of fertilization was applied as basal fertilizers and the rice uptake was low. Then they decreased or leveled off with the rice growth stages except for mineral N in

all treatments. Stepwise regression revealed that NMR was significantly correlated with N-NH_4^+ ($R^2 = 0.954$, $P < 0.01$) at all rice growth stages. So, mineral plus manure fertilizer application and more mineral fertilizer as topdressing were recommended in subtropical paddy soil.

Kumar and Singh (2010) reported the combined application of 100% NPK+ green gram + 5.0 t FYM each year gave significantly higher content of DTPA – extractable micronutrient Zn, Fe, Mn, and Cu in post harvest soil at the end of six year cycle.

Tabasum *et al.* (2010) concluded that the influence of 4-year continuous soybean-wheat cropping system with different fertilizer and organic manure inputs on the transformation of different N fractions and organic C in both surface and subsurface soils in a Vertisol at Jablapur. Repeated applications of fertilizer N alone, N with FYM or poultry manure or urban compost, FYM alone led to a significant increase in total N, hydrolysable N (i.e., amino acid N, hydrolyzable $\text{NH}_4\text{-N}$, hexose amine N) and nonhydrolysable N in both surface and subsurface soils as compared to initial status. The status of various organic N fractions was higher in surface than the subsurface soils. On the other hand, continuous cropping without fertilization and manuring resulted in depletion of total hydrolysable N in control over the initial status by 8.5 % in surface soils and 6.4 % in the subsurface soils. About 3-6 % of total N in surface soils and 2-5 % of total N in subsurface soils got mineralized under waterlogged incubation conditions. The results clearly indicate that the subsurface soils in addition to surface soils also substantially contributed to the N requirement of the crops. The correlation studies revealed that the amino acid and hexose amine N fractions in surface soils and hydrolyzable $\text{NH}_4\text{-N}$ and amino acid N fractions in subsurface soils were better indices of soil N mineralization. This was further supported by a better correlation between amino acid N in surface and hydrolyzable $\text{NH}_4\text{-N}$ in the subsurface soils with yield of and N uptake by soybean and wheat crops.

Arbad and Ismail (2011) also reported that the observed that application of 10 mg/ha FYM with 100% NPK left the maximum organic carbon content in soil which might be due to high (C: N ratio of FYM)

resulting in organic carbon build up in soil and higher availability N, P, K, S and Zn might be due to increased activity of micro-organism leading to greater mineralization of applied and inherent nutrients.

Gudadhe *et al.* (2011) reported that residual effect of gross recommended dose of fertilizer (GRDF) i.e. 10 t FYM ha⁻¹ + RDF application to summer cotton was found at par with 100 % RDN application through vermicompost and 25 % RDF + 75 % RDN through vermicompost and recorded significantly higher values in respect of plant height, plant spread, total dry matter per plant, grain yield and straw yield of chickpea in *rabi* season. This might be due to residual effect of organic manures applied to preceding crop as it provided major as well as micronutrients for longer period in medium black soil

Gitakumari *et al.* (2011) revealed that balanced application of FYM alone or in combination with chemical fertilizers significantly increased organic carbon.

Bahadure *et al.* (2012) reported that the continuous cultivation of rice-wheat cropping sequence on sodic soils at Kanpur significantly reduced soil pH up to 8.75 and 8.70 with application of organic manures over initial value of pH 9.30 and found effective in comparison to without application of organic manure.

Subehia and Swapana Sepehya (2012) conducted a field experiment to study the influence of long term nitrogen substitution through organics on available nutrients on acidic soil and observed that the soil fertility with respect to available macronutrients and micro nutrient cations was increased with the application of 50 % NPK + 50 % N through FYM in kharif followed by 100 % NPK in rabi. Increase in micronutrient content due to application of organic like FYM, wheat straw, and green manure may be due to formation of organic chelates which decreased their susceptibility to adsorption, fixation and precipitation resulting in their enhanced availability in soil and also increased N, P and K in soil.

Bhattacharyya *et al.* (2013) reported that, in rice-rice cropping systems, application of farmyard manure (FYM) with NPK as balanced fertilization resulted in higher labile N pools after a period of 39 years.

Chitale *et al.* (2013) studied the influence of cereal - legume, legume - cereal and cereal - cereal cropping sequence on productivity, economics and soil fertility status. They reported that after completion of two crop cycles there was improvement in available N and P status due to increase in fertilizer rate from 75 to 100% to legume crop including green manuring provided considerable amount of residual N to the forthcoming cereal crops. It was that IPNS was the best followed by organic nutrient supply system, while the application of chemical fertilizer alone recorded the lowest value of available N.

Nazmus Salahin *et al.* (2013) observed that the application of green manure has significantly increased soil organic matter, soil health and crop growth. Soil densities, porosity, texture, field capacity and soil moisture were influenced due to the green manure crops and tillage practices. The lowest bulk density (1.45 g cm^{-3}) and particle density (2.48 g cm^{-3}) were found in *S. aculeata* and deep tillage practice. The highest porosity (41.73%) and field capacity (24.24%) were also observed in *S. aculeata* and deep tillage practice.

Patrick *et al.* (2013) found that six years after treatment establishment near Frick, Switzerland indicated significantly lower soil pH under conservation tillage compared to conventional tillage at a 0–10 cm soil depth. Soil organic C under conservation tillage was numerically greater than conventional tillage in all studies for near-surface depths, with absolute and relative differences between treatments averaging 1.1 g C kg^{-1} and 6 %. Differences in SOC between conservation and conventional tillage for surface depths ranged from 0.2 to 4.5 g C kg^{-1} . Long-term use of conservation tillage can contribute to near-surface accumulation of plant nutrients and greater nutrient mineralization potential in non-organic production systems.

Puli *et al.* (2013) reported that, continuous application of 100% NPK along with FYM @ 10 t ha⁻¹ to sorghum- wheat sequence grown on Vertisols at Akola, resulted improvement in total N, ammoniacal and nitrate N at harvesting stage of wheat. The application of FYM @ 10 t ha⁻¹ also found beneficial in improving the status of ammoniacal and nitrate N.

Sonune *et al.* (2013) indicated that application of 15 t FYM and 50 t FYM along with 50 percent recommended dose of fertilizer recorded significantly higher water stable aggregates, hydraulic conductivity, soil fertility with lower bulk density of soil while numerically higher percent water stable aggregates, organic carbon, total nitrogen and available nutrients (N, P and K) with recorded an minimum tillage as compared to conventional tillage.

Yaduvanshi *et al.* (2013) studied the effect of inorganic fertilizers alone and in combination with organic manures after twelve years under rice-wheat cropping sequence on gypsum-amended sandy loam (Acquic Natrustalfs) sodic soil at Central Soil Salinity Research Institute, Karnal. They reported that the organic carbon was significantly greater with application of green manure and FYM with NPK. The mean Soil Organic Carbon Stock increased to 4.05 g ha⁻¹ in organic manure as compared to 2.34 g ha⁻¹ in organic fertilizer treated treatments. However Available N, P₂O₅ and K₂O was highest in treatments receiving NPK along with GM or FYM. Whereas, application of NPK along with FYM resulted increase in the nitrogen use efficiency for rice (27.3 kg grain kg⁻¹ of N) and wheat (41.7 kg grain kg⁻¹ of N).

Gite *et al.* (2014) studied on effect of long term manuring and fertilization to sorghum-wheat sequence on physical properties of soil and concluded that the application of 100 percent RDF + FYM @ 5 ton/ha significantly reduced the bulk density, improved porosity, hydraulic conductivity, mean weight diameter and available water capacity this might be due to the favourable effects of FYM on physical properties of soil and also as a source of plant nutrients, which are released on mineralization and become available to plants.

Mali *et al.* (2014) studied on effect of long term fertilization and manuring to sorghum-wheat sequence on micronutrient availability in Inceptisols and concluded that the application of various levels of RDF (50,75 and 100 %) along with organics (FYM, wheat straw, leuceana lopping) exhibited profound influenced on the availability of different micronutrients as compared to chemical fertilizers alone. The micronutrient status was maintained under integrated nutrient management for long period which might be due to the addition of organic materials which form chelates and increase the availability of micronutrients.

Umesh *et al.* (2014) studied the effect of fertilizers and organic manures (biogas slurry, green manure, sulphitation pressmud and sugarcane trash) on the amount and distribution of nitrogen (N) fractions in soil. After 17th crop cycles of sugarcane based cropping system, application of fertilizers alone and in combination with organic manures significantly increased all the forms of N except $\text{NO}_3^{-\text{N}}$ over control ($\text{N}_{50}\text{P}_{100}\text{K}_{100}$).

Ojha *et al.* (2014) reported that, soil organic carbon was found significantly highest from the treatment 35 tons FYM ha⁻¹ in either season. The level of organic carbon was less in second season. Soil organic carbon was decreased in residual level of FYM. There is an increase in the organic carbon content with the application of FYM and composts in each year but organic carbon decreases as the applied fertilization with FYM and composts in successive years. Decrease in organic matter content in two successive seasons might be due to rate of decomposition of active pool of organic carbon because there was no addition of the FYM in the successive season.

Gabhane *et al.* (2014) revealed that the tillage practices did not show any significant change on pH, EC and organic carbon of soil. While, slight improvement in OC (5.72 g kg⁻¹) was observed in minimum tillage compared to conventional tillage. The pH of soil ranged from 7.96 to 8.05. The application of FYM and in situ green manuring of dhaincha significantly lowered the EC of soil over 100 % RDF through chemical fertilizers. The highest organic carbon (6.33 g kg⁻¹) was observed in 50 % RDF + FYM @

15 t ha⁻¹ followed by 50% RDF + FYM @ 10 t ha⁻¹ (6.03 g kg⁻¹) which were found to be on par with each other. Organic carbon content of soil is an indication of organic fraction in soil from the microbial decomposition of organic residues and its amount depends upon the type and quality of organic matter and also stage of decomposition.

Shokati and Ahangar (2014) showed that potential N mineralization, total N, and extractable P were directly related to surface accumulation of crop residues promoted by conservation tillage management. No-tillage management increases soil organic matter and improves soil fertility and has potential for increasing the nutrient supply to crops through changes in the mineralization.

Kuotsu and Singh (2016) studied on integrated nutrient management on soil fertility and concluded that incorporation of FYM @ 5t ha⁻¹ along with NPK 75% registered highest available nutrients in soil after harvest of soybean crop.

Chandra *et al.* (2017) found that tillage systems have profound effect on the physical as well as biochemical properties of the soil. ZT technology is very effective in moderating soil evaporation and minimizing erosion losses. Consistent to the previous findings, our data shows that the NH₄⁺-nitrogen content was highest at 20- 30 cm depth under ZT and there was a decreasing trend observed under tilled conditions i.e. both RT and ZT. Soil nitrogen is expected to percolate down the deeper soil layers in well drained and tilled soils hence, the low levels of NH₄⁺-nitrogen and nitrate nitrogen can be explained. The expected trend for phosphorus and potassium could be explained by the related findings that show least variation on soil potassium and phosphorus levels under varying tillage practices.

Yadav *et al.* (2017) stated that No till with INM increased total soil organic carbon (2.8 %), total soil organic carbon stock (2.8 %), carbon sequestration rate (336.5 kg ha⁻¹ year⁻¹), cumulative carbon stock (142.9 %) and carbon retention efficiency (141.0 %) over conventional tillage of 0 –20 cm depth after three year.

Molina *et al.* (2017) stated that SOC changes simulated in Vertisols, after a change in soil use from Traditional Tillage to Conservation Tillage, were in the range of 0.1 to 2.6 Mg ha yr⁻¹ and, on average, were 1.2 Mg ha yr⁻¹.

Reddy *et al.* (2017) noted that the continuous use of farm yard manure, blue green algae and green manure in conjunction with fertilizers, higher values were recorded in 150% NPK (13.55 t ha⁻¹) followed by 100% NPK+FYM (12.87 t ha⁻¹) and the lower values were recorded in Control (9.43 t ha⁻¹) followed by 100% N (9.93 t ha⁻¹).

2.1.3 Biological properties

In long term field experiments in Denmark, Powlson *et al.* (1987) showed that straw manure could increase soil microbial biomass up to 45 per cent. The greater amount of crop residue incorporation and burying in plot remaining with conservation practices might have provided available substrate for maintenance of larger SMB pool and higher C and N mineralization.

Swarup (1991) reported that combined application of Gypsum + green manure and gypsum + FYM significantly increased the yield and Zn, Fe and Mn concentration in the crop.

Bharadwaj and Omanwar (1992) studied the impact of the long-term fertility treatments on bulk density, water contents and microbial population after nine years of continuous cropping (rice-wheat-cowpea) on Aquic Hapludoll at Pantnagar. The increasing graded doses of NPK fertilizers showed lesser bulk density than control. Similarly, 100% NPK + FYM showed lower bulk density (1.31) than those under fallow plots (1.32) and soil water retention at 33 and 1500 kPa and available water in the surface soil (0-15 cm) varied from 28.8 to 37.7 per cent, 14.5 to 20.2 per cent and 14.3 to 19.6 per cent respectively. Water content in fallow soil was more than that in control. The fallow soils and FYM treated plots (100% NPK + FYM) recorded higher available water content than those of fertilizer treated plots. Application of NPK + FYM also showed increase in microbial counts over NPK treated plots.

The drastic reduction in yield of both crops was noted under farmers practice, with lacks of addition of organics and balanced use of fertilizers. This was also reflected in soil quality deterioration. Organic manure directly added an appreciable amount of major and micronutrients to soil which could contribute to the enhanced yield. In addition to this the improved physical properties like bulk density, available water capacity, mean weight diameter and hydraulic conductivity provided a desirable soil condition for root development, enhanced nutrient uptake, crop growth and yield Naphade *et al.* (1993).

Singaram and Kamalakumari (1995) reported that application of 100% NPK+10 t FYM recorded highest values of dehydrogenase activity (DHA) as compared to NPK alone.

Manna *et al.* (1996) reported that FYM application @ 4 t ha⁻¹ increased microbial biomass but further increase in FYM level caused reduction in biomass turnover. The N and P content and microbial biomass were found higher under soybean than under wheat crop. There was a significant correlation between soil organic carbon and microbial biomass C, N, dehydrogenase activity.

Bouma *et al.* (1997) observed that the temperature has a marked effect on CO₂ evolution from the soil. They found a strong relationship between CO₂ evolutions and mean daily temperature. The CO₂ evolution at 10°C was not observed, while logarithmic increase in CO₂ evolution between 20°C to 40°C while above 50°C it declines rapidly. Further they reported that, at higher temperature partial inhibition of microbial respiration, which was attributed to inactivation of biological oxidation system.

Sriramachandrasekharan *et al.* (1997) observed that green manures have potentials to maintain higher dehydrogenase activity over farmyard manure, coir pith compost and paddy straw. Nature of the plant materials incorporated probably governs the type and number of microbial communities that can flourish under given conditions.

Salinas-Garcia *et al.* (1997) reported that reduction in tillage increased soil organic carbon present as SMBC while mould board ploughing exhibited the lowest SMBC throughout the growing season and decreased in SMBC with increase in tillage intensity.

Sudhir *et al.* (1998) reported that soil microbial biomass carbon (SMBC) and dehydrogenase activities (DHA) were increased by 51.8, and 8.78 per cent respectively with the combined application of FYM and inorganic fertilizers when compared with chemical fertilizers.

Malewar *et al.* (1999) studied on long-term fertilizer experiment started in 1983-84 at Parbhani, Maharashtra on Vertisols for two years 1994 to 1996 to evaluate the impact of application of organics and inorganic on soil microbial population under sorghum-wheat cropping sequence. The soil microbial properties were significantly influenced due to various combinations of manural treatments. The population of bacteria, fungi and actinomycetes decreased in higher proportion in control followed by farmers practice; however, highest population of microbes was observed in the treatment receiving 50:50 inorganic + organic combinations. Fertilizer application alone showed relatively less increase in population of microbes. However, 50 per cent organics either in the form of FYM, wheat straw, green manure with subabul leaves in combination with fertilizers helped to increase bacteria, actinomycetes, fungi and total microbes and CO₂ evolution.

Naidu *et al.* (1999) observed that application of manures and vermicompost with biofertilizers significantly harboured more microbes (bacteria, fungi and actinomycetes) in soil over control.

Maheswarappa *et al.* (1999) reported that the microbial population and dehydrogenase activity were found to be increased under FYM and vermicompost treatments, while in control and application of NPK alone, there was decrease in microbial count.

Kandeler *et al.* (1999) found that FYM (30 t ha⁻¹), applied every second year doubled microbial biomass under spring barley.

Suresh *et al.* (1999) studied the long-term effects of fertilizers and manures on the yield of sorghum-cumbu rotation and soil fertility build up under dry farming in Vertisol since 1982 at Kovilpatti, Tamilnadu. It was revealed that, the inclusion of organics in the treatment schedule maintained higher organic carbon status and highest available N, P and K, thereby sustaining the soil health. Significant positive correlation coefficient were obtained with available N, available K and DTPA-Zn with sorghum and organic available N, available P and DTPA-Zn with *cumbu* yield. The omission of K in the fertilizer schedule has caused a continuous depletion in the $\text{NH}_4\text{OAc-K}$ status over years.

Santhy *et al.* (1999) found that the highest microbial biomass C and N content were observed under the integrated application of organic manure (FYM) + inorganic fertilizer (NPK).

Chafle *et al.* (1999) reported the significantly higher seed yield of soybean (1206 kg ha^{-1}) and straw yield (2360 kg ha^{-1}) with application of 30 kg N through urea and 90 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ through SSP

Surya *et al.* (2000) reported that application of $\text{N}_{20} + \text{P}_{40} + \text{Mg}_6$ resulted in tremendous increase in microbial population in black soil. The bacterial population predominated over fungi and actinomycetes.

Casals *et al.* (2000) observed that soil moisture affects the soil respiration and hence CO_2 evolution. In general, increase in soil moisture would increase CO_2 evolution up to optimum levels above which, it would reduced CO_2 evolution. Periodic drying and wetting of soil which has pronounced influence on CO_2 evolution, when the soil is reverted the activity of the microbes, which were in a latent state in the dry soil, increase accompanied by release of air trapped in the soil pores contributing to an increase in CO_2 evolution.

The stronger effects of FYM on DHA might be due to easily decomposable components of crop residues on the metabolism of soil microorganisms and due to increase in microbial growth with addition of carbon substrate. The FYM application was superior in improving DHA as it

stratified microbial population. Also, being chief carbon source, it provides energy for soil microorganism, and increase number of pores, which are considered important in soil-water-plant relationship and maintains good soil structure accompanied by better DHA activity reported by Marinari *et al.* (2000)

Sharma *et al.* (2000) found highest population of bacteria and fungi in FYM treated plots followed by co-incorporation of crop residue while lowest population of microorganisms were recorded in only chemical fertilizer plots.

Kumar and Gosh (2000) reported that the decomposition of crop residues is microbial mediated progressive break down of organic materials with ultimate products C and nutrients released into the biological circulation in the ecosystem.

Kanchikerimath and Dhyan Singh (2001) studied the changes in soil organic matter and biological properties as influenced by long-term application of manure and fertilizers in maize-wheat-cowpea cropping system in a Cambisol. It is continued since 1971 at Indian Agricultural Research Institute, New Delhi in semi-arid region of India. The crop yield, soil organic carbon and mineralizable C and N increased with the application of inorganic fertilizers. However, there was greater increase of these parameters when manure was applied along with inorganic fertilizers. Soil microbial biomass carbon was increased from 122 mg kg⁻¹ in unfertilized treatments to 331 mg kg⁻¹ in soil amended with 100 % NPK + manure. The dehydrogenase, urease and alkaline phosphatase activities increased significantly with the addition of balanced nutrients and manure. The results indicated that soil organic matter content and soil microbial activities are, vital for the nutrient turnover and long-term productivity of the soil.

Patil and Puranik (2001) studied the effect of irrigated and rainfed cropping systems on soil microbial biomass carbon and N at Akola during 1997-99. Higher biomass C and N were found under irrigated condition during summer season. The maximum SMBC (soil microbial

biomass carbon) and SMBN (soil microbial biomass nitrogen) were observed under 100 per cent NPK + 10 t FYM ha⁻¹ in sorghum-wheat crop sequence. FYM, wheat straw and green manuring application to soybean-wheat increased the SMBC and N content in soil.

Tiwari et al. (2001) showed that microbial biomass had shown larger variation due to different levels of green manure in conjunction with varying levels of N. Microbial biomass was maximum with the application of 7.5 t ha⁻¹ green biomass at 100 kg N ha⁻¹ level followed by 50 kg N ha⁻¹. The green manure serves as an excellent substrate for soil microbes in increasing their population.

Chandramohan (2002) observed that the population of fungi, actinomycetes and bacteria were higher during vegetative and flowering stages as compared to with harvest stage. He also reported significantly higher microbial population in sunhemp + vermicompost followed by sunhemp + poultry treatment. The lowest population was recorded in the treatment receiving inorganic source of nitrogen

Reddy et al. (2002) observed that microbial population was significantly influenced by crop residues like wheat straw, black gram straw. Among the microbiota, the population of bacteria was more followed by actinomycetes and fungi.

Chitale et al. (2003) studied influence of cereal-legume, legume-cereal and cereal - cereal sequences on productivity economics and soil fertility status. Results indicated that after completion of two crop cycles; there was improvement in available N and P status due to increase in fertilizer rate from 75 to 100% of RDF. Legume crop including green manuring provided considerable amount of residual N to the forth coming cereal crops. Soybean and green manuring added rice at the end of *Kharif* season and chickpea only with 100 % RDF at the end of *rabi* season left significant amount of nitrogen over cereal crops of the respective season.

Hangarge et al. (2004) reported that microbial population was significantly enhanced due to application of vermicompost and coirpith compost alone and in combination with either other organic and inorganic

fertilizers over control. Vermicompost and coirpith compost significantly increased the bacteria and fungi population over their individual application.

Venkateswarlu and Srinivasrao (2004) noticed that microbial population majority occur in 40 cm of top soil and bacteria predominant followed by actinomycetes and fungi. Management practices such as irrigation, fertilizer application and residue incorporation have major impact on diversity of biological population.

Saini *et al.* (2005) reported that integrated nutrient management under both soybean and winter maize significantly influenced the biomass carbon at different stages. Application of 50% N,P + all the bio-inoculants was significantly higher followed by 25% N, P + all the bio-inoculants was significantly higher followed by 50% N,P through chemical fertilizers. Although sole application of chemical fertilizer and organic manure showed marked improvement in biomass carbon but integration of both chemical fertilizer and organic manure had shown significant increase in biomass carbon than sole application as well as control.

Addition of organic sources acts as good source of carbon and energy to heterotrophs by their population increased with an increase in enzymatic activities. Similar relationship between organic carbon and enzymatic activities were reported by Bohme and Bohme (2006).

Khaddar and Yadav (2006) studied on effect of integrated nutrient management practices in soil microbial population in a soybean-wheat cropping sequence and reported that the application of biofertilizers significantly showed higher bacterial population during both years of study. The fungal population increased in treated plots over control. Among the organics, biofertilizers increased fungal population at 25 days of the crop.

Rudrappa *et al.* (2006) studied the influence of long term effect of fertilizers and manures application on different organic carbon fractions in Typic Haplustept under different intensive cropping sequence with maize-wheat-cowpea in semi arid sub-tropics of India and observed that the integrated use of FYM with 100 % NPK emerged as the most efficient management system in accumulating largest amount of carbon

and significantly enhanced other organic carbon fractions like SMBC, particulate organic carbon (POC) and KMnO_4 oxidisable carbon in all three soil depths.

Behera *et al.* (2007) reported that the higher sustainability yield index was observed under use of full dose of NPK with FYM or poultry manure also suggest that productivity of wheat-soybean cropping system can not only be improved but also sustainable in long-run with balanced fertilization and integration with available organics. Although the yield of wheat could possibly be increased further with additional N through urea fertilizers as well as organics resources, the use of organic might have other beneficial effects such as cheaper cost, regulated N supply, increased fertility and biological activity of soil.

Mandal *et al.* (2007) conducted a long term fertilizer experiment on inceptisol at IARI, New Delhi and found higher value (517 mg kg^{-1}) of soil microbial biomass carbon with the treatment with application of 100% RDF + FYM than control which was 396 mg kg^{-1} . The soil microbial biomass nitrogen and dehydrogenase activity was also significantly increased by different fertilizer treatment.

Kumar *et al.* (2007) observed that rotation of legumes with cereals increased stabilization of dehydrogenase activity when the field study was conducted at Central Research Farm, Central Arid Zone Research Institute, Jodhpur, Rajasthan in TypicHaplocambid soils.

Bhattacharyya *et al.* (2008) reported that application of FYM recorded significantly higher levels of soil-microbial biomass and dehydrogenase activity compared to the plots that did not receive manure for the past 30 years. The NPK + FYM treated plots recorded the highest SMBC and dehydrogenase activity whereas alkaline phosphatase activity was higher under N + FYM compared to full dose of NPK and NPK + FYM. Bulk density was significantly decreased after 30 annual addition of FYM to the soil along with N and NPK fertilizers. The decrease over initial values was 6.8% under NPK + FYM treated plots. This might be due to higher soil

organic carbon content and a probable increase in root biomass which resulted in better soil aeration and improved soil structure.

Kaur and Brar (2008) observed that 65.1 per cent more soil biomass carbon in 100 % NPK + FYM treated plot as compared to control. They reported that the supply and availability of additional mineralizable and readily hydrolysable carbon due to manure application might be responsible for microbial carbon in soil.

Vineela *et al.* (2008) studied the effects of long-term cropping, fertilization, manuring and their integration on microbial community in soil samples from five long-term fertilizer experiments being conducted since 1970 at Anantapur, Bangalore, Bellary, Coimbatore and Solapur centres of various rainfed production systems in the semi-arid tropics of India. The counts were high in treatments where combinations of organic and inorganic fertilizers were applied compared to control. Vertisols showed larger organic carbon levels than Alfisols. Fungal population was higher in acidic soils and in treatments under continuous inorganic fertilization, whereas a high number of bacteria were found in integrated use of organic and inorganic fertilizers. At most of the locations soil organic C and microbial biomass C showed significant positive correlation with microbial populations. It has been further suggested that even under arid and semi-arid tropical conditions, regular addition of nutrients in an integrated manner could improve soil organic carbon and microbial population.

Goyal *et al.* (2009) indicated that SMBC increased from 136 to 258 mg kg⁻¹ of soil and increased (DHA) from 66 to 118 µg TPF per kg soil 24 hr⁻¹ in treatment receiving rice straw compost @ 5 t ha⁻¹ along with half of the recommended dose of inorganic fertilizer under rice. Mohammadi (2011) studied the Tillage systems and fertilization play an important role in crop growth and soil improvement. This study was conducted to determine the best tillage and fertilization system for wheat production. Experiments were arranged in a split plot based on randomized complete block design with three replications in 2008-09 and 2009-10 growing seasons. Main plots consisted of no tillage (T₁), minimum tillage (T₂) and conventional tillage (T₃). Six methods of fertilization including (N₁): farmyard manure;

(N₂): compost; (N₃): chemical fertilizers; (N₄): farmyard manure + compost; (N₅): farmyard manure + compost + chemical fertilizers and (N₆): control were arranged in sub plots. Addition of compost or farm yard manure significantly increased soil microbial biomass carbon in comparison with chemical fertilizer. No tillage system increased microbial biomass carbon compared to other tillage systems. The dehydrogenase, phosphatase and urease activities in the N₃ treatment were significantly lower than in the farm yard manure and compost treatments. Urease activity under T₁N₄ treatment in the two years of our study was the highest of all treatments. N₅ treatment had a significant difference with other treatments. The highest rate of grain yield was produced in minimum tillage system.

Murugandam *et al.* (2009) reported that no-till practices increases soil microbial biomass C (216 mg kg⁻¹) as compared to chisel plough and mould board plough.

Verma and Mathur (2009) studied the effect of integrated nutrient management on active pools of soil organic matter (SOM) viz., soil microbial biomass carbon, nitrogen, phosphorus and dehydrogenase activity after 9 years of the maize-wheat crop rotation on a Typic Haplustept in a long-term field experiment initiated during *kharif* 1997 at, Udaipur. They reported that application of FYM @ 20 t ha⁻¹ significantly increased the microbial biomass carbon, whereas dehydrogenase activity was found in 100% NPK + 10 t FYM ha⁻¹ treatment compared to sole use of chemical fertilizers. Integrated use of FYM with chemical fertilizers or use of FYM alone exerted significant effect on the active pools of soil carbon. The C/N ratio was highly and significantly correlated with soil microbial biomass carbon and dehydrogenase activity under maize crop.

Lal and Jacinthe (2009) reported that no-till increases the soil microbial biomass carbon (270 mg kg⁻¹) as compared to conventional tillage (95.5 mg kg⁻¹).

Chakraborty *et al.* (2011) investigated some aspects of soil quality and community-level physiological profiles of bacteria in soil under a long-term (37 years) trial with either exclusive inorganic fertilizers or

fertilizers combined with farmyard manure cultivated with jute-rice-wheat cropping system at the Central Research Institute for Jute and Allied Fibres, Barrackpore. Long-term application of 150% RD of NPK lowered the soil pH considerably while the soils in the other treatments remained near neutral. The 100% RD of NPK + FYM treated plot showed significantly highest organic carbon, total nitrogen, microbial biomass carbon, basal soil respiration among the treatments.

Mathew *et al.* (2012) conducted the field experiment in a randomized complete block factorial design of four replications with tillage being the main factor. The no-tillage plots were established in 1990 and conventionally tilled plots in 1994 from previously established no-till plots. Conventional tillage involved disking and chisel plowing in the fall followed by disking and field cultivating in the spring. Cotton was planted at the study site until 2003 and corn from 2004. The effects of long-term conventional and no-tillage practices on microbial community structure, enzyme activities, and selected physicochemical properties were determined in a continuous corn system on a silt loam soil. The long-term no-tillage treatment resulted in higher soil carbon and nitrogen contents, viable microbial biomass at the 0–5 cm depth than the conventional tillage treatment. In no-till soils, the accumulation of crop residues on the soil surface results in enrichment of soil organic matter in the surface layer and as a consequence increased abundance of microorganisms. This study demonstrated a consistent increase in the abundance of fungi, bacteria, arbuscular mycorrhizal fungi, and actinobacteria in the no-till surface soil.

Patrick *et al.* (2013) found greater microbial biomass C under conservation tillage compared to conventional tillage by an average 64 mg C kg⁻¹, reflecting a 7 % difference between treatments

Shokati and Ahangar (2014) showed that higher levels of soil organic C, microbial biomass C and N, potential N mineralization, total N, and extractable P were directly related to surface accumulation of crop residues promoted by conservation tillage management. No-tillage management increases soil organic matter and improves soil fertility and

has potential for increasing the nutrient supply to crops through changes in the mineralization and immobilization of nutrients by microbial biomass.

Gabhane *et al.* (2014) A field experiment was conducted to study the effect of integrated nutrient management in conventional and reduced tillage system on soil quality and productivity of rainfed cotton in Vertisols at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experiment was carried out during 2005-06 to 2009-10 in Factorial Randomized Block Design with twelve treatment combinations and three replications. The treatments consisted of tillage (conventional and minimum), nutrient management viz., 100% RDF, 50% RDF with graded doses of farmyard manure (5, 10 and 15 t/ha) and in situ green manuring with dhaincha (*Sesbania aculeata*). The tillage practices had significant influence on biological properties of soil. Significant improvement in these properties was observed in minimum tillage compared to conventional tillage. Among the various nutrient management treatments, significantly highest improvement in SMBC (281.6 mg/kg) and SMBN (46.8 mg/kg) was noticed under the plots receiving 50% RDF + FYM @ 15 t/ha which was superior over rest of the treatments. While, in case of DHA, the application of 50% RDF + FYM @ 10 t/ha was found on par with the application of 50% RDF + FYM @ 15 t/ha.

Meena and Biswas (2014) reported that the to prepare an enriched compost using rice straw mixed with rock phosphate, waste mica and *Aspergillus awamori* and to study their effect on changes in microbial properties in soils with and without chemical fertilizers under wheat-soybean rotation. Data revealed that significant increase in dehydrogenase activity, in soil was maintained in enriched compost than ordinary compost after both the crops. Significant increase in dehydrogenase activity was found in surface soil. The maximum microbial activities were observed in the treatment receiving 50% recommended dose of fertilizer (RDF) + enriched compost at 5 t ha⁻¹ indicating that integrated use of chemical fertilizers and enriched compost significantly improved the biological properties of soil under wheat–soybean rotation.

Mali *et al.* (2015) studied the effect of long-term fertilization on soil biological health in sorghum- wheat sequence on swell-shrink soils of Central India and reported that green manuring with leucaena loppings and crop residue recycling using wheat straw in conjunction with fertilizers recorded significant improvement in soil biological properties over fertilizers alone. The biological properties were drastically deteriorated where no organics were used continuously for 27 years.

Nivelle *et al.* (2016) The five years field experiment was conducted in Northern France using a combination of three factors: i) no-till (NT) vs. conventional tillage (CT); ii) with or without winter cover crops (bare fallow; cover crops with a low prevalence of legumes; cover crop with a high prevalence of legumes); and iii) with or without N fertilization. C and N inputs from cover crops and crop residues, C and N content, enzyme activities, and microbial functional diversity in the topsoil (0–10 cm) were measured over an industrial crop rotation: wheat, pea, corn, wheat, flax. No-till combined with any of the cover crops was characterized by increased total soil organic C and N contents by more than 20% between 2010 and 2015. Dehydrogenase and urease activities were significantly greatest under NT, irrespective of the presence of cover crops. Cover crops without N fertilization under no-till led to higher microbial functional activity and diversity.

Nagar *et al.* (2016) conducted a field experiment was conducted to study the effect of organic manures (FYM and pigeonpea stalk) along with phosphocompost on physico-chemical and biological properties of soil in pigeonpea based intercropping system at Pulses Research Unit, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during Kharif season of 2013-14 on inceptisol. With three replications consisting of three cropping systems viz pigeonpea + greengram, pigeonpea + blackgram and sole pigeonpea, three levels of organic manures viz farm yard manure (FYM) + pigeonpea stalk, FYM + phosphocompost and recommended dose of fertilizers (R DF) The organic manures like FYM, pigeonpea stalk (chopped to 1-2 cm pieces) and phosphocom. Significantly highest SMBC was found with the application of

FYM + phosphocompost which was statistically at par with pigeonpea stalk + phosphocompost and significantly superior to chemical fertilizers (RDF). The higher microbial biomass pool size may accumulate after regular addition of manures and crop residues under organic practices.

Yadav *et al.* (2017) reported that NT systems\ with INM and residue retention had significantly increased SBMC and DHA than that under other treatments. The MBC and DHA under no till with INM were 17.8 and 44%, higher than that under no till respectively.

Molina *et al.* (2017) stated that SOC changes simulated in Vertisols, after a change in soil use from Traditional Tillage to Conservation Tillage, were in the range of 0.1 to 2.6 Mg ha yr⁻¹ and, on average, were 1.2 Mg ha yr⁻¹.

2.3. Effect of tillage and IPNS on yield of soybean and yield of cotton

Hunsigi *et al.* (1972) inferred that 80 per cent variation in seed cotton yield could be attributed to effect of nitrogen. Significant increase in plant height, number of minopodial and sympodial branches, dry matter production, bolls plant⁻¹ and boll weight were recorded with incremental dose of N upto 80 kg ha⁻¹.

Khiani and More (1984) reported that deep tillage involving ploughing up to 18-20 cm depth helped in improving level of P and K in soil, such tillage operation significantly increase the grain as well as fodder yield of rabi sorghum, while it failed to improve the yield of seed cotton, being at par with harrowing.

Chaudhary *et al.* (1985) reported that deep ploughing allows maximum absorption of rain water and reduces weed populations at the initial stage of crop growth, which ultimately increased crop yields under disc and chisel ploughing treatments in fine loamy Typic Ustochrept.

Sethi (1988) concluded that cotton grown as either sole crop or with intercrop be irrigated with irrigation scheduling at 75 mm CPE to achieve higher productivity of cotton and intercrops as well as gross monetary returns.

Singh and Bajpai (1990) reported that the yield attributes of soybean viz., number of pods per plant and grain yield of soybean increased significantly with the application of phosphorus. The number of pods also significantly increased with the application of potassium

Kukreja *et al.* (1991) conducted research trials on long-term, manurial application on sandy loam soil and found that the available N increased with the application of increase in doses of FYM, but it was less in treatments receiving inorganic N. The total N increased in the similar proportion as organic carbon, but the increase in available N was low.

Malewar *et al.* (1992) also observed that the seed cotton yield and groundnut yield were increased with increasing P rates. The uptake of both P and B increased with increasing P rates and was highest from boronated single superphosphate.

Devrajan and Palaniappan (1995) reported that the combined application of 2.5 kg Zn, 0.5 kg Mo, 10 t FYM ha⁻¹, to soybean produced the highest seed yield and enhanced the uptake of Zn, Cu, Fe and Mn by soybean.

Hegde (1996) reported that nutrient application through integrated nutrient supply which includes inorganic fertilizers, FYM, wheat straw and green manuring increased the yield and yield attributing characters.

Halvankar *et al.* (1999) reported the significant improvement in yield attributes and yield of soybean due to conjoint use of chemical fertilizers.

A field experiment was conducted during 1996-97 and 1997-98 to study the influence of organic manures, viz. dhaincha, sunhemp and FYM on productivity and quality of rice. All the sources of organic manures improved the yield and quality. Among the various organic sources, *in situ* incorporation of dhaincha @ 12 t ha⁻¹ remarkably increased the grain (18%) and straw (16%) yields of rice over no organic manure, owing to increase in growth and yield attributing characters of rice (Hemalatha *et al.* 2000).

Navale *et al.* (2000) conducted a field experiment during kharif season of 1996 at Rahuri and found significantly higher seed yield of soybean with the application of 60 kg N and 100 kg P₂O₅ ha⁻¹ over their lower doses.

Subramanian *et al.* (2000) reported that the inclusion of organic manures in the fertilizer schedule not only increased yield but also improved soil moisture content at various soil depth. The combined application of organic and inorganic N fertilizers further enhanced yield and improved soil productivity than the application of inorganic N fertilizer alone.

Ramasamy *et al.* (2000) conducted a field experiment at Vamban (Tamilnadu) during summer and *kharif* season of 1994 and 1995. They observed that the application of phosphorus @ 80 kg ha⁻¹ recorded significantly higher number of pods per plant, plant height and number of branches per plant and ultimately grain yield of soybean.

Prakash *et al.* (2001) reported that application of 10 t FYM ha⁻¹ and N doses increased plant height, number of leaves plant⁻¹, dry matter, leaf area index, number of bolls plant⁻¹ (22.46), boll weight (4.54 g) and seed cotton yield (24.10 q ha⁻¹) over without FYM. He also noticed fibre quality was unaffected due to FYM and N doses to cotton crop.

Wankhade *et al.* (2001) found that application of recommended dose of fertilizer (50:25:0 kg NPK ha⁻¹) recorded 32.2 and 14.7 per cent increase in seed cotton yield over no fertilizer and 50 per cent recommended dose, respectively. Higher dose of fertilizer increased the seed cotton yield and bolls per plant.

Basavanneppa and Biradar (2002) found that the application of FYM @ 10 t ha⁻¹ recorded highest seed cotton yield over incorporation of cotton crop residue @ 5 t ha⁻¹ and vermicompost 2.5 t ha⁻¹. Further, cotton and maize yields were increased with every increment in the levels of RDF. The maximum seed yield of bengalgram was noticed at 50 per cent RDF application with the residual effects of FYM + vermicompost (50 %).

Singh *et al.* (2002) observed that application of wheat residue @ 4 t ha⁻¹ along with recommended dose of N and P enhanced the productivity of cotton wheat cropping system.

Katkar *et al.* (2002) reported that, recommended dose of fertilizer recorded highest seed cotton yield (812 kg ha⁻¹) followed by the treatment receiving 50 per cent RDF + 5 t FYM ha⁻¹ (785 kg ha⁻¹). Among the organic treatments, the application of FYM alone, mulching, glyricidia green foliage lopping and sunhemp green manuring recorded 31.8, 22.7, 25 and 15.2 per cent increase seed cotton yield over control.

Kanwar and Paliyal (2002) studied influence of phosphorus management and organic manuring on uptake and yield of chickpea and reported that there was increasing in available P status of soil with increasing doses of P₂O₅ with or without organic manure in both the years. However, significant increase in available P was found with P application along with organic manures as compared to the P fertilization alone. FYM and vermicompost were equally effective in increasing the available P status of soil.

Prabhakaran *et al.* (2003) conducted field experiment during 2003 at TANU, Coimbatore. The soybean response to fertilizer N besides P and K requirement. The application of N, P, and K together significantly increase the growth attributes and yield of soybean. The higher sustained soybean yields can be obtained with judicious and balanced N, P and K fertilization.

Bandopadhyay *et al.* (2003) studied on integrated nutrient management practices in soybean and sorghum in sole and intercropping system on Vertisols during 2000-2001 at Bhopal and revealed that combined application of organic and inorganic sources of nutrients can improve the root growth of soybean facilitating efficient utilization of stored soil moisture and nutrients from different layers in the profile.

Ogunwole *et al.* (2003) observed 4 t ha⁻¹ seed cotton yield under unstressed conditions and 1.5 t ha⁻¹ under moisture stress conditions. However, under adequate moisture conditions, NPK at 90:39:39 and

60:26:26 kg ha⁻¹ resulted in the highest yields. This indicates that soil nutrition can only be a constraint under moisture stress conditions.

Mehetre *et al.* (2003) at MPKV, Rahuri while studying response of cotton varieties to different fertility level during *kharif* season 1997-98 to 2001-02 on vertisol recorded higher number of bolls plant⁻¹ (24), boll weight (2.55 g), seed cotton yield plant⁻¹ (78.59 g) and seed cotton yield (17.81 q ha⁻¹) with application of 100:50:50 kg NPK ha⁻¹. Further, it was observed that fertilizer dose of 100:50:50 and 80:40:40 kg NPK ha⁻¹ were at par with each other.

Nehra and Kumawat (2003) recorded that the number of bolls plant⁻¹, boll weight and seed cotton yield increased significantly by foliar spraying of urea, DAP, KNO₃ and KCL @ 2 per cent and reflected 20.8, 18.1, 16.8 and 13.1 per cent higher seed cotton yield over water spray.

Sonune *et al.* (2003) studied the long-term effect of manures and fertilizers on fertility and crop productivity of Vertisols under sorghum-wheat sequence in semi-arid climatic conditions of Vidarbha region of Maharashtra. The application of recommended dose of NPK (100:50:40 for sorghum and 120:60:60 to wheat) and 10 t FYM ha⁻¹ improved the available NPK and organic carbon content of soil. The available NPK showed positive correlation with crop yield and there was positive balance of N and P but K showed negative balance. Thus, the balanced use of NPK fertilizers along with FYM is essential for augmenting the fertility of Vertisol in cereal-cereal cropping sequence.

Blaise and Ravindran (2003) while his studies over cotton, recorded that yield improvements in deep tillage practices over minimum tillage system could be due to a host of factors, namely, lower weed density, reduced competition to resources, improved soil water regimes and better water extraction, aeration and fertilizer use by way of improved soil physical status.

Ghatage *et al.* (2003) studied fertilizer economy through phosphocompost (PC) for sequence cropping and reported that the significantly higher grain (1409 kg ha⁻¹) of green gram was obtained under

RDN + phosphocompost over application of RDN alone. However, it was on par with 75 % RDN + phosphocompost and 50 % RDN + phosphocompost and RDF. The application of RDN + PC in kharif season and its residual effect on sorghum crop in rabi season favourably increased grain (1001 kg ha^{-1}) and fodder yield (8131 kg ha^{-1}) which were 19 and 8.16 per cent more over RDN alone.

Tanwar and Shaktawat (2003) studied the effect of phosphorus levels and organics on yield of soybean-wheat cropping in alkaline calcareous soils and reported that Incorporation of FYM @ 10 t ha^{-1} with or without PSB significantly improved the yield of soybean and succeeding wheat.

Ghosh *et al.* (2004) studied the comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer – NPK on three cropping system in Vertisols of semi arid tropics and reported that application of 75% NPK in combination with poultry manure, FYM or phosphocompost to preceding rainy season crop (soybean and sorghum) and 75% NPK to wheat produced significantly higher grain yield of wheat than under inorganic and control. This indicating noticeable residual effect on the succeeding wheat crop and saving of 25 per cent fertilizer – NPK. The effect of PC on rainy season crops was not prominent as those of FYM and PM, but its residual effect on grain yield of wheat was comparable to those two organic manures. Among the cropping system, soybean as preceding crop recorded the highest seed yield of wheat.

Chittapur (2004) concluded that in cotton + soybean intercropping, incorporation of crop residues with and without a cellulose degrader (*Phanerochaete chrysosporium*) increased seed cotton yield by 17 per cent over no residue.

Babalad and Itnal (2004) reported that the crop residue incorporation found to be beneficial in increasing the dry matter, plant height, monopodial and sympodial branches over rest of the treatments and concluded that combined application of RDF + FYM recorded significantly higher seed cotton yield over rest of the treatments followed by

RDF + vermicompost and significantly superior to RDF. They also observed that significantly higher seed cotton yield with CR + PC and CR as compare to no residue and the increase in yield was to the extent of 16.8 and 15.3 per cent respectively

Hulihalli and Patil (2004) compared the organic material as a source of soil amendment and found that incorporation of FYM + poultry manure @ 2.5 t ha⁻¹ recorded significantly higher seed cotton yield (1017 kg ha⁻¹) as compared to cotton stalk @ 5 t ha⁻¹ (910 kg ha⁻¹) and other organic manurial treatments were on par with manures FYM + poultry manure @ 2.5 t ha⁻¹.

Hongal *et al.* (2004) found that sunhemp green manuring was found to be significantly superior in increasing numbers of harvested bolls and seed cotton yield (932 kg ha⁻¹) as compared with other green manuring crops and fallow.

Deshmukh *et al.* (2004) observed significantly higher seed cotton yield in furrow irrigated crop over no irrigation.

Adarsha *et al.* (2004) reported significantly higher seed cotton yield under irrigation (17.54 q ha⁻¹) as compared to rainfed condition (7.73 q ha⁻¹).

Halemani *et al.* (2004) observed that increased in fertilizer application from 75 to 100 per cent of RDF (120:60:60 kg NPK ha⁻¹ to Bt cotton hybrids improved the cotton yield from 2112 to 2428 kg ha⁻¹. Further, they reported that the performance of Bt cotton hybrids at different levels of fertilizer under protective irrigation and found that Bt cotton shows increase in the yield as the levels of NPK levels increased from 75 to 100%. It also shows increase in plant height, number of bolls and yield per plant.

Aykas and Onal (2004) reported that the highest seed cotton yield of 1431 kg ha⁻¹ was recorded under deep tillage which was 78.21, 53.05 and 5.06 per cent more than no tillage (803 kg ha⁻¹), conventional tillage (935 kg ha⁻¹) and deep+conventional tillage (1362 kg ha⁻¹) respectively. The higher seed cotton yield under deep tillage was due to

higher number of bolls plant⁻¹ (30.5) and the yield/plant (92.5 g) as compared to no tillage, conventional tillage and deep+conventional tillage.

Bandopadhyay *et al.* (2004) studied on integrated nutrient management practices in soybean and sorghum in sole and intercropping system in vertisols during 2000-2001 at Bhopal and observed that integrated use of farmyard manure @ 5 tonne per hectare, or phosphocompost @ 5 tonne per hectare or poultry manure @ 1.5 tonne per hectare along with NPK improved total dry matter yield (12.9 %), seed yield (12.7 %) over application of 100 % NPK.

Paradkar and Deshmukh (2004) observed that application of 130 % RDF + 10 t FYM recorded significantly higher plant height, branches, number of pods per plant and number of root nodules than the lower levels.

Pettigrew *et al.* (2004) conducted field experiments under both dryland and irrigated condition and observed that the irrigation delayed cut-out, the slowing of vegetative growth due to strong reproductive demand for assimilates, by an average of 6 days. This delayed maturity enabled those plants to sustain flowering later in the growing season compared with dryland plants. He further noted that when sufficient moisture deficits occurred, the lint yield of dryland plants was reduced 25 %, primarily because of a 19 % reduction in number of bolls. Irrigated plants produced higher number of bolls and sympodial branches than the dryland plants

Singh *et al.* (2004) conducted the study to evaluate seven treatments comprised of various combinations of green manure (GM; *Sesbania Cannabina* L.); wheat straw (WS), farmyard manure (FYM), and urea on yields and yield trends; P and K balance; and soil fertility in a rice-wheat experiment (1988-2000) on a loamy sand at Punjab Agricultural University, Ludhiana, Punjab. Rice yields were comparable with GM + urea, WS + GM + urea, and urea alone but after 5 years of continuous application, FYM and WS were at par in increasing rice yields. Organic materials applied to rice had no residual effect on wheat yields except FYM, which increased yield by about 6 per cent compared with urea alone.

Gormus (2005) studies the effect of application rates on N and B on cotton yield and fibre quality. The application of 1.12 kg ha⁻¹ B and 160 kg ha⁻¹ N resulted in the highest number of bolls. B increased boll weight 5.93 to 6.92 g boll⁻¹ and bolls bearing from 15.9 to 18.8 bolls plant⁻¹ in 2003.

Application of nutrients in organic and inorganic form and their combination in vertisol increased grain yield of soybean significantly over control. The highest yield was obtained with the application of 150 % RD NPK + S + Zn (9.23 q ha⁻¹) which was at par with RD NPK + S + Zn with 50 % N through leucaena loppings (9.14 q ha⁻¹) and RD NPK + Zn with 50 % N through FYM (9 q ha⁻¹) which were significantly superior to RD of NPK reported by Guldekar *et al.* (2005)

Ghosh *et al.* (2005) studied the different nutrient combination on deep Vertisols and showed that significant influence on yield and dry matter production of soybean. The performance of nutrient combinations followed the order of 70% NPK + FYM > 75 % NPK + Poultry manure > 75 % NPK + Phosphocompost > 100 % NPK. Thus the combined use of manures and inorganic fertilizers played a significant role in increasing the above and below ground dry matter, water use efficiency, pod number and its weight resulting in higher seed and oil yield of soybean.

Kaur *et al.* (2005) conducted an experiment at Hisar on soil receiving organic manure with and without chemical fertilizer for the 7 years with pearl millet-wheat cropping sequence. The application of farmyard manure, poultry manure, and sugarcane filter cake alone or in combination with chemical fertilizers improved the soil organic C, total N, P and K status. The increase in soil microbial-biomass C and N was observed in soils receiving organic manures only or with the combined application of organic manures and chemical fertilizers compared to soils receiving chemical fertilizers only.

Bhoite and Thombre (2006) recorded that seed cotton yield was significantly higher with 100 per cent RDF + FYM @ 10 t ha⁻¹ which was at par with 50 per cent RDF + intercropping of sunnhemp for *in situ*

green manure. The number of bolls per plant and 100 seed weight was maximum in 100 per cent RDF + FYM @ 10 t ha⁻¹ which was at par with 50 per cent RDF + intercropping of sunnhemp for *in situ* green manure. Seed cotton weight per boll was maximum in the treatment 50 per cent RDF+ FYM @ 10 t ha⁻¹ + foliar spray of 2 per cent urea + 2 per cent DAP at boll development. 50 per cent reduction in RDF may possible without decreasing seed cotton yield significantly with the treatment 50 per cent RDF+ intercropping of sunnhemp for *in situ* green manuring.

Dhawan *et al.* (2006) reported highest soybean grain and straw yield on Vertisol with application of 100% phosphorus was applied through chemical fertilizer and FYM to preceding crop in soybean-safflower cropping sequence.

Katkar *et al.* (2006) revealed that maximum seed cotton yield was recorded by the treatment of FYM @ 5 t ha⁻¹ + 50 % RDF (1095 kg ha⁻¹) followed by glyricidia green lopping at 30 DAE @ 5 t ha⁻¹+ 50 % RDF (1070 kg ha⁻¹) and 100 per cent RDF (1055 kg ha⁻¹).

Giri *et al.* (2006) conducted a field on clayey soils during the rainy season of 1999-2003 at Parbhani to study the nutrient management in cotton (*Gossypium hirsutum* L.) based intercropping system. The result indicated that sole cotton recorded significantly higher seed cotton yield than cotton + black gram (*Phoseolus mango* L.) and cotton + soybean (*Glycine max* L.) intercropping systems. However, highest and significant cotton equivalent yields were enhanced significantly with every higher fertilizer level and highest value were recorded with 100 % RDF.

Hulihalli and Patil (2006) reported that effect of integrated nutrient management practices on yield and nutrient uptake by cotton (*G. herbacium* L.) has been studied in field experiment conducted for two years 1998-99 and 1999-2000 in fixed site at agricultural research station, Annigeri (Karnataka) under rainfed condition. The result indicated that application of 100 per cent RDF recorded significantly higher seed cotton yield (1052 kg ha⁻¹) as compared to control (890 kg ha⁻¹) and 50 per cent

RDF (985 kg ha⁻¹). The variation in seed cotton yield between fertilizer levels was mainly attributed higher growth and yield components.

Kalaichelvi *et al.* (2006) carried out investigation on fertilizers use have conclusively proved that the efficiency of nitrogen in improving cotton yield and response of cotton to incremental nitrogen to certain level is well known fact.

Singh *et al.* (2006) noticed that among various nutrient combinations, there was an increase in plant height number of boll per plant and seed cotton yield with increased nutrient combinations. However, significant increase in plant height, number of bolls per plant and the highest seed cotton yield was observed with data over the two years, indicated an increased seed cotton yield to the tune of 13.5, 27.1, 29.8 and 36.3 per cent for recommended NP, recommended NPK, recommended NPKS and recommended NPKSZn respectively over that of control.

Awasya *et al.* (2006) reported that the significantly highest seed cotton yields (17.63 q ha⁻¹) were recorded with 120:60:50 NPK kg ha⁻¹.

Pinjari *et al.* (2006) studied on the response of irrigated cotton (JLH-168) to different levels and sources of fertilizers was undertaken by at Rahuri on medium black clay soil. They found that seed cotton yield increased significantly with every successive increasing levels of fertilizers. The highest seed cotton yield was recorded with the application of 120:60:60 kg NPK ha⁻¹ and it was significantly higher over lower fertilizer levels.

Giri *et al.* (2006) carried out a field on clayey soils during the rainy season of 1999-2003 at Parbhani to study the nutrient management in cotton (*Gossypium hirsutum* L.) based intercropping system. The results indicated that sole cotton recorded significantly higher seed cotton yield than cotton + black gram (*Phaseolus mungo* L.) and cotton + soybean (*Glycine max* L.) intercropping systems. However, highest and significant cotton equivalent yields were enhanced significantly with every higher fertilizer level and highest values were recorded with 100 % RDF.

Bhalerao *et al.* (2007) reported highest seed cotton and yield contributing parameters with the application of FYM @ 10 t ha⁻¹ + 100 per cent RDF (50+25+25 N, P and K kg ha⁻¹) as compare to FYM @ 5 t ha⁻¹ + 100 per cent RDF and FYM @ 10 t ha⁻¹ + 50 per cent RDF + foliar spaying of 2 per cent urea at flowering and 2 per cent DAP at boll development stage.

Brar and Kaur (2007) reported that deep tillage produced significantly higher seed cotton yield (1431 kg ha⁻¹) which was 78.21 and 53.05 per cent more than no tillage (803 kg ha⁻¹) and conventional tillage (935 kg ha⁻¹), respectively. Similarly in deep tillage 82.63 and 28.15 per cent higher number of bolls per plant was recorded as compared to no tillage and conventional tillage, respectively. In deep tillage, the seed cotton yield per plant was 92.5 g which was significantly higher as compared to no tillage and conventional tillage but at par with deep+conventional tillage.

Rashidi and Keshavarzpour (2007) investigated the effect of different tillage methods on crop yield of watermelon. Tillage treatments in the study were moldboard plow + two passes of disk harrow as conventional tillage (CT), two passes of disk harrow as reduced tillage (RT), one pass of disk harrow as minimum tillage (MT) and no-tillage (NT) as direct drilling method. The statistical results of the study indicated that tillage method significantly ($P \leq 0.05$) affected crop yield and total soluble solids, but there was no significant differences in other components such as number of plants per hectare, number of fruits per plant, root length and root dry matter. The maximum value of crop yield, number of plants per hectare, root length and root dry matter was observed in case of CT treatment compared with other tillage treatment.

However, in BT cotton increase in seed cotton yield of Bt cotton hybrid with the application of 150 per cent RDF + vermicompost @ 1 tonne per hectare over 150 per cent RDF was observed by Kumar *et al.* (2007), while the response of non Bt cotton hybrid to increasing nutrient supply through vermicompost over 150 per cent RDF was non significant, indicating more nutrient requirement by Bt cotton.

Paslawar *et al.* (2007) Significantly highest soybean yield was recorded with the 50% RDF + 3t vermicompost + BF (Broad furrow). The higher yield in INM treatment might be attributed to rapid mineralization of N from FYM, which might have met the N requirement of crop at the critical stages.

Rao and Setty (2007) conducted a field experiment on medium black soil at RARS, Raichur. They revealed that organic manures increase the seed cotton yield significantly over no organic manure application. Among the organic manures FYM+VC+CR (33 % each) recorded significantly the highest seed cotton yield (1469 kg ha^{-1}) over rest of the manures.

Sisodia and Khamparia (2007) reported that 166 % NPK recorded maximum dry matter production, higher number of bolls plant⁻¹ and seed cotton yield than 133 % and 100 % NPK ha⁻¹.

Balwinder Kumar *et al.* (2008) noticed that the application FYM with 100 percent NPK produced the significantly higher grain yield of rice (6.7 t ha^{-1}) than 100 percent NPK alone treatment (6.09 t ha^{-1}) and crop residues in rice produced significantly higher grain yield of succeeding wheat (5.62 t ha^{-1}).

Chaudhary *et al.* (2008) reported that grain yield of chickpea was the highest under RDF which was at par with FYM 5 t ha^{-1} + seed treatment of soil application of rhizobium and PSB, vermicompost 3 t ha^{-1} + seed treatment of soil application of rhizobium and PSB. However, the straw yield was highest under FYM 5 t ha^{-1} + rhizobium and PSB seed treatment which were at par with RDF. This might be due to slow and insufficient availability of nutrient from FYM or vermicompost and reduced dose of inorganic fertilizer, whereas full RDF or organic manure coupled with dual inoculation of biofertilizers might have directly catered to the need of various plant nutrients of the crop in sufficient quality.

Maheshbabu *et al.* (2008) conducted a field experiment on black soil to show the effect of organic manure and observed that the application of recommended dose of fertilizer (40:80:25 kg NPK ha⁻¹ with

recommended dose of FYM (5 t ha⁻¹) recorded significantly higher seed yield (22:35 q ha⁻¹).

Patil *et al.* (2008) conducted a field experiment on alkaline soil to show the effect of conjoint use of manure and fertilizer and observed that the grain yield increased significantly by the manures and fertilizer application over control. Grain yield varied from 13.11 q ha⁻¹ (control) to 24.48 q ha⁻¹.

Katkar *et al.* (2008) concluded that the highest seed cotton yield (1417 kg ha⁻¹) was recorded in treatment receiving 100 per cent recommended dose of fertilizers.

Mahavishnan *et al.* (2008) investigated the response of cotton to integrated nutrient management in cotton –sunflower cropping system. Highest seed cotton yield (23.47 and 26.93 q ha⁻¹) and stalk yield (57.84 and 64.32 q ha⁻¹) were obtained with combined application of all the three sources of N [50 % RDF + FYM + Mungbean Intercrop Incorporation] that remained at par with individual application of 100 % RDF as well as combined application of 50 % RDF and FYM. Quality parameters *viz.*, ginning percentage, lint index, seed index, Bartlett's index, fibre length, fibre fineness, bundle strength and maturity coefficient were remained unaffected due to various N management practices in cotton, however, higher values were observed with either application of FYM alone or in combination with other N sources.

Rao and Janawade (2009) concluded that the application of sunhemp (1531 kg ha⁻¹) and Lucerne green manuring (1435 kg ha⁻¹) recorded significantly higher seed yield over no green manuring (1285 kg ha⁻¹). Among organic manures, application of FYM @ 10 t ha⁻¹ recorded significantly higher seed cotton yield (1515 kg ha⁻¹) than cotton stalks @ 5 t ha⁻¹ (1406 kg ha⁻¹) and no organics (1317 kg ha⁻¹).

Mehta and Saharan (2009) reported that seed cotton yield per plant was maximum under 100 per cent recommended dose of N but remain at par with 75 per cent N through chemical fertilizer + 25 per cent

through vermicompost and 75 per cent N through chemical fertilizer + 25 per cent through FYM.

Sakarvadia *et al.* (2009) conducted a field experiment on medium black calcareous soil (Typic Ustochrepts) with cotton (G-Cot-Hy-10) using five levels of K (0, 90, 120, 150 and 180 kg ha⁻¹) and 3 levels of ZnSO₄ (0, 25 and 50 kg ha⁻¹). The significantly higher seed cotton (2345 kg ha⁻¹) and stalk (3679 kg ha⁻¹) yield of cotton were recorded with K₁₂₀ and K₁₈₀ treatment respectively whereas the higher seed cotton yield (2269 kg ha⁻¹) and stalk yield (3540 kg ha⁻¹) were recorded with application of ZnSO₄ @ 50 kg ha⁻¹.

Shweta *et al.* (2009) studied the integrated use of organic manures *viz.*, compost vermicompost, GLM and fermented organic *viz.*, Beejamurth and Panchagavya in soybean-wheat cropping system and observed that grain yield of soybean, wheat and their soybean equivalent yield were significantly higher in RDF + FYM and combined used of organic manures + fermented organics.

Singh *et al.* (2009) studied the effect of phosphocompost on rice-wheat system in non calcareous Typic Haplustepts and reported that higher grain yield (7.41 t ha⁻¹) of rice was obtained under half recommended level of inorganic P in combination with 2 tonnes of phosphocompost ha⁻¹ (N₁₂₀ P₁₃ V₂). Maximum wheat grain yield (5.41 t ha⁻¹) was obtained under recommended dose of fertilizers along with 2 t phosphocompost (N₁₂₀ P₂₆ V₂) the yield of rice and wheat was 110 and 104%, respectively in the treatment receiving 2 t ha⁻¹ of phosphocompost of to each rice and wheat along with inorganic fertilizers (N₁₂₀ P₂₆ V₂).

Deshmukh *et al.* (2010) revealed that significantly higher grain yield of soybean (1536 kg ha⁻¹) was obtained with the application of 4 t wheat straw ha⁻¹ + RDF compared to application of 4 t sugarcane trash + RDF. reported that incorporation of crop residue alone as well as in combination with 50 to 100% RDF to soybean-chickpea sequence significantly increased yield of soybean and chickpea.

Chaturvedi *et al.* (2010) reported that the integrated use of RDF with FYM or soil application of Fe/B being at par increased the seed yield of soybean significantly over RDF alone ($3.13 \text{ tonne ha}^{-1}$). Highest net returns were recorded with the application of RDF + 10 tonne FYM ha^{-1} . Use of FYM and micronutrients helped in maintaining soil fertility and rhizospheric microbial population. RDF resulted in significantly higher number of pods/ plant, seeds/pod, and test weight as compared to control. These attributes also increased significantly due to integration of FYM/iron/boron with recommended dose of fertilizer. However, maximum values of yield attributes were recorded in combined application of RDF + FYM, indicating that complimenting fertilizers with FYM improved the general soil environment, physico-chemical and biological conditions. This resulted in improved soybean growth and yield contributing characters. The combined application of FYM/Fe/B with RDF also increased grain and biological yield of soybean.

Kumari *et al.* (2010) reported that the pooled mean yield of cotton was highest (13.85 q ha^{-1}) in the treatment of 100 per cent NPK+FYM 10 t ha^{-1} followed by 150 per cent NPK (13.07 q ha^{-1}).

Mohod *et al.* (2010) recorded significantly higher straw yield of 35.34 q ha^{-1} with application of 125 per cent RDF (25 % N substituted through FYM) over 125 per cent RDF inorganic. This was because of increased use efficiency of added fertilizer due to organic fertilizers and similarly because the organic manure also contain almost all the essential elements in variable quantities which has synergistic effect with other essential elements for their availability.

Nawlakhe and Mankar (2010) reported that in 25 kg N through fertilizer + 25 kg N through FYM + 25 kg P_2O_5 treatment recorded maximum total dry matter accumulation of cotton and green gram. The same treatment also proved to be the best in respect of yield of cotton (6.99 q ha^{-1} , pooled mean) as well as green gram (4.36 q ha^{-1} , pooled mean) under cotton+greengram intercropping followed by $50 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ inorganic fertilizer i.e. 100 % RDF treatment.

Sharma *et al.* (2010) carried out a field experiment at Selakui, Dehradun to study tillage and legume mulching effects on productivity of rainfed maize- wheat cropping system and observed the beneficial effect of live mulching with sunhemp or leucaena, while their combined application increased the maize yield by 19.1 % over no mulching.

Bhalerao and Gaikwad (2011) noticed that among the organic source application of FYM @10 t ha⁻¹ recorded significantly higher seed cotton yield than application of vermicompost 1.25 t ha⁻¹ + CR (cotton stalk residue) @ 2.5 t ha⁻¹.

Sekhon *et al.* (2011) reported that deep tillage resulted in significantly higher seed cotton yield as compared to conventional tillage with flat sowing. Bt cotton hybrid responded to nitrogen application and the maximum seed cotton yield was obtained with application of 120 kg N ha⁻¹ under conventional and deep tillage treatments.

Solunke and Fatak (2011) reported that bolls, boll weight and seed cotton yield/plant were significantly affected by the different combination of organic and inorganic sources of nutrients. Treatment combinations of FYM @ 10 t ha⁻¹+ 50:25:25 kg NPK ha⁻¹ (O₁ I₂) and vermicompost @ 2 t ha⁻¹+ 50:25:25 kg NPK ha⁻¹ (O₂ I₂) being at par recorded significantly maximum seed cotton yield (14.44 and 16.27 and 14.15 and 15.87 q ha⁻¹) over remaining treatment combinations of organic and inorganic sources of nutrients.

Blaise (2011) conducted experiment with tillage practices as main plots (conventional tillage {CT}, RT with two inter-row cultivations {RT1} and RT with no inter-row cultivation {RT2}). In the sub-plot, in situ green manure (GM) was included along with 100 (GM + N100), 80 (GM + N80) and 60 kg N ha⁻¹ (GM + N60) and were compared to N alone (N100). Growth, yield and fibre quality of Bt transgenic cotton hybrid (RCH-2 Bt) were monitored during the study. RT treatment had seed cotton yield (1717–1740 kg ha⁻¹) significantly higher than the CT treatment (1489 kg ha⁻¹). The treatments N100, GM + N 100 and GM + N 80 (1687–1734 kg ha⁻¹) did not differ and were significantly better than the GM + N60 (1303 kg

ha⁻¹). Tillage-GM interaction was significant in two of three years and data combined over years. The RT plots with GM had significantly greater yield than the CT plots. Compared to the CT treatment, the RT plots had significantly greater proportion of water stable aggregates (48.6% vs. 54.4–56.0%) and mean weight diameter (0.47 mm vs. 0.49–0.51 mm). The GM plots had significantly higher WSA and MWD than those without. Further, soil moisture content was greater in the GM mulched plots up to 0.60 m depth compared to without GM treatment (CT + N100). Favourable soil physical properties may have contributed to improved seed cotton yield in the RT treatments with GM than in the CT treatment. Fibre quality was not affected by either the tillage systems or GM. This study indicates that Bt transgenic cotton can be grown under RT systems with an in situ legume GM.

Narayana *et al.* (2011) reported that opening of an alternate furrow at last interculture recorded the highest seed cotton yield with increased sympodia, boll/plant BCR (3.42) and higher seed index (11.7 g). Application of RDF based on soil test values plus two sprays of KNO₃ (2 per cent) each at flowering and boll development stage recorded the highest seed cotton yield (4550 kg ha⁻¹) which was closely followed by 75 per cent inorganic and 25 per cent organic in the form of well decomposed FYM (4490 kg ha⁻¹).

Thakur *et al.* (2011) studied the continuous use of various inorganic fertilizers and organic manure in a Vertisol. Results indicated that the application of recommended dose of N, P and K 20:80:20 kg ha⁻¹ to soybean and 120:80:40 kg ha⁻¹ to wheat) with organic manure @ 15 t FYM ha⁻¹ resulted in 145 and 292 per cent increase in soybean and wheat yields, respectively over control.

Singh and Kumar (2012) conducted a field experiment on Tarai Mollisols to study the effect of FYM, vermicompost (VC), vermiwash (VW) and NPK nutrients on nodulation, growth, microbial biomass and yield of soybean (*Glycine max.*(L) Merrill) and observed that the treatments having FYM @ 5 t ha⁻¹, VC @ 2.5 t ha⁻¹, VW @ 10 % along with 50 % NPK recorded maximum number of nodules, highest nodule

dry weight and plant dry weights at 60 DAS ,soil microbial biomass carbon, grain yield and seed protein.

Waghmare *et al.* (2012) also emphasized on the use of integrated nutrient management and reported maximum seed yield, straw yield and biological yield with at 75% RDF applied with rhizobium, PSB and FYM at 5 t ha⁻¹. Thus, the combined use of manures and inorganic fertilizers along with biofertilizers played a significant role in increasing yield attributes, yield and quality of soybean.

Sonune *et al.* (2012) conducted the experiment in medium deep soil (Vertisols) with four types of moisture conservation practices and two cotton genotypes under rainfed condition of northern Maharashtra. Among the various moisture conservation practices, tied ridges and furrow produce significantly higher seed cotton yield, stalk yield and was found at par with ridges and furrow.

Shah and Verma (2012) conducted the field experiment to find out the suitable nutrient management strategies for hirsutum cotton variety JK-4 under rainfed conditions for three years during kharif 2005-2006, 2006-2007 and 2007-08 in sandy clay loam soil at All India Coordinated Cotton Improvement Project, Khandwa (M.P.), India. The treatments were absolute control, FYM @ 10 t ha⁻¹, Recommended dose (RD) of NPK, RD of N alone, RD of N and P, RD of NPK + 5 t ha⁻¹ FYM, 50 percent RD of NPK + 10 t ha⁻¹ FYM, 50 per cent Rd of NPK + 10 t ha⁻¹ FYM + 2% urea, RD of NPK + 10 t ha⁻¹ FYM and RD of NPK + sun hemp @ 15 kg ha⁻¹. Application of RD of NPK + 10 t ha⁻¹ FYM (T₉) recorded highest seed cotton yield during all the three years of experimentation (1924, 1723 and 2010) kg ha⁻¹, respectively. Lowest seed cotton yield was record with absolute control.

Devi *et al.* (2013) reported that grain yield was governed by different yield components such as number of pods plant⁻¹, number of seeds pod⁻¹, seed index and grain yield. Number of pods plant⁻¹ and seeds pod⁻¹ was significantly influenced by the integrated application of 75% RDF with vermicompost at the rate of 1 t ha⁻¹ and PSB than the rest of the other

treatments. The increase in the number of pods plant⁻¹ with the integrated application of 75% RDF with vermicompost at the rate of 1 t ha⁻¹ and PSB over control and 100% RDF were 172% and 43% respectively. The highest number of seeds per pod (2.96) was recorded at 75% RDF along with vermicompost at the rate of 1 t ha⁻¹ and PSB as compared to other treatments. This was perhaps due to a continuous supply of nitrogen, phosphorus, potassium to the crop at the early stages and through organic manure at later stages of crop growth, as slow release nutrients. Better growth and development of crop plants due to phosphorus supply and nitrogen uptake might have increased the supply of assimilates to seed, which ultimately gained more weight.

Mohammadi *et al.* (2013) conducted a research in Sanandaj (west of Iran) using a randomized complete block design in a split-plot arrangement. Three types of tillage including conventional tillage (moldboard plow to soil depth of 30 cm plus disk harrow twice), minimum tillage (chisel plow to soil depth of 15 cm plus disk harrow once) and tillage were assigned to the main plots. Results showed that, the highest rate of grain yield was obtained in the minimum tillage system. Minimum tillage improved soil physical properties and wheat growth compared with the other tillage systems.

Arbad *et al.* (2014) conducted the field experiment on Typic Haplustert to study the effect of inorganic fertilizers and farm yard manure (FYM) applied in combination or alone on productivity and nutrient availability in soil grown with soybean–safflower cropping system. Results indicated that significantly highest grain yield of soybean and safflower in the treatment receiving 150% NPK and it was at par with 100 % NPK+ FYM. There was overall increase in the soil bacteria, actinomycetes and fungal population.

Sharma and Subehia (2014) application of FYM and GM proved better than WS. Grain and straw yields of rice and wheat were recorded after 20th and 21st cropping cycles (2010-11 and 2011-12). Pooled data of two years revealed that continuous substitution of 50 % N through green manure in rice produced maximum rice grain (7.37 t ha⁻¹) and straw

(6.21 t ha⁻¹) yield which was 16.8 and 14.8 percent higher over 100 % NPK added through chemical fertilizers. However, 50 % N substitution through FYM in rice was not only statistically at par with 50 % N substitution through GM in respect of crop yields but also recorded the highest improvement in soil properties.

Choudhary (2014) conducted a field experiment to evaluate the performance of two types of tillage, conventional tillage (CT) and zero tillage (ZT) systems with four mulches, paddy straw mulch (PSM), maize stubble (MS), *Imperata cylindrica* (thatch grass, TG) and no mulch (NM) on yield. CT and PSM have registered 11.1% and 36.1% highest pod yield of pea. The findings clearly suggested that CT along with PSM registered improvement in pod yield of pea.

Parvin *et al.* (2014) conducted a long-term field experiment with the objective of assessing the effect of shallow tillage (ST) and mouldboard ploughing (MP) on important soil physical properties and crop performance. Results revealed that, the number of seedlings and yield was better in shallow tillage (ST) than in mouldboard ploughing (MP) in this investigation. Therefore, it is concluded that, the changes of subsoil physical properties under the shallow tillage (ST) treatment are better for crop performance.

Choulwar *et al.* (2015) conducted a Field experiments with cotton+soybean (1:1) in 2005, 2007, 2009 rotated with soybean+pigeonpea (4:2) in 2006 and 2008 to identify an efficient tillage practice in a semi-arid vertisol at Parbhani. The cotton equivalent yield (CEY) ranged from 994 to 1419 kg ha⁻¹ with mean of 1193 kg ha⁻¹ and variation of 9.8 %; while relative water use efficiency (RWUE) of ranged from 1.21 to 1.69 kg ha⁻¹ mm with mean of 1.43 kg ha⁻¹ mm and variation 2 per cent over years. Conventional tillage (CT) and reduced tillage (RT) gave significantly highest CEY and RWUE compared to other treatments.

Khan *et al.* (2015) conducted field experiments to evaluate cotton response to tillage (ZT, RT, and CT) and intra-row spacing (15.0, 22.5, 30.0, 37.5 cm). Results revealed that, reduced tillage (RT) produced

higher bolls plant⁻¹, boll weight, seed cotton yield, ginning out turn, fiber length and strength than zero tillage (ZT) and conventional tillage (CT).

Ozpinar and Ozpinar (2015) conducted a study in western Turkey for 5 years with three types of tillage including conventional (mouldboard plough) and conservation (rototiller and chisel). Results revealed that, rototiller caused significantly higher root, leaf and stems biomass and plant height than the other systems. Rototiller improved soil properties and maize growth compared to other systems in 2 of 5 years. Rototiller provided higher grain yield than plough and chisel over the 5-year average.

Mehdi et al. (2016) conducted a field experiment to assess the effect of different tillage methods on growth period of two safflower cultivars at research field of Isfahan Branch, Islamic Azad University Isfahan, Iran. The horizontal factors were three tillage methods comprising conventional, low tillage and no tillage. The results showed significant effect of tillage methods on days to greening, days to stem elongation, days to maturity and capitulum development. So no tillage and conventional had the lowest and the highest amount of these traits.

Shekhawat *et al.*, (2016) reported after four year of the experimentation that the highest mustard seed yield was obtained under FIRB (2765 kg ha⁻¹) which was 23.6 % higher over CT. The seed yield obtained under zero tillage (2533 kg ha⁻¹) was 17.5 % higher over CT. The seed yield recorded under RT was found similar with ZT, but significant higher over CT due to higher dry matter accumulation, higher translocation efficiency and greater sink-source potential at the seed filling stage.

Naveen kumar and Babalad (2017) conducted a Field experiments on a fixed site of Conservation Agriculture Project at main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during 2014-15 and 2015-16 to study the effect of conservation tillage and land configuration on growth and yield of cotton under rainfed situations. The experimental findings showed that, all the conservation tillage systems viz, No tillage with broad bed and furrow (BBF) and crop

residues retained on the surface, reduced tillage with BBF and incorporation of crop residues, no tillage with crop residues retained on the surface and reduced tillage with flat bed with incorporation of crop residues recorded significantly higher growth and yield parameters as compared to conventional tillage systems. No tillage with broad bed and furrow (BBF) and crop residues retained on the surface and reduced tillage with BBF and incorporation of crop residues produced significantly higher kapas weight (150.78 and 150.72 g plant⁻¹, respectively) and seed cotton yield (1,756 and 1,743 kg ha⁻¹, respectively) over conventional tillage with incorporation of crop residues (145.42 g plant⁻¹ and 1,572 kg ha⁻¹, respectively) and conventional tillage without crop residues (139.26 g plant⁻¹ and 1,324 kg ha⁻¹, respectively).

Khambalkar *et al.* (2017) studied effect of INM on yield of cotton recorded the significantly higher cotton stalk yield (1198.13 kg ha⁻¹) was observed with the application of 50 % N through gliricidia + 50 % N through inorganics + biofertilizers + 100 % P + 25 kg K ha⁻¹ (T10) and it was found to be on par with application of 100 % NP + biofertilizers + 25 kg K ha⁻¹ of 2200 kg ha⁻¹ in control

Bagal *et al.* (2018) studied effect of tillage depth and irrigation scheduling on yield attributes and yield. And found that number of bolls per plant was significant and maximum value was noted under tillage depth upto 22.5 cm This might be due to profused vegetative growth ultimately more sympodial branches per plant provided better room for number of bolls.

2.3 Effect of tillage and IPNS on nutrient content and uptake by soybean and cotton

Khare *et al.* (1970) studied the distribution of nitrogen content and its uptake in leaves, stem, roots and fruiting parts of cotton plants. They reported that more than 90 percent of the nitrogen was taken up by the plant till the flower initiation stage and its content was much higher in leaves up this stage and decreased considerably with age, being translocated to the fruiting parts. The content of N was reported to be 2.64, 2.25 and 2.28 per cent; 1.24, 1.05, and 1.11 per cent; 0.70, 0.87 and

0.69 per cent and 2.81, 2.37 and 2.20 per cent during flower initiation, fruiting and picking stage, when N was applied @ 60 kg per hectare. The translocation was less from the leaves containing lower N content, while in leaves higher concentration of N caused more depletion of N occurred resulting in an increase in the fruiting parts. The uptake of N by leaves was higher at all the stages than in stem and roots, the former containing higher quantity. The fruiting parts being few at square initiation stages, showed low N uptake, but it increased considerably at the flowering and picking stages, due to large number of them have been formed.

Bairathi *et al.* (1974) conducted an experiment to study the effect of different legume crop residues on yield and nutrient uptake by succeeding crop and observed that fertilizers applied alone and after burial of legume residues increased significantly the grain yield as well as nutrient uptake over control and legume residues only.

Tailakov and Meredov (1984) observed that the application of NPK alone and especially with FYM and compost increased the soil nutrient contents. The nitrate N and P contents increased up to the middle of the vegetative growth period and decreased thereafter. The available K content in soil was highest at the beginning, and lowest at the end, of the vegetative growth period.

Narkhede and Ghugare (1987) reported that the application of green lopping of subabul increased the N and P content of sorghum by 69.3 and 22.7 per cent respectively, over the control at 30 days age of the crop.

In maize crop Bhandari *et al.* (1989) reported that the uptake of N, P and K increased significantly with increasing levels of fertilizer nitrogen upto 90 kg N ha⁻¹ and the effect of still higher dose was not significant. Both the green manure sources (cow pea and sesbania) alone or in combination with 60 kg N ha⁻¹ were statistically at par with each other in raising nutrient uptake and significantly superior to control. The increase in nutrient uptake with fertilizer addition is obvious. Green manuring of cowpea and *sesbania sp.* in the treatment plots added sufficient quantity of

total nutrients to the soil, which become available to succeeding maize during their decomposition thereby resulting in increased uptake under these treatments.

Singh *et al.* (1991) observed that the uptake nitrogen by lentil grain was more due to one ploughing (36.3 kg ha^{-1}) than zero-tillage (36.3 kg ha^{-1}) In straw the uptake of nitrogen was higher due to one ploughing (11.2 kg ha^{-1}) than zero tillage (11.0 kg ha^{-1}).

Hirekurubar *et al.* (1991) observed increase in bulk density decreased nitrogen uptake due to low aeration, high mechanical impendence and low water retention. He also reported that phosphorus uptake was $15.9 \text{ mg plot}^{-1}$, $19.9 \text{ mg plot}^{-1}$ and due to no compaction with bulk density 1.25 mg m^{-3} and 1.35 mg m^{-3} bulk density respectively and further observed that increase in bulk density with decreased in phosphorus uptake.

Dick *et al.* (1992) reported that the application of N @ 56 kg ha^{-1} increased N uptake into the grain plus residue under conventional tillage by 45 kg ha^{-1} while a similar comparison under no-tillage showed only a 29 kg ha^{-1} increase in N uptake.

A field study on black clay soil for seven consecutive years under soybean-safflower sequence indicated that, the nutrient status of available N, P, K and S was improved significantly by the use of 6 t ha^{-1} FYM along with half recommended dose of N against control as well as $25 \text{ kg ZnSO}_4 \text{ ha}^{-1} + 100\% \text{ N}$ reported by Sharma *et al.* (1992).

Sharma *et al.* (1993) found that nitrogen content of leaves, stem and fruiting parts of healthy plants of four different locations varied from 1.54 to 2.10, 0.80 to 1.26, and 1.28 to 1.96 per cent respectively. While content of phosphorus and potassium were not much varied which ranged from 0.55 to 0.97, 0.42 to 0.50 and 0.80 to 0.85 per cent and 1.24 to 1.41, 0.92 to 1.24 and 2.68 to 3.36 per cent in leaves, stem and fruiting parts respectively. He also reported that zinc content of leaves, stem and fruiting partsof healthy plants of four different locations varied from 63 to 88, 53 to 63, and 54 to 72 ppm respectively. Whereas content of copper

and manganese were ranged from 14 to 15, 14 to 16 and 14 to 16 ppm and 82 to 158, 52 to 60 and 67 to 72 ppm in leaves, stem and fruiting parts respectively. They also reported that the concentration of micronutrients was above

Kubde and Lakhdive (1993) noted that, uptake of nitrogen by cotton crop increased significantly with each successive increase in nitrogen level. The highest uptake (51.2 kg ha^{-1}) was observed with the application of 75 kg ha^{-1} and superior over 50 and 25 kg N ha^{-1} . He further reported that the nitrogen uptake was increased with higher rate of nitrogen and phosphorus in cotton crop.

Tiwari *et al.* (1994) reported that the P and K contents in all the varieties increased upto flowering stage and thereafter decreased. This might be due to uptake of these two elements in larger quantity upto flowering stage. Thereafter, their concentration decreased in leaves which might be due to their transfer to bolls and seed cotton.

Acharya and Sharma (1994) reported that N uptake by maize grain under no-tillage was significantly less than conventional tillage. N uptake by grain generally increased significantly in conventional tillage + mulch compared with conventional tillage. He also observed that no-tillage + mulch treatment resulted in higher P uptake of maize and wheat compared with no-tillage. The uptake of K by grain under no-tillage + mulch significantly increased than conventional tillage.

Patil *et al.* (1994) studied that the nitrogen uptake was observed in stem, petiole and leaf were found significantly higher when cotton was grown with 160 kg N ha^{-1} tended to increase relatively the nitrogen uptake by all parts.

Ravankar and Deshmukh (1994) reported varying levels of nitrogen i.e., 0, 30, 60 and 90 kg N ha^{-1} to cotton and observed that the increase in levels of N increased the dry matter production at all the growth stages, consequently N, P and K uptake was also increased. They also reported that there was a linear uptake of N, P and K at every growth stage. The nutrient uptake pattern of cotton at square formation, flowering

and picking stages and found that highest dry matter production and N, P and K uptake at square formation stage and increased linearly towards the flowering and picking stages during both years of experimentation.

Pagaria *et al.* (1995) noticed higher dry matter production and seed cotton yield (25.34 ha^{-1}) with 20 cart load ha^{-1} FYM application. Also indicated that the application of nitrogen significantly increased the uptake of nutrients at both the growth stages (square formation and flowering stage) of cotton and maximum uptake of all nutrients was observed with the application of 50 kg N ha^{-1} ; while uptake of these nutrients was increased with application of $25 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ at both the stages.

Mathan *et al.* (1996) conducted field experiment and observed that application of 25 kg N ha^{-1} (as urea) + $50 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (as Single super phosphate) and 750 kg ha^{-1} enriched FYM significantly increased 75.0 and 54.5 per cent more seed yield in first and second crop respectively over control in blackgram.

Sharma (1997) The studies conducted by on effect of different levels of N, P, FYM, crop residues and conjunctive application of organics and fertilizer sources of nutrients on productivity of soybean-safflower cropping sequence, revealed that highest productivity of both the crops was obtained conjunctive use of 6 t ha^{-1} FYM and fertilizer N and P @ 20 and 13 kg ha^{-1} .

Salinas-Garcia *et al.* (1997) reported that N uptake increased from planting to flowering for no-tillage, conventional tillage and mouldboard treatment but decreased with minimum tillage and chisel plough.

Taneja *et al.* (1997) observed that N, P, and K content of *hirsutum* genotypes varied in the leaves from 1.03 to 2.24, 0.290 to 0.352 and 1.98 to 2.31 per cent, in stem 1.21 to 1.43, 0.193 to 0.270 and 1.63 to 1.88 per cent and in fruiting parts 1.17 to 1.41, 0.293 to 0.386 and 2.50 to 3.04 per cent respectively.

Wankhade *et al.* (1997) studied the content and uptake of micronutrients in cotton at fifteen days interval. They found that the

concentration was highest during square formation stage and decreased as the crop growth advances towards maturity. The concentration of Zn, Fe, Mn, Cu and B during square formation stage were 66.7, 334.5, 66.2, 24.7 and 42.1 ppm, during flowering stage 61.2, 249.0, 45.3, 26.7 and 30.4 ppm and during boll development stage 39.3, 212.8, 34.2, 23.3 and 19.4 ppm, respectively. They also reported that the uptake was increased as the crop growth advances towards maturity. The uptake of Zn, Fe, Mn, Cu and B per plant during square stage were 1.90, 9.53, 1.88, 0.70 and 1.20 mg per plant, during flowering stage 4.59, 18.67, 3.39, 1.99 and 2.28 mg per plant, during boll development stage 4.92, 26.60, 4.28, 2.91 and 2.34 mg per plant, respectively.

Santhy *et al.* (1998) concluded that total uptake of N, P and K increased with progressive increase in supply of NPK due to higher availability of these nutrients to crops. Application of NPK at 100% of optimum level along with FYM 10 t ha⁻¹ increased the uptake greatly as compared to the application of 100% NPK alone. In the absence of P application (N alone and control) considerable reduction in P uptake was noticed due to the P becoming limiting nutrient and consequently lower biomass production.

Puri and Jaipurkar (2000) reported that the relative proportion of K content in seed cotton was approximately one and half times more than that in stalk.

Prasad and Sinha, (2000) further, the economic analysis indicated that recycling of crop residues is economical, profitable and healthy for sustainable rice and wheat production. Available N, P, K and S increased in soil when different levels of fertilizers were applied along with crop residues and organic manure and Zn, Cu, Fe, and Mn requirement of rice and wheat could be met by the incorporation of crop residues. Available Zn, Fe, Cu and Mn increased in soil when different levels of fertilizers were applied along with crop residues and organic manure. The highest soil aggregation was recorded under balanced use of fertilizer with organic manure and crop residues. Improvement in soil aggregation with

the application of crop residues and organic manure resulted in increase in hydraulic

Dangarwala (2001) stated that supplementing the NPK fertilizers with organics helped in maintaining micronutrient concentrations adequately in soil and there is continuous uptake of micronutrients, the amount was increasing with increase in soil fertility.

Mishra *et al.* (2001) studied the nutrient status of phosphocompost and its effect on maize-wheat cropping sequence and reported that grain and straw yields of both maize and wheat were significantly superior in all the treatments containing P as phosphocompost and single superphosphate. The highest yield (3404 kg ha⁻¹ maize grain and 2481 kg ha⁻¹ wheat grain) over control were recorded under N100 P60 as single superphosphate which was at par with N100 P60 as phosphocompost. It increases the yield of maize and wheat 54.5 per cent and 90.8 per cent, respectively over control.

Rao and Tak (2001) found that there was a significant improvement in the uptake of N, P, K and Mg in all the plant species upon incorporation of various organic amendments. Maximum enhancement was observed with sewage sludge. Uptake of N, P, Na and Ca by different plant species was significantly improved with organic amendments could not significantly influence the K and Mg uptake.

Pattanayak *et al.* (2001) found that in rice the N uptake ranged from 42.4 to 67.7 kg ha⁻¹, highest being in the treatment receiving green manuring of dhaincha with SSP + Udaipur rock phosphate source of P and the lowest in no green manuring treatment with Udaipur rock phosphate source. The per cent increase in N uptake due to dhaincha, Azolla and sunhemp was to the tune of 28.3, 23.5 and 4.4 respectively over no green manuring. Uptake of P by rice crop ranged from 10.2 to 14.9 kg ha⁻¹. Green manuring with sunhemp did not influence P uptake much (4.4 per cent) but dhaincha and Azola influenced it significantly by 26.5 and 21.2 per cent, respectively over no green manuring. Rice crop grown with green manure treatment showed significantly higher uptake of K over no

green manure treatment. Daincha, Azolla and sunhemp as green manure crops influence K uptake by 4.5, 2.1 and 7.1 per cent respectively over no green manuring.

Guled *et al.* (2002) indicated that *in situ* incorporation of green gram residue and sunhemp green manure integrated with chemical fertilizer application increased micronutrient content.

Mundra *et al.* (2002) observed that under INM in pearl millet wheat sequence the treatment 125 per cent RDF to kharif and rabi crop alongwith green manuring in kharif and 10 t FYM ha⁻¹ in rabi recorded maximum nutrient uptake (643.3 kg ha⁻¹).

Chandramohan (2002) observed that application of 50 per cent N through sunhemp + 50 per cent N through vermicompost to cotton had comparable uptake of nitrogen, phosphorus and potassium with recommended NPK through inorganic sources. He also found that the uptake of N, P and K per hectare was increased from vegetative growth stage to flowering and boll development stage.

Ravankar *et al.* (2003) observed that NO₃-N content in cotton leaf petiole ranged within the optimum level (12000-18000, 3000-7000 and 1500-3000 ppm, at square initiation, 50 % flowering and first boll opening stage, respectively) at all critical stages of crop growth during both the years of experimentation. The highest NO₃-N content at all stages were under 100 per cent RDF (crobar) followed by 100 per cent RDF (Conventional). The content of phosphorus in the petiole was also within the optimum level (1500-2000, 1200-1500 and 1000-1200 ppm, respectively) at the three growth stages during both the years. The phosphorus contents at square initiation and 50 % flowering were slightly higher with three splits than with five splits. The potassium concentration in leaf petiole was within the optimum level (4.0 - 4.55, 3-4 and 2-3 %, respectively) at three growth stages during both the years. The results as regards the three or five splits were similar to that observed in NO₃-N and phosphorus content in petiole. Further, they found that N, P and K

concentration in cotton leaf petiole decreased from square initiation to first boll opening stage as the crop age advances towards maturity.

Sarode *et al.* (2003) concluded an experiment comprised two planting patterns (single and paired), two intra-row distances (60 and 90 cm) and three moisture regimes (irrigations at 0.4, 0.6 and 0.8 ET_c) and found that intra-row distance of 60 cm enhanced the growth and yield attributes and seed cotton yield compared with 90 cm. They further noted that the irrigation scheduling at 0.6 ET_c was more effective than 0.4 and 0.8 ET_c.

Sonune *et al.* (2003) studied the long-term effect of manures and fertilizers on fertility and crop productivity of Vertisols under sorghum-wheat sequence in semi-arid climatic conditions of Vidarbha region of Maharashtra. The application of recommended dose of NPK (100:50:40 for sorghum and 120:60:60 to wheat) and 10 t FYM ha⁻¹ improved the available NPK and organic carbon content of soil. The available NPK showed positive correlation with crop yield and there was positive balance of N and P but K showed negative balance. Thus, the balanced use of NPK fertilizers along with FYM is essential for augmenting the fertility of Vertisol in cereal-cereal cropping sequence

Namdeo *et al.* (2003) studied the effect of phosphorus enriched compost on the uptake of P by soybean at Indore (MP) on Vertisols and noted maximum uptake of P (10.90 kg ha⁻¹) with the application of phosphocompost @ 2.5 tonnes ha⁻¹ and which was at par with 60 kg P₂O₅ ha⁻¹ through SSP + 5 tonnes FYM.

Suresh and Chellamuthu (2004) reported increasing uptake of N, P and K with the advancement of age of the crop due to increase in biomass accumulation. The uptake of N by cotton genotypes ranged from 7.25 to 8.72, 22.98 to 24.92 and 36.06 to 39.92 kg ha⁻¹ at 60, 90 and 120 days after sowing respectively. The P uptake varied from 2.08 to 3.24, 4.94 to 6.72 and 6.83 to 8.68 kg ha⁻¹ at 60, 90 and 120 days after sowing respectively. The K uptake varied from 8.15 to 9.59, 24.89 to 26.83 and

38.02 to 43.87 kg ha⁻¹ at 60, 90 and 120 days after sowing respectively. The uptake of K in general was higher than P and N.

Talati *et al.* (2004) reported that the application of N ha⁻¹ + 5 t FYM ha⁻¹ recorded significantly higher nitrogen and phosphorous uptake by seed and stover of soybean.

Adarsha *et al.* (2004) reported significantly higher uptake of nitrogen, phosphorus and potassium in irrigated crop with three irrigations at critical growth stages as compared to rainfed cotton crop.

Raskar (2004) conducted an experiment during summer seasons 2000-2002 at Rahuri to study the irrigation methods, fertilizer levels and green manuring on yield and nutrient balance in summer cotton and indicated that combined use of irrigation method, fertilizer levels and green manuring under cotton crop increased nutrient uptake might be due to adequate and sustained availability of nutrient throughout the growth stages of crop and mineralization of N and slow release of fixed P and K to cotton crop which favoured highest soil nutrient uptake.

Chaturvedi and Chandel (2005) field experiment was conducted at Pantnagar, during the rainy season (kharif) of 2002 and 2003, to assess the effect of various fertilizer and manurial treatments on soybean [*Glycine max* (L.) Merr]. Integrated use of recommended fertilizers with supplementary nutrients increased the yield attributes and yield. Increase in yield varied from 58.7 to 124.4% and 61.9 to 136.9% during 2002 and 2003, respectively, over the control. NPK uptake was recorded with the application of 100% recommended dose of NPK + FYM @ 10 tonnes/ha. Use of organic sources helped in maintaining soil fertility in terms of available nutrients.

Rajarajan *et al.* (2005) conducted a field experiment. They concluded that the uptake of N, P and K at flowering stage ranged from 62.5 to 99.06, 2.86 to 8.12 and 46.16 to 65.61 kg ha⁻¹, respectively and the cotton crop taken up the N, P and K in the ratio 16:1:11, respectively. The uptake of N, P and K showed that lowest uptake and the highest uptake in the recommended level.

Katkar *et al.* (2005) reported that NPK uptake was higher with higher level of NPK application to soil than lower level. Higher NPK uptake was found with fertilizer dose of 75 : 37.5 : 0 kg NPK ha⁻¹ followed by 50 : 25 : 0 kg NPK ha⁻¹ and 25 : 12.5 : 0 kg NPK ha⁻¹.

Kote *et al.* (2005) observed that the nitrogen concentration and uptake by cotton plants at harvest increased significantly by recommended fertilizer dose and 75 per cent RDF than 50 per cent RDF. Every higher level of fertilizer application noted significant increase in P and K concentration and uptake over its lower levels. Balanced and optimum application of NPK fertilizer increased the concentration and uptake of NPK by cotton plants.

Shete *et al.* (2005) concluded that highest nitrogen content in seed (6.29 %) and dry matter (1.13 %) of soybean was recorded with the application of RDF followed by 75 % RD of N + 25 % N through vermicompost + biofertilizer. The highest phosphorus content in seed (0.547 %) and dry matter (0.248 %) was observed with the application of 75 % RD of N + 25 % N through vermicompost + biofertilizer followed 50 % RD of N + 50 % N through vermicompost + biofertilizer whereas, the highest potassium content in seed (0.55 %) and dry matter (0.863 %) was recorded with the application of 75 % RD of N + biofertilizer.

Charjan and Gaikwad (2005) reported that the application of 100 per cent RDF (100: 50: 50 kg NPK ha⁻¹) recorded significantly higher nutrient uptake and soil available NPK in cotton over 75 per cent RDF.

Katkar *et al.* (2006) observed statistically similar NPK uptake in the treatment 100 per cent RDF, FYM 5 t ha⁻¹ + 50 per cent RDF and glyricidia + green foliage lopping @ 5 t ha⁻¹ + 50 per cent RDF.

Dhillon *et al.* (2006) reported that N, P and K uptake per unit area was inversely related to plant spacing. N and P uptake in plant and seed increased with increasing level of fertilizer. Maximum N and P uptake was recorded under the treatment (120 kg N : 80 kg P₂O₅) which was at par with recommended fertilizer dose (30 kg N : 30 kg P₂O₅).

Giri *et al.* (2006) observed that, N, P and K uptake by cotton was significantly higher in sole cotton and black gram intercrop than cotton intercropped with soybean. Further an application of 100 per cent RDF increased the N, P and K uptake in cotton significantly than 75 per cent and 50 per cent RDF which were found at par with each other for N and K uptake where as P uptake was significantly more in 75 per cent RDF than 50 per cent RDF.

Hulihalli and Patil (2006) studied the effect of various organic manures alone and in combination and with inorganic fertilizers. They reported higher uptake of N, P and K with combined application of FYM @ 2.5 t + cotton stalk @ 2.5 t ha⁻¹ + recommended dose of fertilizers and press mud @ 2.5 t + cotton stalk @ 2.5 t ha⁻¹ + recommended dose of fertilizers at all growth stages than their individual incorporation. The uptake of N, P and K at 60, 120 and 180 DAS was found increasing as the growth of the crop advances towards maturity.

Katkar *et al.* (2006) reported that the highest uptake of nitrogen phosphorous and potassium with application of FYM @ 10 t ha⁻¹ + 100% RDF and which was at par with FYM @ 10t ha⁻¹ + 50% RDF + Spraying of 2% urea and DAP and FYM @ 5 t ha⁻¹ + 100% RDF.

Kumar *et al.* (2006) conducted field experiment at Bangalore to study the effect of INM on nutrient uptake of soybean and observed that application of 50 % N through fertilizer + 10 t FYM ha⁻¹ recorded higher nutrient uptake by seed and haulm (122, 37 and 110 Kg N, P and K ha⁻¹, respectively).

Raskar (2006) reported that the uptake of N, P and K by cotton was higher due to application of 100 per cent recommended dose of fertilizer. However, the application of either 50 or 75 per cent recommended dose of fertilizer registered lower nutrient uptake by crop.

Bhalerao *et al.* (2007) obtained highest seed cotton and yield contributing parameters with the application of FYM @ 10 t ha⁻¹ + 100 per cent RDF (50+25+25 N, P and K kg ha⁻¹) as compared to FYM @ 5 t ha⁻¹ + 100 per cent RDF and FYM @ 10 t ha⁻¹ + 50 per cent RDF + foliar spaying

of 2 per cent urea at flowering and 2 per cent DAP at boll development stage.

Khader and Prakash (2007) observed that reddening is generally observed 90 days after sowing particularly where cotton is grown in red or laterite soils. The leaf initially starts yellowing and finally the entire leaf turns red leaving the midrib and other vascular regions green. Deficiency of nutrient, high temperature during the day coupled with low temperature at night, water stress or water logging are some of the important factors attributed to leaf reddening.

Behera et al. (2007) studied long term experiment of integrated nutrient management on Vertisols and reported that uptake of P and K was more by wheat than soybean. However, the reverse was true for N uptake. The total nutrient removal by the soybean-wheat system was highest for N followed by K and P. Evidently, the highest nutrient uptake by wheat or soybean was under 1.0 NPK + poultry manure or FYM which was significantly higher than all other treatments. The increases in nutrient uptake of wheat were marked under different nutrient management treatments over control.

Chaudhary et al. (2008) reported that total uptake of N, P and K in gram significantly influenced due to various treatments. FYM 5 t ha⁻¹ + Rhizobium + PSB as soil application recorded highest total nitrogen uptake (104.48 kg ha⁻¹) which was at par with RDF (104.57 kg ha⁻¹). FYM 5 t ha⁻¹ + rhizobium + PSB as soil application recorded highest total phosphorus uptake (19.10 kg ha⁻¹) and it was at par with RDF (18.21 kg ha⁻¹) and FYM @ 5 t ha⁻¹ + rhizobium + PSB as seed treatment (18.53 kg ha⁻¹). The highest total potassium uptake was recorded with vermicompost @ 3 t ha⁻¹ + Rhizobium + PSB as soil application (40.56 kg ha⁻¹) and it was at par with RDF (40.36 kg ha⁻¹) and FYM @ 5 t ha⁻¹ + Rhizobium and PSB as seed treatment (40.04 kg ha⁻¹). Application of organic manures and biofertilizers might have enhanced the availability of nutrients to the crop leading to their increased content in grain and straw.

Kundu *et al.* (2008) estimated the annual average harvestable above ground biomass of soybean and wheat crop to study the carbon sequestration potential of inceptisols under long term soybean - wheat rotation in sub-temperate rainfed agro-ecosystem of North-West Himalayas. They found that because of the yield response to the applied fertilizers N, P, K, and FYM, the mean harvestable above ground biomass ranged from 1520 kg ha⁻¹ (control) to 6918 kg ha⁻¹ (NPK+ FYM) for soybean and 2106 kg ha⁻¹ (control) to 5367 kg ha⁻¹ (NPK+ FYM) for wheat.

Dhage and Kachhave (2008) conducted a field experiment on clay and slightly alkaline soil to show the effect of dual inoculation of rhizobium and PSB and observed that the highest grain yield of 15.46 q ha⁻¹ recorded in 100 % RDF + Rhizobium + PSB. The residual fertility in soil was also more due to 100 % RDF + Rhizobium + PSB treatment.

Mishra *et al.* (2008) studied the changes in chemical, microbial and enzymatic activities of on acid soil in a long term fertilizer experiment continued since 1956, in an Alfisol at Ranchi continuous organic manure application or in combination with inorganic fertilizer significantly influenced the grain yield, uptake of nutrients, organic carbon, available N,P K and soil, CO₂ evolution, Urease and phosphates over 100% NPK. Grain yield, uptake of nutrients, CO₂ evolution and urease were significantly higher than 100 % NPK. The CO₂ evolution, MBC, urease and phosphates were significantly higher in treatment receiving 100 % NP over treatment receiving only 100% N or control. The 100 % NPK treatment did not show significant changes in microbial and enzyme activity over 100% NP treatment. The PH, organic carbon, CO₂ evolution, MBC, urease and phosphates enzyme were found highly significantly correlated with grain yield and nutrient uptake.

Shirale and Khating (2009) conducted a field experiment on clay soil (Typic Haplusterts) at MAU, parbhani to study the effect of application of organic, inorganic and organic combined with inorganic nutrient sources on yield of various cropping system, NPK uptake and balance in soil. Recommended dose of fertilizer and combine application of glyricidia @ 1.5 t ha⁻¹ + 25 % RDF increase grain yield and NPK uptake.

The highest total grain yield (2335 kg ha^{-1}) was recorded by RDF followed by glyricidia @ 1.5 t ha^{-1} + 25 % RDF (2213 kg ha^{-1}) and it was atpar with each other. The cropping system sorghum+pigeon pea recorded highest yield (2438 kg ha^{-1}) the maximum N, P, and K uptake (142.16 , 23.92 and 63.71 kg ha^{-1} respectively) was recorded with the soybean + pigeon pea cropping system. There, was more buildup of available N, P and K in soil with soybean + pigeonpea cropping system with FYM followed by glyricidia.

Mehta and Saharan (2009) reported that the seed cotton yield per plant and Bolls plant⁻¹ (26.2), Boll weight (2.28 gm), seed cotton yield plant⁻¹ (63.8 gm), seed cotton yield (17.7 g ha^{-1}) was maximum under 100 % recommended dose of N but remain at par with 75 % N through chemical fertilizer + 25 % through vermicomposting and 75 % N through chemical fertilizer + 25 % through FYM.

Mehta *et al.* (2009) reported maximum nitrogen content (4.06 per cent) and phosphorus content (0.96 per cent) in cotton seed, where 100 per cent recommended dose of fertilizer through chemical fertilizer recorded higher nitrogen uptake (84.66 kg ha^{-1}) and phosphorus uptake (19.58 kg ha^{-1}) over control and rest of organic and inorganic combination treatment.

Rao and Janawade (2009) reported that uptake of nitrogen, phosphorus and potassium by cotton at harvest was significantly higher with 100 per cent recommended dose of fertilizer as compared to 50 and 75 per cent. The uptake of major nutrients was attributed to higher dry matter production.

Singh *et al.* (2009) A field experiment was carried out by during kharif season of 2004 and 2005 and reported that the application of RDF, Rhizobium + Azatobacter + PSB + FYM @ 5 t ha^{-1} and Rhizobium + PSB + FYM @ 5 t ha^{-1} was equally effective and registered markedly higher value 4.05 , 1.61 and 3.98 t ha^{-1} respectively, over rest of the treatments.

Gaur and singh (2010) reported that with increasing level of P upto 90 kg P_2O_5 ha⁻¹ and B upto 20 kg borax ha⁻¹ to wheat crop increased the P uptake.

Bhalerao and Gaikwad (2010) reported that application of 125 per cent RDF showed maximum uptake of N being at par with RDF but significantly superior over 75 per cent RDF. In respect of P uptake 125 and 100 per cent RDF were statistically equal but both the levels were significantly superior over 75 per cent RDF. Similar trend was observed in K uptake.

Singh *et al.* (2011) recorded significant increase in uptake of iron, zinc and manganese by the grains of rice, wheat and green gram when two or more organic sources (Azolla, FYM, Vermicompost, Azotobacter and BGA) of nutrient were applied together compared to control. Total uptake of Fe, Zn, Mn and Cu in rice-wheat-green gram cropping system ranged between 177.01 to 414.7, 175.0 to 381.0, 177.3 to 420.2 and 71.2 to 181.0 g ha⁻¹, respectively.

Naidu and Mahalakshmi (2011) reported that there was a reduction in nitrogen, phosphorus, potassium, calcium and magnesium in reddened leaves, whereas the content of sodium, iron and copper is decreased compared to normal leaf. Maximum reduction was observed with magnesium. Reduction in nitrogen, phosphorus and potassium content of leaves turned red.

Vidyavathi *et al.* (2011) worked on influence of nutrient management practices on crop response and economics in different cropping systems in a Vertisols at Dharwad and reported that integrated application of manure and fertilizers resulted in Significantly higher uptake of N, P and K by *Kharif* and *rabi* crops was recorded in integrated practice compared to inorganic nutrient management practice.

Sikka *et al.* (2012) conducted the field experiment (2005-07) under irrigated condition to study the influence of nutrient management on growth, yield and nutrient uptake by soybean and soil health. The results revealed that application NPK improved the yield of over NP alone

treatment. The application of N, P, and K in different treatments, significantly improved the N, P, and K, uptake by soybean. The available N and P of the soil also increased but the changes in available K remained inconsistent with different growth factor. Application of NPK increased the organic carbon content of the soil in different treatments.

Rathod *et al.* (2012) studied the effect of N management on soil fertility and nutrient uptake by soybean and reported that both seed and straw yield were significantly increased with increasing level of nitrogen. Integration of chemical fertilizer with rhizobium increase seed yield and NPK uptake.

Modhvadia *et al.* (2012) revealed that 240 kg N ha⁻¹ registered significantly higher value of N, P and K total uptake by cotton. Application of phosphorus significantly affected the total uptake of N, P and K by cotton. The uptake of N, P and K by cotton was increased significantly with the increase of K levels. Highest N, P and K uptake by cotton were noticed with the application of 120 kg K₂O ha⁻¹.

Marimuthu *et al.* (2014) studied different cotton-based intercropping system along with balanced nutrient management practices and observed that cotton intercropped with dhaincha recorded highest uptake of N, P, and K and among the nutrient management practices, application of 100 % recommended NPK with bioinoculants showed highest uptake of N, P and K.

Sanjay Kumar *et al.* (2015) conducted experiment to assess the response of different summer green manuring on nutrient uptake under rice-wheat cropping system and observed that the nutrient balance sheet of soil after harvest of rice crop in green manuring plot showed positive balance of nutrients whereas in wheat crop almost all nutrients had negative balance in soil.

Kuotsu and Singh (2016) studied on integrated nutrient management on uptake of soybean and concluded that nutrient uptake was observed maximum in the case of NPK 75 % + NPK @ 5t ha⁻¹ this can be attributed to the more biomass production in the case NPK 75 % + FYM @

5 t ha⁻¹. The better growth of the plants due to the better soil conditions and combined effect of organic manure and concentrated inorganic fertilizers could be the reason behind the higher biomass production thus leading to higher nutrient uptake. Nutrient uptake increased in direct proportion to biomass production.

2.4 Nutrient balance

In different cropping sequences available N was found highest under cowpea (166 kg ha⁻¹) by Bangar *et al.* (2003) the depletion in soil available N after harvest of *rabi* sorghum was more in fallow (118 kg N ha⁻¹) than the rest of the treatments. The soil available N content was increased with an increase in N levels from 0 to 50 kg ha⁻¹ irrespective of *kharif* treatments. The N balance was higher due to application of 50 kg N ha⁻¹ to *rabi* sorghum irrespective of *kharif* treatments, the highest being under soybean - sorghum sequence (+ 33.12 kg ha⁻¹).

Sonune *et al.* (2003) studied the long-term effect of manures and fertilizers on fertility and crop productivity of Vertisols under sorghum-wheat sequence in semi-arid climatic conditions of Vidarbha region of Maharashtra. The application of recommended dose of NPK (100:50:40 for sorghum and 120:60:60 to wheat) and 10 t FYM ha⁻¹ improved the available NPK and organic carbon content of soil. The available NPK showed positive correlation with crop yield and there was positive balance of N and P but K showed negative balance. Thus, the balanced use of NPK fertilizers along with FYM is essential for augmenting the fertility of Vertisol in cereal-cereal cropping sequence.

Abraham and Lal (2004) conducted a field experiment during 1998-99 to study performance of blackgram under integrated nutrient management in a legume based cropping system on Inceptisols of NEPZ and observed that the application of farm compost @ 5 tonne per hectare + poultry manure @ 5 t per ha⁻¹, improved the organic carbon, available phosphorous and potassium during both the years.

The data on balance sheet revealed that in general, there is net gain in case of nitrogen and potash while loss in case of available

phosphorous at the end of three year of cropping. Among the treatments of crop sequence, the data further revealed that the highest net gain in available nitrogen and potash was recorded in sorghum chickpea groundnut wherein two legumes were included. The lowest gain in nitrogen and potassium was observed in case of sorghum wheat cowpea where only one legume was incorporated in crop sequence. As regards net loss in available phosphorous, the lowest loss is observed in sorghum –wheat-cowpea crop sequence while highest in case of soybean -wheat -cluster bean sequence by Dahatonde *et al.* (2004).

Dev and Sarawgi (2004) conducted a field experiment during 1997-1998 on clay loam soil to study the balance sheet of N, P and K as influenced by nutrient management in sunflower. They observed maximum build up of available N and K under 150 % recommended level of nutrient combination. However, in case of phosphorus build up of available phosphorus (2.6 kg ha^{-1}) was recorded with 75 % of recommended dose.

Surekha *et al.* (2004) conducted experiment during 1998-2000 on a sandy clay loam soil (Deep Aquic Ustorthent) to evaluate the influence of different crop residue management practices on rice yield and nutrient balance. Significant improvement in rice productivity was observed with recycling of 100 % straw directly or its ash or straw + GM over straw removal or 50 % straw addition after two crop cycles. Recycling of crop residues substantially improved partial N balance in the system. Partial K balance was positive with crop residue treatments and negative when straw was removed.

Wani *et al.* (2007) studied the farm nutrient depletion and build up in Vertisol under soybean based cropping sequence and stated that soybean-chickpea system removed more nutrient than soybean-wheat system. Among nutrients N and K were depleted from soil while P was build up under both the cropping system.

Shalini Pillai *et al.* (2007) studied the nutrient balance of soil nitrogen. Rice-rice-sesamum sequence and noticed the negative impact on soil nitrogen. The substitution of chemical nitrogen applied to rice with

vermicompost and azospirillum resulted in a positive balance of available nitrogen. The actual balance of soil nitrogen was higher than the computed balance in a crop sequence rice-rice-groundnut and rice-rice-cowpea. Thus irrespective of whether the balance sheet was positive or negative, there existed some amount of unaccountable nitrogen. Crop rotation with legumes and integration of nutrient sources improve the multiplication of microbes which could convert the organically bound nitrogen to inorganic forms.

Nilam Kanase (2010) studied the effect of nutrient management on nutrient balance under soybean-sunflower cropping system and reported that maximum actual gain of nitrogen was recorded under use of 100 % NPK + safflower stalk which was followed by 100 % NPK + FYM. The maximum actual gain of phosphorus was recorded in 100 % NPK + FYM which was followed by 150 % NPK. While, maximum actual gain of potassium was recorded in 100 % NPK + FYM which was followed by 100 % NPK + S + B + Zn.

Arbad and Ismail (2011) stated that inorganic sources combined with organic or organics alone showed a positive building of nitrogen, phosphorous and potassium balance in soil as compared to initial value. The control plot showed a negative balanced of available N, P₂₀₅ and K₂₀ in soil. The actual N balanced in soybean - safflower sequence after harvest of 2nd cycle showed maximum build up with 100 % NPK + FYM and 150 % NPK. P balanced was maximum in 100 % N and maximum build of K recorded in treatment 100 % NPK + 100 FYM.

The nutrients applied and nutrient uptake indicated positive balance of P and negative balance of N and K under best management practices for soybean-wheat cropping sequence. The maximum available nitrogen status was observed under 100 % NPK + FYM from its initial values. Apparent P balance increased with increase in quantity of P applied from 50 to 150 percent. The negative P balance is obviously due to absence of P in fertilization schedule where as positive P balance is because of addition of P in excess of its uptake by crops. The maximum negative balance of K in soil was recorded under use of 100 % NP There

was net mining of 150-200 kg ha⁻¹ at normal to good productivity levels Thakur *et al.* (2011).

Mali *et al.* (2012) reported that nutrients applied (inputs) and nutrient uptake (output) indicated, in general a positive balance of N and P and negative balance of K. However, the magnitude of balance of N and P was more in INM treatments as compared to those in chemical fertilizers alone. The balance of potassium at wheat straw was positive due to its slow decomposition. In general net mining of 25 to 70 kg K ha⁻¹ has been observed at various treatments. The magnitude of K mining was more under application chemical fertilizers alone as compared to the treatments involving use of organics suggesting the importance of organics in their conjunctive use with chemical fertilizers.

Kuotsu and Singh (2016) concluded that balance sheet of nitrogen, phosphorous and potassium showed that actual difference of initial and final was positive only under treatments NPK 75 % + FYM @ 5t ha⁻¹.

2.5 Soil quality index

Chaudhary *et al.* (2005) identified total soil N, available P, dehydrogenase activity and mean weight diameter of the aggregates as the key indicators of alluvial soils. Also, concluded that the highest soil quality index was found in 100 % NPK +FYM treatment followed by 100 % NPK, 100 % NP, 100 % N and control treatment, respectively.

Masto *et al.* (2007) stated that the soil quality concept provides a tool to help to quantify the combined biological, chemical and physical response of soil to crop management practices. The study was conducted to quantify effects of 10 fertilizer and farm yard manure (FYM) treatments applied for 31 years to a rotation that included maize (*Zea mays*), pearl millet (*Pennisetum americanum*), wheat (*Triticum aestivum*) and cowpea (*Vigna unguiculata*) on an Inceptisol. SQI ratings ranged from 0.552 (unfertilized control) to 0.838 for the combined NPK fertilizer plus manure treatments. The control (-11.4 %) and N alone (-5.1 %) resulted in degradation compared to a reference soil (no fertilizer/manure, no crop)

and NP alone or sub-optimal rates of NPK were on the verge of degradation. The lower SQI rating associated with N or NP-only treatments suggests that two of the most common fertilizer management practices in India may not be sustainable.

Mohanty *et al.* (2007) reported that the Soil quality in rice (*Oryza sativa* L.) wheat (*Triticum aestivum* L.) cropping system is governed primarily by the tillage practices used to fulfill the contrasting soil physical and hydrological requirements of the two crops. The objective of this study was to develop a soil quality index (SQI) based on bulk density (BD), penetration resistance (PR), water stable aggregates (WSA) and soil organic matter (OM) to evaluate this important cropping system on a Vertisol in India. Regression analysis between crop yield and SQI values for various tillage and crop residue management treatments indicated SQI values of 0.84–0.92, 0.88–0.93 and 0.86–0.92 were optimum for rice, wheat and the combined system (rice + wheat), respectively. The maximum yields for rice and wheat were 5806 and 1825 kg ha⁻¹ occurred at SQI values of 0.85 and 0.99, respectively. Using zero tillage (ZT) for wheat had a positive effect on soil quality regardless of the treatments used for rice. Regression analyses to predict sustainability of the various tillage and crop residue treatments showed that as puddling intensity for rice increased, sustainability without returning crop residues decreased from 6 to 1 years. When residue was returned, the time for sustainable productivity increased from 6 to 15 years for direct seeded rice, 5 to 11 years with low-intensity puddling (P1) and 1 to 8 years for high-intensity (P2) puddling. For sustainability and productivity, the best practice for this or similar Vertisols in India would be direct seeding of rice with conventional tillage and residues returned.

Sharma *et al.* (2009) conducted the study on two ongoing long-term experiments on crop pearl millet from 1982 and cotton-sorghum crop from 2000 in Vertisols at Kovilpatti, Tamilnadu. In order to assess the impact of integrated nutrient management (INM) on soil quality, 19 soil quality indicators were assessed. In pearl millet, the key soil quality indicators identified and their percent contribution towards soil quality was

electrical conductivity (19 %), available N (23 %), P (18 %), S (8 %), microbial biomass carbon (MBC) (10 %). In cotton-sorghum the key soil quality indicators identified and their per cent contributions towards soil quality were: P (20 %), S (16 %), Fe (22 %), Mn (10 %), MBC (8 %) and bulk density (24 %).

Katkar *et al.* (2010) reported that integrated use of inorganic fertilizers and organic manure is proved better for long term sustained crop productivity and improvement of soil quality under sorghum–wheat cropping sequence. Significantly highest SQI was noticed under use of 100 % NPK + FYM (2.45) followed by use of only FYM (2.16) and 150 % NPK (2.15). The soil quality index was found to decrease in the order of NPK > NP > N > control.

Kharche *et al.* (2010) reported that conjunctive use of organics like FYM, wheat cut straw and green manure have strongly influenced dynamic soil properties and were found beneficial for restoring soil quality. The decline in soil quality in Vertisol under long term experimentation revealed that soil quality degradation especially in reduction of SOC, MWD, water retention and depletion of available nutrient status due to lack of organic matter addition and crop residue incorporation in soil and use only chemical fertilizers. The rainfed semi-arid tropical Vertisols of the Indian subcontinent encountered many problems on account of the physical, chemical, and biological soil qualities and consequently have poor crop yields.

Sharma *et al.* (2011) to ensure sustainable crop production, there is a need to improve and periodically assess the quality of these soils by adopting suitable soil and nutrient-management practices on a long-term basis. Hence, soil quality assessment studies were conducted at the Central Research Institute for Dryland Agriculture, Hyderabad, India, by adopting an ongoing long-term experiment from Akola Centre (Maharashtra) of All-India Coordinated Research Project for Dryland Agriculture (AICRPDA) for the rainfed Vertisol. This long-term experiment was initiated in 1987 with six soil and nutrient management treatments: T₁, control; T₂, 50 kg nitrogen (N) + 25 kg phosphorus pentoxide (P₂O₅) ha⁻¹;

T₃, 25 kg N ha⁻¹ through leuceana; T₄, 25 kg N ha⁻¹ through farmyard manure (FYM); T₅, 25 kg N + 25 kg P₂O₅ + 25 kg N ha⁻¹ through FYM; and T₆, 25 kg P₂O₅ ha⁻¹ + 50 kg N ha⁻¹ through leuceana under cotton + greengram intercropping (1:1). Out of the 19 soil quality parameters studied, significant influence of the soil and nutrient-management treatments was observed on almost all the parameters except exchangeable calcium (Ca), available iron (Fe), labile carbon (LC), and bulk density (BD). A standard methodology using principal component analysis (PCA) and linear scoring technique (LST) was adopted to identify the key indicators and for computation of soil quality indices. The various key soil quality indicators identified for these Vertisols under cotton + green gram system were pH, electrical conductivity (EC), organic carbon (OC), available K, exchangeable magnesium (Mg), dehydrogenase assay (DHA) and microbial biomass carbon (MBC). The soil quality indices as influenced by different long-term soil and nutrient management treatments varied from 1.46 to 2.10. Among the treatments, the conjunctive use of 25 kg P₂O₅ ha⁻¹ + 50 kg N ha⁻¹ through leuceana green biomass (T₆) maintained significantly higher soil quality index with a value of 2.10 followed by use of 25 kg N + 25 kg P₂O₅ + 25 kg N ha⁻¹ through FYM (T₅) (2.01). The order of percent contribution of these identified indicators to soil quality indices was OC (28 %) > MBC (25 %) > available K (24 %) > EC (7 %) > pH (6 %) = DHA (6 %) > exchangeable Mg (4 %). Thus, the findings of the present study could be of immense use to the researchers, land managers, farmers, nongovernment organizations (NGOs) and other stakeholders for making periodical assessment of key indicators of soil quality, identifying the best soil and nutrient-management treatments and practices, and planning for improving soil quality to achieve higher productivity goals on a sustainable basis in rainfed semi-arid tropical Vertisol regions. The methodology of the study could also be useful for other rainfed semi-arid tropical Vertisol regions of the world.

In a field experiment three value-added manures viz., vermicompost, NADEP compost and FYM were evaluated for crop production and maintaining soil mineral N and organic C pools in an

Inceptisol under a maize-wheat cropping system. The conjoint use of value-added manure (5 Mg ha^{-1}) and 50 % NPK fertilizers than plots amended with value-added manure alone. Pearson's correlation matrix showed significant and positive relationships between yield, N uptake by crops with soil mineral N, MBN and pools of SOC. The results demonstrated that integrated use of value added manures along with 50 % NPK fertilizers could maintain higher mineral N and SOC pools, which may be considered as a feasible and environment-friendly option for recycling various farm wastes including crop residues and cattle dung into a value added product, there by effecting a 50% saving on costly chemical fertilizers Basak *et al.* (2012).

Mali (2012) studied long term effect of manures and fertilizers on sorghum-wheat cropping system in Inceptisol and reported that long term use of organics *viz.*, FYM, wheat straw and green manuring with leucaena loppings in conjunction with chemical fertilizers and recorded improvement in physical, chemical and biological properties resulting into enhancement in soil quality. Application of FYM (50 % N) along with chemical fertilizers over a long-term (26 years) showed highest soil quality index. However, wheat straw and green manuring in conjunction with chemical fertilizers although improved the soil quality over a long term did not sustain the yields under cereal-cereal cropping system. The need of addition of organics however has been emphasized irrespective of cropping system to enhance the soil quality and advocated the necessity of legume based cropping systems for soil restoration point view. Both of the studies in black swell-shrink soils based on long term impact of INM identified the sensitive soil quality indicators useful for further enhancement of soil health.

CHAPTER III

MATERIAL AND METHODS

The field experiment was carried out to study the “Effect of tillage and IPNS on soil properties, uptake of nutrients and productivity of soybean-cotton rotation in Vertisol” on the Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidayapeeth, Akola during 2016-17 and 2017-18. The details of material used and methods adopted during the course of investigation are described below under appropriate heads.

- 3.1 Material required
 - 3.1.1 Climate and weather conditions
 - 3.1.2 Soil
 - 3.1.3 Experimental details
- 3.2 Methods adopted
 - 3.2.1 Collection and processing of soil samples
 - 3.2.2 Soil analysis
 - 3.2.2.1 Soil physical properties
 - 3.2.2.2 Soil chemical properties
 - 3.2.2.3 Soil biological properties
 - 3.2.3 Plant analysis
 - 3.2.4 Yield
 - 3.2.5 Soil Quality Index
 - 3.2.6 Nutrient balance
 - 3.2.7 Statistical analysis
- 3.3 Location / Duration / Seasons of experiment

3.1 Material required

3.1.1 Climate and weather conditions

Akola is situated in between 22° 41' N latitude and 77° 02' longitudes at an altitude of 307.4 m above mean sea level and has a subtropical climate. The climate is characterized by three distinct seasons viz., summer becoming hot and dry from March to May. Monsoon characterized as warm and rainy from June to October and winter with dry mild cold from November to February. Most of the rainfall is received from South West monsoon.

3.1.1.1 Weather and Season (2016-2017)

Weekly weather data recorded at Agromet, Department of Agronomy, Dr. PDKV, Akola during 2016-2017 along with corresponding normal are presented in Table 2 and described below in brief. Relevant data are presented in Table 1. It was observed that the annual rainfall (5th March 2016 to 4th March 2017) amounted to 666.0 mm and was received in 46.0 rainy days as against the normal of 783.7 mm in 42.9 rainy days. Rainfall was 84.8 per cent of normal and the rainy days were 107.8 per cent than normal. During summer season (from 5th March to 27th May) 20.9 mm rainfall was recorded which accounted to 94.1 per cent, pre - monsoon rain during 22nd and 23rd MW was 0.0 mm which was deficit than the normal (-100 %). Monsoon rains during 24th to 39th MW i.e. 11th June to 30th September amounted to 644.6 mm as against the normal of 642.0 mm which was 100.3 per cent of normal. The distribution of rainfall during the monsoon was fairly good. Post monsoon rains received during 1st October to 2nd December (40 to 48 MW) were 0.5 mm, as against the normal of 71.9 mm. During winter season rains during 3rd December 2016 to 4th March 2016 (49th to 09th MW) were 0.0 mm as against the normal of 27.7 mm which was not found beneficial for Rabi crops.

The data on rainfall are presented in Table 1, 2 and depicted in Figure 1 and 2, which indicated that during summer (5 March to 27 May) 68.8 mm and pre monsoon (28 May to 10 June) it was 0.00 mm. First rainfall of 53.8 mm was received during 11-17 June (24 MW) which facilitated land preparation. Sowing of cotton and other crops started after

17th June after receipt of 57 mm of rains and thereafter, but 26, 27 and 28 MW were rainless and long dry spell was observed which resulted in lack of moisture to which resulted in poor germination at some areas.

The monsoon started to withdrawals started from 20 September 2016 (i.e. 38th MW) which was early by 5-6 weeks than normal. The performance of kharif crop was not satisfactory whereas, rabi was also not benefited because of lower rainfall during the October. The rainfall during June, July, August, September October, November and December was 88.1, 72.1,,320.1,,164.3,,0.5, 0 and 0mm respectively which was 62, 36.6, 157, 142 , 0.98, 0.0 and 0.0 per cent of normal, respectively. Total rainfall during June to December was 645.1 mm which was only 87 per cent of normal. Overall, the rainfall and its distribution were not satisfactory for early and mid late crops.

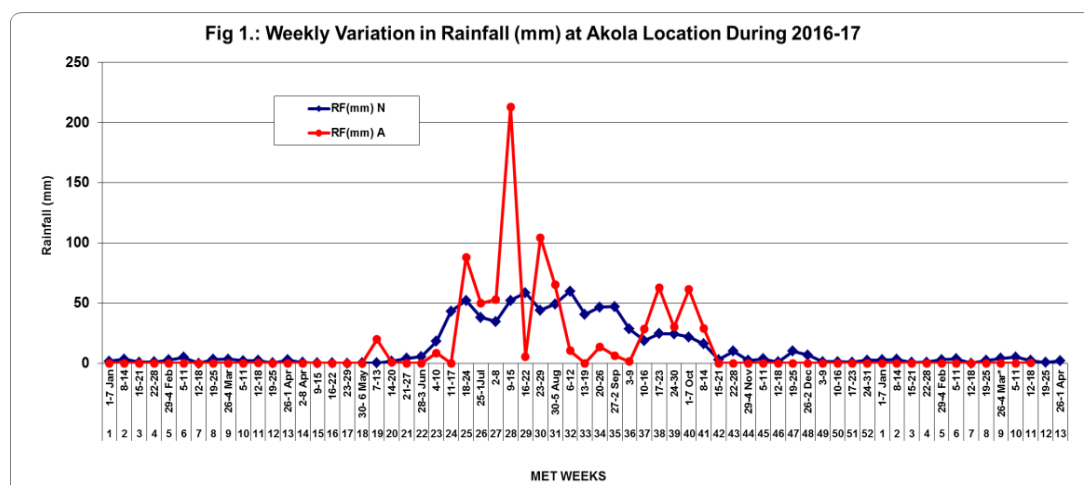


Fig. 1a. Rainfall at Akola (2016-17)

Table 1. Rainfall distribution at Akola during 2016-2017

Rainfall Classification as per IMD			Dates / Period	Normal RF	Actual Mean RF
Sr. No.	Particulars	MW			
1	Summer	10-21	5 March to 27 May	22.2	20.9
2	Pre Monsoon	22-23	28 May to 10 June	22.6	0.0
3	Monsoon	24-39	11 June to 30 Sept.	642.4	644.6
4	Post Monsoon	40-48	1 Oct. to 2 Dec	69.6	0.5
5	Winter	49-09	3 Dec. to 4 March	28.1	0.0
Total				785.01	666.0

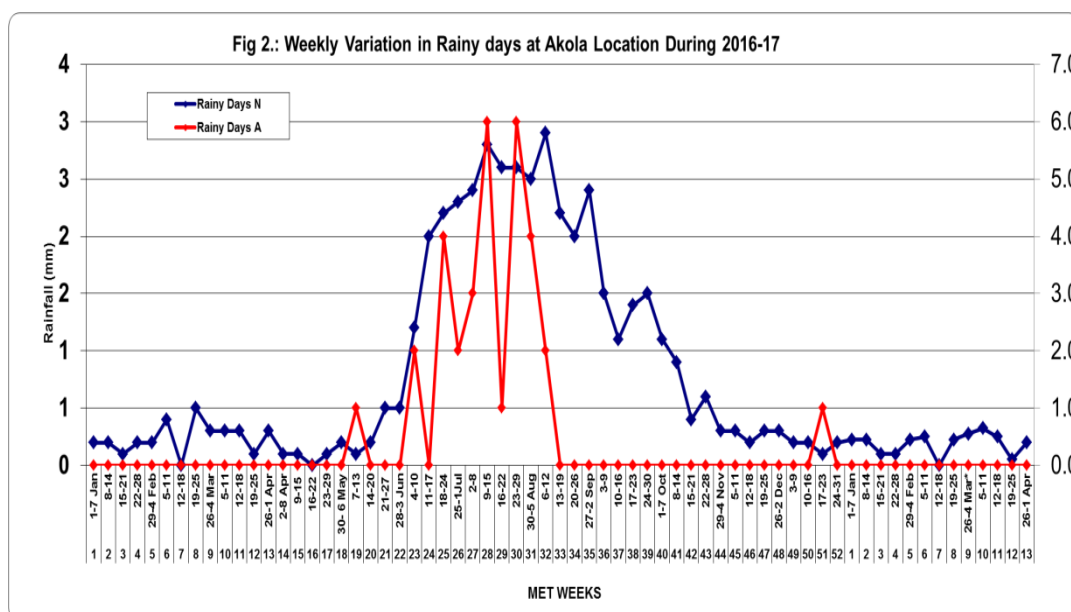


Fig. 1b. Weekly rainfall at Akola (2016-17)

3.1.1.2 Weather and Season Report 2017-2018

Relevant data are presented in Table 2. It was observed that annual rainfall from 5th March, 2017 to 4th March 2018 onwards accounted to 518.3 mm and was received in 43 rainy days as against the normal of 788.8 mm in 41.2 rainy days. The rainfall received was 104.2 per cent of normal and the rainy days were 104.1 per cent as compared to normal.

In summer season (from 5th March to 27th May) 0.3 mm rainfall was recorded which accounted to 1.4 per cent, pre - monsoon rain during 22nd and 23rd MW was 25.4 mm which was excess than the normal (10 %). Monsoon rains during 24th to 39th MW i.e. 11th June to 30th September amounted to 429.9 mm as against the normal of 643.9 mm which was 66.8 per cent of normal.

During 2017-18 total 43 rainy days were recorded as against of normal of 41 rainy days which accounted to 104.1 per cent to normal. During the monsoon 24-39 MW (11 June to 30 Sept) total 37 rainy days were recorded as against normal of 32 rainy days which accounted to 116 per cent to the normal during Post monsoon and winter rainy day were 5.0 and 0.0 as against the normal of 4 and 2.

Table 2. Rainfall distribution at Akola during 2017-2018

Rainfall Classification as per IMD			Dates / Period	Normal RF	Actual Mean RF
Sr. No.	Particulars	MW			
1	Summer	10-21	5 March to 27 May	21.3	0.3
2	Pre Monsoon	22-23	28 May to 10 June	23.1	25.4
3	Monsoon	24-39	11 June to 30 Sept.	643.9	429.9
4	Post Monsoon	40-48	1 Oct. to 2 Dec	74.0	62.0
5	Winter	49-09	3 Dec. to 4 March	26.5	0.7
Total				788.8	518.3

During this year Monsoon rainfall was grouped under different phenophases of cotton crop, so as to know the crop behaviour to monsoon during different phenophases of the crop. The onset of monsoon was right time during the kharif season of 2017. Sowing of cotton crop was undertaken from 20-24 June. Thereafter there is occurrence of dry spell. Sufficient rains about 100 mm rainfall received on 2nd July. Sowing of other trials was done from 5- 10 July 2017. Emergence of cotton occurs in first and second week of July. The seasonal rainfall was 517.3 mm in 43 rainy days (1st June to 31st Dec. 2017). In this season, about 67.3 % rainfall is received and there is about 32.7 % rainfall deficit as against normal rainfall. The germination of cotton was satisfactory but growth of cotton was hampered due to dry spell during June to Sept months. Inter-culture practices i.e. gap filling, thinning, fertilizers applications, hoeing were done in the month of July-August 2017 and weed flora was less. Thereafter weed infestation was increased. The monsoon was withdrawn from 26th September 2017. Winter (October) rains 62 mm were received mostly 8-12 October during boll development favoured the growth of bolls in cotton and second flush was good in Hirsutum, arboreum and BT genotypes, which delayed second picking of cotton.

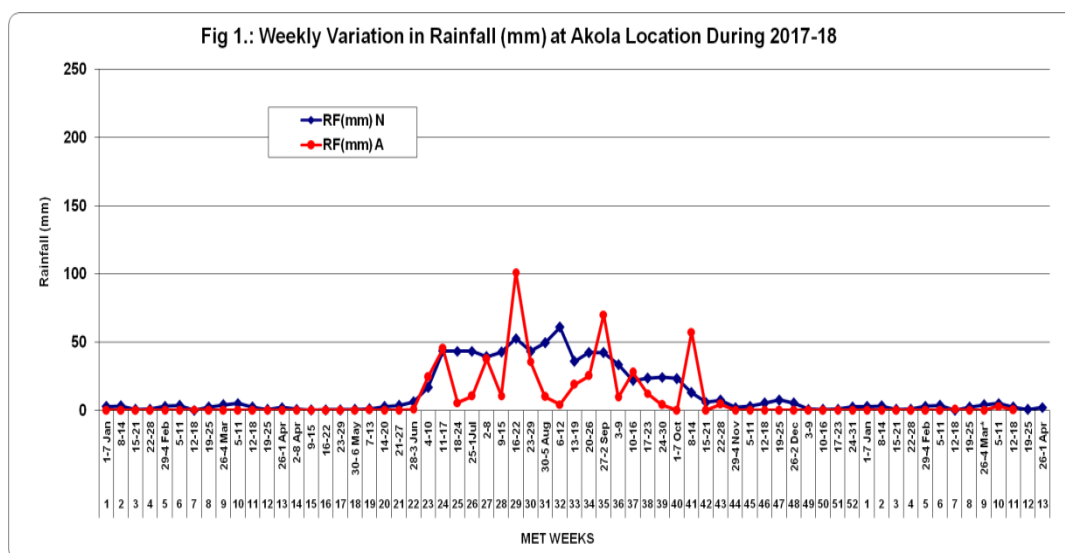


Fig. 2a. Rainfall at Akola (2017-18)

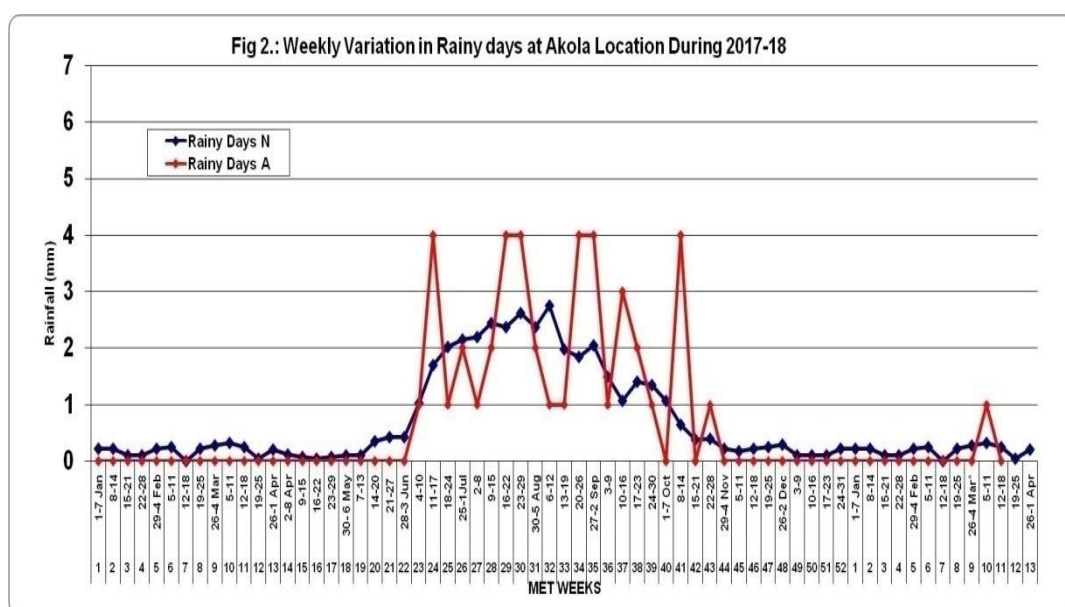


Fig. 2b. Weekly rainfall at Akola (2017-18)

3.1.2 Soil

The soil of experimental site was Vertisol belonging to fine, smectitic, hyperthermic, Typic Haplusterts. It was calcareous in nature and moderately alkaline in reaction. The fertility status of the soil indicates that the soil was moderate in organic carbon, available nitrogen and phosphorus and very high in available potassium.

Table 3. Physical and chemical properties of experimental soil at start of experiment (Kharif 2010)

Sr. No.	Particulars	Value
A.	Physical properties	
1.	Bulk density (Mg m^{-3})	1.38
2.	Mean weight diameter (mm)	0.61
3.	Saturated hydraulic conductivity (cm hr^{-1})	0.66
4.	Water retention at 33 kPa	43.31
5.	Water retention at 1500 kPa	18.83
6.	Available water capacity (%)	24.48
7.	Mechanical analysis	
	a. Sand (%)	31.20
	b. Silt (%)	16.60
	c. Clay (%)	52.20
B.	Chemical properties	
1.	pH (1:2.5)	8.10
2.	EC (dS m^{-1})	0.29
3.	Free lime (%)	8.12
4.	Organic carbon (g kg^{-1})	5.40
5.	Available nitrogen (kg ha^{-1})	212.5
6.	Available phosphorus (kg ha^{-1})	14.34
7.	Available potassium (kg ha^{-1})	347.8
8.	Available sulphur (mg kg^{-1})	9.61
9.	DTPA Zn (mg kg^{-1})	0.51
10.	DTPA Fe (mg kg^{-1})	4.80
11.	DTPA Mn (mg kg^{-1})	8.42
12.	DTPA Cu (mg kg^{-1})	1.64
13.	Available B (mg kg^{-1})	0.36

3.1.2.1 Cropping history of the experimental plot

The field experiment was conducted on research farm of Department of Soil Science and Agricultural Chemistry. The experiment was conducted on the same place where, cotton was grown for six years using the conservation and conventional tillage practices. The site has history of six year experimentation of conservation tillage; this was added advantage of identifying the effect of various treatments on accumulated carbon and its further effect on other properties. The cultivation of this experimental plot started in 2010-11. The effect of conventional and conservation tillage was assessed along with different organic and inorganic fertilizers. The yield was not sustained even after six years of

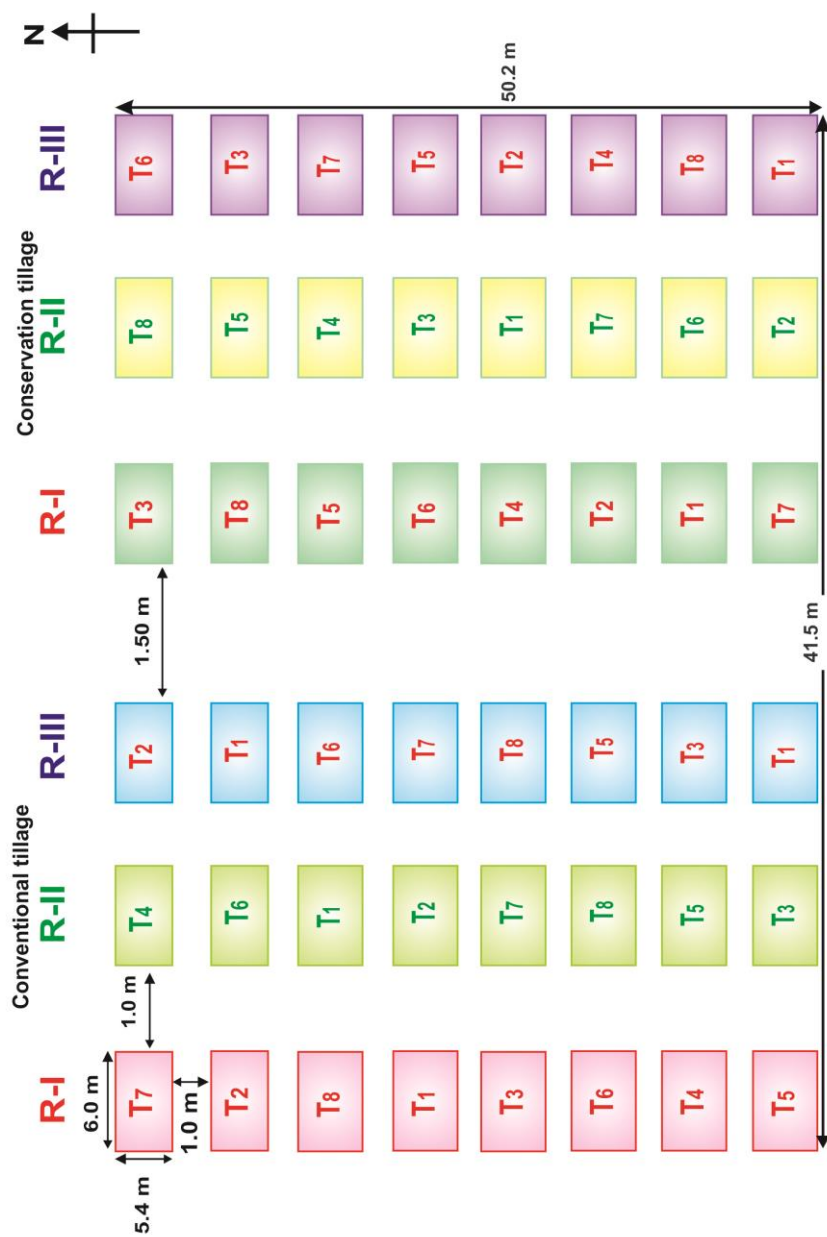


Fig. 3 Plan of layout

experimentation hence, it was rotated with soybean as a legume to maintain residual fertility of soil and also to avoid monocropping of cotton. The result are placed considering the history of six years. The treatments defined for soybean-cotton rotation have been slightly changed to assess the effect of tillage and IPNS. Similarly the carryover effect of earlier crop and treatments have also considered. The finding of present experiment have been compared over initial status of soil at the start of the experiment (2010-11) (Table 3). The treatment wise soil samples were also collected to monitor the further changes in soil physical, chemical and biological properties under soybean-cotton rotation (annexure I (C)). The study was conducted in Kharif 2016-2017 and 2017-18 and during the summer the land was fallow. The effect of tillage and organic sources were studied on soil properties of soil using soybean and cotton crop rotation. Cropping history of the experimental plot from six years is presented in Table 4.

Table 4. Cropping history of the experimental plot

Year	Crop grown	
	<i>Kharif</i>	Summer
2010-11	Cotton	Fallow
2011-12	Cotton	Fallow
2012-13	Cotton	Fallow
2013-14	Cotton	Fallow
2014-15	Cotton	Fallow
2015-16	Cotton	Fallow

3.1.3 Experimental details

Location	: Research Farm, Department of Soil Science and Agril. Chemistry, Dr PDKV, Akola
Soil type	: Vertisol
Year of start	: 2016-17
Year of the study	: 2016-17 and 2017-18
Name of crop	: Soybean (kharif) 2016-17 Cotton (kharif) 2017-18
Variety	: Soybean (JS 335) 2016-17 Cotton (AKH 9916 Non Bt)
Season	: <i>Kharif</i> season

Design of experiment : Randomized Block Design (RBD)
(Two set of condition)
Set I - Conservation tillage
Set II - Conventional tillage

Number of treatments : 8

Number of replications : 03

Spacing : Soybean (45 x10 cm)
Cotton (60 x 30 cm)

Plot size : Gross = 6.0 x 5.4 m²
Net = 5.4 x 4.8 m²

Method of sowing : Soybean (seed drill)
Cotton (Dibbling)

Total number of plots : 48

Fertilizer dose (RDF) : Soybean 30:75:30 NPK kg ha⁻¹
Cotton 60:30:30 NPK kg ha⁻¹

Date of sowing :

1 st year (2016-17)	Soybean
Date of sowing	30-06-2016
Date of Harvesting	13-10-2016
2 nd year(2017-18)	Cotton
Date of sowing	03-07-2017
Date of picking	
Cotton picking 1 st	05-12-2017
Cotton picking 2 nd	18-12-2017
Cotton picking 3 rd	11-01-2018
Cotton picking 4 th	22-02-2018

3.1.3.1 Treatment Details

Tillage

The two separate experiment each in conservation and conventional tillage were conducted on same site and hence randomization with similar set of nutrient management treatments.

In conservation tillage one harrowing and two weeding operations were carried every year. In conventional tillage one ploughing

(once in two year), one harrowing, two hoeing and two hand weeding operations were carried out every year.

Tr.	Soybean (2016-17)	Cotton (2017-2018)
T ₁	Control	Control
T ₂	100% RDF	100% RDF
T ₃	50% N through FYM+ remaining RD through chemical fertilizer	50% N through FYM+ remaining RD through chemical fertilizer
T ₄	50% N through wheat straw + remaining RD through chemical fertilizer	50% N through wheat straw + remaining RD through chemical fertilizer
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer
T ₆	50% N through composted cotton stalk + remaining RD through chemical fertilizer	50% N through composted cotton stalk + remaining RD through chemical fertilizer
T ₇	50% N through vermicompost + remaining RD through chemical fertilizer	50% N through vermicompost + remaining RD through chemical fertilizer
T ₈	100% N through phoshpocompost + remaining P through chemical fertilizer	100% P through phoshpocompost + remaining N through chemical fertilizer

Different treatments consists balance use of chemical fertilizer along with organic source of nutrient in which 50 per cent N applied through chemical fertilizer and remaining N was applied through various sources like FYM, crop residues (composted wheat straw) composted cotton stalk, green manuring (glyricidia), vermicompost and phoshpocompost. The quantity of P and K supplied through different organics, green manuring and crop residues, the compensation remaining P and K compensated through chemical fertilizers.

3.1.3.2 Sources and application of manures and fertilizers

The N, P and K were applied in the form of urea, single super phosphate and muriate of potash. Treatment wise basal doses (half nitrogen and full phosphorus and potassium) of fertilizers were calculated and applied at the time of sowing and remaining half dose of nitrogen was applied at flowering to soybean and cotton, thoroughly mixed in the soil. The crop residues were decomposed by PDKV decomposer. FYM, wheat

straw, composted cotton stalk, vermicompost and phoshpocompost and glyricidia foliage lopping applied as a source of nutrient in soil. The different organics and crop residues were applied based on NPK content. The crop residues and Glyricidia loppings were applied in between two rows of soybean & cotton crop respectively and thoroughly mixed in the soil. Simultaneously the crop residue samples were collected and analyzed for nutrient composition (Table 6).

Table 5. Chemical composition of organics added in soil (oven dry basis)

Organics added year	N	P	K
	(%)		
FYM			
2016	0.53	0.22	0.60
2017	0.49	0.25	0.61
Composted Wheat straw			
2016	0.40	0.21	0.51
2017	0.42	0.22	0.53
Glyricidia foliage lopping			
2016	2.40	0.20	1.80
2017	2.60	0.22	1.75
Composted cotton stalk			
2016	0.47	0.15	0.60
2017	0.49	0.18	0.57
Vermicompost			
2016	1.21	0.75	0.90
2017	1.27	0.79	0.92
Phoshpocompost			
2016	0.76	1.70	0.68
2017	0.74	1.73	0.65

3.1.3.3 Cultural operations

Gap filling and thinning operations were carried out in time and plant population was maintained. A weeding and hoeing operation were carried out as per treatment details. Due care was taken to protect the crops from insects by spraying insecticides as per recommendations.



Plate 2. Compost preparation

Table 6. Sources and quantity of fertilizers and manures added in soybean during 2016-17

Tr. No.	Soybean (2016-17)	Nutrient added through chemical fertilizers (kg ha ⁻¹)			Organics used	Nutrient added through organics (kg ha ⁻¹)			Quantity of organics added (kg ha ⁻¹)	Quantity of organics added (kg per plot)
		N	P	K		N	P	K		
T ₁	Control	-	-	-	-	-	-	-	-	-
T ₂	100% RDF(30:75:30)	30	75	30	-	-	-	-	-	-
T ₃	50% N through FYM+ remaining RD through chemical fertilizer	15	69.34	13.02	FYM	15	6.22	16.98	2830	9.20
T ₄	50% N through wheat straw + remaining RD through chemical fertilizer	15	67.13	10.88	Composted WS	15	7.87	19.72	3750	12
T ₅	50% N through GLM + remaining RD through chemical fertilizer	15	74.98	18.75	GLM	15	0.044	11.25	625	2.02
T ₆	50% N through composted cotton stalk + remaining RD through chemical fertilizer	15	69.22	10.86	Composted Cotton stalk	15	4.78	19.14	3191	10.33
T ₇	50% N through vermicompost + remaining RD through chemical fertilizer	15	65.71	18.85	vermicompost	15	9.29	11.15	1239	4.01
T ₈	100% N through phoshpocompost + remaining P through chemical fertilizer	-	7.91	3.17	phoshpocompost	30	67.07	26.83	3947	12.78

Table 7. Sources and quantity of fertilizers and manures added in cotton during 2017-18

Tr. No.	Cotton (2016-17)	Nutrient added through chemical fertilizers (kg ha ⁻¹)			Organics used	Nutrient added through organics (kg ha ⁻¹)			Quantity of organics added (kg ha ⁻¹)	Quantity of organics added (kg per plot)
		N	P	K		N	P	K		
T ₁	Control	-	-	-	-	-	-	-	-	-
T ₂	100% RDF(60:30:30)	60	30	30	-	-	-	-	-	-
T ₃	50% N through FYM+ remaining RD through chemical fertilizer	30	14.70	-	FYM	30	15.30	37.33	6122	19.83
T ₄	50% N through wheat straw + remaining RD through chemical fertilizer	30	14.29	-	Composted WS	30	15.71	37.5	7142	5.64
T ₅	50% N through GLM + remaining RD through chemical fertilizer	30	27.47	9.83	GLM	30	2.53	20.17	1153	3.73
T ₆	50% N through composted cotton stalk + remaining RD through chemical fertilizer	30	16.25	-	Composted Cotton stalk	30	13.75	33.12	6250	20.25
T ₇	50% N through vermicompost + remaining RD through chemical fertilizer	30	7.57	18.85	vermicompost	30	18.78	22.43	2439	7.90
T ₈	100% P through phoshpocompost + remaining N and K through chemical fertilizer	47.17	-	18.73	phoshpocompost	12.83	29.99	11.27	1734	5.61



Plate 3. Organics application in soybean



Plate 4. Organics application in cotton

3.2 Methods adopted

3.2.1 Collection and preparation of soil samples for analysis

The treatment wise initial surface soil samples (0-20 cm) before sowing in *kharif* (2016-17) from experimental site and after harvest of *kharif* was collected. For determination of soil moisture the surface soil samples (0-20 cm) were collected at critical growth stages of soybean and cotton. Soil samples were air dried in shade and stored in polythene bags for further analysis. The air dried samples were carefully and gently ground with the wooden pestle to break soil lumps (clods) and passed through sieve of 2 mm diameter. The sieved samples were mixed thoroughly and stored in polythene bags, properly labelled and preserved for subsequent analysis. Similarly the soil clod were also collected from different depths and used for MWD analysis by wet sieving method and bulk density by clod coating methods. Soil samples were collected for soil moisture analysis at critical growth stages of crops. Soil samples for biological parameters will be collected during peak growth stages of crop and immediately analyzed.

3.2.2 Soil analysis

3.2.2.1 Soil physical properties

3.2.2.1.1 Bulk density

Soil bulk density was determined by clod coating technique as described by Blake and Hartge (1986).

3.2.2.1.2 Mean weight diameter (MWD)

MWD was determined by Yoder's wet sieving method described by Kemper and Rosenau (1986).

3.2.2.1.3 Hydraulic conductivity

The core soil samples were fully saturated with distilled water and hydraulic conductivity was determined by constant head method as described given by Klute and Dirksen (1986).

3.2.2.1.4 Soil moisture

Soil moisture was determined by gravimetric method (Black, 1965).

3.2.2.2 Soil chemical properties

3.2.2.2.1 Soil reaction

The soil pH was determined in soil suspension (1:2.5 soil: water) by a glass electrode pH meter after equilibrating the soil with water for 30 minutes with occasional stirring (Jackson, 1973).

3.2.2.2.2 Electrical conductivity

The electrical conductivity was determined in soil suspension (1:2.5 soil : water) after equilibrating the soil with water and keeping the sample undisturbed till the supernatant is obtained and measured using conductivity meter (Jackson, 1973).

3.2.2.2.3 Organic carbon

For the determination of organic carbon the modified Walkley and Black method was followed (Nelson and Sommers , 1982).

3.2.2.2.4 Available nutrients

3.2.2.2.4.1 Nitrogen

Available nitrogen was determined by alkaline permanganate method using microprocessor based automatic distillation system (Subbiah and Asija, 1956).

3.2.2.2.4.2 Phosphorus

Available phosphorus was determined by Olsen's method using 0.5 M sodium bi-carbonate as an extractant using UV based double beam spectrophotometer (Watanabe and Olsen, 1965).

3.2.2.2.4.3 Potassium

Available potassium was determined by neutral normal ammonium acetate method using flame photometer (Hanway and Heidal , 1952).

3.2.2.2.4.4 Available Sulphur

Available sulphur was determined by Morgan's reagent as extractant (Turbidimetric method) using UV based double beam spectrophotometer (Chesnin and Yien, 1950).

3.2.2.2.5 Available Micronutrients

Available micronutrients viz. Zn, Fe, Mn and Cu were determined by DTPA as extractant (Lindsay and Norvell, 1978) using atomic absorption spectrophotometer.

3.2.2.2.6.1 Nitrate nitrogen ($\text{NO}_3\text{-N}$)

Nitrate nitrogen ($\text{NO}_3\text{-N}$) was determined by Devardas alloy stem distillation method by (Bremner, 1965).

3.2.2.2.6.2 Ammonical nitrogen ($\text{NH}_3\text{-N}$)

Ammonical nitrogen ($\text{NH}_3\text{-N}$) was determined by MgO stem distillation method by (Bremner, 1965).

3.2.2.2.6.3 Mineral nitrogen

Mineral nitrogen was determined by MgO and Devardas alloy stem distillation method by (Bremner, 1965).

3.2.2.3 Biological properties

3.2.2.3.1 Soil microbial biomass carbon (SMBC)

SMBC was estimated using chloroform fumigation extraction method by (Jenkinson and Powlson, 1976).

3.2.2.3.2 Dehydrogenase activity (DHA)

DHA was estimated by TTC method by Klein *et al.*, (1971).

3.2.2.3.3 CO_2 evolution

CO_2 evolution was estimated using Alkali trap method by Anderson (1982).

3.2.2.3.4 Soil organic stock (SOC)

Soil organic stock was determined by using organic carbon and bulk density in surface and subsurface soil.

3.2.3 Plant analysis for nutrient content

3.2.3.1 Collection of plant samples and processing

The treatment wise plant samples were selected randomly from each net plot at harvest stage of both years. The samples were firstly cleaned with clothes, followed by rinsing with detergent 0.02 N HCl and finally with ionized water. After cleaning the plant samples were dried in shade and then placed in oven at 64 °C till the constant weight obtained. The oven dried weights were recorded. These plant samples were ground in electrically operated stainless steel blade grinder (Willey mill) up to maximum fineness. The ground samples were stored in polythene bags with proper labelling for chemical analysis. The total nutrients content in stalk and cotton seed was determined and uptake was computed by multiplying the respective nutrient concentration in per cent by dry matter yield.

3.2.3.2 Nitrogen

Total nitrogen was determined by digesting the plant sample in microprocessor based digestion system (KES-12L) using conc. H₂SO₄ and catalyst mixture (Kjeldahl's method) and distillation with automatic distillation system (Piper,1966).

3.2.3.3 Preparation of plant sample extract

Finely ground and well mixed plant samples of weighted accurately (0.2 g) transferred into micro digestion tube and 10 ml di-acid mixture was added and digested on microprocessor based (KES-12L) digester. After completion of digestion (clear white) the extract was diluted and filtered through Whatman filter paper No. 42. These extracts were used for determination of phosphorus, potassium, sulphur.

3.2.3.4 Phosphorus

Phosphorus was estimated from di-acid extract by vanado-molybdate phosphoric acid yellow colour method (Kitson and mellon, 1966) using UV based double beam spectrophotometer.

3.2.3.5 Potassium

Potassium was estimated from di-acid extract by using flame photometer (Piper, 1966).

3.2.3.6 Sulphur

Sulphur was determined from di-acid extract by turbidimetric method (Chesnin and Yien, 1950) using UV based double beam spectrophotometer.

3.2.4 Yield

Plotwise soybean seed and straw yield and seed cotton yield and stalk yield were recorded of cotton.

3.2.5 Soil Quality Index (SQI)

Soil quality index was determined by linear scoring method from principle component analysis of variables described by Doran and Parkin (1994). For assessment of soil quality as influenced by integrated nutrient management the following steps were followed. First of all 24 parameters were used for principle component analysis and the minimum data set was selected.

$$SQI = \sum_{i=1}^n (W_i S_i)$$

Where,

S_i = Score for subscripted variable

W_i = Weighing factor derived from the PCA

n =no.of variables

3.2.6 Nutrient balance

The nutrient balance was calculated as suggested by Thakur *et al.* (2011).

3.2.7 Statistical analysis

Experimental data were analyzed by adopting standard statistical methods of analysis of variance as given by Gomez and Gomez (1984). The field experiment was conducted at Research Farm, Department of Soil Science and Agricultural Chemistry. The performances of eight treatments on IPNS treatments were separately analyzed for conservation and conventional tillage using RBD. To compare the interaction effect of tillage with treatments on IPNS, the data was analyzed using factorial randomised block design.

3.3 Location / Duration / Seasons of experiment

Field experiment was conducted at Research Farm Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* seasons of 2016-17 and 2017-18. Geographically, Akola is located at 20° 42' 01''N latitude and 77° 04' 05'' E longitudes with an elevation of 297.41 meters above mean sea level.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the field experimentation entitled “Effect of tillage and integrated plant nutrient system (IPNS) on soil properties and uptake of nutrients and productivity of soybean- cotton rotation in Vertisol” conducted at Research Farm , Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidayapeeth, Akola have been presented in this chapter. The site has history of six year experimentation of conservation tillage; this was added advantage of identifying the effect of various treatments on accumulated carbon and its further effect on other properties. The cultivation of this experimental plot started in 2010-11. The effect of conventional and conservation tillage was assessed with different IPNS organics and inorganic fertilizers. The yield was not sustained after six year of experimentation hence it was rotated with soybean as a legume to maintain residual fertility of soil and also to avoid monocropping of cotton. The result are placed considering the history of six years. The treatments defined for soybean-cotton rotation have been slightly changed to assess the effect of tillage and IPNS. Similarly the carryover effect of earlier crop and treatments have also considered. The findings of present experiment have been compared over initial status of soil at the start of the experiment (2010-11) presented in (Table 3). The treatment wise soil samples were also collected to find out the interime result of tillage and nutrient management on soil (annexure I (C)). The study was conducted in Kharif 2016-2017 and 2017-18 and during the summer the land is fallow and related laboratory analysis of soil are presented and discussed under the following heads.

- 4.1 Effect of tillage and Integrated plant nutrients system (IPNS) on soil properties under soybean and cotton
 - 4.1.1 Physical properties
 - 4.1.2 Chemical properties
 - 4.1.3 Biological properties
- 4.2 Effect of tillage and Integrated plant nutrients system (IPNS) on

soybean and cotton yield

- 4.3 Effect of tillage and Integrated plant nutrients system (IPNS) on total uptake of nutrients by soybean
- 4.4 Effect of tillage and Integrated plant nutrients system (IPNS) on total uptake of nutrients by cotton
- 4.5 Apparent nutrient balance
- 4.6 Soil quality Index
- 4.7 Correlation and regression
- 4.8 Economic studies

4.1.1 Physical properties

4.1.1.1 Bulk density

The data regarding bulk density under soybean and cotton was assessed and compiled under tillage and nutrient management and same is presented in Table.8

Based on the data compiled it was observed that the effect of tillage and integrated plant nutrient system (IPNS) on bulk density of soil was found to be significant. The results obtained of individual tillage, integrated plant nutrients system (IPNS) and their interaction is discussed under sub title.

Effect of Tillage

During the present investigation the bulk density has shown significant variation in conservation and conventional tillage. The lower bulk density was recorded in conservation tillage than the conventional tillage system during the soybean and cotton rotation. However, it appears necessary to monitor the changes in bulk density in black soils under various tillage practices. Bauer and Black (1981) reported little differences in soil structural characteristics among tillage systems in arid and semi arid regions due to low precipitation and high temperature.

Effect of Integrated plant nutrient system

The Bulk density of soil was significantly influenced by nutrient management. In *kharif* season (2016-17), under soybean crop effect of different integrated plant nutrients system (IPNS) on bulk density of soil was

significant. However, significantly lower values of bulk density (1.29 Mg m^{-3}) recorded in application of 50 % N through FYM + remaining RD through chemical fertilizer which was found beneficial in decreasing bulk density over the other treatments. The highest value of bulk density (1.36 Mg m^{-3}) was recorded in control. The decrease in bulk density was associated with improvement in per cent water stable aggregates and mean weight diameter might be ascribed to more moisture available which leads to better soil structure.

In *kharif* season (2017-18) under cotton crop, the effect of different nutrient management practices on bulk density of soil was significant. The lowest bulk density (1.27 Mg m^{-3}) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer. The highest value of bulk density (1.36 Mg m^{-3}) was recorded in control.

Bulk density decreased with the application of FYM due to higher SOC and increased root biomass, which resulted in better soil aggregation and aeration. Sonune *et al.* (2012) reported that the reduction in bulk density may be attributed to better aggregation, increase in organic matter under the treatments of integrated use of chemical fertilizers and organic manures. Significant reduction in bulk density with increase in water holding capacity under treatments which received N through organic sources in sequence cropping was reported by Sharma and Gupta (1998) and Gattani *et al.* (1976). Ismail *et al.* (1998) also observed significant decrease in bulk density (1.21 to 1.15 Mg m^{-3}) with the application of FYM @ 30 Mg ha^{-1} over control.

Surekha and Rao (2009) studied the bulk density under direct and residual effects of organic sources on soil quality of Vertisols at Hyderabad for three years and reported that bulk density was significantly reduced due to the continuous application of organic amendments. Continuous application of balanced fertilization along with organics significantly reduced bulk density under NPK levels over control but did not differ among other treatments by Selvi *et al.* (2005).

Table 8. Effect of tillage and IPNS on bulk density of soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		BD (Mg m ⁻³)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		1.32	1.31
	Set II -Conventional tillage		1.34	1.33
	SE(m)±		0.007	0.005
	CD at 5 %		0.021	0.013
	(b) Integrated plant nutrients system			
	Soybean	Cotton		
T ₁	Control	Control	1.36	1.36
T ₂	100 % RDF	100 % RDF	1.35	1.35
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	1.29	1.27
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	1.35	1.33
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	1.33	1.32
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	1.34	1.33
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	1.32	1.31
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	1.34	1.33
	SE(m)±		0.013	0.010
	CD at 5 %		0.039	0.032
	Initial (2010-11)		1.38	
	(c) Interaction		NS	NS

Addition of crop residues with application of 50 % N through FYM + remaining RD through chemical fertilizer, 50% N through WS+ remaining RD through chemical fertilizer and use of 50% N through GLM + remaining RD through chemical fertilizer showed decreasing bulk density from previous year. Bharambe *et al.* (1999) also reported that crop residue of *kharif* grown sorghum stalk incorporation was more effective in decreasing bulk density of soil. When the crop residues decompose, the humified fraction of soil helped in improving the soil structure and tilth, thereby, increasing the aeration and aggregation, this in turn, reduced the bulk density of soil. The decreasing trend in soil bulk density by amending the soil with crop residues was also observed by Badanur *et al.* (1990) and Kharche *et al.* (2010) in Vertisol. It is indicated that incorporation of decomposed crop residues, green manuring and FYM in soil could be more effective in reducing bulk density. Such a soil conditions can be beneficially used to great extent in optimizing the response of fertilizer application *vis-a-vis* raising the soil and crop productivity.

Interaction

The interaction between tillage and Integrated plant nutrients system (IPNS) on bulk density in soybean and cotton rotation was non significant.

4.1.1.2 Hydraulic conductivity

Data pertaining to hydraulic conductivity of soil under tillage and integrated plant nutrients system (IPNS) after harvest of soybean and cotton rotation are presented in Table 9 and depicted in Fig 4. Effect of tillage on hydraulic conductivity was varied significantly among in conservation and conventional tillage (0.71 and 0.78 cm hr⁻¹) in soybean and cotton rotation respectively. The hydraulic conductivity varied from 0.65 to 0.76 cm hr⁻¹ during start of the experiment (annexure III (C)). However it varied from 0.67 to 0.78 cm hr⁻¹ after harvest of soybean (2016-17) and 0.68 to 0.80 cm hr⁻¹ after harvest of cotton (2017-18).

Effect of Tillage

The effect of tillage on hydraulic conductivity was significant. Significantly higher value of hydraulic conductivity was recorded in

conservation tillage (0.76 cm hr^{-1}) as compared to conventional tillage (0.71 cm hr^{-1}) after harvest of soybean and it was (0.72 cm hr^{-1}) as compared to conservation tillage (0.78 cm hr^{-1}) after harvest of cotton. This might be due to the ploughing and harrowing in conventional tillage because of which the soil become loose and porous which may result into downward movement of water there by increasing the hydraulic conductivity of soil.

Effect of integrated plant nutrient system

The hydraulic conductivity of soil was significantly influenced by IPNS. The highest hydraulic conductivity was recorded with the application of 50 % N through FYM and remaining RD through chemical fertilizer (0.78 cm hr^{-1}) followed by addition of 50 % N through glyricidia green leaf manuring and remaining RD through chemical fertilizer and 100 % N through phoshpocompost and remaining RD through chemical fertilizer which was significantly at par with each other and over the control during (2016-17) under soybean. These treatments found beneficial in increasing hydraulic conductivity over the other treatments. Lowest hydraulic conductivity was observed control (0.67 cm hr^{-1}). The treatments devoid of organic manure and crop residues resulted in to lesser accumulation of organic matter in the soil, leading to comparatively poor soil physical condition.

It is well known that the better aggregation and increased porosity as consequence of addition of organics have favourable influence on physical properties such as hydraulic conductivity which influences the soil water dynamics. Improvement in hydraulic conductivity due to organics in combination with inorganic as compared to inorganic alone was reported by Rajkankan *et al* (2001). Singh and mannika (2000) also reported significant improvement in hydraulic conductivity due to application of FYM. Apart from manures and form of fertilizer, nature of crops also influenced the hydraulic conductivity. Soybean through its leaf litter might have been significantly contributed in improvement of hydraulic properties of soil. The green manuring were also found beneficial for improving hydraulic conductivity in both years which can be attributed to the biomass added to the soil which helps in improving water transmission characteristics of soil. Similarly the results are in consequences with many past studies which reported the

Table 9. Effect of tillage and IPNS on hydraulic conductivity of soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Hydraulic conductivity (cm hr ⁻¹)	
			Soybean	Cotton
	(a)Tillage			
	Set I-Conservation tillage		0.76	0.78
	Set II -Conventional tillage		0.71	0.72
	SE(m)±		0.009	0.005
	CD at 5 %		0.027	0.016
	(b) Integrated plant nutrients system			
	Soybean	Cotton		
T ₁	Control	Control	0.67	0.68
T ₂	100 % RDF	100 % RDF	0.71	0.72
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	0.78	0.80
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	0.76	0.79
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	0.77	0.80
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	0.72	0.76
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	0.73	0.76
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	0.76	0.77
	SE(m)±		0.018	0.010
	CD at 5 %		0.056	0.030
	Initial (2010-11)		0.66	
	(c) Interaction		NS	NS

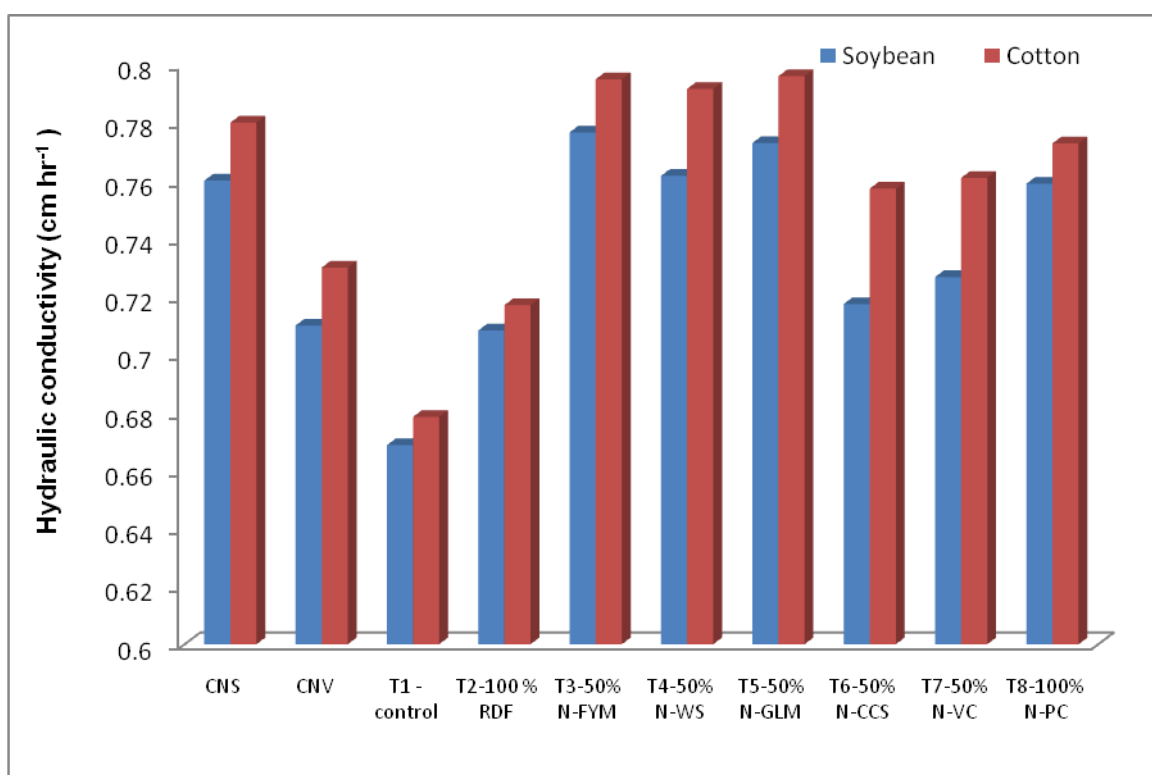


Fig. 4. Effect of tillage and IPNS on hydraulic conductivity of soil after harvest of soybean and cotton

beneficial effect of different organics such as FYM, crop residues and green manuring on hydraulic conductivity (Bellakki and Badanur 1997, Malewar *et al.* 1998, Babhulkar *et al.* 2000, Ray and Gupta *et al.* 2001, Reddy *et al.* 2002, Selvi *et al.* 2005).

Further, incorporation of organics in soil increases the population of earthworms than inorganic fertilizers and high levels of organic matter accumulation seemed to be responsible for enhanced saturated hydraulic conductivity reported by (Prasad and Power, 1991). By and large, it could be seen that increase in hydraulic conductivity by addition of crop residues in combination with 50 per cent recommended dose of fertilizers attributed to modified soil structure, proportion of macrospores and aggregate stability, which might have helped in enhancing hydraulic conductivity of the soil (Katkar *et al.* (2008). Many research workers have reported earlier that, incorporation of wheat straw @ 5 t ha⁻¹ (Reddy, 1997), green manuring with sunhemp in loamy sand (Ghuman *et al.* 1997), crop residues in Vertisol (Bellakki *et al.* 1998; Bellakki and Badanur, 2000; Bharambe *et al.*, 2001, Marathe and Bharambe, 2005) significantly enhanced the hydraulic conductivity of the soil.

The data regarding hydraulic conductivity under cotton crop revealed that the highest hydraulic conductivity (0.80 cm hr⁻¹) was recorded with the application of 50 % N through FYM and remaining RD through chemical fertilizer followed by 50 % N through glyricidia green leaf manuring and remaining RD through chemical fertilizer and 100 % P through phoshpocompost+ remaining N through chemical fertilizer which was statistically at par with each other and significantly superior over the control. Lowest hydraulic conductivity (0.68 cm hr⁻¹) was observed in control and 100% RDF. Application of FYM and fertilizers had favourable effect on the hydraulic conductivity of soil (Patnaik *et al.* 1989).

The significant decrease in bulk density resulted into increase in hydraulic conductivity of soil due to integrated use of FYM and chemical fertilizers. Beleker *et al.* (1995) also reported that saturated hydraulic conductivity were significantly higher under the use of FYM, green manure and wheat straw over 100 % NPK through fertilizer. The improvement in

hydraulic conductivity may be due to significant change in soil pore geometry. These results are in conformity with the findings reported by Laddha and Totawat (1997), Rajkanan *et al.* (2001) and Reddy *et al.* (2002).

Interaction

The Interaction between tillage and integrated plant nutrients system (IPNS) on hydraulic conductivity was non significant (Table 2). It was also interesting to note that the hydraulic conductivity was significantly higher under conservation tillage with FYM, glyricidia green manuring and phoshpocompost, vermicompost and crop residues.

4.1.1.3. Mean weight diameter

The data in respect of mean weight diameter (MWD) under different treatments are presented in Table 10 and depicted in Fig 5. The mean weight diameter varied from 0.61 to 0.70 mm (annexure III (C)) before sowing of *kharif* soybean in (2016-17).

Effect of Tillage

The mean weight diameter was significantly influenced by tillage. However, in the first year significantly higher MWD were recorded in conservation tillage (0.68 mm) as compared to conventional tillage (0.65 mm). In the second year higher values of MWD were recorded in conservation tillage (0.69 mm) as compared to conventional tillage (0.66 mm). Increased intensity of tillage due to higher input of energy decreased mean weight diameter. Lal *et al.* (1989) observed that the higher organic matter content and lack of mechanical disturbance in no-tillage may be responsible for relatively higher aggregation. These findings are in accordance with Mohanty and Painuli (2003) reported that, the tillage practices decreases the mean weight diameter of the soil. He *et al.* (2009) reported that conservation tillage contained more macro-aggregates (13-37%) and micro-aggregates (25-59%) and increases water storage than traditional tillage while, Mikha and Rice (2004) indicated that greater amount of macro aggregates was present in no tillage and minimum tillage when compared with conventional tillage.

Effect of integrated plant nutrient system

The effect of different integrated plant nutrients system (IPNS) on MWD of soil under soybean during (2016-17) was significant. The mean weight diameter of soil varied from (0.62 mm to 0.72 mm) after harvest of soybean. Higher value of MWD recorded in application of 50 % N through FYM + remaining RD through chemical which was significantly superior over remaining treatments followed by 100 % N through Phosphocompost + compensation RD by chemical fertilizer and 50 % N through vermicompost + remaining RD through chemical fertilizer. The lowest mean weight diameter was recorded in control. It was also observed that application of inorganic fertilizers along with 50 % N compensate FYM during *kharif* season caused beneficial effect on MWD. The increase in MWD in FYM applied plots could mainly be due to the results of basal application of FYM, which significantly improved the soil aggregation (Bhatia and Shukla, 1982 and Selvi *et al.* 2005, Hati *et al.* 2007). This may be ascribed to the improvement in physical condition of soil and to the increased organic carbon content which might be responsible for stabilization of aggregates and hence higher mean weight diameter with the application of only organics, FYM and inorganic fertilizers. This observation is in conformity with the findings of Rasool *et al.*, (2008).

Thus, addition of FYM in combination with NPK fertilizers improved the water movement in fine textured soils through the formation of larger water stable aggregates, while it reduced the water movement in coarse-textured soil through reduction in non capillary porosity, thereby moderating both the adverse soil conditions.

The mean weight diameter of aggregates ranged from (0.62-0.74 mm) under cotton (2017-18). The highest mean weight diameter (0.74 mm) was observed in the treatment of 50 % N through FYM + remaining RD through chemical which was significantly higher over remaining treatments followed by 100 % P through phosphocompost + remaining N through chemical fertilizer and 50 % N through vermicompost + remaining RD through chemical fertilizer which was found at par with each other. The highest MWD was observed in application of only organics i.e. FYM and Phosphocompost followed by Vermicompost during the both years. This increase in mean weight diameter was also due to continuous addition of FYM

Table 10. Effect of tillage and IPNS on mean weight diameter of soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		MWD (mm)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		0.68	0.69
	Set II -Conventional tillage		0.65	0.66
	SE(m)±		0.007	0.006
	CD at 5 %		0.019	0.018
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	0.62	0.62
T ₂	100 % RDF	100 % RDF	0.63	0.64
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	0.72	0.74
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	0.64	0.65
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	0.67	0.68
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	0.65	0.66
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	0.68	0.69
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	0.71	0.73
	SE(m)±		0.013	0.012
	CD at 5 %		0.039	0.036
	Initial (2010-11)		0.61	
	(c) Interaction		NS	NS

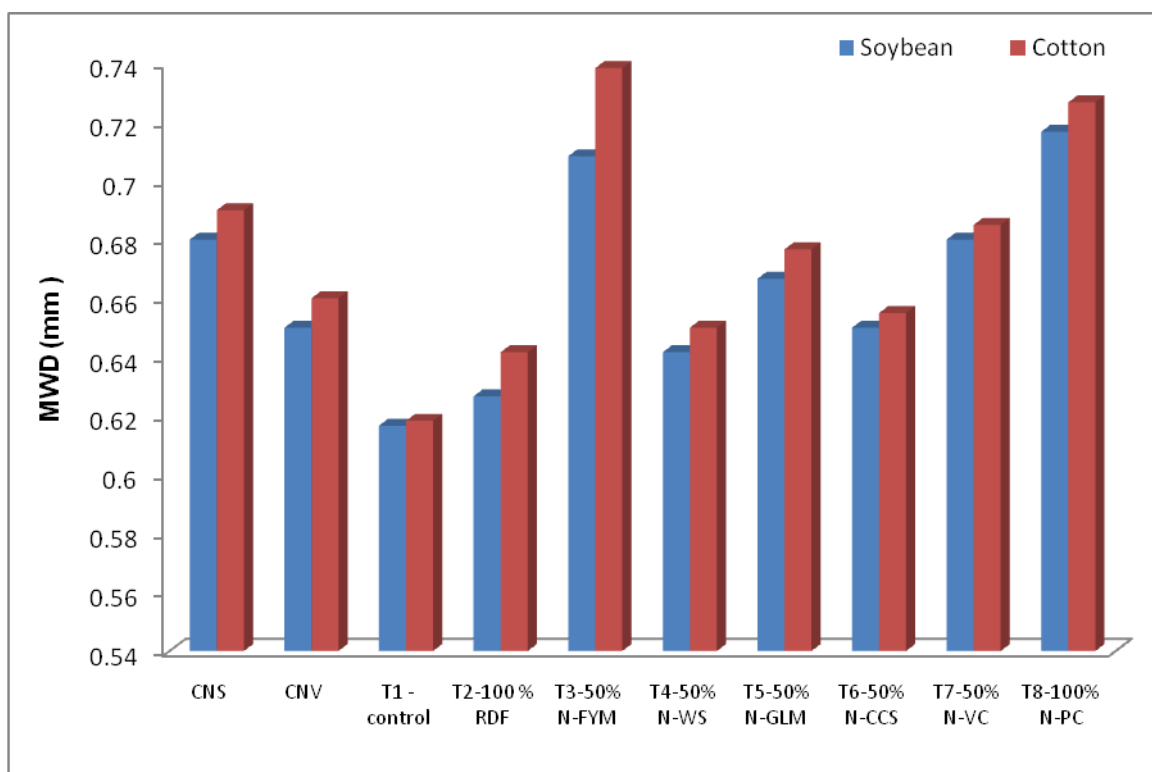


Fig. 5. Effect of tillage and IPNS on Mean weight diameter of soil after harvest of soybean and cotton

and Phospocompost during *kharif* season which improved physical condition of soil.

In the present study the enhancement was observed in MWD due to use of green manures, crop residue and FYM indicates aggregative effect of these practices on soil which will be of more helpful in subsequent years. The added organics could supply additional fresh organic residues (water soluble and hydrolysable substrates) and carbon to the soil resulting in the production of microbial polysaccharides that increase aggregate cohesion, which could explain the progressive increase in aggregate stability to mechanical breakdown. The structure especially in black clayey smectitic soils is considerably hard and many times moderate to coarse in the form of large hard clods. The continuous application of only chemical fertilizers did not show much improvement in the MWD in the long run indicating an immense need of organics to improve such an important soil physical property which is reflected in the IPNS.

The increased soil aggregation might be due to the cementing effect of humic substances produced from the organic matter in soil. The results are in consensus with many past studies which reported the beneficial effect of different organics such as FYM, crop residue and green manuring on MWD. Similar results were reported by Lal and Mathur (1989) and Selvi *et al.* (2005).

Interaction

The Interaction between tillage and IPNS on MWD was non significant during both the year of the experimentation.

4.1.1.4. Soil moisture

Moisture content is largely depends on climatic factors i.e. rainfall pattern, rate of PET and storage in soil. Soil moisture content at critical growth stages of soybean – cotton rotation in surface soil and Tables are presented in Annexure III (E) and (F) and graphically depicted in Fig.6 to Fig. 7.

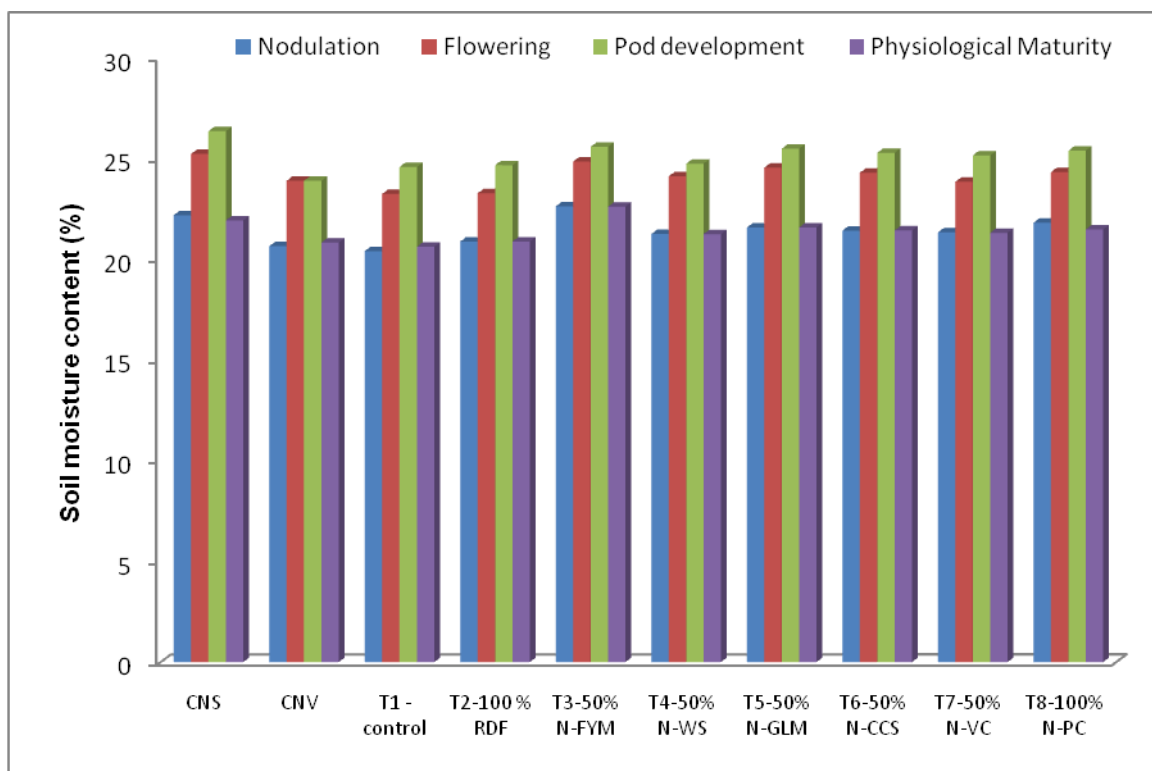


Fig. 6. Effect of tillage and IPNS on Soil moisture content of soil at critical growth stages of soybean

Effect of Tillage

The effect of tillage on soil moisture content was significant. However, numerically higher value of soil moisture was recorded in conservation tillage at all critical growth stages of soybean and cotton as compared to conventional tillage. Similar results were reported by Gulad *et al.*, (2002) , Mohanty and Painuly (2003) , Mehdi *et al.*, (2016), Qamar *et al.* (2015) and Salahin *et al.* , (2017).

Effect of integrated plant nutrient system

The data on effect of different nutrient management practices on moisture content at critical growth stages under soybean crop is presented in annexure III (H). At sowing time, pod development stage and at harvest stage showed non significant results. However, the soil moisture content was influenced significantly at flowering stage of soybean. Significantly higher soil moisture content (24.86 %) was recorded with the application of 50 % N through FYM + remaining RD through chemical and was found significantly superior over rest of the treatments followed by 50 % N through glyricidia green leaf manure + remaining RD through chemical (24.55 %), 100 % N through phoshpocompost+ remaining P through chemical fertilizer (24.33 %), and 50 % N through vermicompost + remaining RD through chemical (23.85 %). Lowest moisture content observed under 100% RDF (23.28%) and control (23.25%). Similar significant improvement results were observed at nodulation and physiological maturity stage of soybean crop. Due to application of FYM, GLM and Phospocompost there was significantly improvement in soil moisture content this might be due to decomposed organic material having capacity to increase maximum water holding capacity and moisture retention of soil (Khiani and More 1984, Bharadwaj and Omanwar 1992).

The moisture content irrespective of critical growth stages of cotton did not have consistent trend. The effect of different nutrient management practices on moisture content at critical growth stages of cotton is given annexure III (I) , The various nutrient management practices did not showed significant effect on moisture content at sowing, 50 % boll bursting and after last picking stage. However, moisture content was significantly influenced with different treatments at square formation, flowering and boll

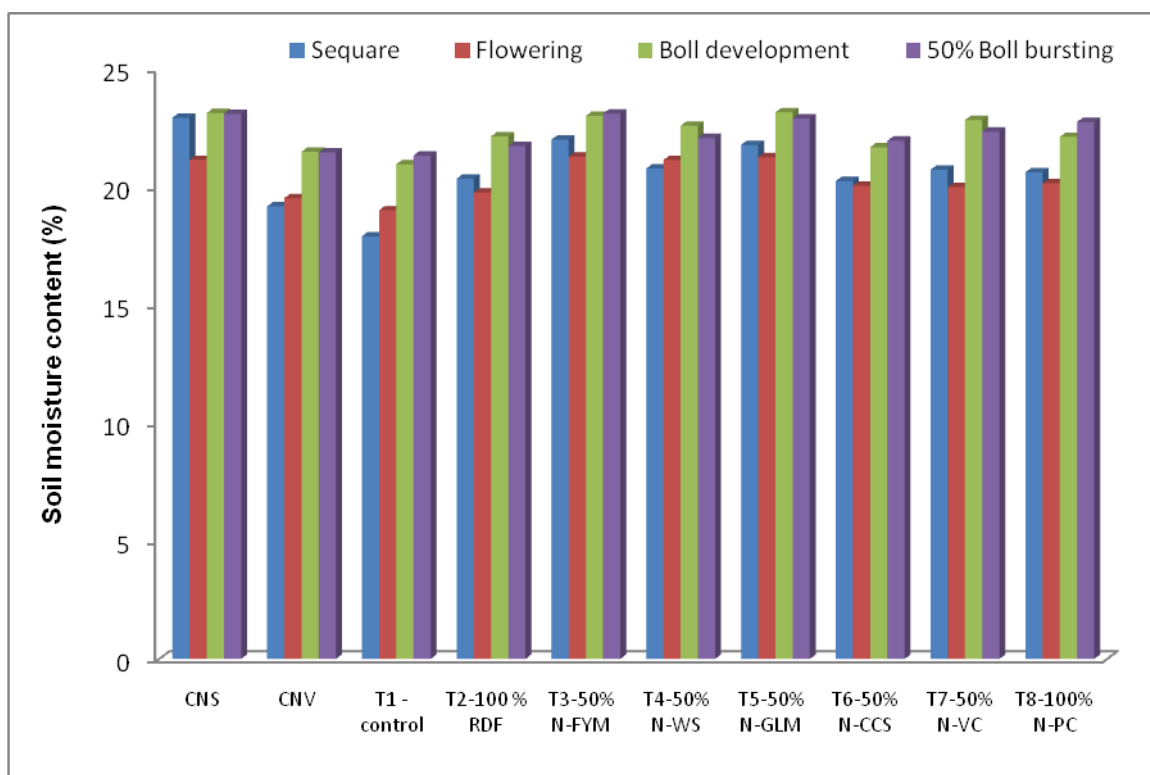


Fig. 7. Effect of tillage and IPNS on Soil moisture content of soil at critical growth stages of cotton

development stage. The application of 50 % N through FYM + remaining RD through chemical helped in maintaining relatively higher moisture containing at square formation (22.01%), flowering (21.29 %) and boll development stage (23.57%) and was significantly superior over rest of the treatments followed by 21.79 %, 20.26 % and 23.16 % with the application of 100 % P through phosphocompost + remaining N through chemical fertilizer. Lowest soil moisture content observed under 100 % RDF and control at all the critical growth stages of cotton.

Application of organics increased the soil moisture content, bio mulching with cowpea, green gram and sunhemp conserved soil moisture to the extent of 12.8, 10.6 and 11.3 % at flowering stage and 7.72, 10.10 and 8.71 at harvesting stage as reported by Wankhade *et al.* (2001), Solaiappan *et al.* (1999). Also, Gurav *et al.* (2006) reported that application of 50 % RDF + 50 % N through FYM alone or along with 2 % urea spray at flowering and 2 % DAP at boll development stage recorded maximum moisture content. Whereas, application of RDF alone or along with foliar spray of 2 % urea at flowering + spray of 2 % DAP at boll development stage recorded minimum moisture percentage.

Interaction

The Interaction between tillage and IPNS on soil moisture content was non significant annexure III (H) and (I). The conservation tillage helps to store the moisture over conventional tillage during both the year. Among two crops, the higher moisture content was observed under soybean as compared to cotton this might be due to canopy and plant density which helps to improving moisture content.

4.1.2 Chemical properties

4.1.2.1 Soil pH

Soil reaction (pH) is most important chemical characteristics of soil that influences physical, chemical and biological properties of soil and also important factors for nutrient availability.

Effect of Tillage

The influence of tillage pH of soil was non significant (Table 11). The pH of soil slightly reduces due to tillage treatments. The initial values of soil pH values before start of the experiment in 2015-16 (annexure III (C)) varied from 8.11 to 8.17 in conservation and conventional tillage. During first year, the pH of soil noticed 8.09 in conservation and conventional tillage (8.13). During second year, the pH of soil was significantly influenced by tillage treatments. The lowest pH was observed in conservation tillage (8.08) as compared to conventional tillage (8.12). Similar results were reported by Dalal *et al* (1989).

Effect of integrated plant nutrient system

The effect of integrated plant nutrients system (IPNS) on pH of soil was non significant. It was observed that there was reduce in pH among treatments with conjunctive use of organics and chemical fertilizers over a period of two years due to organic history of the experiment. The pH of soil ranged from 8.01 to 8.18 under soybean during 2016-17, which could be attributed to the buffering effect caused due to organic matter and secondly due to pH the high buffering capacity of the clayey soil. Lokhare (1980) studied the effect of various levels of FYM and NPK fertilizers alone and in combination for 15 years on black soils and found that the long term use of FYM and fertilizers caused slight decrease in pH due to FYM. Similar findings were reported by Sujata *et.al* (2007) on Vertisol. Jain *et.al* (2005) also reported soil pH did not deviated much from its initial value under the application of FYM @ 10 tonnes ha⁻¹ to soybean under soybean-wheat system in hill zone of Madhya Pradesh.

The similar trend in pH of soil was also observed in succeeding cotton crop where pH of soil ranged between 7.99 to 8.15 respectively, during 2017-18. There was no significant variation among treatment due to addition of amendments. However, Ismail *et al*. (1998) observed a significant reduction (8.07 to 7.99) in pH value of Vertisol with application of FYM @ 30 Mg ha⁻¹ over control within one year.

Table 11. Effect of tillage and IPNS on pH of soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		pH	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		8.09	8.08
	Set II -Conventional tillage		8.13	8.12
	SE(m)±		0.05	0.08
	CD at 5 %		NS	NS
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	8.18	8.15
T ₂	100 % RDF	100 % RDF	8.11	8.09
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	8.01	7.99
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	8.13	8.11
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	8.06	8.07
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	8.12	8.11
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	8.14	8.13
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	8.14	8.12
	SE(m)±		0.35	0.16
	CD at 5 %		NS	NS
	Initial (2010-11)		8.10	
	(c) Interaction		NS	NS

There was decreasing in pH recorded with application of 100 per cent RDF (8.09) which might be due to addition of large amount of leaf litter biomass. Prasad and Power (1991) noticed slight decrease in soil pH with the treatments where crop residues were incorporated in combination with 50 to 75 per cent inorganic fertilizers. Leaving crop residues on the soil surface reduced the soil pH, organics, crop residue or plant parts contain large amount of organic nitrogen such as proteins and amino acids, which mineralizes to nitrate in soil producing protons during nitrification and hence acidifying the soils (Kumar and Gosh, 2000). Similar observations were also reported earlier by Katkar *et al.* (2006), Kumar *et al.* (2008) and Rao and Janawade (2009) who has reported that soil pH and electrical conductivity reduced slightly with the application of FYM, crop residue and green manure. Application of FYM along with chemical fertilizer slightly reduces the soil pH with increasing level of FYM. The acidifying effect of urea and organic acids produced during the course of decomposition of organic amendments is a well known fact and established through a large number of experimentation.

Interaction

The Interaction between tillage and integrated plant nutrients system (IPNS) in respect of soil pH was non significant.

4.1.2.2 Electrical conductivity

The electrical conductivity (EC) is most important chemical characteristics of soil that influences physical, chemical and biological properties of soil and also important factors for nutrient availability. The electrical conductivity of soil varied from 0.31 to 0.36 during 2015-16. However, it varied from 0.29 to 0.34 and 0.27 to 0.33 dS m⁻¹ during first year and second year respectively.

Effect of Tillage

The EC of soil was significantly influenced by tillage practices (Table 12). Among two tillage practices, the lower EC was noted in conservation tillage (0.31 dS m⁻¹) followed by conventional tillage (0.33 dS m⁻¹.) During second year the EC of soil was significantly influenced by tillage treatments. The significantly lower EC was observed in conservation tillage

(0.29 dS m⁻¹) as compared to conventional tillage (0.32 dS m⁻¹). Similar results were reported by Dalal *et al* (1989).

Effect of integrated plant nutrient system

It was also observed that, the differences of electrical conductivity among the different IPNS treatments were significant, electrical conductivity varied from 0.29 to 0.34 dS m⁻¹ under soybean. The significantly lowest EC (0.29 dS m⁻¹) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer followed by 50% N through GLM + remaining RD through chemical fertilizer (0.30 dS m⁻¹) and 100% N through phosphocompost + remaining RD through chemical fertilizer (0.30 dS m⁻¹) which were found to be at par with each other. The electrical conductivity of soil was significantly influenced by nutrient management. The lowest EC was observed with 50% N through FYM + 50 % RDF which was at par with all treatments except control, 100% RDF and 50 % N through composted cotton stalk + remaining RD through chemical fertilizer.

The effect of integrated plant nutrients system (IPNS) on electrical conductivity was significant after harvest of cotton. The significantly lowest EC (0.27 dS m⁻¹) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer followed by 50% N through GLM + remaining RD through chemical fertilizer (0.28 dS m⁻¹) and 100 % P through phosphocompost + remaining N through chemical fertilizer (0.29 dS m⁻¹) which were found at par with each other. Highest EC was recorded in control. Similar reduction in EC was also observed by Tyagi and Bharadwaj (1994) due to continuous use of manures and fertilizer. Similar observations were also reported earlier by Prasad and Power (1991) and observed that leaving crop residues on the soil surface reduced the soil EC. Organics and crop residue or plant parts contain large amount of organic nitrogen such as proteins and amino acids, which mineralizes to nitrate in soil producing protons during nitrification and hence acidifying the soils observed by (Kumar and Gosh, 2000). Similar observations were also reported earlier by Katkar *et al*. (2006) and Kumar *et al*. (2008). Rao and Janawade (2009) reported that pH and EC reduced slightly with application of FYM, crop residue and green manure.

Table 12. Effect of tillage and IPNS on electrical conductivity of soil after harvest of soybean and cotton under soybean-cotton rotation

Treatments		Electrical conductivity (dS m ⁻¹)	
(a)Tillage		Soybean	Cotton
Set I-Conservation tillage		0.31	0.29
Set II -Conventional tillage		0.33	0.32
SE(m)±		0.012	0.008
CD at 5 %		0.034	0.023
(b) Integrated plant nutrient system			
	Soybean	Cotton	
T ₁	Control	Control	0.34 0.35
T ₂	100 % RDF	100 % RDF	0.34 0.36
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	0.29 0.27
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	0.30 0.30
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	0.30 0.28
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	0.34 0.33
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	0.33 0.32
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	0.30 0.29
SE(m)±		0.024	0.016
CD at 5 %		0.068	0.047
Initial (2010-11)		0.29	
(c) Interaction		NS	NS

Similar results were also noticed by Kaur *et.al*, (2008) that application of organic and inorganic amendments increase electrical conductivity initially but decrease the same subsequently due to creation of favourable soil physical condition.

Interaction

The Interaction between tillage and integrated plant nutrients system (IPNS) on soil EC was non significant during both the year.

4.1.2.3. Organic carbon

Soil organic carbon dynamics is of paramount importance for sustaining long term soil quality and productivity under intensive cropping. It is also a storehouse of all essential plant nutrients and provides energy material for the soil organism. The data pertaining to organic carbon as influenced by tillage and IPNS are presented in Table 13 (a) and Fig 8.

Effect of Tillage

The effect of tillage on organic carbon content was found significant. However, slightly higher values of organic carbon (6.00 g kg^{-1}) were observed in conservation tillage as compared to conventional tillage (5.80 g kg^{-1}) in the first year. Higher values of organic carbon (6.04 g kg^{-1}) were observed in conservation tillage as compared to conventional tillage (5.83 g kg^{-1}) in the second year. Conservation tillage helps in leaving crop residues to accumulate on the soil surface and increase carbon sequestration by reducing oxidation of SOC in soil as compared to conventional tillage.

The significant increase organic carbon content under conservation tillage can be attributed to less disturbance of the soil which might have helped in preservation of more carbon in soil reducing oxidation of carbon. Novak *et al.* (2009) noticed conservation tillage increases the soil organic carbon as compared to disc tillage system. Sainju *et al.* (2009) concluded that no tillage increases organic carbon in soil as compared to tilled plot.

Effect of integrated plant nutrient system

The soil organic carbon content varied from 5.28 to 6.27 and 5.32 to 6.31 g kg^{-1} during first and second year respectively. Further, it was observed that the organic carbon significantly influenced due to different IPNS

treatments during the both year of investigation. Application of 50 % N through FYM + remaining RD through chemical fertilizer recorded significantly more organic carbon content in soil (6.27 g kg^{-1}) after harvest of soybean followed by 50 % N through GLM + remaining RD through chemical fertilizer and application of 100 % N through phosphocompost + remaining RD through chemical fertilizer which were found to be on par with each other than that of treatments receiving inorganic fertilizers and control.

In next year, after harvest of cotton crop in *kharif* (2017-18) the organic carbon content as influenced by various treatments under soybean-cotton rotation revealed that the organic carbon varied from 5.32 to 6.31 g kg^{-1} . There was quite higher increase in organic carbon in all the treatment except that control and 100 % RDF during second year as compared to first year. Higher organic carbon (6.31 g kg^{-1}) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer followed by (6.21 g kg^{-1}) application of 50 % N through GLM + remaining RD through chemical fertilizer and (6.09 g kg^{-1}) application of 100 % P through phosphocompost+ remaining N through chemical fertilizer which were found to be on par with each other than that of treatments receiving inorganic fertilizers and control.

However, the conjoint use of chemical fertilizers with FYM, glyricidia green manure and phosphocompost were found beneficial for maintaining organic carbon content compared to the use of only chemical fertilizers. The increase in organic carbon content under integrated use of chemical fertilizers and organic manure treatments might have been due to direct incorporation of organic matter, better root growth and more plant residues addition. The treatments of organics also recorded higher organic carbon in comparison to 100 % RDF, which is due to the use of fertilizer and organics, which helped in higher contribution of biomass to soil in the form of greater root biomass through crop stubbles and residues. The subsequent decomposition of these materials might have resulted into enhanced organic carbon content of soil.

Table 13 a.Effect of tillage and IPNS on organic carbon of soil after harvest of soybean and cotton under soybean-cotton rotation

Treatments			Organic carbon (g kg ⁻¹)	
(a)Tillage			Soybean	Cotton
Set I-Conservation tillage			6.00	6.04
Set II -Conventional tillage			5.80	5.83
SE(m)±			0.04	0.05
CD at 5 %			0.12	0.14
(b) Integrated plant nutrients system				
	Soybean	Cotton		
T ₁	Control	Control	5.28	5.32
T ₂	100 % RDF	100 % RDF	5.62	5.66
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	6.27	6.31
T ₄	50% N through WS + remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	5.81	5.96
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	6.11	6.21
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	5.75	5.80
T ₇	50 % N through vermicompost + remaining RD through chemical fertilizer	50 % N through vermicompost + remaining RD through chemical fertilizer	5.90	5.92
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	6.03	6.09
SE(m)±			0.08	0.09
CD at 5 %			0.23	0.27
Initial (2010-11)			5.40	
(c) Interaction			Sig	Sig

Table 13 b: Interaction of tillage and IPNS on organic carbon of soil after harvest of soybean and cotton

IPNS	Organic carbon (g kg ⁻¹)					
	Soybean			Cotton		
	CNS	CNV	Mean	CNS	CNV	Mean
Control	5.35	5.21	5.28	5.39	5.25	5.32
100 % RDF	5.68	5.59	5.62	5.71	5.61	5.66
50 % N through FYM + remaining RD through chemical fertilizer	6.37	6.17	6.27	6.47	6.34	6.31
50% N through WS+ remaining RD through chemical fertilizer	5.94	5.66	5.81	6.05	5.87	5.96
50% N through GLM + remaining RD through chemical fertilizer	6.19	6.02	6.11	6.34	6.08	6.21
50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	5.88	5.62	5.75	6.00	5.60	5.80
50 % N through vermicompost+ remaining RD through chemical fertilizer	5.96	5.86	5.90	6.10	5.73	5.92
100 % N through phoshpocompost + remaining P through chemical fertilizer for soybean /100 % P through phoshpocompost + remaining N through chemical fertilizer for cotton	6.17	5.93	6.03	6.19	5.98	6.09
Mean	6.00	5.80	-	6.04	5.83	
	Tillage	NM	Int.	Tillage	NM	Int.
SE (m) ±	0.04	0.08	0.12	0.05	0.09	0.13
CD (at 5%)	0.12	0.23	0.34	0.14	0.27	0.38
Initial (2010-11)	5.40					

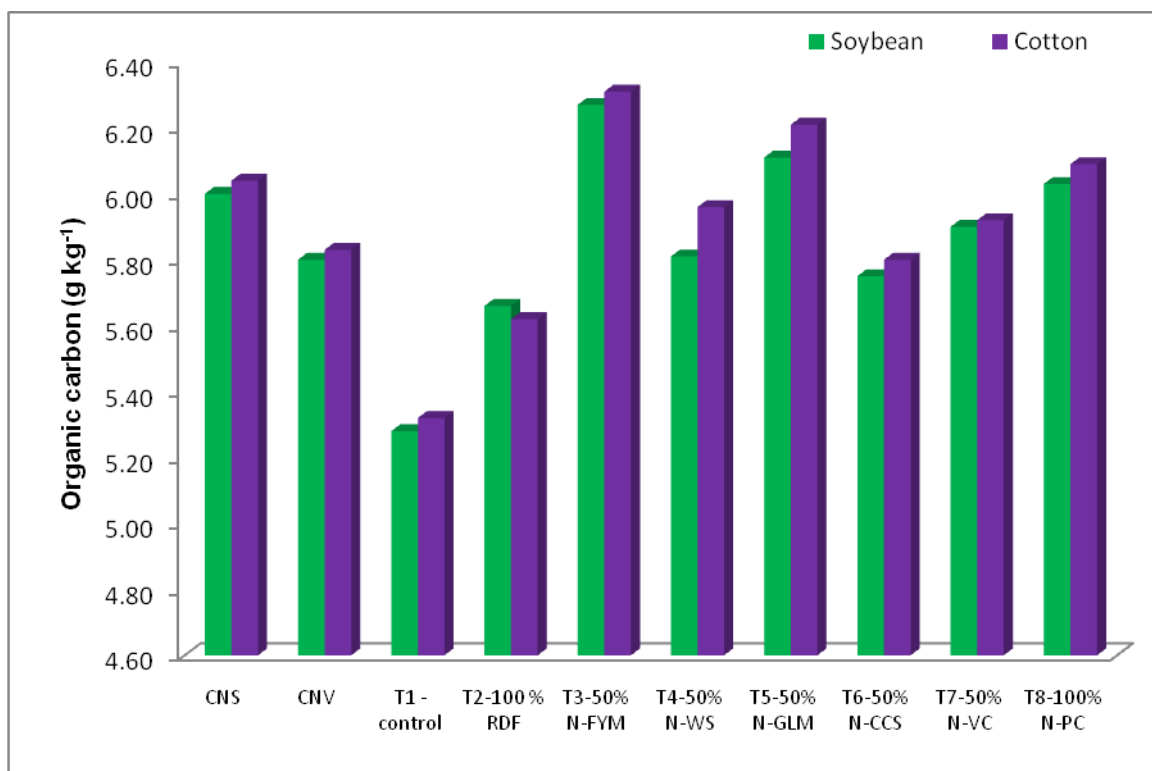


Fig. 8. Effect of tillage and IPNS on Organic carbon of soil after harvest of soybean

Ravankar *et al.* (2005) reported that, the highest organic carbon was found in the plot receiving inorganic fertilizers in combination with organics under sorghum-wheat cropping sequence in Vertisols in the long-term fertilizer experiments. Prakash *et al.* (2002) also reported an increase in organic carbon content of the soil with the addition of FYM @ 9.0 Mg ha⁻¹, 7.5 Mg ha⁻¹ FYM + 50% NP and vermicompost, respectively. The effect of crop residues on organic carbon content was strongly related to the amount of residue added and weakly related to type of residue added (Kumar and Gosh, 2000).

The build up of soil organic carbon as a result of combined application of manures and fertilizers supported the earlier findings of Chaudhary *et al.* (1981), Bellaki and Badanur (1997), Verma and Mathur (2009), Surekha and Rao (2009), Vineela *et al.* (2008), Mishra *et al.* (2008), Masto *et al.* (2007). In which they have reported significant increase in organic carbon with the application of FYM or green manuring in combination with chemical fertilizer as compared to RDF.

Interaction

Interaction between tillage and IPNS was found significant during both the years of experimentation (Table 13 (b)). In the first year the interaction among the conservation tillage practice the application of 50 % N through FYM + remaining RD through chemical fertilizer (6.37 g kg⁻¹) recorded significantly highest values followed by 50% N through GLM + remaining RD through chemical fertilizer (6.19 g kg⁻¹), and 100 % N through phosphocompost + remaining P through chemical fertilizer (6.17 g kg⁻¹). These values were found on par with each others. In the second year significantly higher values of available organic carbon (6.47 g kg⁻¹) was observed in conservation tillage in combination with 50 % FYM+ remaining RD through chemical fertilizer, followed by 50% N through GLM + remaining RD through chemical fertilizer (6.34 g kg⁻¹), and 100 % P through phosphocompost + remaining N through chemical fertilizer (6.19 g kg⁻¹). These values were found on par with each others. However, the lowest organic carbon was recorded in the treatment combination conventional tillage and control during both the years of study indicating only application of inorganic fertilizers could not sustain to enhance the SOC status of soil.

Hence, there is need to follow conservation tillage in Vertisols along with integrated nutrient management.

4.1.2.4 Available nutrients

The available nutrients should be optimally allocated among the crops to get maximum returns by allowing optimization of nutrient production functions which relate the crop responses to applied nutrients under given soil climate especially rainfall and management factors. Nitrogen (N) is generally considered to be a major limiting factor (low soil N status) and is usually applied in sufficient amounts to meet the crop needs. Mineralization-immobilization processes in soil affect the availability of N to the crop. High C/N ratios and lignin contents cause slow mineralization of cotton crop residues.

4.1.2.4.1 Available nitrogen

The data pertaining to the available nitrogen as influenced by tillage and various treatments of IPNS are presented in Table 14 (a) and depicted in Fig 9. The initial available nitrogen content was varied from 202.4 to 235.7 kg ha⁻¹ annexure III (C).

Effect of Tillage

The data in respect of available nitrogen as influenced by tillage was found to be significant. Available nitrogen was recorded significantly higher in conservation tillage (233.4 kg ha⁻¹) as compared to conventional tillage (220.4 kg ha⁻¹). While the available nitrogen during second year was also found significantly higher in conservation tillage (240.4 kg ha⁻¹) as compared to conventional tillage (230.9 kg ha⁻¹). Similar observations were reported by Dick (1983). The higher availability of nitrogen was recorded by Khiani and More (1984), due to harrowing than ploughing in Vertisol due to enhanced, decomposition process and mineralization of the nutrients in the soil. Improved nitrogen status after harvest of crop was due to addition of biomass which was stayed long period under conservation tillage

On the contrary, the nitrogen in the soil was conserved under conservation tillage due to less disturbance of soil. Similarly, the highest nitrogen recorded under conservation tillage because of less mechanical disturbance of soil. There is accumulation of significant quantity of organic

carbon in soil which is positively correlated with available nitrogen of the soil. Dick (1983) reported greater amount of nitrogen under no-tilled surface (0-30 cm) soil compared to minimum and conventional tillage. Khiani and More (1984) observed through a long term experiment that available nitrogen was higher due to harrowing (85.4 kg ha^{-1}) than ploughing (81.1 kg ha^{-1}) in Vertisol. The results are in accordance with the findings reported by Bharambe *et al.* (1999), Bharambe *et al.* (2002), Halemani *et al.* (2004) and Sainju *et al.* (2009). In 2016-17 there is 5.56 percent and in 2017-18 (6.02 per cent) increase in conservation over conventional tillage respectively.

Effect of integrated plant nutrient system

The available nitrogen differs significantly in all treatments during both the years. The soil available nitrogen varied from 206.9 to 239.9 kg ha^{-1} after soybean (2016-17). The data showed significant difference in all treatments. It was observed that gain of nitrogen after harvest of soybean crop in all treatments over initial.

The effect of IPNS on available nitrogen was found to be significant. The significantly highest available nitrogen (239.9 kg ha^{-1}) was recorded with the application of 50% N through FYM + remaining RD through chemical fertilizers followed by application of 100 % RDF (236.7 kg ha^{-1}), application of 50% N through GLM + remaining RD through chemical fertilizer (233.7 kg ha^{-1}) and with application of 100 % N through phosphocompost + remaining P through chemical fertilizer (229.7 kg ha^{-1}) which was found at par with each other. Lowest available N (206.9 kg ha^{-1}) was recorded in control. This increase in available N might be due to the direct addition of the N through FYM, green manuring to the available pool of soil. Increase in available N due to organic materials application could also be attributed to the greater multiplication of soil microbes which could convert organically bound N to inorganic Katkar *et al.*, (2002).

In long term cropping system some crops are efficient in utilizing the residual fertility from preceding crop. Nitrogen is the most important primary nutrient largely required by the crops and at the same time it is very difficult to maintain in the soils in its plant utilizable form. This further suggests that the use of crops which adds enough biomass to the soil can save the

chemical fertilizers partly reducing the cost of chemical fertilizers. Malewar and Hasnabade (1995), Katkar *et al.* (2005) and Babhulkar *et al.* (2000) reported that the regular application of FYM is highly essential to maintain the sustainability of soil in respect of available nutrients. Organic matter helps in increasing adsorptive power of soil for cations and anions which released slowly particularly nitrate and phosphorus.

The available N status after harvest of cotton in (2017-18) was significantly influenced by various nutrient management practices. Highest soil available nitrogen (248.0 kg ha^{-1}) was recorded with 50% N through FYM + remaining RD through chemical fertilizers followed by 100 % RDF (244.4 kg ha^{-1}), application of 50 % N through GLM + remaining RD through chemical fertilizer (243.9 kg ha^{-1}) and with application of 100 % P through phoshpocompost + remaining N through chemical fertilizer (241.9 kg ha^{-1}) which was found at par with each other. Lowest available N (208.9 kg ha^{-1}) was recorded in control. Application of organics along with chemical fertilizers helps in increasing available nitrogen status of soil. The application of inorganic fertilizers along with organic and addition of previous soybean biomass helped in maintaining available nitrogen status of soil at the completion of 2nd cycle of cotton under soybean-cotton rotation.

It was observed that considerable improvement in available N status was observed in all the treatments which involve combined application of crop residues and inorganic fertilizer over initial status. This might be attributed to improved physical properties of the soil coupled with enhanced microbial population. The microbial activity further increased due to availability of organic matter along with readily available N from inorganic fertilizers. Several earlier studies also showed an increase in available N with the application of FYM + inorganic fertilizers (Bellakki and Badanur 1997, Katkar *et al.* 2002, Surekha and Rao 2009). The increase in available nitrogen due to organic material application can be attributed to greater multiplication of soil microbes, which could convert organic nitrogen in to inorganic form (Reddy and Malewar 2002). Although the available N status showed increase under INM, however it has not been increased much due to the prevailing climatic conditions accelerating oxidation of organic matter as well as the nature of

Table 14 a. Effect of tillage and IPNS on available nitrogen in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available nitrogen (kg ha ⁻¹)	
			Soybean	Cotton
	(a)Tillage			
	Set I-Conservation tillage		233.4	240.4
	Set II -Conventional tillage		220.4	230.9
	SE(m)±		1.67	1.10
	CD at 5 %		4.83	3.13
	(b) Intergrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	206.9	208.0
T ₂	100 % RDF	100 % RDF	236.7	244.4
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	239.9	248.04
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	228.5	235.9
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	233.7	243.9
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	228.7	231.6
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	227.7	236.5
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	229.7	241.9
	SE(m)±		3.35	2.21
	CD at 5 %		9.66	6.38
	Initial (2010-11)		220.5	
	(c) Interaction		Sig	Sig

Table 14 b: Interaction of tillage and IPNS on Available N of soil after harvest of soybean and cotton

IPNS	Avail N (kg ha ⁻¹)					
	Soybean			Cotton		
	CNS	CNV	Mean	CNS	CNV	Mean
Control	205.0	200.9	206.9	210.5	207.1	208.9
100 % RDF	242.8	230.7	236.7	247.0	242.0	244.5
50 % N through FYM + remaining RD through chemical fertilizer	243.7	236.5	239.9	253.8	243.2	248.0
50% N through WS+ remaining RD through chemical fertilizer	234.7	222.3	228.5	240.0	231.8	235.9
50% N through GLM + remaining RD through chemical fertilizer	240.5	226.8	233.7	245.0	242.2	243.2
50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	235.1	217.2	223.7	243.2	219.0	231.6
50 % N through vermicompost+ remaining RD through chemical fertilizer	236	220.8	227.7	243.6	229.4	236.5
100 % N through phospocompost + remaining P through chemical fertilizer for soybean /100 % P through phospocompost + remaining N through chemical fertilizer for cotton	237.1	222.0	229.7	244.6	236.6	241.1
Mean	233.4	220.4	-	240.4	230.9	
Initial (2010-11)	220.5					
	Tillage	NM	Int.	Tillage	NM	Int.
SE (m) ±	1.67	3.35	4.73	1.10	2.21	3.12
CD (at 5%)	4.83	9.66	13.67	3.13	6.38	9.02

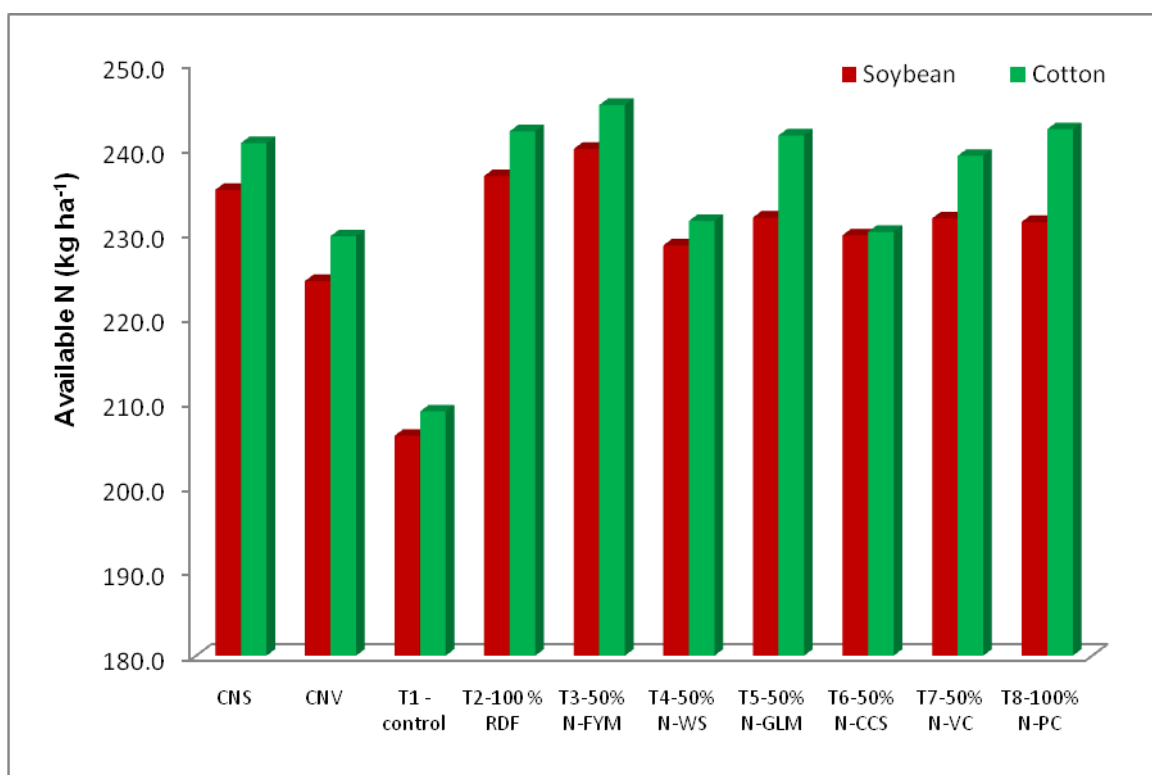


Fig. 9. Effect of tillage and IPNS on available N of soil after harvest of soybean and cotton

nitrogen forms in soil in the form of its losses through volatilization and leaching. The various research trials on long term fertilizer application also reported higher nitrogen availability with the application of organics as leuceana alone , sunhemp and FYM (Badanur *et al.* 1990) and also reported by Katkar *et al.* (2006), over only fertilizer application.

In this view, the results of present investigation suggest that the maintenance of soil available N levels is more challenging. The available nitrogen although showed increase under INM, it has not been increased much due to the prevailing climatic condition accelerating oxidation of organic matter as well as its losses through volatilization and leaching. This necessitates regular addition of organics for maintained of soil fertility in the soils of semi arid areas. After two years of experimentation, the considerable improvement in available N status was observed in all the treatments which involved combined application of organic and inorganic fertilizers over initial values. This might be attributed to improved physical properties of the soil coupled with enhanced microbial population. The microbial activity further increased due to availability of organic matter along with readily available N from inorganic fertilizers. The results are having close agreement with findings given by Puranik *et al.* (1978) and Chaturvedi and Chandel (2005).

Interaction

Interaction between tillage and IPNS was found significant. (Table.14 (b)). In the first year interaction of conservation practice with various nutrient management option viz., 50 % N through FYM + remaining RD through chemical fertilizer (243.2 kg ha⁻¹) recorded significantly highest values followed by 100 % RDF (242.7 kg ha⁻¹), 50% N through GLM + remaining RD through chemical fertilizer (240.8 kg ha⁻¹) and 100 % N through phoshpocompost + remaining P through chemical fertilizer (237.1 kg ha⁻¹). These values were found on par with each others. In the second year significantly higher available nitrogen (253.8 kg ha⁻¹) was observed in application of 50 % N through FYM + remaining RD through chemical fertilizer followed by 100 % RDF, (247 kg ha⁻¹), 50% N through GLM + remaining RD through chemical fertilizer (245.0 kg ha⁻¹) and 100 % P through phoshpocompost + remaining N through chemical fertilizer (244.6 kg

ha⁻¹) conservation tillage practices which were found on par with each others.

4.1.2.4.2 Available phosphorus

The data regarding to the available phosphorus in soil are presented in Table 15 and depicted in Fig 10. The availability of phosphorus content in soil differs among the various treatments. The initial status of available phosphorus was in the range of 13.07 to 15.50 kg ha⁻¹ *kharif* 2015-16 (annexure III (C)).

Effect of Tillage

The effect of tillage on available phosphorus was found to be significant. In first year, significantly higher available phosphorus was observed in conservation tillage (21.80 kg ha⁻¹) as compared to conventional tillage (19.95 kg ha⁻¹) while during second year, also significantly higher available phosphorus was observed in conservation tillage (23.20 kg ha⁻¹) as compared to conventional tillage (21.11 kg ha⁻¹). Conservation tillage involves minimum surface tillage, leaving crop residue to accumulate at the soil surface and increase in organic matter ultimately enhance availability of nutrient like phosphorus. Similar observations were also recorded by Dick (1983). Gaikwad and Khupse (1976) observed that available P was higher due to harrowing than ploughing in black soil. Sonune *et al.* (2012) also observed higher available P in black cotton soils and minimum tillage compared to conventional tillage. Significant variation was observed in available phosphorus due to the tillage practices. This implies that high organic carbon in soil due to conservation tillage reduces phosphorus fixation due to release of various organic acids as a results of which more phosphorus becomes readily available to plant roots in the soil.

Effect of integrated plant nutrient system

The effect of IPNS on available phosphorus after harvest of soybean in *kharif* (2016-17) was significantly influenced by various treatments. It varied from 14.46 to 23.82 kg ha⁻¹ after harvest of soybean. The highest available phosphorus (23.82 kg ha⁻¹) was observed in 100 % N through phoshpocompost+ remaining P through chemical fertilizer which was

significantly superior over all the other treatments and lowest available phosphorus was observed in control (14.46 kg ha^{-1}). Available phosphorus was found maintained under balanced fertilizer use and marginal increase was obtained in the treatment where organic manures and fertilizer was applied in combination. Application of organics in combination with fertilizers increased the available phosphorus status of soil, this could be attributed to the effect of applied fertilizer and mineralization of organic sources or through solubilization of the nutrients from the native sources during the process of decomposition. Similar observation recorded by Bharguvanshi (1988), Ismail *et al.* (1998), Reddy and Malewar (2002), More and Hangare (2003), Katkar *et al.* (2002) and Tiwari *et al.*, (2002).

Continuous application of phosphate fertilizer resulted in build-up of available phosphorus in soil profile while depletion was observed in treatment where phosphorus was not applied under soybean-wheat system after 24 years was reported by Ghosh *et al.*, (1998).

The increase in available phosphorus status under all INM treatments might be due to residual effect of organics applied as well as inclusion of legume crop in the cropping system, as legume absorb more soil phosphorus from subsurface and a part of which is left in the surface layer and part of which is left in subsurface soil with roots. The results are in conformity with Thakur *et al.* (1990), Babhulkar *et al.* (2000) and Mohanthy *et al.* (2007).

In next year, the available phosphorus was significantly increased under cotton crop during *kharif* season (2017-18). The highest available phosphorus (25.78 kg ha^{-1}) observed with 100 % P through phosphocompost + remaining P through chemical fertilizer which was significantly superior over all the other treatments and lowest available phosphorus was observed in control (14.96 kg ha^{-1}) and 100 % RDF (20.07 kg ha^{-1}). The application of 50% N through organic sources with inorganic fertilizers (T_3 to T_7) also showed increase in available phosphorus which might be due to residues added through legumes. The increase in available phosphorus due to legume cultivation can be ascribed to the development of phosphorus solubilising organisms in the root zone of legumes reported by Sharma *et al.* (1986).

Table 15. Effect of tillage and IPNS on available phosphorus in soil after harvest of soybean and cotton under soybean-cotton rotation

Treatments			Available phosphorus (kg ha ⁻¹)	
(a)Tillage			Soybean	Cotton
Set I-Conservation tillage			21.80	23.20
Set II -Conventional tillage			19.95	21.11
SE(m)±			0.18	0.32
CD at 5 %			0.53	0.93
(b) Integrated plant nutrient system				
	Soybean	Cotton		
T ₁	Control	Control	14.46	14.96
T ₂	100 % RDF	100 % RDF	18.35	20.07
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	22.76	25.52
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	20.46	22.44
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	21.77	21.95
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	22.41	22.45
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	22.96	24.04
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	23.82	25.78
SE(m)±			0.52	0.64
CD at 5 %			1.76	1.86
Initial (2010-11)			16.34	
(c) Interaction			NS	NS

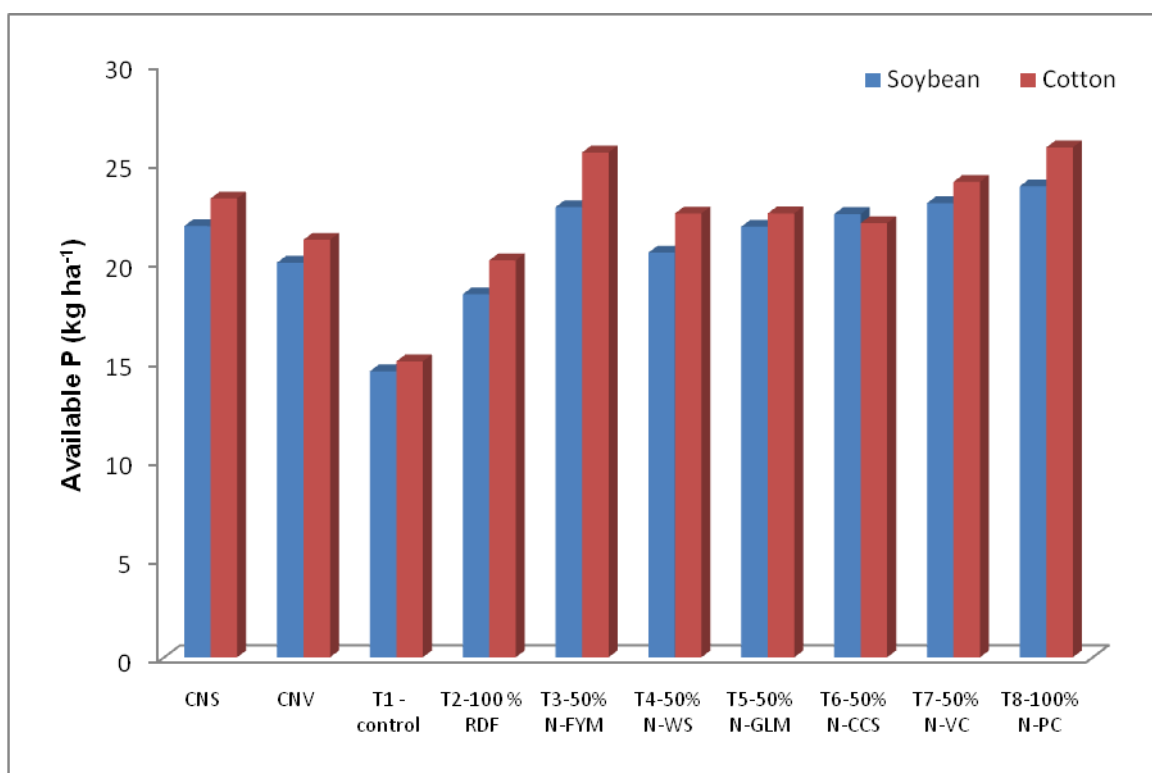


Fig. 10. Effect of tillage and IPNS on available P of soil after harvest of soybean and cotton

Significant increase in available phosphorus with application of chemical fertilizer along with organic manures as compared to only chemical fertilizers was also reported by Kanwar and Paliyal, (2002) and Chitale *et al.* (2003). The black soils which have high phosphorus fixation capacity are specially becoming deficient under the intensive cropping system. Under these circumstances the crops having potential of adding considerable biomass to the soil have special significance in black soils. The decomposition of leaf litter is useful for slight reduction in pH which favours availability of phosphorus in these soils. The appreciable build up in available phosphorus may also be due to influence of organic matter in increasing the labile phosphorus in soil through complexing of cations like Ca^{2+} which is mainly responsible for fixation in swell shrink soils. The conjunctive use of organics with chemical fertilizers is beneficial for improving available P which is also evidenced by the reduced calcium carbonate content of the soil there by reducing phosphorus fixations. Similar results were reported by Kharche *et al.* (2011). The organic material forms a cover on calcium carbonate powder and nodules and thus reduced phosphate fixing capacity and increases availability. Available phosphorus was influenced significantly due to integrated nutrient management and could be attributed to the effect of applied fertilizer and mineralization of organic sources or through solubilization of the nutrients from the native sources during the process of decomposition. Similar observation also recorded by Bellakki *et al.* (1998), More and Hangarge (2003). The increase in available phosphorus status is due to use of FYM, being direct source of phosphorus and it might have also solubilized the native phosphorus in the soil through release of various organic acids which had chelating effect, that reduced phosphorus fixation. These findings are in conformity with findings of Sonune *et al.* (2003).

The decomposition of organic matter is accompanied by the release of appreciable quantities of CO_2 when dissolved in water, forms carbonic acid, which is capable of decomposing certain primary minerals and release of nutrients (Bharadwaj and Omanwar, 1994 and Suresh *et al.* 1999). Similarly, Tolanur and Bajpai *et al.* (2006) also noticed that organic manure with inorganic fertilizers had the beneficial effect on increasing the phosphate availability. The results also suggest that in spite of phosphorus fixation in swell-shrink soil the

conjunctive use of organics with chemical fertilizers is beneficial for improving available phosphorus which is also evidenced by the reduced calcium carbonate contents of the soil there by reducing phosphorus fixation. The build up of available P even in the plots getting only inorganic fertilizers, may be ascribed to lower uptake than amount added externally. Similar results were also observed by the Yaduvanshi *et al.* (2003).

Interaction

The Interaction between tillage and IPNS on soil available P was non significant.

4.1.2.4.3 Available potassium

Data pertaining to available potassium as influenced by different treatments are presented in Table 16 and graphically depicted in Fig.11. The initial status (before *kharif* 2015-16) of available potassium was in the range of 357.3 to 365.2 kg ha⁻¹.

Effect of Tillage

In first year of experimentation, significantly higher available potassium was observed in conservation tillage (354.12 kg ha⁻¹) as compared to conventional tillage (349.30 kg ha⁻¹), while during second year slightly higher available potassium was observed in conservation tillage (356.13 kg ha⁻¹) as compared to conventional tillage (351.30 kg ha⁻¹). Similar observation recorded by Gaikwad and Khupse (1976) in Vertisol and reported that available potassium was higher due to harrowing than ploughing in black soil. Similar results were also observed by Sonune *et al.* (2012). The increase in available potassium might be due to the fact that available soil moisture would have helped in hastening the decomposition process and its subsequent mineralization helps in improving the status of available K. The results corroborates with the findings reported by Bharambe *et al.* (2002) and Halemani *et al.* (2004).

Effect of integrated plant nutrient system

The data in respect of available potassium under soybean (*kharif* 2016-17) as influenced by different nutrient management practices was significant. The highest available potassium (364.93 kg ha⁻¹) was

observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer followed by (362.30 kg ha⁻¹) 50% N through GLM + remaining RD through chemical fertilizer and (361.99 kg ha⁻¹) with 50% N through vermicompost + remaining RD through chemical fertilizer , 100 % N through phoshpocompost+ remaining P through chemical fertilizer (359.10 kg ha⁻¹) which was found at par with each other.

The increase in availability of potassium can be attributed to direct addition of potassium through fertilizers and FYM to the available pool of soil and also the interaction of organic matter added through FYM with clay reduce potassium fixation and releases potassium in soil solution. Considerable increase in soil available potassium was also reported by Katkar *et al.* (2002), Tiwari *et al.* (2002), Sonune *et al.* (2003), Katkar *et al.* (2007) and Kumar *et al.* (2008). The increased available potassium with the addition of crop residues (sorghum stubbles and safflower stalks) and green manuring was also reported by Badanur *et al.* (1990), crop residues contain considerable concentration of potassium having enough to compensate 50% N fertilizer through FYM was significantly superior over control. Increase in available K might be attributed to the direct addition of K to the available pool of soil besides the reduction of K fixation and release of K due to interaction of organic matter with clay. The results are in the line with the findings of Bhardwaj and Owmanvar, (1994) and Sonune *et al.* (2005). The lowest available potassium (314.09 kg ha⁻¹) was recorded in treatment control.

Babhulkar *et al.* (2000) reported, higher available potassium under 15:30 NP + 7.5 t FYM ha⁻¹ after soybean which might be due to addition of FYM that help to stimulate the growth activity of micro organisms. Similar results were also reported by Chaturvedi and Chandel (2005).

During kharif (2017-18) in cotton, maximum available potassium (366.52 kg ha⁻¹) was noted under application of 50 % N through FYM + remaining RD through chemical fertilizer followed by (365.88 kg ha⁻¹) 50% N through GLM + remaining RD through chemical fertilizer, (364.26 kg ha⁻¹) 50 % N through vermicompost + remaining RD through chemical fertilizer and (362.97 kg ha⁻¹) 100 % P through phoshpocompost + remaining N through

Table 16. Effect of tillage and IPNS on available potassium in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available potassium (kg ha ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		354.12	356.13
	Set II -Conventional tillage		349.30	351.31
	SE(m)±		1.57	1.04
	CD at 5 %		4.52	3.01
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	314.09	311.60
T ₂	100 % RDF	100 % RDF	350.82	353.58
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	364.93	365.52
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	347.50	349.94
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	362.30	365.88
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	350.10	356.37
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	361.99	364.26
T ₈	100 % N through phosphocompost+ remaining P through chemical fertilizer	100 % P through phosphocompost+ remaining N through chemical fertilizer	359.10	362.97
	SE(m)±		3.13	2.08
	CD at 5 %		9.05	6.02
	Initial (2010-11)		347.8	
	(c) Interaction		NS	NS

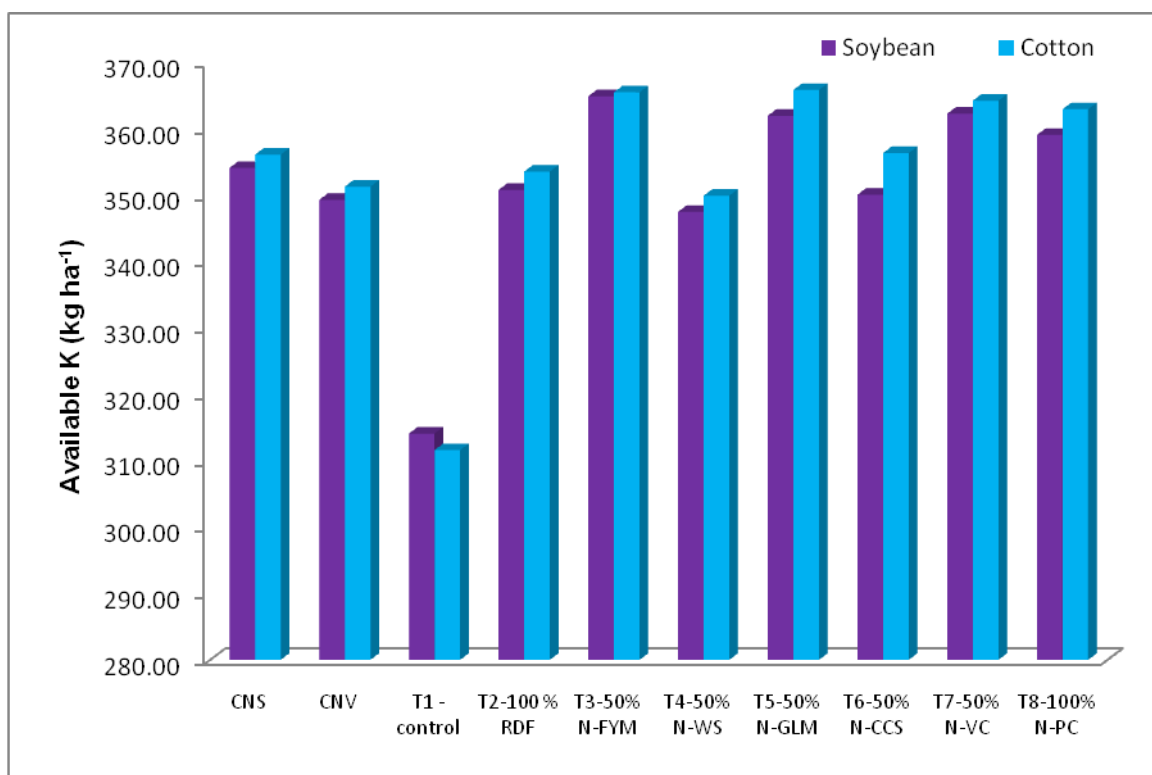


Fig. 11. Effect of tillage and IPNS on available K of soil after harvest of soybean and cotton

chemical fertilizer. The increase in available K might be due to the reduction in potassium fixation and release of K due to the interaction of organic matter with clay, besides the direct K addition in available K pool to the soil reported by Suresh *et al.* (1999).

Singh *et al.* (2001) reported that significant increase in available K content has been due to either FYM or green manure which helps to maintain the supply of K by releasing the K from reserve source. Subabul and sunhemp also increased potassium content of soil significantly over fertilizer application. The wheat straw found to be most effective in increasing potassium availability in soil followed by sunflower heads and FYM. Patil *et al.* (1993). Similar results are also reported by given by Bharambe *et al.* (1999) and Katkar *et al.* (2002).

Interaction

The Interaction between tillage and IPNS on available potassium was non significant.

4.1.2.4.4. Available sulphur

Data pertaining to available sulphur as influenced by different treatments are presented in Table 17 and graphically depicted in Fig.12.

Effect of Tillage

The effect of tillage on available sulphur was found to be significant. Significantly higher available sulphur was observed in conservation tillage (12.39 mg kg⁻¹) as compared to conventional tillage (10.96 mg kg⁻¹) and during second year of study similar trends was observed. The increased availability of sulphur might be due to enhance the decomposition process and mineralization of the organic manures in conservation tillage. Improvement in available sulphur status under crop residues and green manuring also due to its ameliorative effect on improvement of physical and chemical properties which helps to improve the availability of native sulphur in the soil. The results corroborates with the findings reported by Bharambe *et al.* (2002) and Halemani *et al.* (2004).

Table 17. Effect of tillage and IPNS on available sulphur in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available sulphur (mg kg ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		12.39	12.84
	Set II -Conventional tillage		10.96	11.30
	SE(m)±		0.04	0.21
	CD at 5 %		0.12	0.61
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	9.41	9.46
T ₂	100 % RDF	100 % RDF	11.08	11.23
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	12.29	12.96
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	11.46	12.15
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	12.03	12.50
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	11.89	12.38
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	11.57	12.30
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	12.07	12.81
	SE(m)±		0.08	0.42
	CD at 5 %		0.24	1.23
	Initial (2010-11)		9.61	
	(c) Interaction		NS	NS

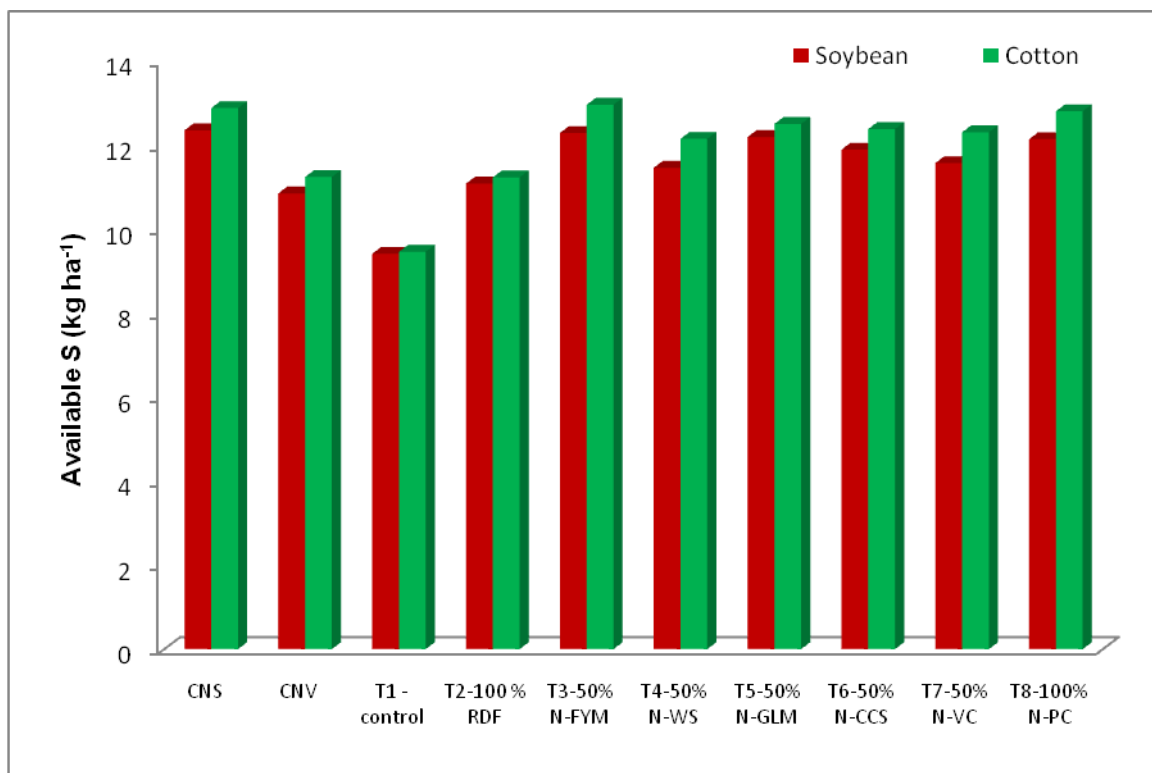


Fig. 12. Effect of tillage and IPNS on available S of soil after harvest of soybean and cotton

Effect of integrated plant nutrient system

The effect of integrated plant nutrient system on available sulphur was found to be significant. The significantly highest available sulphur (12.29 mg kg^{-1}) was recorded in treatment receiving 50 % N through FYM + remaining RD through chemical fertilizer followed by with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer (12.07 mg kg^{-1}) and application of 50 % N through glyricidia green leaf manuring + remaining RD through chemical fertilizer (12.03 mg kg^{-1}) and application of 50 % N through composted cotton stalk+ remaining RD through chemical fertilizer (11.89 mg kg^{-1}) which was significantly superior over control. The lowest available sulphur was recorded in control (9.41 mg kg^{-1}). The increase in available sulphur under Phosphocompost and FYM application might be due to solubilisation of the nutrients from native sources during the process of decomposition, which in turn the conservation of organics to more available sulphate form, similar results were also noted by Babhulkar *et al.* (2000), Chaudhary and Das (1996). There was also significant increase available sulphur with integrated use of fertilizers. Increase in available S might be attributed to the use of SSP as a source of P which contain appreciable quantity of S. This is evidenced from the initial status of S, which was improved in all the treatments except control. This implies that use of SSP is beneficial in improving the status of S over high analysis fertilizers like DAP. The results are in the line with the findings of Bhardwaj and Owmanvar, (1994) and Sonune *et al.* (2005).

In next year the highest available sulphur (12.96 mg kg^{-1}) was recorded in treatment receiving 50 % N through FYM + remaining RD through chemical fertilizer followed by application of 100 % P through phosphocompost + remaining N through chemical fertilizer (12.81 mg kg^{-1}), with application of 50 % N through GLM + remaining N through chemical fertilizer (12.50 mg kg^{-1}) which was significantly superior over control. The lowest available sulphur (9.46 mg kg^{-1}) was recorded in treatment control. Available sulphur in both the crops (cotton and soybean) has shown increase over initial values which may be due to addition of biomass from previous year

soybean crop. Dikshit *et al.* (1995) also noticed increased the available sulphur content with fertilization under continuous cropping (16 cycles of soybean-wheat and maize-fodder) in Vertisol.

Interaction

The Interaction between tillage and IPNS on available sulphur was non significant.

4.1.2.5. Available Micronutrients

The micronutrient deficiency is emerging in swell- shrink soil due to intensive agriculture, use of high analysis NPK fertilizers and lack of addition of organic manures.

The long term use of manure, crop residues, and green manure under soybean-cotton rotation grown on Vertisol revealed that the integrated nutrient management was found beneficial in mitigating the micronutrient deficiency.

4.1.2.5.1. Available Zn

The data in respect of available zinc as influenced by tillage and IPNS are presented in Table 18 and available zinc status at the end of crop rotation (2017-18) is graphically depicted in Fig13. The initial available zinc status varied from 0.45 to 0.53 mg kg⁻¹ during (2015-16).

Effect of Tillage

The effect of tillage on available zinc was found to be significant. In first year, slightly higher available zinc was observed in conservation tillage (0.59 mg kg⁻¹) as compared to conventional tillage (0.52 mg kg⁻¹), while during second year higher zinc was recorded in conservation tillage (0.62 mg kg⁻¹) as compared to conventional tillage (0.54 mg kg⁻¹). Similar results about effect of tillage on the distribution of DTPA extractable Mn, Cu, Fe and Zn in soil reported by Shuman and Hargrove (1984) and also noticed by Jacinthe and Lal (2009), Liu *et al.* (2005), Mohanty *et al.* (2007). In 2016-17 there were 13.46 per cent and in 2017-18 (14.81 per cent) available Zn was increased in conservation over conventional tillage.

Effect of integrated plant nutrient system

The data in respect of available zinc in soil after harvest of soybean influenced by various treatments of IPNS was found to be significant. The available zinc content in soil was enhanced over initial DTPA extractable zinc where organics like FYM, Phosphocompost, green manuring and crop residues were included. It supplies nutrients and added to the soil through the process of mineralization and which showed residual effect of previous year crops.

The lowest available Zn (0.46 mg kg^{-1}) was observed under control. The higher available zinc was recorded in application of 50 % N through FYM + remaining RD through chemical fertilizer and application of 100 % N through phosphocompost+ remaining P through chemical fertilizer. This might be due to the mineralization of organically bound forms of Zn in the organic materials, which encouraged the formation of organic chelates of higher stability, because zinc is known to form relatively stable chelates with organic ligands which decrease their susceptibility to absorption, fixation and/or precipitation (Bellakki *et al.* 1998). The other possible reason for increased zinc availability could be an enhanced microbial activity in the soil and consequent release of complex organic substances (chelating agents), which could have prevented micronutrients from precipitation, fixation, oxidation and leaching. The results are in conformity with Guled *et al.* (2002) and Ismail *et al.* (1998).

In next year *kharif* (2017-18) under cotton, the available zinc content varied from 0.47 to 0.65 mg kg^{-1} . The available zinc in soil was found highest (0.65 mg kg^{-1}) under the use of 50 % N through FYM + remaining through chemical fertilizer followed by treatment (T_8), (T_7) and (T_5) and lowest available Zn (0.47 mg kg^{-1}) was recorded in treatment control, results are same with previous year. The available Zn in soil was maintained with treatment supplied with FYM. The application of FYM appreciably increased the availability of applied and native micronutrient cations in the order of their increase $\text{Fe} > \text{Cu} > \text{Mn} > \text{Zn}$. The organic materials form chelates and increase the availability of zinc. The similar findings were also reported by Verma *et al.* (2005) and Masto *et al.* (2007).

Table 18. Effect of tillage and IPNS on available Zn in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available Zn (mg kg ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		0.59	0.62
	Set II -Conventional tillage		0.52	0.54
	SE(m)±		0.011	0.006
	CD at 5 %		0.032	0.018
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	0.46	0.47
T ₂	100 % RDF	100 % RDF	0.47	0.48
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	0.61	0.65
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	0.52	0.56
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	0.57	0.62
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	0.54	0.60
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	0.60	0.63
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	0.60	0.64
	SE(m)±		0.022	0.012
	CD at 5 %		0.064	0.036
	Initial (2010-11)		0.51	
	(c) Interaction		NS	NS

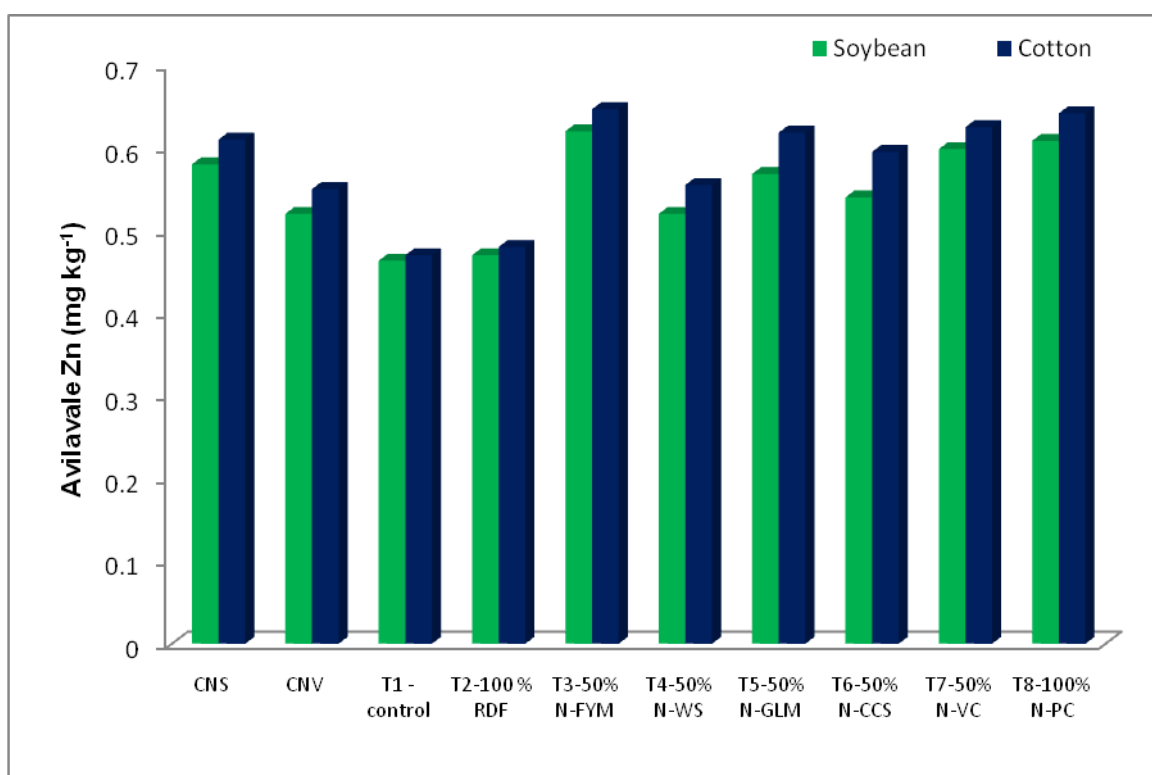


Fig. 13. Effect of tillage and IPNS on available Zn of soil after harvest of soybean and cotton

The identical results were also observed by Babhulkar *et al.* (2000), Poongothai and Chideshwari (2003).

The available zinc was influenced significantly due to combined use of organic and inorganic fertilizers from its initial status, Gupta *et al.* (2000). The results indicated that due to continuous cropping with only chemical fertilizers without addition of organics there was considerable depletion of zinc in soils, which indicates immense necessity of regular application of organics either through FYM, green manures or crop residues to maintain the zinc status of soils. Application of 50 percent nitrogen through crop residues with inorganic fertilizers increased zinc content than inorganic fertilizer alone. This might be due to incorporation of crop residues in combination with fertilizers were highly effective in increasing soil available Zn over the treatments of inorganic fertilizers alone (Sharma *et al.* 2000, Mali *et al.* 2014, Subehia and Sepehya 2012).

The highest magnitude of response of cotton to zinc alone might be due to marginal value of DTPA extractable Zn (0.60 to 1.20 ppm) in soil. Zinc deficiency is more frequently noticed in calcareous soil and also in soils that are excessively high in phosphorus. The phosphorus fertilization high clay and CaCO_3 content immobilised the applied phosphorus and resulted in increase zinc adsorption on cation exchange site to form soluble Zn-PO_4 complex (Indulkar and Malewar 1994). The results thus clearly indicated that without addition of organics there is considerable depletion of zinc and soils show depletion of zinc which indicate immense necessity of regular application of organics either FYM or crop residues and /or green manures to maintain the zinc status of soils.

Interaction

The Interaction between tillage and IPNS on available zinc was non significant.

4.1.2.5.2 Available Fe

The data in respect of DTPA extractable iron as influenced by various treatments is presented in Table 19 and depicted in Fig 14. Before

start of the experiment i.e. during kharif 2015-16, the available Fe content of soil varied from 6.08 to 7.06 mg kg⁻¹ annexure III (C).

Effect of Tillage

In first year significantly higher available iron was observed in conservation tillage (7.01 mg kg⁻¹) as compared to conventional tillage (6.69 mg kg⁻¹). Significantly higher iron was observed in conservation tillage (7.27 mg kg⁻¹) as compared to conventional tillage (6.76 mg kg⁻¹) after harvest of cotton. Similar results about effect of tillage on the distribution of Manganese, Copper, Iron, and Zinc in soil reported by Shuman and Hargrove (1984) and also noticed by Jacinthe and Lal (2009), Liu *et al.* (2005) and also reported by Mohanty *et al.* (2007).

Effect of integrated plant nutrient system

The available iron after harvest of soybean was significantly influenced by various IPNS treatments. The highest available Fe was found with the use of 50 % N through FYM and remaining RD through chemical fertilizer (7.22 mg kg⁻¹) followed by 50% N through vermicompost + remaining RD through chemical fertilizer (7.10 mg kg⁻¹) and 100 % N through phosphocompost+ remaining P through chemical fertilizer (6.95 mg kg⁻¹). The lowest available Fe (6.17 mg kg⁻¹) was observed under control. The enhancement in available iron due to the addition of organic substances may be ascribed to the presence of appreciable quantity of iron in the organics and residual effect of FYM added to this treatment while cultivation of soybean which enhances the iron due to their ability to form stable water soluble complexes preventing the reaction with soil constituent and also increasing the Fe content through releasing from the native sources Ghosh *et al.* (2001), and Patil and Patil (1982)

In next year during *kharif* (2017-18) under cotton the DTPA extractable Fe content in soil varied from 6.13 to 7.38 mg kg⁻¹. The maximum available iron content noticed in use of 50 % N through FYM and remaining RD through chemical fertilizer (7.38 mg kg⁻¹) followed by application of 50% N through vermicompost + remaining RD through chemical fertilizer (7.31 mg kg⁻¹) and application of 100 % P through

Table 19. Effect of tillage and IPNS on available Fe in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available Fe (mg kg ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		7.01	7.27
	Set II -Conventional tillage		6.69	6.76
	SE(m)±		0.11	0.09
	CD at 5 %		0.32	0.25
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	6.10	6.13
T ₂	100 % RDF	100 % RDF	6.36	6.39
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	7.22	7.38
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	6.90	7.04
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	6.76	7.21
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	6.93	7.04
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	7.10	7.31
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	6.95	7.25
	SE(m)±		0.22	0.17
	CD at 5 %		0.64	0.49
	Initial (2010-11)		6.23	
	(c) Interaction		NS	NS

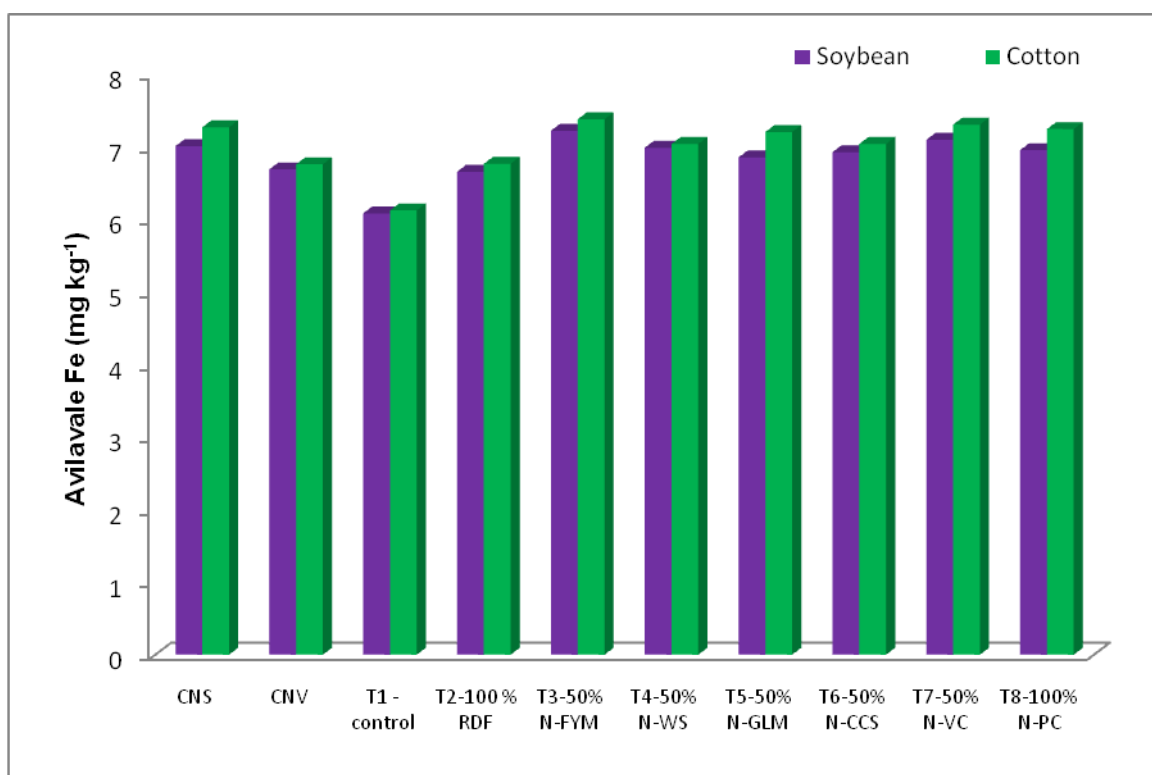


Fig. 14. Effect of tillage and IPNS on available Fe of soil after harvest of soybean and cotton

phosphocompost + remaining N through chemical fertilizer (7.25 mg kg^{-1}) and application of 50% N through GLM + remaining RD through chemical fertilizer (7.21 mg kg^{-1}). The lowest available Fe was observed under control (6.13 mg kg^{-1}). This can be attributed to the residual effect of FYM added to this treatment while cultivation of soybean-cotton rotation which enhances the iron content by forming stable water soluble complexes also increasing Fe content through release from native sources. The results are in agreement with the observations recorded by Hegde (1996) and Prakash *et al.* (2002). Addition of higher quantity of organic matter favoured increase in iron accompanied with decrease in soil pH. Lowest available Fe (6.39 mg kg^{-1}) observed in treatment of 100 % RDF, chemical fertilizers alone or with organics showed marginally higher iron status.

The available iron showed emerging deficiencies in alkaline calcareous soils due to intensive cropping and Thus integrated nutrient management is therefore imperative to maintain the iron status of soils. The present results strongly support the fact necessitating importance of INM. These results are in conformity with the findings reported by Katkar *et.al* (2006).

Interaction

The Interaction between tillage and IPNS on available Fe was non significant.

4.1.2.5.3 Available Mn

The data in respect of available Mn as influenced by tillage and various nutrient management treatments is presented in Table 20 and depicted in Fig 15. Before start of the experiment (2015-16). The available Mn content of soil varied from 8.29 to 9.15 mg kg^{-1} .

Effect of Tillage

In first year after harvest of soybean slightly higher available manganese was observed in conservation tillage (9.25 mg kg^{-1}) as compared to conventional tillage (8.94 mg kg^{-1}) and during second year after harvest of cotton higher manganese was observed in conservation tillage (9.31 mg kg^{-1}) as compared to conventional tillage (9.08 mg kg^{-1}). Similar results about effect

of tillage on the distribution of Mn, in soil reported by Shuman and Hargrove (1984) and also noticed by Simon *et al.* (2009), Liu *et al.* (2005) and also reported by Mohanty *et al.* (2007).

Effect of integrated plant nutrient system

The available manganese after harvest of soybean was significantly influenced by nutrient management practices. The maximum available Mn was observed with application of 50 % N through FYM + remaining RD through chemical fertilizer (9.62 mg kg⁻¹) followed by application of 50 % N through vermicompost + remaining RD through chemical fertilizer (9.57 mg kg⁻¹), and receiving 100 % N through phoshpocompost + remaining P through chemical fertilizer (9.28 mg kg⁻¹) however, at par with control. Lowest available manganese (8.51 mg kg⁻¹) was observed under control. The maximum increase in available manganese with use of FYM and vermicompost, phoshpocompost which enhances the microbial activity and releases of organic substances which act as chelating agent and enhances the availability of manganese (Babhulkar *et al.* 2000).

In next year the soil available manganese after harvest of cotton during 2017-18 varied from 8.55 to 9.75 mg kg⁻¹. The highest available Mn was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer (9.75 mg kg⁻¹) followed by application of 50 % vermicompost + remaining RD through chemical fertilizer (9.66 mg kg⁻¹), and 100 % P through phoshpocompost + remaining N through chemical fertilizer (9.34 mg kg⁻¹) and found at par each other. Lowest available manganese (8.55 mg kg⁻¹) was observed under control. The increase in available manganese with the combined application of organics over control and RDF inorganics may be due to residual effect of theses organics (T₃ to T₈) added to soybean and cotton which act as a chelating agent cations enhances availability of manganese. The availability of manganese increased significantly with application of FYM over the rest of treatments and initial status of the soil. This might be due to decomposition of FYM and consequent released of micronutrients (Mathur, 1997).

Table 20. Effect of tillage and IPNS on available Mn in soil after harvest of soybean and cotton under soybean-cotton rotation

Treatments			Available Mn (mg kg ⁻¹)	
(a)Tillage			Soybean	Cotton
Set I-Conservation tillage			9.25	9.31
Set II -Conventional tillage			8.94	9.08
SE(m)±			0.22	0.08
CD at 5 %			0.62	0.24
(b) Integrated plant nutrient system				
Soybean	Cotton			
T ₁	Control	Control	8.51	8.55
T ₂	100 % RDF	100 % RDF	8.75	8.77
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	9.62	9.75
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	9.13	9.07
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	9.23	9.32
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	9.00	9.10
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	9.57	9.66
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	9.28	9.34
SE(m)±			0.43	0.16
CD at 5 %			1.24	0.47
Initial (2010-11)			8.42	
(c) Interaction			NS	NS

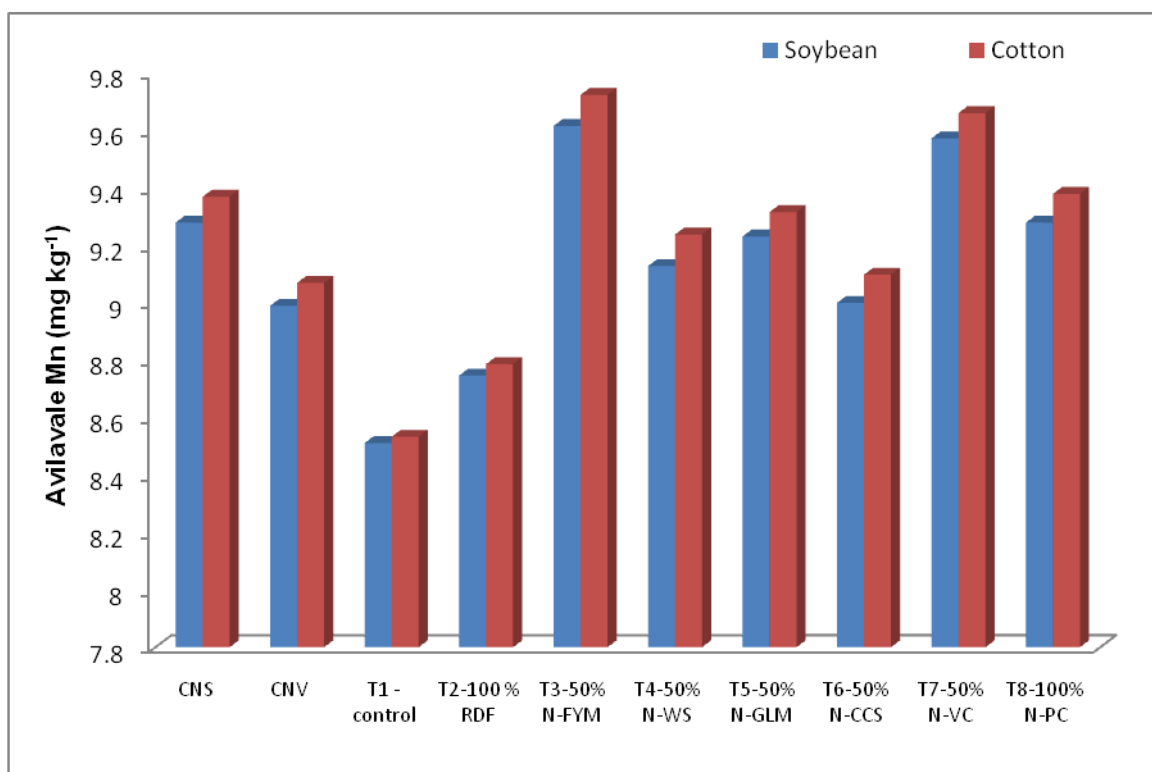


Fig. 15. Effect of tillage and IPNS on available Mn of soil after harvest of soybean and cotton

Further, the availability of micronutrients increased with increase in organic carbon and formation of chelate complexes in the soil (Yadav and Meena, 2009).

Interaction

The Interaction between tillage and IPNS on available manganese was non significant.

4.1.2.5.4 Available Cu

The data pertaining to the available copper as affected by various treatments are presented in Table 21 and depicted in Fig 16 .The data in respect of availability of copper in soil indicated that the available copper varied from (1.69 to 2.16 mg kg⁻¹), before start of the experiment (2015-16) annexure III (C).

Effect of Tillage

In first year significantly higher available copper was recorded in conservation tillage (1.99 mg kg⁻¹) as compared to conventional tillage (1.90 mg kg⁻¹). In second year numerically higher copper was recorded in conservation tillage (2.11 mg kg⁻¹) as compared to conventional tillage (2.04 mg kg⁻¹), Similar results about effect of tillage on the available copper in soil reported by Shuman and Hargrove (1984) and also noticed by Simon *et al.* 2009, Liu *et al.* (2005) and also reported by Mohanty *et al.* (2007).

Effect of integrated plant nutrient system

The available copper after harvest of soybean in *kharif* (2016-17) was significantly influenced by various treatments. The maximum available copper (2.21 mg kg⁻¹) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer which was significantly superior over all the other treatments and lowest available copper (1.70 mg kg⁻¹) was observed under control. This increase in available copper may be due to application of organic manures which enhances the microbial activity and consequently releases complex organic substances would have prevented copper from precipitation, fixation, oxidation and leaching (Swarup, 1984). Available copper increased in all INM treatments with the use of FYM, green manures and crop residues have the potential in maintaining micronutrient status in soils which can overcome the emerging deficiency

problems and their regular use in conjunction with chemical fertilizers is more beneficial over use of only chemical fertilizers. These findings are in line with the results reported by Bellakki *et al.*, (1998), Sharma *et al.*, (2000), Mali *et al.* (2014), Subehia and Sepehya (2012).

In next *kharif* season of cotton highest Cu (2.33 mg kg^{-1}) was observed under 50 % N through FYM + remaining RD through chemical fertilizer followed by 50 % N through vermicompost+ remaining RD through chemical fertilizer (2.25 mg kg^{-1}), 100 % P through phosphocompost + remaining N through chemical fertilizer (2.23 mg kg^{-1}), 50% N through GLM + remaining RD through chemical fertilizer (2.11 mg kg^{-1}), Thus results, suggested that the use of FYM, Phosphocompost, crop residues and green manuring with chemical fertilizers help in maintaining available micronutrient status of soil over control and RDF alone. There was a considerable increase in available micronutrients with continuous use of chemical fertilizer and FYM (Prasad and Singh, 1980). Lal and Mathur (1989) also reported removal of micronutrients by the crop for 30 years did not bring their level below critical limit, though they were not supplied from outside sources. Constant supply through native minerals (feldspar, hornblende, biotite, tourmaline, etc.) and fertilizer carrying these nutrients as impurities was the probable reason for the same. They further observed higher amount of available Zn, Cu and Mn in plots supplied with only organics than those in inorganic or half organic + inorganic applied plots. These results are in conformity with Mohanty *et al.* (2007).

Addition of organic materials might have enhanced the microbial activity in the soil and consequently the release of complex organic substances like humic and fulvic acids acting as chelating agents during the decomposition of organic manure and crop residue. This could have prevented micronutrients from precipitation, fixation, oxidation, leaching and augmented the solubility, mobility, availability of insoluble micronutrients. Prasad and Sinha (2000) in their studies on long term effect of fertilizers and organic manures on soil properties in calcareous soils of Pusa (Bihar) also reported available Zn, Fe, Cu and Mn increased in soil when different levels of fertilizers were applied along with crop residues and organic manure.

Table 21. Effect of tillage and IPNS on available Cu in soil after harvest of soybean and cotton under soybean-cotton rotation

	Treatments		Available Cu (mg kg ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		1.99	2.11
	Set II -Conventional tillage		1.90	2.04
	SE(m)±		0.04	0.033
	CD at 5 %		0.13	0.094
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	1.70	1.71
T ₂	100 % RDF	100 % RDF	1.74	1.76
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	2.21	2.33
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	1.94	2.04
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	1.80	2.11
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	2.08	2.16
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	2.08	2.25
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	1.98	2.23
	SE(m)±		0.09	0.065
	CD at 5 %		0.27	0.189
	Initial (2010-11)		1.64	
	(c) Interaction		NS	NS

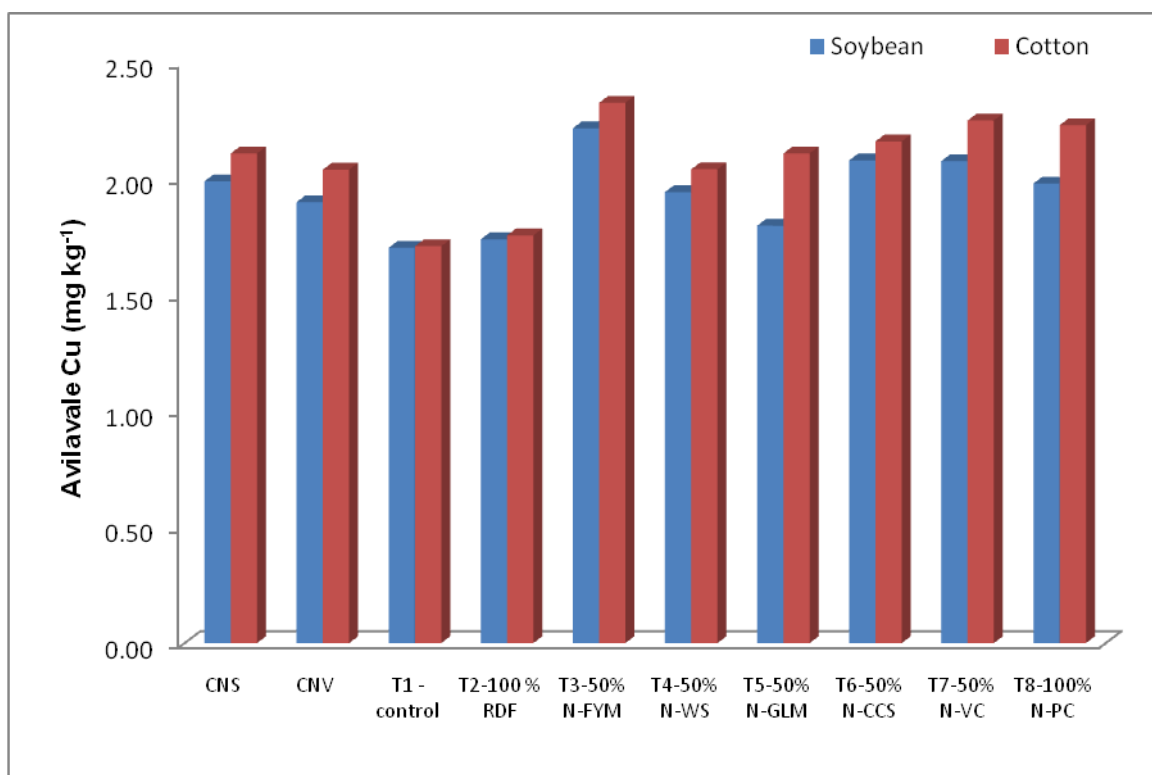


Fig. 16. Effect of tillage and IPNS on available Cu of soil after harvest of soybean and cotton

Application of FYM significantly increased availability of micronutrients over rest of the treatments probably due to the decomposition of FYM and consequent release of micronutrients (Swarup, 1991), and Ismail *et al.* (2002).

Interaction

The Interaction between tillage and IPNS on available copper was non significant.

4.1.2.6.1 Inorganic N Forms of soybean

The data pertaining to the various inorganic N forms as influenced by tillage practices and nutrient management treatments are presented in Table 22 and depicted in Fig17.

Effect of Tillage

The data indicated that significantly higher ammonical N was recorded in conservation tillage (13.94 mg kg⁻¹) as compared to conventional tillage (10.23 mg kg⁻¹) after harvest of soybean. The highest nitrate N was recorded in conservation tillage (17.61 mg kg⁻¹) as compared to conventional tillage (16.37 mg kg⁻¹). The total mineral N was recorded in conservation tillage (31.55 mg kg⁻¹) as compared to conventional tillage (26.60 mg kg⁻¹) after harvest of soybean. This increase in all the inorganic N fractions and total mineral may be due to less disturbance of soil, which maintain soil moisture and improve biomass addition through conservation tillage. Similar results were reported by Chandra *et al.*, (2017), Guldekar *et al.*, (2005) and Tabasum *et al.*, (2010).

Effect of integrated plant nutrient system

The ammonical nitrogen after harvest of soybean in *kharif* (2016-17) was significantly influenced by various treatments. The maximum ammonical N was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (14.30 mg kg⁻¹) followed by with use of 50% N through GLM + remaining RD through chemical fertilizer (13.67 mg kg⁻¹), with application of 50 % N through vermicompost + remaining N through chemical fertilizer (13.13 mg kg⁻¹), with application of 100 % N through phosphocompost + remaining P through chemical fertilizer (12.88 mg kg⁻¹) which was found at par with each other and significantly superior

over control and lowest ammonical nitrogen (8.20 mg kg^{-1}) was observed under control. Similar result was reported by Basumatary and Talukdar (1998), they reported that ammonium N content of the soil increased significantly with integrated treatments where NPK fertilizers were combined with 25% or 50% N through different organic sources. They also reported that, continuous integrated treatments resulted in higher accumulation of organic matter and its subsequent decomposition and mineralization might have contributed in accumulating higher ammonium N over other treatments.

The nitrate nitrogen after harvest of soybean in *kharif* (2016-17) was significantly influenced by various nutrient management treatments. The maximum nitrate nitrogen was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (19.41 mg kg^{-1}) followed by with application of 50% N through GLM + remaining RD through chemical fertilizer (19.21 mg kg^{-1}), with application of 50 % N through vermicompost + remaining P through chemical fertilizer (18.98 mg kg^{-1}), with application of 100 % N through phosphocompost + remaining P through chemical fertilizer (18.61 mg kg^{-1}) which was found at par with each other and significantly superior over control treatments and lowest nitrate nitrogen (10.95 mg kg^{-1}) was noticed under control. Among the two inorganic N fraction was significantly improved with the tillage practices, on the contrary the Nitrate N was almost similar in both the practices followed for soybean and cotton. This might be due to oxidation of ammonium N to nitrate N under conservation tillage. The rate of conversion of ammonium N to nitrate N was quite slow which reflects in release of N in later stage of crops. Similar findings were reported by Zang et al. (2009), Ghuman et al. (1997), Bhattacharyya et al., (2013) and Puli et al., (2013).

The mineral nitrogen after harvest of soybean in *kharif* (2016-17) was significantly influenced by various treatments. The maximum mineral nitrogen was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (33.71 mg kg^{-1}) followed by with application of 50% N through GLM + remaining RD through chemical fertilizer (32.88 mg kg^{-1}) with application of 50 % N through vermicompost + remaining N through chemical fertilizer (32.10 mg kg^{-1}) and with application

Table 22. Effect of tillage and IPNS on inorganic N forms in soil after harvest of soybean under soybean-cotton rotation

Treatments			Inorganic N forms (mg kg ⁻¹)		
(a)Tillage			NH ₃ -N	NO ₂ -N	Total Mineral N
Set I-Conservation tillage			13.94	17.61	31.55
Set II -Conventional tillage			10.23	16.37	26.60
SE(m)±			0.23	0.29	0.31
CD at 5 %			0.66	0.84	0.90
(b) Integrated plant nutrient system					
	Soybean	Cotton			
T ₁	Control	Control	8.20	10.95	19.15
T ₂	100 % RDF	100 % RDF	11.25	16.75	28.00
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	14.30	19.41	33.71
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	11.60	15.94	27.55
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	13.67	19.21	32.88
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	11.64	16.07	27.71
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	13.13	18.98	32.10
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	12.88	18.61	31.49
SE(m)±			0.46	0.58	0.63
CD at 5 %			1.32	1.67	1.81
(c) Interaction			NS	NS	NS

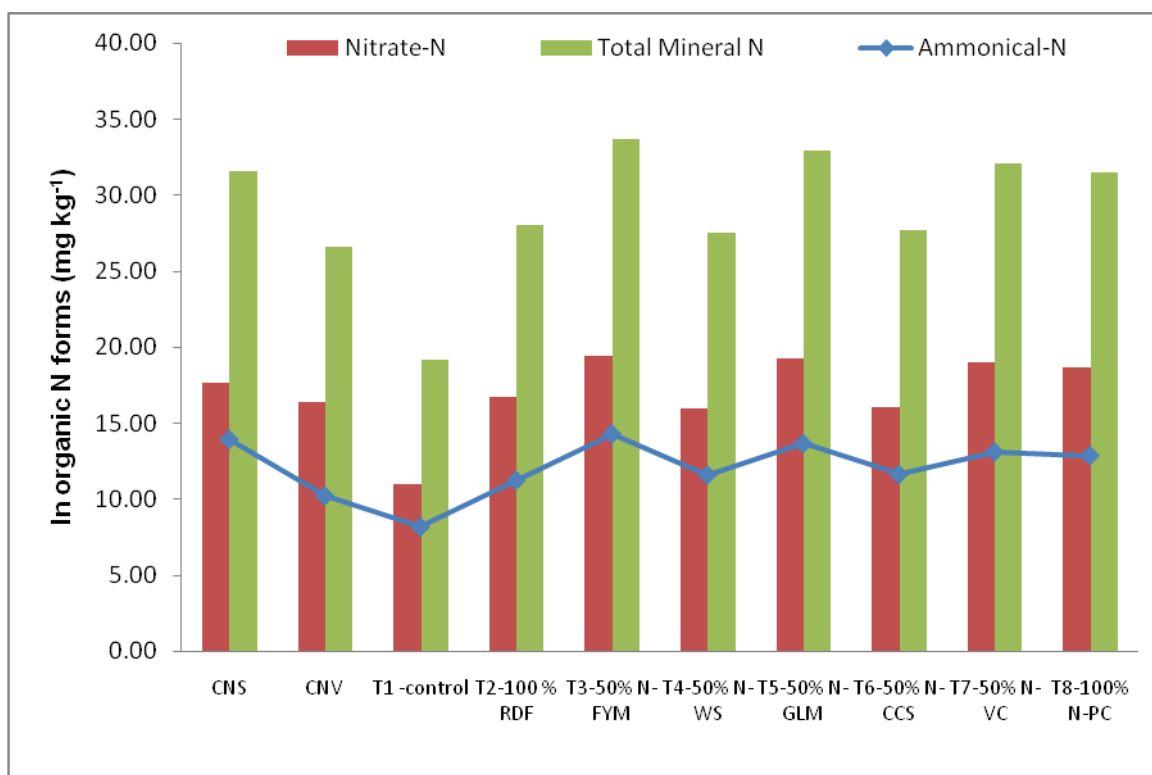


Fig. 17. Effect of tillage and IPNS on inorganic N forms of soil after harvest of soybean

of 100 % N through phosphocompost + remaining P through chemical fertilizer (31.49 mg kg⁻¹) which was found at par with each other and significantly superior over control treatments. Lowest total mineral N was noticed in control (19.15 mg kg⁻¹). Santhy et al. (1999) reported that continuous cropping and fertilization had significantly increased available N content of soil over initial status but with 100% NPK +FYM, available N content was higher due to higher organic carbon content of soil. However, the highest NH₄-N and NO₃-N with combined application of NPK and FYM, which was ascribed due to increased microbial activity and resultant enhanced nitrification process with a reduction in leaching losses.

Interaction

The Interaction between tillage and IPNS on nitrate N, ammonical N and mineral N was non significant.

4.1.2.6.2 Inorganic N forms of cotton

The data pertaining to the various nitrogen forms as affected by various treatments are presented in Table 23 and depicted in Fig 18.

Effect of Tillage

The data indicated that after harvest of cotton the significantly higher ammonical N was recorded in conservation tillage (12.83 mg kg⁻¹) as compared to conventional tillage (7.55 mg kg⁻¹). The significantly higher nitrate N was recorded in conservation tillage (14.66 mg kg⁻¹) as compared to conventional tillage (11.92 mg kg⁻¹). The significantly higher total mineral N was recorded in conservation tillage (27.49 mg kg⁻¹) as compared to conventional tillage (19.47 mg kg⁻¹). The nitrate N was higher as compared to ammonium N in conservation tillage might be due to more retention of moisture which prevent to large extent to further oxidation of ammonium to nitrate. Similar results about effect of tillage on the distribution of various nitrogen forms in soil were reported by Chandra *et al.* (2017), Tabasum *et al.* (2010).

Effect of integrated plant nutrient system

The ammonical N after harvest of cotton in *kharif* (2017-18) was significantly influenced by various treatments. The maximum ammonical N was observed with the addition of 50 % N through FYM + remaining RD

through chemical fertilizer (12.58 mg kg^{-1}) followed by with the application of 50 % N through GLM + remaining RD through chemical fertilizer (11.72 mg kg^{-1}), with the use of 50 % N through vermicompost + remaining P through chemical fertilizer (11.50 mg kg^{-1}) and with the application of 100 % P through phosphocompost + remaining N through chemical fertilizer (10.97 mg kg^{-1}) which was found at par with each other and significantly superior over control.

The nitrate N after harvest of cotton in *kharif* (2017-18) was significantly influenced by various treatments. The higher nitrate N was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (16.00 mg kg^{-1}) followed by with application of 50% N through GLM + remaining RD through chemical fertilizer (15.73 mg kg^{-1}), with application of 50 % N through vermicompost + remaining P through chemical fertilize (14.69 mg kg^{-1}) and with application of 100 % P through phosphocompost + remaining N through chemical fertilizer (14.33 mg kg^{-1}) which was which was found at par with each other and significantly superior over control. Lowest nitrate N was observed under control (8.20 mg kg^{-1}).

The total mineral N after harvest of cotton in *kharif* (2017-18) was significantly influenced by various treatments. Total mineral N is the sum of ammonical N and nitrate N fraction of soil N. As a result, the trend was almost similar as ammonical N and nitrate N form. However, the higher total mineral N was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (28.58 mg kg^{-1}) followed by with application of 50% N through GLM + remaining RD through chemical fertilizer (27.45 mg kg^{-1}), with the application of 50 % N through vermicompost + remaining P through chemical fertilizer (T₇) (26.19 mg kg^{-1}) and with the application of 100 % P through phosphocompost + remaining N through chemical fertilizer (25.30 mg kg^{-1}) which was significantly superior over control treatments. The lowest mineral nitrogen was observed under control (14.64 mg kg^{-1}). This result conformity with the findings of Ghuman *et al.*, (1997), Zang *et al.*, (2009), Bhattacharyya *et al.*, (2013) and Puli *et al.*, (2013).

Table 23. Effect of tillage and IPNS on inorganic N forms in soil after harvest of cotton under soybean-cotton rotation

	Treatments		Inorganic N forms (mg kg ⁻¹)		
	(a)Tillage		NH ₃ -N	NO ₂ -N	Total Mineral N
	Set I-Conservation tillage		12.83	14.66	27.49
	Set II -Conventional tillage		7.55	11.92	19.47
	SE(m)±		0.18	0.11	0.23
	CD at 5 %		0.51	0.32	0.67
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	6.44	8.20	14.64
T ₂	100 % RDF	100 % RDF	8.10	12.28	20.38
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	12.58	16.00	28.58
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	10.15	12.92	23.07
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	11.72	15.73	27.45
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	10.07	12.22	22.29
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	11.50	14.69	26.19
T ₈	100 % N through phoshpocompost + remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	10.97	14.33	25.30
	SE(m)±		0.35	0.22	0.46
	CD at 5 %		1.02	0.63	1.34
	(c) Interaction		NS	NS	NS

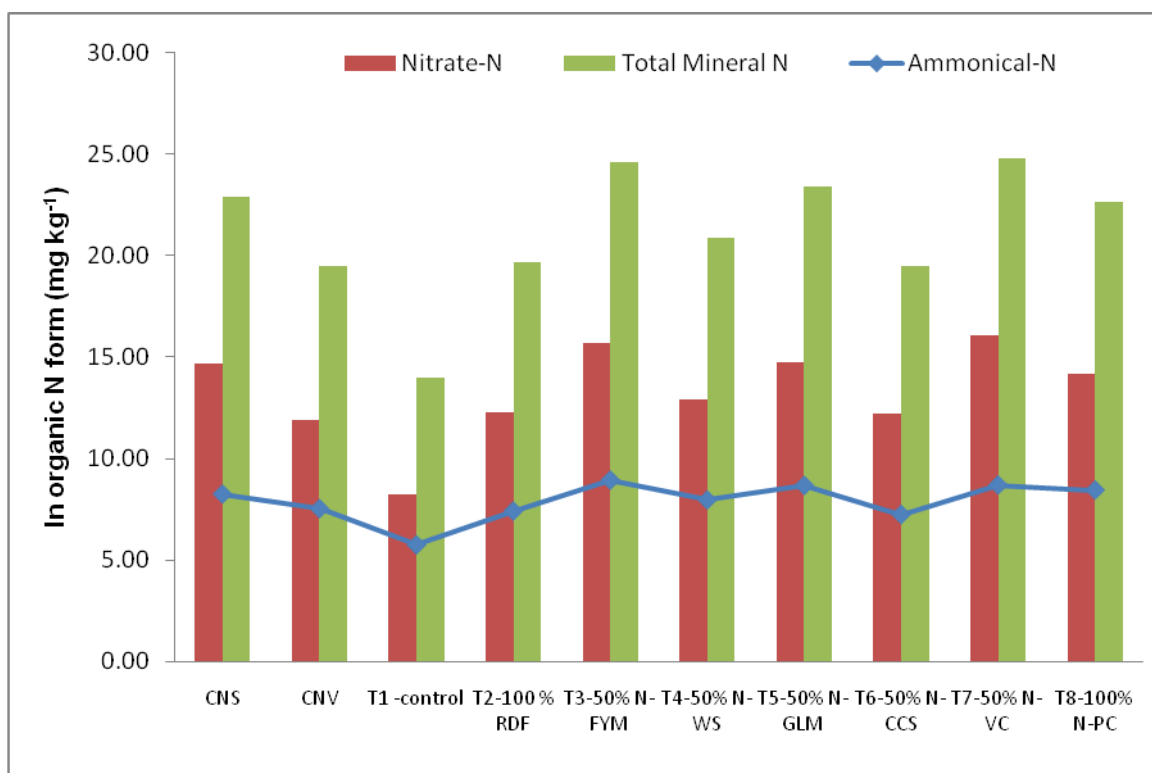


Fig. 18. Effect of tillage and IPNS on inorganic N forms of soil after harvest of cotton

Interaction

The Interaction between tillage and IPNS on nitrate nitrogen, ammonical nitrogen and mineral nitrogen was non significant.

4.1.3. Biological properties

The soil biological properties are useful for improving soil structure, which is necessary for increasing crop productivity. They also have profound influence on nutrient availability in soil.

4.1.3.1 Soil Microbial Biomass Carbon (SMBC)

The soil microbial biomass carbon act as the transformation agent of the organic matter in soil. As such, the biomass is a both source and sink of the carbon, nitrogen and phosphorus contained in the organic matter. It is the centre of majority of biological activity in soil.

Data pertaining to soil microbial biomass carbon (SMBC) as influenced by different treatments are presented in Table 24 and graphically represented in Fig 19. Represent the considerable variation in SMBC under the influence of tillage and nutrient management.

Effect of Tillage

The data indicated that, the effect of tillage on soil microbial biomass carbon was found to be significant. In first year significantly higher soil microbial biomass carbon was observed in conservation tillage ($276 \mu\text{g g}^{-1}$ soil) as compared to conventional tillage ($263 \mu\text{g g}^{-1}$ soil) and in second year higher soil microbial biomass carbon was observed in conservation tillage ($258 \mu\text{g g}^{-1}$ soil) as compared to conventional tillage ($241 \mu\text{g g}^{-1}$ soil). Rita Patil (1999) has also reported higher soil microbial biomass carbon in irrigated cropping system as compared to rainfed condition.

The greater amount of crop residue incorporation and burying in plot remaining with conservation tillage might have provided available substrate for maintenance of larger SMB pool and higher C and N mineralization. The results were in consonance with the findings of Garcia *et al.* (1997), Murugandam *et al.* (2009), Lal and Jacinthe (2009) and Gabhane *et al.*, (2014). Similar observations were recorded by Rao (2007) indicating

greater amount of microbial biomass carbon in minimum tillage as compared to conventional tillage.

Effect of integrated plant nutrient system

The SMBC was significantly increased under all nutrient management practices with the treatments (T₃, T₅, T₇, and T₈) as compared to control and chemical fertilizers application during both the years under study for soybean and cotton. The sources of organics under study have recorded on par results in soil microbial biomass carbon. However, application of 50 % N through FYM + remaining RD through chemical fertilizer recorded significant improvement in soil microbial biomass carbon (279 µg g⁻¹ soil) over all other treatments and application of 100 % N through phosphocompost + remaining P through chemical fertilizer was found on par with control. It was also noted that the application of 50% N through GLM + remaining RD through chemical fertilizer and 50 % N through vermicompost + remaining RD through chemical fertilizer recorded maximum increase in SMBC over control and 100% RDF. It was a soil restorative practice causing considerable improvement in soil health.

The treatment where only organics were added including crop residues, phosphocompost, vermicompost and glyricidia green leaf manuring with inorganic fertilizers showed increase in soil microbial biomass carbon over 100 % RDF. It might be due to the supply of readily available and mineralizable carbon by the addition of organic matter resulted in higher microbial activity and it turns increased the microbial biomass carbon. This indicated that, systems with high organic matter inputs and easily available soil organic matter compounds tends to have higher microbial biomass contents and activities because they are preferred energy sources for microorganisms. These results are in conformity with Manna *et al.* (1996), Goyal *et al.* (2009), Verma and Mathur (2009), Chakraborty *et al.* (2011), Manna *et al.* (2005), Mishra *et al.* (2008) and Nager *et al.*,(2017) .

In next kharif season, it was observed that during 2017-18 under cotton significantly highest value of SMBC (267 µg g⁻¹ soil) was recorded in application of 50 % N through FYM + remaining RD through chemical fertilizer followed by application of 100 % P through phosphocompost + remaining N

through chemical fertilizer for cotton ($264 \mu\text{g g}^{-1}$ soil) and the treatment receiving 50 % N through vermicompost + remaining RD through chemical fertilizer ($262 \mu\text{g g}^{-1}$ soil). The lowest SMBC value recorded in control ($219 \mu\text{g g}^{-1}$ soil) and in 100% RDF ($231 \mu\text{g g}^{-1}$ soil). During seasons for soybean and cotton crop, the soil microbial biomass carbon was found much low in chemical fertilizers which was slightly improved under use of crop residues and green manuring treatments. However, it was considerably improved due to INM indicating the importance of addition of organic matter to soil along with chemical fertilizers for achieving good soil biological activity. Inputs of readily metabolizable C and N in organic manure are the most important factors contributing to the microbial biomass carbon increase in the FYM treatments (Vineela *et al.* 2008).

SMBC was found to increase at grand growth stage of soybean crop, where the microbial activity was more. The FYM amended plots provided a steady source of organic C to support the microbial community compared to NPK- treated plots. Generally, FYM applied to soil has long been employed to enhance favorable soil conditions. Decomposition of manure in soil releases essential nutrients such as N, P and S that are required by micro-organisms. Kandeler *et al.* (1999) found that FYM (30 t ha^{-1}), applied every second year doubled microbial biomass under spring barley.

This might be due to the supply of additional mineralizable and readily hydrolysable C due to organic manure application which resulted in higher microbial activity and in return higher microbial biomass carbon. Similar observations were also recorded by Kukreja *et al.* (1991) Manna *et al.* (1996) and Nager *et al.*, (2017). The lowest SMBC was observed in 100% RDF through chemical fertilizers.

Interaction

The Interaction between tillage and IPNS on soil microbial biomass carbon was non significant.

Table 24 : Effect of tillage and IPNS on Soil Microbial Biomass Carbon of soil at grand growth stage of soybean and cotton under soybean-cotton rotation

	Treatments		SMBC ($\mu\text{g g}^{-1}$)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		276	258
	Set II-Conventional tillage		263	241
	SE(m) $\pm$		1.99	1.28
	CD at 5 %		5.76	3.70
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	248	219
T ₂	100 % RDF	100 % RDF	262	231
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	279	267
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	269	251
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	278	259
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	265	242
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	277	262
T ₈	100 % N through phoshpocompost + remaining P through chemical fertilizer for soybean	100 % P through phoshpocompost + remaining N through chemical fertilizer for cotton	279	264
	SE(m) $\pm$		3.99	2.56
	CD at 5 %		11.52	7.40
	(c) Interaction		NS	NS

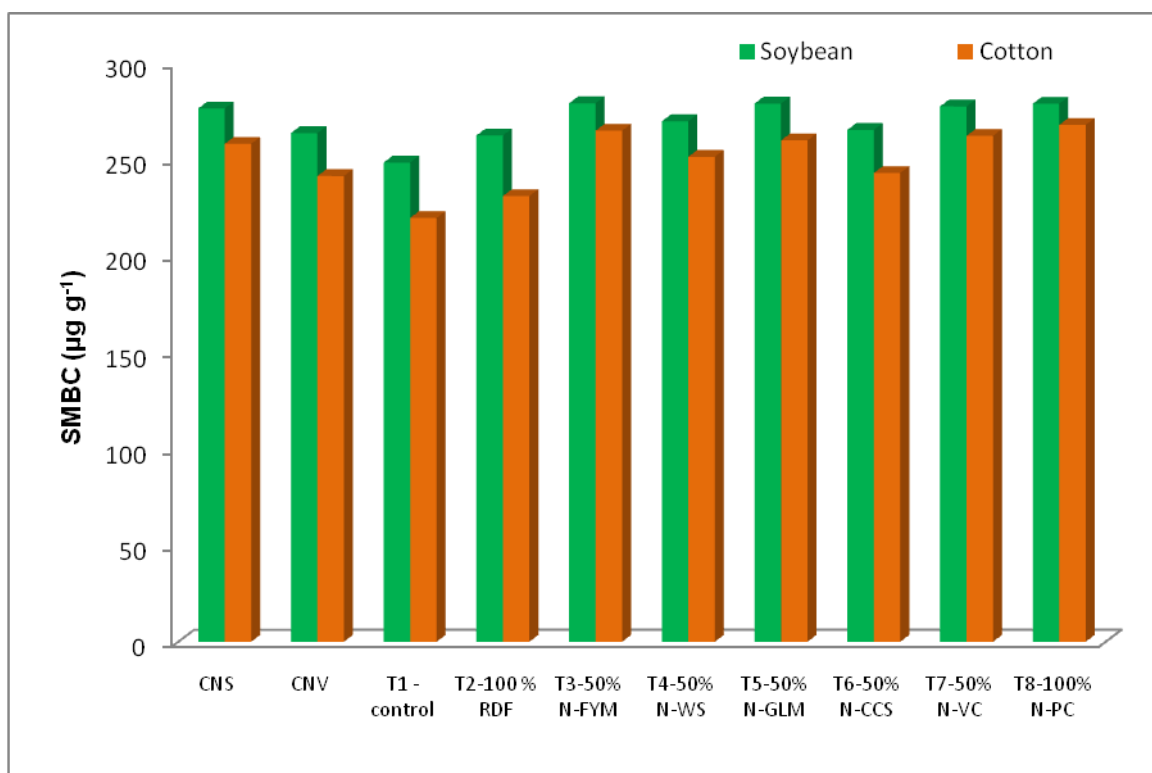


Fig. 19. Effect of tillage and IPNS on SMBC of soil at grand growth of soybean and cotton

4.1.3.2. Dehydrogenase activity (DHA)

All biological reactions in soil are catalysed by enzymes. Soil enzyme activities are believed to indicate the extent of specific processes in soil and in some cases acts as indicators of soil fertility. The activity of dehydrogenase enzyme was strongly influenced by long term fertilizer use. Biological activity of a soil is the function of number of microorganism present in soil and physiological efficiency. Monitoring of dehydrogenases, which are respiratory enzymes and integral part of all the soil organisms is a measure of biological activity of soil. Crop contributes to the enzyme pool in the soil either through dehydrogenase exudation or indirectly through exudation of C - substrates, which promote increase in the microbial growth in soil.

To depict the considerable variation in activity of microorganisms in dehydrogenase activity as influenced by tillage and nutrient management are presented in Table 25 and graphically depicted in Fig.20 .

Effect of Tillage

On examination of data, it could be noticed that the effect of tillage on dehydrogenase activity was significant. In first year numerically higher dehydrogenase activity was observed in conservation tillage ($67.72 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) as compared to conventional tillage ($58.08 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$). In second year numerically higher dehydrogenase activity was observed in conservation tillage ($58.97 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) as compared to conventional tillage ($50.90 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$). Similar findings were reported by Nager *et al.*, (2017) and Gabhane *et al.*, (2014). Rita Patil (1999) has also reported higher dehydrogenase activity in irrigated cropping system as compared to rainfed condition.

Effect of integrated plant nutrient system

The significant improvement of dehydrogenase activity was observed due to 50 % FYM + remaining RD through chemical fertilizer ($72.32 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) followed by ($70.44 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 100 % N through phosphocompost + remaining P through chemical fertilizer for soybean and ($69.33 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 50% N through GLM + remaining RD through chemical fertilizer and ($68.91 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 50 % N through

vermicompost + remaining RD through chemical fertilizer. The lowest dehydrogenase activity ($48.03 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) was observed in control and 100% RDF. Significant increase in dehydrogenase activity with the application of FYM might be due to increase in microbial growth with addition of carbon substrate Mandal *et al.* (2007), Verma and Mathur (2009) and Kharche *et al.*, (2010).

The stronger effects of FYM on dehydrogenase activity might be due to the more easily decomposable components of crop residues on the metabolism of soil microorganisms and due to the increase in microbial growth with addition of carbon substrate. The FYM application was superior in improving DHA as it stratified microbial population. Also, being chief carbon source, it provides energy for soil microorganisms, and increases number of pores, which are considered important in soil-water-plant relationships and maintain good soil structure accompanied by better dehydrogenase activity (Marinari *et al.* 2000).

In next kharif season in (2017-18) under cotton the highest DHA activity ($62.87 \text{ TPF g}^{-1} 24 \text{ h}^{-1}$) was observed with addition of on 50 % FYM + remaining RD through chemical fertilizer followed by ($61.50 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 100 % P through phosphocompost + remaining N through chemical fertilizer and ($61.03 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 50% N through GLM + remaining RD through chemical fertilizer and ($58.92 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) and 50% N through vermicompost + remaining RD through chemical fertilizer. The lowest dehydrogenases activity ($37.34 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) was observed in control and ($43.38 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) 100% RDF. Addition of organic sources acts as good source of carbon and energy to heterotrophs by their population, increased with an increase in enzymatic activities. Similar relationship between organic carbon and enzymatic activities were reported by Bohme and Bohme (2006). Balanced nutrition of crop resulted in to better proliferation of root (rhizosphere) responsible for the maximum activity of enzymes. These findings corroborated the findings of Gupta and Bhardwaj (1990) and Kumar *et al.*, (2007).

Table 25. Effect of tillage and IPNS on Dehydrogenase activity of soil at grand growth period of soybean and cotton under soybean-cotton rotation

	Treatments		DHA ($\mu\text{gTPF g}^{-1} 24 \text{ h}^{-1}$)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		67.72	58.97
	Set II-Conventional tillage		58.08	50.90
	SE(m) $\pm$		0.68	0.52
	CD at 5 %		1.95	1.50
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	48.03	37.34
T ₂	100 % RDF	100 % RDF	59.48	43.38
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	72.32	62.87
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	63.20	57.72
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	69.33	61.03
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	51.36	56.86
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	68.91	58.92
T ₈	100 % N through phoshpocompost + remaining P through chemical fertilizer for soybean	100 % P through phoshpocompost + remaining N through chemical fertilizer for cotton	70.44	61.50
	SE(m) $\pm$		1.35	1.04
	CD at 5 %		3.91	3.01
	(c) Interaction		NS	NS

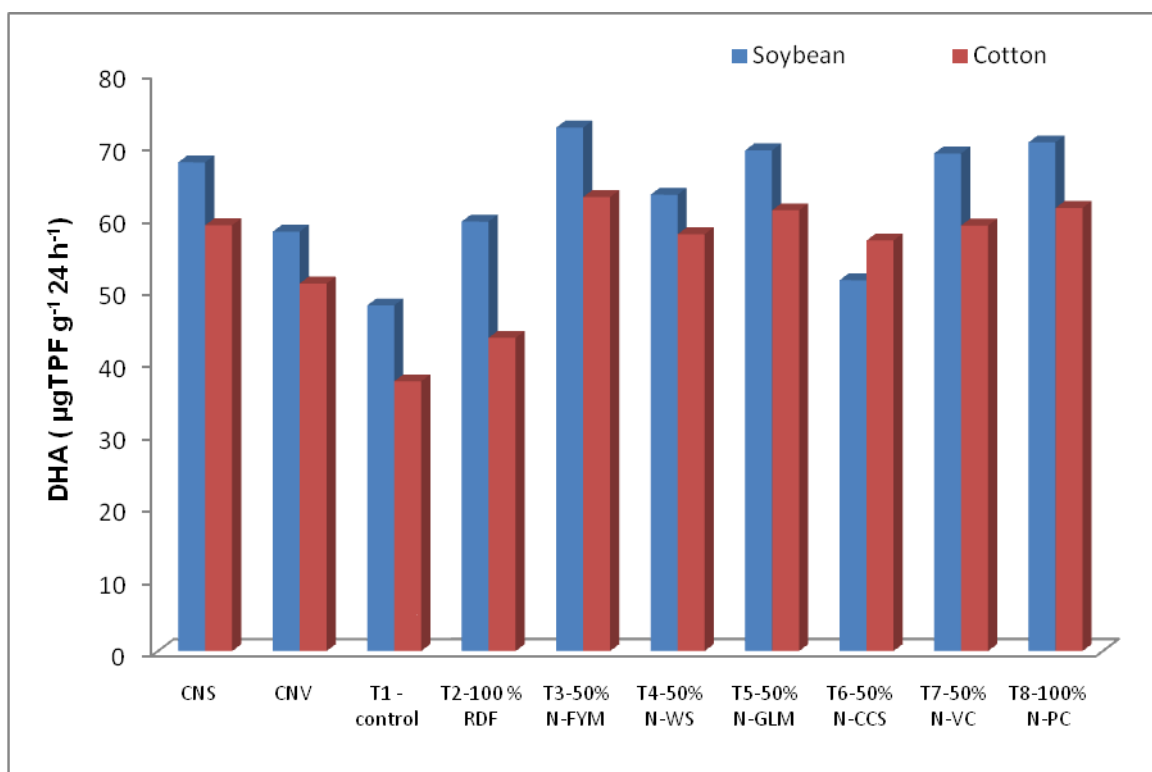


Fig. 20. Effect of tillage and IPNS on DHA of soil at grand growth stage of soybean and cotton

The dehydrogenase activity (DHA) was significantly influenced by nutrient management. The significantly highest DHA ($62.87 \mu\text{g TPF g}^{-1} 24 \text{ hr}^{-1}$) was obtained in treatment 50% N through FYM + remaining RDF through chemical fertilizer which was superior over all other treatments. Significant increase in dehydrogenase activity with the application of FYM might be due to increase in microbial growth with addition of carbon substrate, it provides energy for soil microorganisms and increases number of pores which are considered important in soil water plant relationship and maintain good soil structure accompanied by better dehydrogenase activity. Similar observations were also recorded by Selvi *et al.* (2004) and Verma and Mathur (2009).

The significantly lower DHA at only chemical fertilizer in comparison with high DHA under crop residues, green manuring indicate the importance of organics for soil biological health.

Interaction

The Interaction between tillage and IPNS on dehydrogenase activity of soil was non significant on biological properties of soil.

4.1.3.3 CO₂ Evolution

The CO₂ evolution is an index of microbial activity and fate of decomposition of organic matter in soil. Soil respiration is an evaluation of soil biological activity and extent of organic matter decomposition. Data pertaining to CO₂ evolution as influenced by different treatments are presented in Table 26 and graphically depicted in Fig. 21.

Effect of Tillage

On examination of data, it could be noticed that, the effect of tillage on CO₂ evolution was found to be significant. In first year higher CO₂ evolution was noticed in conservation tillage ($68.58 \text{ mg } 100 \text{ g}^{-1} \text{ soil}$) as compared to conventional tillage ($63.53 \text{ mg } 100 \text{ g}^{-1} \text{ soil}$). In second year numerically higher CO₂ evolution was observed in conservation tillage ($64.44 \text{ mg } 100 \text{ g}^{-1} \text{ soil}$) as compared to conventional tillage ($58.54 \text{ mg } 100 \text{ g}^{-1} \text{ soil}$). Similar trend was also noticed during second year of study. Similar finding were reported by Bouma *et al.*, (1997), Casel *et al.*, (2000) Lal and Jacinthe (2009).

Effect of integrated plant nutrients system

The CO₂ evolution was influenced significantly due to integrated nutrient management. During first year CO₂ evolution (71.25 mg 100 g⁻¹ soil) was found significantly higher in the treatment of 50 % N through FYM + remaining RDF through chemical fertilizer followed by 100 % N through phosphocompost + remaining P through chemical fertilizer (71.02 mg 100 g⁻¹ soil) and application of 50 % N through vermicompost + remaining RD through chemical fertilizer (70.68 mg 100 g⁻¹ soil) which were found to be at par with each other. The lowest CO₂ evolution was recorded in control (53.12 mg 100 g⁻¹ soil).

During second year CO₂ evolution (70.89 mg 100 g⁻¹ soil) was found significantly higher in application of 50 % N through FYM + remaining RDF through chemical fertilizer followed by 100 % P through phosphocompost + remaining N through chemical fertilizer (69.13 mg 100 g⁻¹ soil) and 50 % N through vermicompost + remaining RD through chemical fertilizer (68.45 mg 100 g⁻¹ soil) which were found to be at par with each other. The lowest CO₂ evolution (40.95 mg 100 g⁻¹ soil) was recorded in control.

Higher CO₂ evolution in the FYM treated plots indicated that improvement in microbial population with application of FYM, phosphocompost, vermicompost, glyricidia green leaf manuring and wheat straw might have increased the metabolic activity by utilizing substrates in the form of root exudates whereas, FYM might have helped in evolution of more CO₂. Similar findings were reported by Kaur *et al.* (2005) and Surekha and Rao (2009). This increase in CO₂ evolution with NPK addition may be attributed to their involvement in stimulating microbial activities and subsequently enhancing the rate of decomposition of organic material (Malewar *et al.*, 1999). Hence, the use of organic manure either singly or combination with chemical fertilizers plays a key role in sequestering C and building up soil fertility. Application of organics stimulates and increases the living micro organisms in the soil involved in biochemical activity of importance to soil fertility and plant nutrition. Substantial increase in microbial biomass due to straw incorporation was reported by Powlson *et al.* (1987).

Table 26. Effect of tillage and IPNS on CO₂ evolution of soil at grand growth stage of soybean and cotton under soybean-cotton rotation

	Treatments		CO ₂ evolution (mg 100 g ⁻¹ soil)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		68.58	64.44
	Set II-Conventional tillage		63.53	58.54
	SE(m)±		0.50	0.56
	CD at 5 %		1.45	1.62
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	53.12	40.95
T ₂	100 % RDF	100 % RDF	61.53	51.29
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	71.25	70.89
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	68.11	56.87
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	70.22	68.16
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	69.51	65.15
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	70.68	68.45
T ₈	100 % N through phoshpocompost + remaining P through chemical fertilizer for soybean	100 % P through phoshpocompost + remaining N through chemical fertilizer for cotton	71.02	69.13
	SE(m)±		1.00	1.12
	CD at 5 %		2.89	3.24
	(c) Interaction		NS	NS

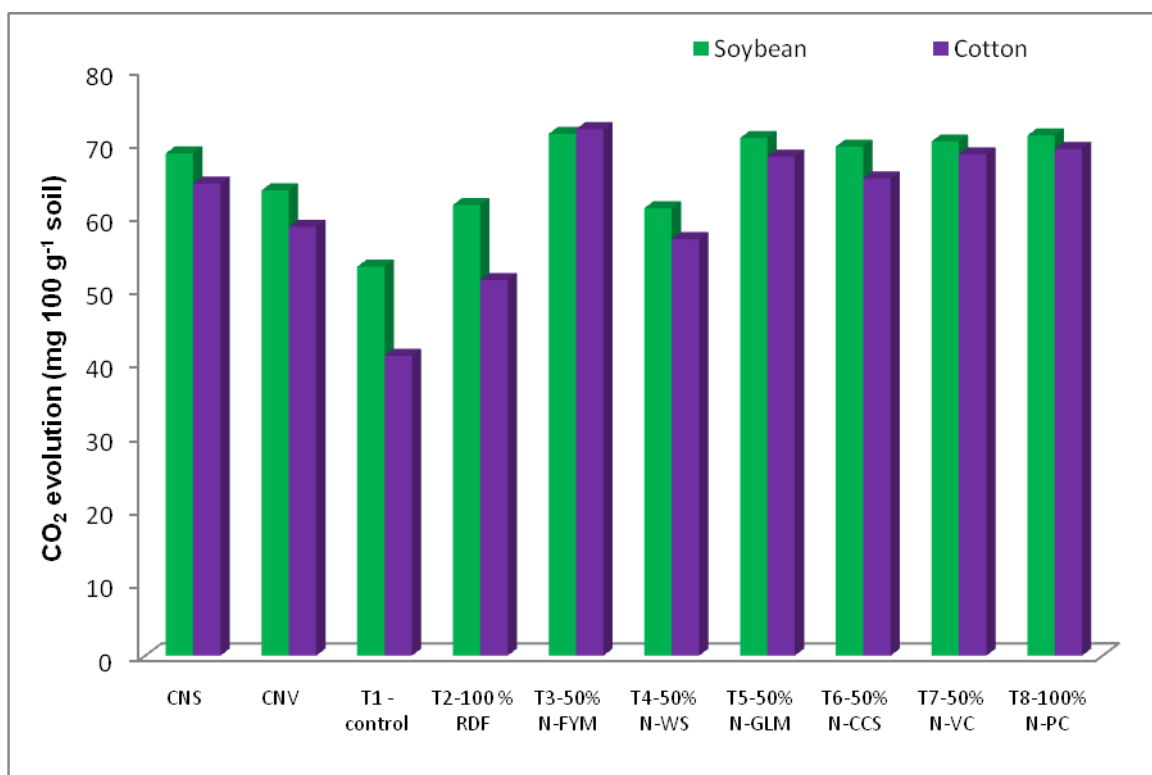


Fig. 21. Effect of tillage and IPNS on CO₂ evolution of soil at grand growth stage of soybean and cotton

Interaction

The Interaction between tillage and IPNS was non significant on biological properties of soil.

4.1.3.3.4. SOC Stock

The data pertaining to the SOC stock as affected by various treatments are presented in Table 27 and depicted in Fig 22.

Effect of Tillage

In first year significantly higher SOC stock was recorded in conservation tillage (11.85 Mg ha^{-1}) as compared to conventional tillage (11.66 Mg ha^{-1}) after harvest of soybean. In second year higher SOC stock was recorded in conservation tillage (11.87 Mg ha^{-1}) as compared to conventional tillage (11.68 Mg ha^{-1}) after harvest of cotton. Similar findings were reported by Liu et al., (2005) and Miukha and Rice (2004).

Effect of integrated plant nutrient system

The SOC stock after harvest of soybean in *kharif* (2016-17) was significantly influenced by various treatments. Significantly higher SOC stock was observed with the addition of 50 % N through FYM + remaining RD through chemical fertilizer (12.16 Mg ha^{-1}) which was significantly superior over all the other treatments and lowest SOC stock was observed under control (11.28 Mg ha^{-1}). In next *kharif* season of cotton significantly highest SOC stock (12.34 Mg ha^{-1}) was observed under 50 % N through FYM + remaining RD through chemical fertilizer followed by application of 50% N through GLM + remaining RD through chemical fertilizer (12.31 Mg ha^{-1}), application of 100 % P through phosphocompost + remaining N through chemical fertilizer (11.96 Mg ha^{-1}) and application of 50 % N through vermicompost + remaining RD through chemical fertilizer (11.89 Mg ha^{-1}). Thus results, suggested that the use of FYM, Phosphocompost, crop residues and green manuring with chemical fertilizers help in maintaining SOC Stock of soil over a long term period.

Addition of organic materials might have enhanced the microbial activity in the soil and consequently the release of complex organic substances like humic and fulvic acids acting as chelating agents during the decomposition of organic manure and crop residue.

Table 27. Effect of tillage and IPNS on SOC Stock in soil after harvest of soybean and cotton under soybean–cotton rotation

	Treatments		SOC Stock (Mg ha ⁻¹)	
	(a)Tillage		Soybean	Cotton
	Set I-Conservation tillage		11.85	11.87
	Set II-Conventional tillage		11.66	11.68
	SE(m)±		0.10	0.11
	CD at 5 %		0.29	0.31
	(b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	11.28	11.31
T ₂	100 % RDF	100 % RDF	11.42	11.38
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	12.16	12.34
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	11.49	11.59
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	12.13	12.31
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	11.52	11.57
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	11.94	11.89
T ₈	100 % N through phoshpocompost + remaining P through chemical fertilizer	100 % P through phoshpocompost + remaining N through chemical fertilizer	12.09	11.96
	SE(m)±		0.20	0.21
	CD at 5 %		0.57	0.61
	(c) Interaction		NS	NS

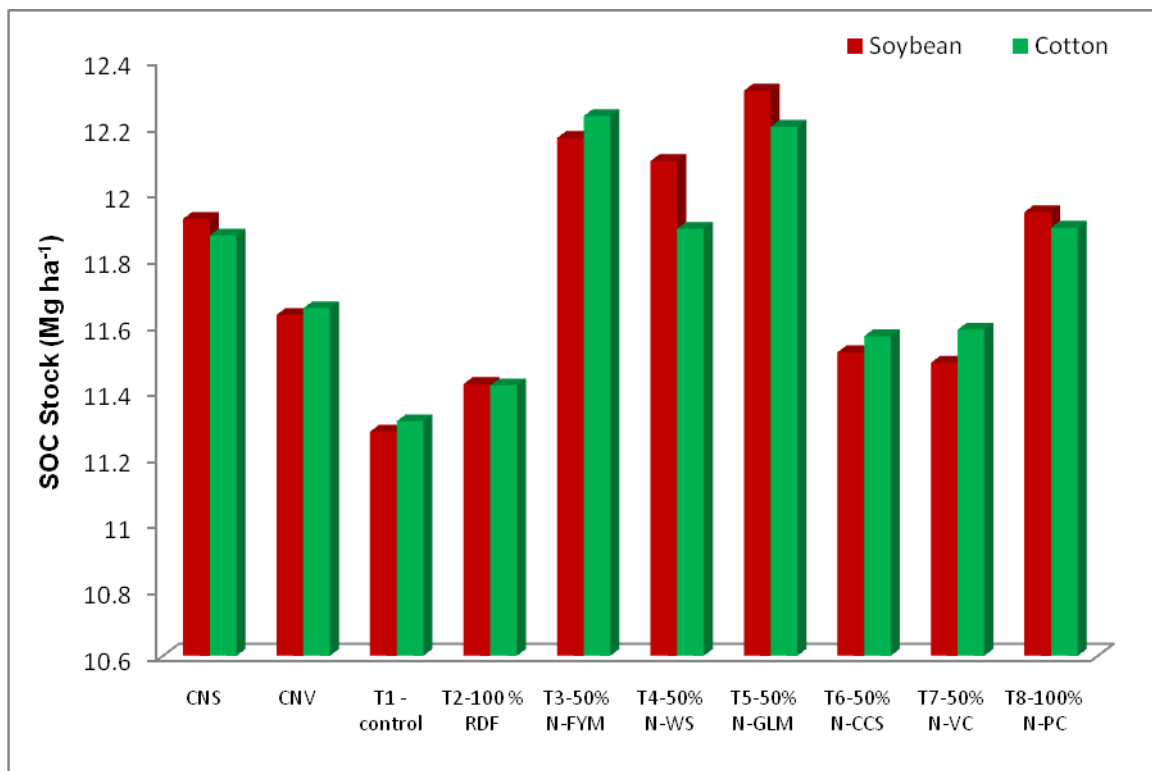


Fig. 22. Effect of tillage and IPNS on SOC stock of soil after harvest of soybean and cotton

This could have prevented carbon from precipitation, fixation, oxidation, leaching and augmented the solubility, mobility, availability of insoluble micronutrients by Swarup *et al.*, (1984) and Manna *et al.*, (2005). Similar finding was reported by Prasad and Sinha (2000) in their studies on long term effect of fertilizers and organic manures on soil properties in calcareous soils of Pusa (Bihar).

Interaction

The Interaction between tillage and IPNS on SOC stock was non significant.

4.2. Soybean and Cotton yield

4.2.1 Seed Yield of Soybean

The data regarding seed and straw yield of soybean (Table 34 a) as influenced by tillage and integrated plant nutrient system under soybean-cotton rotation is depicted graphically in Fig 23.

Effect of tillage

The findings showed that on significantly increased soybean seed yield in conservation tillage as compared to conventional tillage. The soybean seed yield was recorded maximum (24.64 q ha⁻¹) in conservation tillage as compared to conventional tillage (22.61 q ha⁻¹).

The highest soybean seed yield in conservation tillage might be due to its cumulative effect of soil moisture which ultimately helps in improving nutrient supplying capacity of soil, use efficiency thus it directly influences on uptake of higher nutrients in conservation tillage than conventional tillage. Similar finding was reported by Mohanty and Painuly (2003), Namdeo *et al.*, (2003), and Nehra *et al.*, (2006) and Mohammadi *et al.*, (2013), Khan *et al.*, (2015) and Mehdi *et al.*, (2016).

Effect of integrated plant nutrient system

The highest seed yield of soybean was recorded with the application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (25.80 q ha⁻¹) followed by the use of 50 % N through vermicompost + remaining RD through chemical fertilizer (25.67 q ha⁻¹), 50 %

N through FYM + remaining RD through chemical fertilizer (25.00 q ha^{-1}), 50% N through GLM + remaining RD through chemical fertilizer (24.55 q ha^{-1}) and 100 % RDF (23.69 q ha^{-1}). The increase in yield with IPNS treatments may be due addition of organics which enhances soil fertility and resulted in higher yield. These results are in close conformity with the findings Babhulkar *et al.* (2000), Saini *et al.* (2005) and Kundu *et al.* (2008). Due to solubilisation of native as well as applied nutrient fertilizers at higher level with crop residues produces complexing agents and nutrients are released after microbial decay of crop residue ultimately increase the grain yield. Similar findings were reported by Singh *et.al.* (2002), Prasad and Sinha (2000), Deshmukh *et al.* (2010), Kumar *et al.* (2006) Ghatage *et al.* (2003) and Bhalerao *et al.*, (2007).

Seed yield of soybean was also recorded higher with application of chemical fertilizers. The leguminous crop fixes the atmospheric nitrogen by nodule formation. Even though there is a severe decline in yield if nitrogen is not provided externally as its requirement is essential in the initial period before the formation of nodules. The increase in seed yield of soybean with 100 % N through phosphocompost + remaining P through chemical fertilizer could be attributed to cumulative effect of better growth that produced more number of pods which ultimately increased the seed yield. The higher seed yield due to conjoint nutrient use might be due to increased nutrient supply and also as a result of better utilization of applied nutrients. Similar findings were reported by Singh and Kumar (2012), Prabhakaran *et.al* (2003), Sharma *et.al.* (2010), Sikka *et al.* (2012), Singh *et al.* (2009), and Chafle *et al.* (1999) The increased in seed yield due to residual effect of balanced fertilization with secondary nutrients and micronutrients was also recorded by Guldekar *et.al* (2005) and Chaturvedi *et.al.* (2010).

The decomposition and immobilization rates of the green manuring plants depends upon their N and P contents, or their C: N and C: P ratios, the wider the ratios the more are the rates of N and P immobilization. The addition of N and P fertilizers in these plots narrowed the C: N and C: P ratio of both the green manures, and perhaps the decomposition was

increased thereby resulting in increased efficiency of the applied fertilizer by Subehia and Sepheya (2012).

Interaction

The Interaction between tillage and IPNS on seed yield of soybean was significant (Table 34(b)). The seed yield of soybean was increased significantly in conservation tillage along with various organic over the conventional tillage. The seed yield was significantly highest) with the application of 100 % N through phoshpocompost + remaining P through chemical fertilizer in conservation tillage (26.89 q ha⁻¹) followed by use of 50 % N through vermicompost + remaining RD through chemical fertilizer (26.80 q ha⁻¹) and 50 % N through FYM + remaining RD through chemical fertilizer (26.24 q ha⁻¹) over the conventional tillage indicating role of these organic in supplying nutrient to crop. The interaction of conservation tillage with Phoshpocompost, vermicompost and FYM was found most beneficial and recorded highest seed yield of soybean. This can be attributed to the combined effect of conservation tillage in improving soil properties along with FYM resulting into highest seed yield of soybean.

4.2.2 Straw Yield of Soybean

The data regarding straw yield of soybean (Table 28 a) as influenced by tillage and integrated plant nutrient system under soybean - cotton rotation is depicted graphically in Fig 23.

Effect of tillage

The straw yield of soybean was recorded significantly increased with conservation tillage as compared to conventional tillage. The soybean straw yield was recorded maximum (31.24 q ha⁻¹) in conservation tillage as compared to conventional tillage (28.49 q ha⁻¹).

The highest straw yield in conservation tillage and it might be due to supply of required higher quantity of nutrients for soybean growth thus it directly influences on uptake of higher nutrients in conservation tillage than conventional tillage. Similar findings were reported by Mohanty and Painuly (2003) , Namdeo *et al.*,(2003), and Nehra *et al.*, (2006).

Effect of integrated plant nutrient system

The straw yield of soybean significantly influenced with various integrated plant nutrient systems. The straw yield was ranged from 24.07 to 33.54 q ha⁻¹. However the highest straw yield of soybean (33.54 q ha⁻¹) was recorded under use of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by (32.85 q ha⁻¹) 50 % N through vermicompost + remaining RD through chemical fertilizer , 50 % N through FYM + remaining RD through chemical fertilizer (31.57 q ha⁻¹), 50% N through GLM + remaining RD through chemical fertilizer (31.45 q ha⁻¹) and 100 % RDF(30.46 q ha⁻¹). Increased straw yield with organic in combination with inorganic fertilizers which enhances the soil fertility as well as better soil condition for root penetration. The results are in agreement with Ghatange *et al.*,(2003), Ghosh *et.al.* (2005), Singh and Rai (2009), Naphade *et.al* (1993), Singh and Kumar (2012). Addition of 25 and 50 percent nitrogen through organics with chemical fertilizers significantly increased straw yield. Due to IPNS treatment which might have matches the crop demand at different physiological stages and reduces the losses through denitrification and volatilization as reflected in recording of higher dry matter yield. Thus, it can be concluded that there is scope for reduction in fertilizer dose at certain level when combined with organic sources like FYM or glyricidia leaf manuring and crop residues. These findings confirmed with the earlier reports of Hemlata *et al.*, (2000), Sikka *et al.*,(2009), Chaturvedi *et.al.* (2010), Waghmare *et al.* (2012), and Kuostu and Singh (2016).

Nitrogen being an essential component for vegetative growth produced significantly soybean straw yield. Nitrogen influenced the yield through source-sink relationship, resulting in higher production of photosynthates and their increased translocation to reproductive parts as nitrogen being the most important essential plant nutrient needed for growth and development of plant and known to increase the crop yields.



50% N (FYM) in CNV.



50% N (FYM) in CNS.



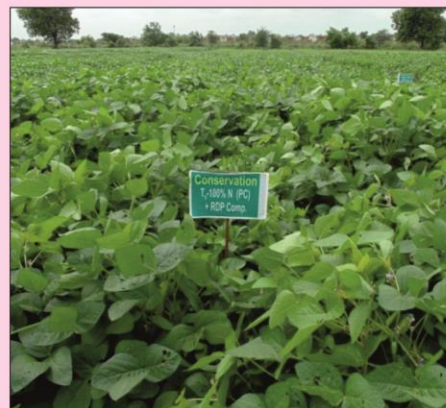
50% N (GLM) in CNV.



50% N (GLM) in CNS.



100% N (PC) in CNV.



100% N (PC) in CNS.

Plate 5. Effect of tillage and IPNS under soybean

Table 28 a. Effect of tillage and IPNS on seed and straw yield of soybean under soybean-cotton rotation

	Treatments		Soybean yield (qha ⁻¹)	
	(a)Tillage		Seed	Straw
	Set I-Conservation tillage		24.64	31.24
	Set II -Conventional tillage		22.61	28.49
	SE(m)±		0.53	0.37
	CD at 5 %		1.53	1.07
	b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	18.57	24.07
T ₂	100 % RDF	100 % RDF	23.69	30.46
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	25.00	31.57
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	23.19	29.43
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	24.55	31.45
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	22.56	29.45
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	25.67	32.85
T ₈	100 % N through phosphocompost+ remaining P through chemical fertilizer	100 % P through phosphocompost+ remaining N through chemical fertilizer	25.80	33.54
	SE(m)±		0.45	0.74
	CD at 5 %		1.30	2.15
	(c) Interaction		Sig	Sig

Table 28 b: Interaction of tillage and IPNS on soybean seed and straw yield under soybean-cotton rotation

IPNS	Soybean yield (q ha ⁻¹)					
	Seed			Straw		
	CNS	CNV	Mean	CNS	CNV	Mean
Control	19.70	17.44	18.57	26.66	21.48	24.07
100 % RDF	24.36	23.02	23.69	31.61	29.31	30.46
50 % N through FYM + remaining RD through chemical fertilizer	26.24	23.76	25.00	34.06	29.09	31.57
50% N through WS+ remaining RD through chemical fertilizer	24.76	21.61	23.19	32.15	26.71	29.43
50% N through GLM + remaining RD through chemical fertilizer	25.76	23.44	24.55	33.03	29.88	31.45
50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	22.74	22.37	22.56	32.41	26.49	29.45
50 % N through vermicompost+ remaining RD through chemical fertilizer	26.80	24.55	25.67	33.30	32.41	32.85
100 % P through phoshpocompost+ remaining N through chemical fertilizer	26.89	24.71	25.80	34.55	32.53	33.54
Mean	24.64	22.61		31.24	28.49	
	Tillage	NM	Int.	Tillage	NM	Int.
SE (m) ±	0.53	0.45	0.64	0.37	0.74	1.05
CD (at 5%)	1.53	1.30	1.84	1.07	2.15	3.03

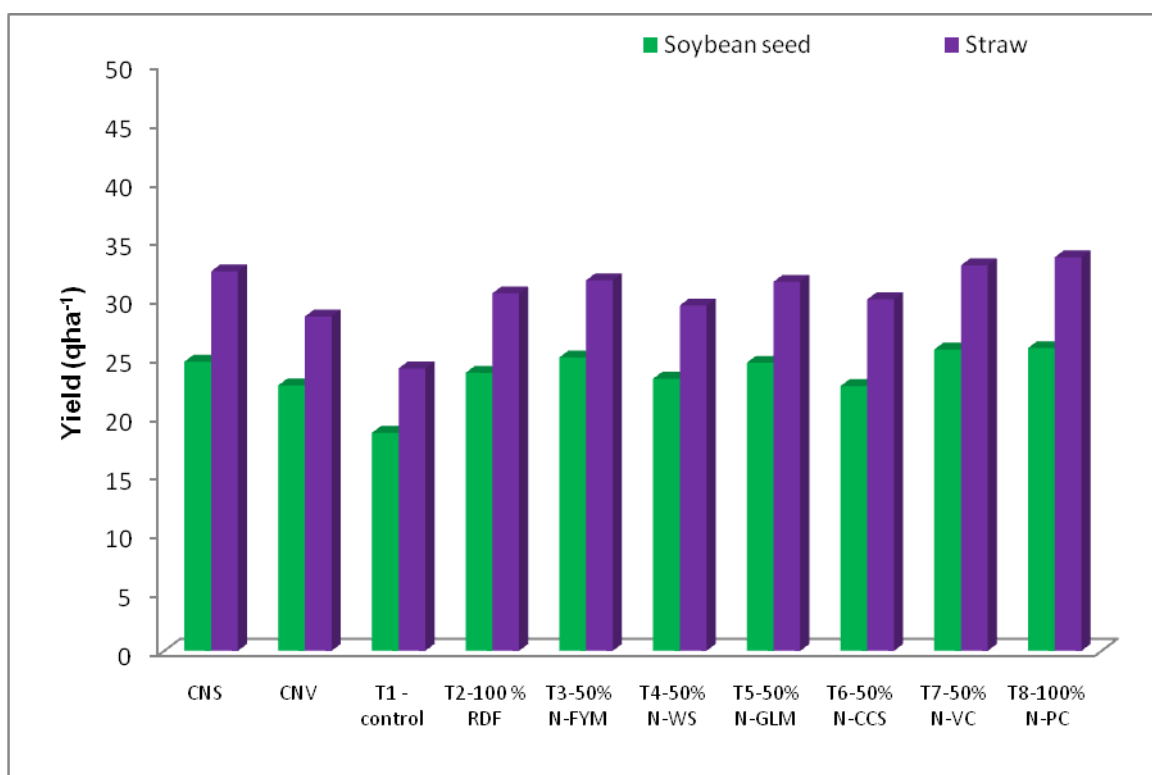


Fig. 23. Effect of tillage and IPNS on seed and straw yield of soybean

Interaction

The significantly highest straw yield was obtained (Table 34 (b)) with application of 100 % N through phosphocompost + remaining P through chemical fertilizer in (34.55 q ha⁻¹) conservation tillage followed 50 % N through use of vermicompost + remaining RD through chemical fertilizer (33.30 q ha⁻¹) and 50 % N through FYM + remaining RD through chemical fertilizer (34.06 q ha⁻¹). The lowest straw yield was observed under control in conservation tillage.

The interaction of conservation tillage with Phosphocompost and FYM was found most beneficial and recorded highest yield of straw. This can be attributed to the combined effect of conservation tillage in improving soil properties along with FYM resulting into highest yield of soybean. The conservation tillage along with glyricidia green leaf manuring also recorded significant yields which were at par with FYM which also signifies the importance of conservation tillage with organics.

4.2.3. Seed Cotton yield

Data in respect of the effect of tillage and IPNS on seed cotton and stalk yield are presented in Table 29 a. and graphically depicted in Fig 24.

Effect of Tillage

The data in respect of seed cotton yield as influenced by tillage was significant. However, numerically higher seed cotton yield was obtained with conventional tillage (12.95 q ha⁻¹) as compared to conservation tillage (11.68 q ha⁻¹). Similar findings were reported by Mohanty and Painuly (2003), Namdeo *et al.*, (2003), Nehra *et al.*, (2006), Rashidi *et al.*, (2007) and Salahi *et al.*, (2017).. Sonune *et al.*, (2012) reported that the yields of cotton grown in Vertisols at the end of fourth year have not shown significant variation from the results obtained on some soils properties indicated that the effect of various intensities of tillage on soil properties and crop yield needs to be the further ascertained.

Effect of integrated plant nutrient system

The results revealed that the seed cotton yield was significantly influenced by IPNS. The significantly highest seed cotton yield was observed

in 100 % P through phoshpocompost + remaining N through chemical fertilizer (13.71 q ha^{-1}) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer (13.38 q ha^{-1}) which were on par with each others. It may infer that increase in seed cotton yield may be due to more availability and efficient use of nutrients. The increase in seed cotton yield due to integrated use of FYM and chemical fertilizers attributed to efficient utilization of nutrient from soil, Bandopadhyay et al. (2010) observed improvement in physical and chemical properties of soils, besides direct addition of nutrients from FYM into soils (Behera et al., 2007) and Ghatage *et al.* (2003). The lowest seed cotton yield was observed with control (8.21 q ha^{-1}).

Interaction

Interaction of tillage and IPNS was on seed cotton yield was found significant (table 35 b). Significantly highest seed cotton yield was recorded with application of 100 % P through phoshpocompost + remaining N through chemical fertilizer in conservation tillage (14.22 q ha^{-1}) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer (14.20 q ha^{-1}). The lowest seed cotton yield was observed under control in conservation tillage.

The interaction of conservation tillage with Phosphocompost and FYM was found most beneficial and recorded highest seed yield of cotton. This can be attributed to the combined effect of conservation tillage in improving soil properties along with FYM resulting into highest yield of cotton. The application of glyricidia green leaf manuring also recorded yields which were at par with FYM which also signifies the importance of conservation tillage with organics.

4.2.4. Stalk yield of Cotton

Data in respect of the effect of tillage and IPNS on seed cotton and stalk yield are presented in Table 35 a. and graphically depicted in Fig 24.

Effect of Tillage

The data in respect of stalk yield of cotton as influenced by tillage was significant. However, significantly higher stalk cotton yield was obtained with conservation tillage (25.62 q ha^{-1}) as compared to conventional tillage (22.72 q ha^{-1}). Similar findings were reported by Mohanty and Painuly



50% N (FYM) in CNV.



50% N (FYM) in CNS.



50% N (GLM) in CNV.



50% N (GLM) in CNS.



100% N (PC) in CNV.



100% N (PC) in CNS.

Plate 6. Effect of tillage and IPNS under cotton

(2003), Namdeo *et al.*, (2003), and Nehra *et al.*, (2006), Rashidi *et al.*, (2007) and Salahi *et al.*, (2017). Sonune *et al.* (2012) although the yields of cotton grown in Vertisols at the end of fourth year have not shown significant variation from the results obtained on some soils properties indicated that the effect of various intensities of tillage on soil properties and crop yield needs to be further ascertained.

Effect of integrated plant nutrient system

The results revealed that the stalk yield of cotton was significantly influenced by IPNS. The significantly highest stalk yield of cotton (28.00 q ha⁻¹) was recorded in 100 % P through phosphocompost + remaining N through chemical fertilizer followed by application of 50 % N through FYM + remaining RD through chemical fertilizer (26.78 q ha⁻¹) which were on par with each others. It may infer that increase in stalk yield of cotton may be due to more availability and efficient use of nutrients. The increase in seed cotton yield due to integrated use of FYM and chemical fertilizers attributed to efficient utilization of nutrient from soil, Bandopadhyay *et al.*, (2010) observed improvement in physical and chemical properties of soils, besides direct addition of nutrients from FYM into soils (Behera *et al.*, 2007). The lowest seed cotton yield was observed with control (16.03 q ha⁻¹). Similar findings were reported by Ghatange *et al.*, (2003), Gosh *et al.*, (2004) and Guldekar *et al.*, (2005).

Interaction

Interaction of tillage and IPNS was found significant on stalk yield of cotton (Table 35 b). The significantly highest stalk cotton yield was observed with application of 100 % P through phosphocompost + remaining N through chemical fertilizer (30.88 q ha⁻¹) in conservation tillage followed by 50 % N through FYM + remaining RD through chemical fertilizer and 50 % N through GLM + remaining RD through chemical fertilizer signifies the role of fully decomposed and degradable organic input in availability of nutrients. The organic inputs used in the present study were fully decomposed except that glyricidia leaf manuring which get mineralized with a very short period of time. The lowest stalk yield of cotton was observed under control in conservation tillage.

Table 29 a. Effect of tillage and IPNS on seed cotton and stalk yield of cotton under soybean-cotton rotation

	Treatments		Cotton yield (qha ⁻¹)	
	(a)Tillage		Seed cotton	Stalk
	Set I-Conservation tillage		12.95	25.62
	Set II -Conventional tillage		11.68	22.72
	SE(m)±		0.12	0.41
	CD at 5 %		0.35	1.19
	b) Integrated plant nutrient system			
	Soybean	Cotton		
T ₁	Control	Control	8.21	16.03
T ₂	100 % RDF	100 % RDF	13.01	23.90
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	13.38	26.78
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	11.57	23.49
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	13.32	26.17
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	12.10	23.76
T ₇	50 % N through vermicompost + remaining RD through chemical fertilizer	50 % N through vermicompost + remaining RD through chemical fertilizer	13.19	25.22
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost + remaining N through chemical fertilizer for cotton	13.71	28.00
	SE(m)±		0.24	0.83
	CD at 5 %		0.71	2.38
	(c) Interaction		Sig	Sig

Table 29 b: Interaction of tillage and IPNS on seed cotton and stalk yield of cotton under soybean-cotton rotation

IPNS	Cotton yield (q ha ⁻¹)					
	Seed cotton yield			Stalk yield		
	CNS	CNV	Mean	CNS	CNV	Mean
Control	8.74	7.68	8.21	16.90	15.15	16.03
100 % RDF	13.99	12.02	13.01	24.68	23.12	23.90
50 % N through FYM + remaining RD through chemical fertilizer	14.20	12.57	13.38	29.70	23.86	26.78
50% N through WS+ remaining RD through chemical fertilizer	13.12	10.03	11.57	23.63	23.36	23.49
50% N through GLM + remaining RD through chemical fertilizer	13.48	13.17	13.32	27.34	25.10	26.17
50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	12.15	12.06	12.10	25.94	21.59	23.76
50 % N through vermicompost+ remaining RD through chemical fertilizer	13.59	12.80	13.19	26.44	24.00	25.22
100 % P through phoshpocompost + remaining N through chemical fertilizer	14.22	13.19	13.71	30.88	25.12	28.00
Mean	12.95	11.68	-	25.62	22.72	-
	Tillage	NM	Int.	Tillage	NM	Int.
SE (m) ±	0.12	0.24	0.35	0.41	0.83	1.17
CD (at 5%)	0.35	0.71	1.00	1.19	2.38	3.37

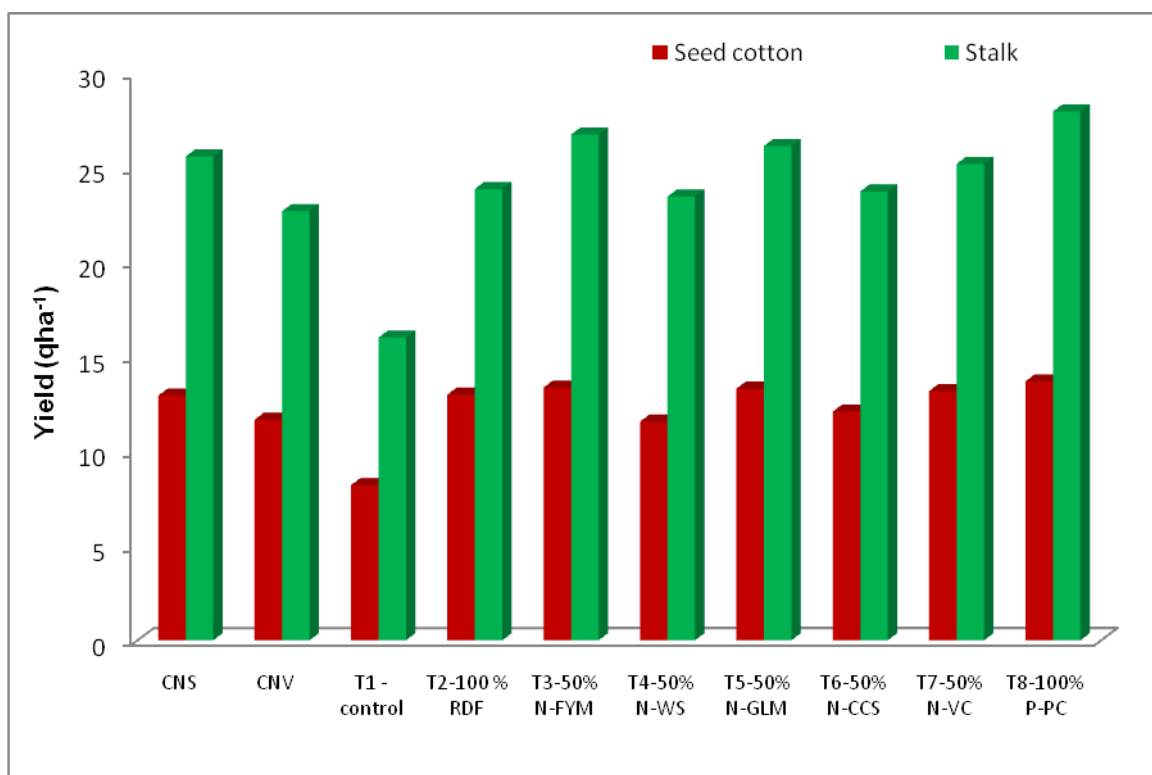


Fig. 24. Effect of tillage and IPNS on seed cotton and stalk yield of cotton

The interaction of conservation tillage with Phosphocompost and FYM was found most beneficial and recorded highest yield of cotton. This can be attributed to the combined effect of conservation tillage in improving soil properties along with phosphocompost and FYM resulting into highest stalk yield of cotton. The conservation tillage practices along with glyricidia green leaf manuring also recorded yields which were at par with FYM which also signifies the importance of conservation tillage with organics.

4.3.1 Nutrient content and uptake by soybean

The N, P, K, and S content in soybean seed and straw of soybean are discussed as below.

4.3.1.1. Nitrogen content in soybean

The data as influenced by various treatments are presented in Annexure IV (J).

Effect of tillage

The result showed that, content of nitrogen in soybean seed and straw of soybean was significantly increased in conservation tillage. The content of nitrogen in seed was recorded maximum (5.73 %) in conservation tillage as compared to conventional tillage (5.64 %). However, the nitrogen content in straw of soybean was recorded significantly highest (0.76 %) in the conservation tillage over the conventional tillage (0.75 %). Further, it was also observed that the content of nitrogen in soybean seed was comparatively higher than the content of nitrogen in soybean straw. The available N under conservation tillage helped to restore high N in soil which led to improved content in soybean. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000), Acharya and Sharma (1994) and Dick (1983) and Dhawan *et al.*, (2006).

Effect of integrated plant nutrient system

The content of nitrogen in soybean seed was in the range of 4.99 to 6.26 kg ha⁻¹. The content of nitrogen in seed varied phenomenally within the treatments and indicated significantly increase over control. Significantly the higher nitrogen content in seed (6.26 %) was recorded with the application of 100 % N through phosphocompost + remaining P through

chemical fertilizer followed by use of 50 % N through vermicompost + remaining RD through chemical fertilizer (5.97 %) and 50 % N through FYM + remaining RD through chemical fertilizer (5.88 %).

The content of nitrogen in straw also influenced by various nutrient management practices and it ranges from 0.67 to 0.86 %. Significantly maximum nitrogen content in seed was recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer (0.86 %) followed by the use of 50 % N through vermicompost + remaining RD through chemical fertilizer (0.79 %) and 50 % N through FYM + remaining RD through chemical fertilizer (0.78 %).

The higher content of nitrogen under combined application of NPK with Phosphocompost, vermicompost, GLM, FYM and composted cotton straw might be due to their optimum availability and complementary interaction among themselves which help in higher content of nitrogen, Higher dry matter production due to increased availability of nutrients from combined application of organic and recommended dose of fertilizer might have increased the nitrogen content. Similar results were also obtained by Singh *et al.* (2010), Sikka *et al.* (2012) and Nimje and Seth (1988).

Interaction

The Interaction between tillage and IPNS on content of nitrogen in soybean seed and straw was non significant.

4.3.1.2. Phosphorus content in soybean

The content of phosphorus in soybean seed and straw as influenced by various treatments are presented in annexure IV (J).

Effect of tillage

The effect of tillage practices on phosphorus content in soybean seed and straw of soybean was non significant. The content of phosphorus in seed was recorded maximum (0.40 %) in conservation tillage as compared to conventional tillage (0.38 %). However, the phosphorus content in straw of soybean was recorded numerical higher (0.14 %) in the conservation tillage over the conventional tillage (0.12 %). Further, it was also observed that the content of phosphorus in seed was comparatively higher than the content of phosphorus in soybean straw. The available P under conservation tillage

helped to restore high P in soil which led to improved uptake by soybean. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000), Dalal (1989), He *et al.*, (2007) and Khan *et al.*, (2015).

Effect of integrated plant nutrient system

The content of phosphorus in soybean seed was in the range of 0.32 to 0.43 %. The content of phosphorus in seed varied phenomenally within the treatments and indicated significantly increase over control. Significantly the higher phosphorus content in seed (0.43 %) was recorded with the application of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by use of 50 % N through vermicompost + remaining RD through chemical fertilizer (0.42 %) and application of 50 % N through FYM + remaining RD through chemical fertilizer (0.41 %).

The content of phosphorus in straw also influenced by various nutrient management practices and it ranges from 0.10 to 0.16 %. Significantly the higher phosphorus content in grain (0.16 %) was observed with the application of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by treatment receiving 50 % N through vermicompost + remaining RD through chemical fertilizer (0.15 %) and with the application of 50 % N through FYM + remaining RD through chemical fertilizer (0.15 %).

The higher content of phosphorus under combined application of NPK with Phoshpocompost, vermicompost, GLM, FYM and composted cotton straw might be due to their optimum availability and complementary interaction among themselves which help in higher content of phosphorus. Higher dry matter production due to increased availability of nutrients from combined application of organic and recommended dose of fertilizer might have increased the nitrogen content. Similar results were also obtained by Mishra *et al.*, (2001), Singh *et al.* (2010), Sikka *et al.* (2012) and Nimje and Seth (1988).

Interaction

The Interaction between tillage and IPNS was non significant on content of phosphorus in seed and straw of soybean.

4.3.1.3. Potassium content in soybean

The content of potassium as influenced by tillage practices by soybean seed and straw and the data as influenced by various treatments are presented in annexure IV (J).

Effect of tillage

The potassium content in seed and straw of soybean was significantly increased with different tillage practices. The potassium content in grain was recorded maximum (0.79 %) in conservation tillage as compared to conventional tillage (0.76 %). However, the potassium content in straw of soybean was recorded significantly highest (0.95 %) over the conventional tillage (0.93 %). Similar findings were reported by Dalal (1989), Brar and kaur (2007) and Gabhane *et al.*, (2014).

Effect of integrated plant nutrient system

The potassium content in seed and straw of soybean was in the range of 0.70 to 0.81 % and 0.84 to 0.98 % respectively. Significantly the highest potassium content in grain (0.81 %) was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by use of 50 % N through FYM + remaining RD through chemical fertilizer (0.80 %) and addition of 50 % N through vermicompost + remaining RD through chemical fertilizer (0.79 %).

The of potassium content in straw also influenced significantly with different nutrient management practices However, the trend was similar as K content in soybean seed. Similar observations are also, recorded by Patil *et al.* (2002), Guldekar *et al.*, (2005),Gajbhiye (2003) ,Singh *et al.* (2007) and Sikka *et al.*,(2012).

Interaction

The Interaction between tillage and IPNS on potassium content in soybean seed and straw was non significant.

4.3.1.4. Sulphur content in soybean

The sulphur content in soybean seed and straw as influenced by various treatments are presented in annexure IV (J).

Effect of tillage

The sulphur content in soybean seed and straw is ranged between 0.42 to 0.47 % and 0.23 to 0.25 % respectively. The content of sulphur in seed was recorded maximum (0.47 %) in conservation tillage as compared to conventional tillage (0.42 %). However, the sulphur content in straw of soybean was recorded significantly highest (0.25 %) in the conservation tillage over the conventional tillage practices (0.23 %). Further, it was also observed that the content of sulphur in seed was comparatively higher than the content of sulphur in soybean straw. Similar findings were reported by Nehra (2006), He *et al.*, (2007), Singh *et al.*, (1991) and Yadav *et al.*, (2017).

Effect of integrated plant nutrient system

The sulphur content in soybean seed and straw was in the range of 0.41 to 0.50 % and 0.21 to 0.28 % respectively. The content of sulphur in seed varied within the treatments and indicated significant increase over control. Significantly maximum sulphur content in seed was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (0.50 %) followed by use of 50 % N through vermicompost + remaining RD through chemical fertilizer (0.49 %) and application of 50 % N through FYM + remaining RD through chemical fertilizer (0.47 %).

The sulphur content in straw also influenced significantly with the adoption of various nutrient management practices. Significantly the maximum sulphur content in straw was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (0.28 %) followed by addition of 50 % N through vermicompost + remaining RD through chemical fertilizer (0.26 %) and 50 % N through FYM + remaining RD through chemical fertilizer (0.257 %).

The higher content of sulphur under combined application of NPK with Phoshpocompost, vermicompost, glyricidia green leaf manure, FYM and composted cotton straw might be due to their optimum availability and complementary interaction among themselves which help in higher content of sulphur, higher dry matter production due to increased availability of nutrients

from combined application of organic and recommended dose of fertilizer might have increased the nitrogen content. Similar results were also obtained by Singh *et al.* (2010), Sikka *et al.* (2012) and Nimje and Seth (1988).

Interaction

The Interaction between tillage and IPNS on content of sulphur in soybean grain and straw was non significant.

4.3.2.1 Total uptake of Nitrogen by soybean

The content of nitrogen was calculated by considering the nitrogen uptake by soybean seed as well as straw and the data as influenced by various treatments are presented in Table 30 and it is depicted graphically in Fig 25.

Effect of tillage

The total nitrogen uptake by soybean was ranged between 150 to 166 kg ha⁻¹. The uptake of nitrogen by soybean seed was recorded maximum (142 kg ha⁻¹) in conservation tillage as compared to conventional tillage (128 kg ha⁻¹). However, the nitrogen uptake in straw of soybean was recorded significantly highest (24.64 kg ha⁻¹) in the conservation tillage over the conventional tillage (21.63 kg ha⁻¹). The total nitrogen uptake was significantly increased (166 kg ha⁻¹) with the adoption of conservation tillage over the conventional tillage (150 kg ha⁻¹).

Further, it was also observed that the uptake of nitrogen in soybean seed was comparatively higher than the uptake of nitrogen by soybean straw. The available N under conservation tillage helped to restore high N in soil which led to improved uptake by soybean. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000), Dick *et al.*, (1992) and Tomar (2005) and Gandura *et al.*, (2017). The highest uptake of N in conservation tillage might be due to supply of required higher quantity of nutrients for soybean growth thus it directly influences on uptake of higher nutrients in conservation tillage than conventional tillage.

Effect of integrated plant nutrient system

The effect of different IPNS on uptake of nitrogen by seed, straw and total uptake of soybean proved most effective and significantly increased total uptake. The uptake of nitrogen by soybean seed was in the range of 93 to 162 kg ha⁻¹. The uptake of nitrogen by seed varied phenomenally within the treatments and indicated numerical increase over 100 % RDF. Significantly the maximum nitrogen uptake by seed (162 kg ha⁻¹) was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by the use of 50 % N through vermicompost + remaining RD through chemical fertilizer (153 kg ha⁻¹) and 50 % N through FYM + remaining RD through chemical fertilizer (147 kg ha⁻¹).

The uptake of nitrogen by straw also influenced by various nutrient management practices and it ranges from 16.06 to 28.97 kg ha⁻¹. The significantly highest N uptake by straw (28.97 kg ha⁻¹) was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer followed by 50 % N through vermicompost + remaining RD through chemical fertilizer (25.70 kg ha⁻¹) and 50 % N through FYM + remaining RD through chemical fertilizer (23.54 kg ha⁻¹) recorded significantly higher nitrogen uptake by soybean straw as compared to control.

The total uptake of nitrogen by soybean varied from 109 to 191 kg ha⁻¹ during kharif 2016-17. The significantly maximum total nitrogen uptake by soybean was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (191 kg ha⁻¹) which was at par with total uptake recorded with application of 50 % N through vermicompost + remaining RD through chemical fertilizer. The higher uptake of nitrogen under combined application of NPK with phoshpocompost, vermicompost, GLM, FYM wheat straw, and composted cotton straw might be due to their optimum availability and complementary interaction among themselves which help in higher uptake of nitrogen, higher dry matter production due to increased availability of nutrients from combined application of organic and recommended dose of fertilizer. Similar results were also obtained by Singh *et al.* (2010), Sikka *et al.* (2012), Nimje and Seth (1988), Bhandari *et al.* (1989), Dangarwala (2001) and Prabhakaran *et al.* (2003).

Table 30. Effect of tillage and IPNS on total uptake of nitrogen by soybean under soybean-cotton rotation

Treatments			Total N uptake (kg ha ⁻¹)		
(a)Tillage			Seed	Straw	Uptake
Set I-Conservation tillage			142	24.64	166
Set II -Conventional tillage			128	21.63	150
SE(m)±			2.27	0.48	2.53
CD at 5 %			6.54	1.40	7.31
(b) Integrated plant nutrient system					
	Soybean	Cotton			
T ₁	Control	Control	93	16.06	109
T ₂	100 % RDF	100 % RDF	132	23.50	155
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	147	23.54	170
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	129	20.46	150
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	140	23.44	164
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	125	23.42	149
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	153	25.70	179
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	162	28.97	191
SE(m)±			4.53	0.97	5.06
CD at 5 %			13.08	2.80	14.61
(c) Interaction			NS	NS	NS

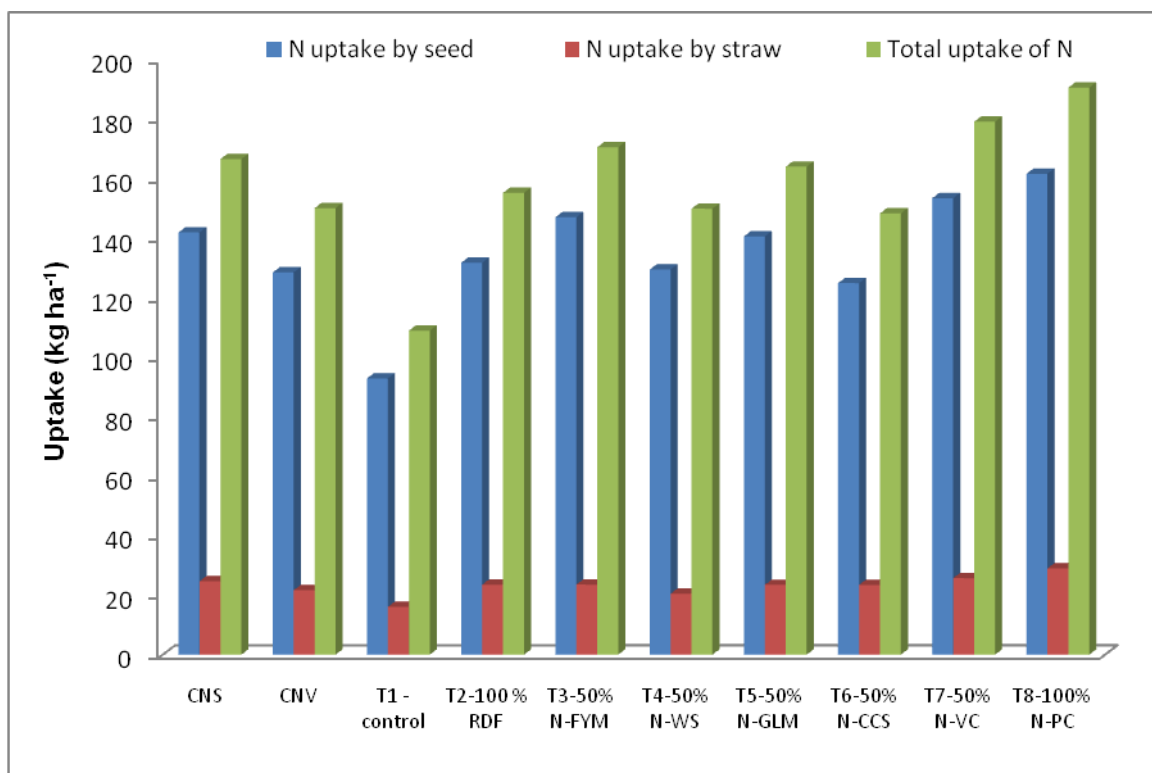


Fig. 25. Effect of tillage and IPNS on uptake of nitrogen by soybean

Interaction

The Interaction between tillage and IPNS on nitrogen uptake by soybean was non significant.

4.3.2.2 Total uptake of phosphorus by soybean

The data pertaining to the total uptake of phosphorus as influenced by tillage and various integrated plant nutrients system are presented in Table 31 and it is depicted graphically in Fig 26.

Effect of tillage

The total uptake of phosphorus was significantly increased with adoption of conservation tillage. However, the significantly highest phosphorus uptake by grain (9.98 kg ha^{-1}) and straw (4.51 kg ha^{-1}) was recorded with the conservation tillage practice followed by conventional tillage. Similar trend was exhibited with respect to the total uptake of phosphorus. Further, it was also observed that the uptake of phosphorus in grain was comparatively higher than the uptake of phosphorus by soybean straw. The available P under conservation tillage helped to restore high P in soil which led to improved uptake by soybean. This can be ascribed to the immediate availability of readily assimilable form of phosphorus in fertilizer treatment by plants, while in organic treatments P availability is initially less due to immobilization which is released subsequently, thereby, ensured availability of P throughout the growing period. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000) and Tomar (2005). The highest uptake of P in conservation tillage might be due to proper moisture level maintains which help in release of fixed P from total P regime of soil thus it directly influences on uptake of higher nutrients in conservation tillage than conventional tillage.

Effect of integrated plant nutrient system

The total uptake of phosphorus was significantly increased with IPNS treatments. The uptake of phosphorus by soybean seed and straw was in the range of 5.90 to 11.30 kg ha^{-1} and 2.33 to 4.78 kg ha^{-1} respectively. The uptake of phosphorus by soybean seed and straw varied phenomenally within the treatments and indicated numerical increase over 100 % RDF and control.

Significantly the maximum phosphorus uptake by seed was recorded with application of 100 % N through phosphocompost + remaining P through chemical fertilizer (11.30 kg ha⁻¹) followed by with application of 50 % N through vermicompost + remaining RD through chemical fertilizer (10.82 kg ha⁻¹). Similar trend was observed regarding the uptake of phosphorus by soybean straw.

The total uptake of phosphorus by soybean varied from 8.23 to 16.08 kg ha⁻¹. The significantly maximum total phosphorus (16.08 kg ha⁻¹) uptake by soybean was recorded in treatment which was at par with total uptake recorded in treatments with application of 50 % N through vermicompost + remaining RD through chemical fertilizer and 50 % N through FYM + remaining RD through chemical fertilizer. The higher uptake of phosphorus under combined application of NPK with phosphocompost, vermicompost, GLM, FYM and wheat straw were also reported by Bagade *et al.*, 2003. Katkar *et al.*, 2002 observed that P uptake by cotton mulched with greengram, glyricidia, sunhemp, FYM was found to be higher than no fertilizers. The improvement in soil physical condition caused due to addition of organics is beneficial for enhanced uptake at INM. The organics also help in enhancing nutrients available in soil by reducing fixation of phosphorus, which improves the efficient use of added phosphorus. The results are in confirmation with the findings of Ravankar *et al.* (2005), Pathak *et al.* (2005) and Tatarwal *et al.* (2011).

The significance of green manures and organic manures in combination with inorganic for providing nutrients to the crop and maintaining soil health is well known. Green manuring crop enhanced moisture and nutrient contribution due to the added mulch material lead to increased biomass production and hence uptake of nutrients reported by Marimuthu *et al.* (2014) and Kuostu and Singh (2016).

Table 31. Effect of tillage and IPNS on total uptake of phosphorus by soybean under soybean-cotton rotation

	Treatments		Total P uptake (kg ha ⁻¹)		
	(a)Tillage		Seed	Straw	Uptake
	Set I-Conservation tillage		9.98	4.51	14.50
	Set II -Conventional tillage		8.72	3.59	12.31
	SE(m)±		0.15	0.09	0.21
	CD at 5 %		0.42	0.27	0.60
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	5.90	2.33	8.23
T ₂	100 % RDF	100 % RDF	9.30	4.14	13.44
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	10.31	4.65	14.96
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	8.86	3.75	12.61
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	9.79	4.37	14.16
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	8.53	3.72	12.25
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	10.82	4.67	15.49
T ₈	50 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	11.30	4.78	16.08
	SE(m)±		0.29	0.19	0.42
	CD at 5 %		0.84	0.54	1.20
	(c) Interaction		NS	NS	NS

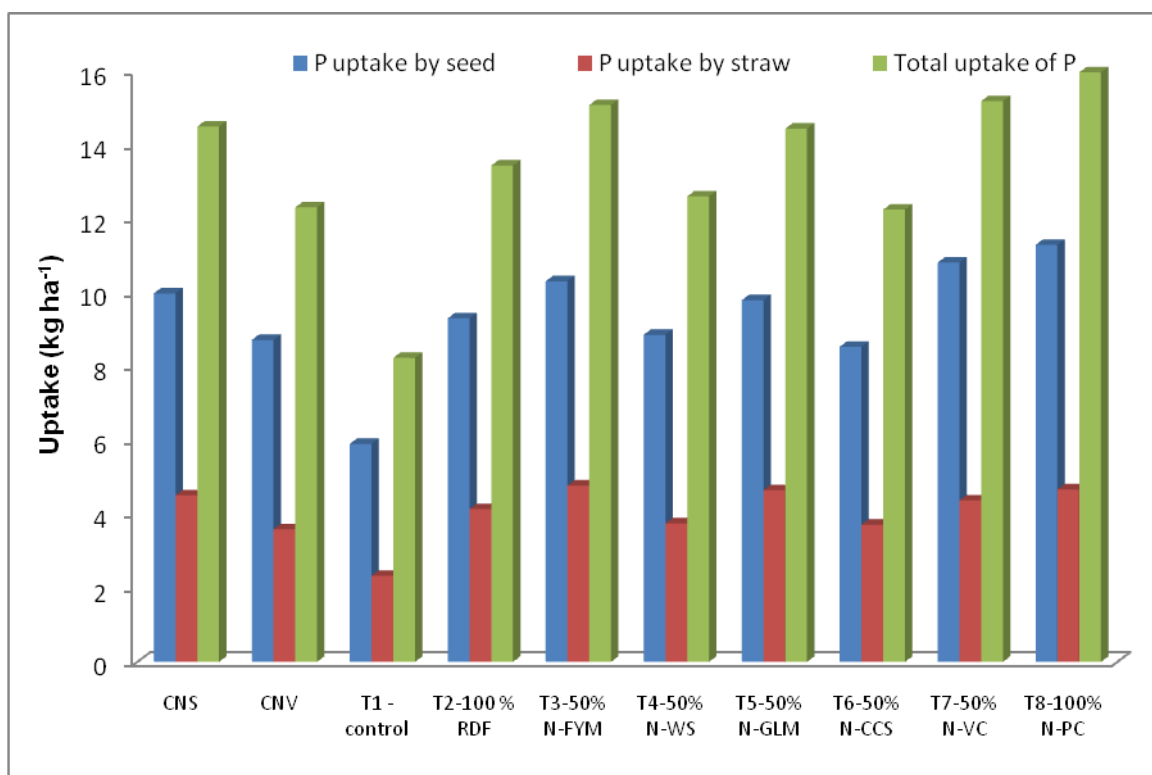


Fig. 26. Effect of tillage and IPNS on uptake of phosphorus by soybean

Interaction

The Interaction between tillage and IPNS on uptake of phosphorus by soybean seed, straw and total uptake was non significant.

4.3.2.3 Total uptake of potassium by soybean

The total uptake of potassium as influenced by various treatments are presented in Table 32 and it is depicted graphically in Fig 27.

Effect of tillage

The uptake of potassium by soybean seed and straw influenced significantly with the tillage. The uptake of potassium by soybean seed was recorded maximum (19.50 kg ha^{-1}) in conservation tillage as compared to conventional tillage (17.32 kg ha^{-1}). The potassium uptake in straw of soybean was recorded significantly highest (33.59 kg ha^{-1}) in the conservation tillage over the conventional tillage (28.31 kg ha^{-1}). However, the potassium uptake was recorded significantly highest (50.15 kg ha^{-1}) in the conservation tillage over the conventional tillage (43.90 kg ha^{-1}). Further, it was also observed that the uptake of potassium in straw was comparatively higher than the uptake of potassium by soybean grain. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000), Tomar (2005).

Effect of integrated plant nutrient system

The effect of different nutrient management practices on uptake of potassium by soybean seed, straw and total uptake proved most effective as it significantly increased uptake of potassium by seed and straw. The uptake of potassium by soybean seed was in the range of 13.06 to 21.10 kg ha^{-1} . The significantly maximum potassium uptake by seed was recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer (21.10 kg ha^{-1}) followed by application of 50 % N through vermicompost + remaining RD through chemical fertilizer (20.34 kg ha^{-1}) and 50 % N through FYM + remaining RD through chemical fertilizer (20.11 kg ha^{-1}) which was found at par with each other.

Table 32. Effect of tillage and IPNS on total uptake of potassium by soybean under soybean-cotton rotation

Treatments			Total K uptake (kg ha ⁻¹)		
(a)Tillage			Seed	Straw	Uptake
Set I-Conservation tillage			19.50	33.59	50.15
Set II -Conventional tillage			17.32	28.31	43.90
SE(m)±			0.24	0.47	0.53
CD at 5 %			0.68	1.37	1.52
(b) Integrated plant nutrient system					
	Soybean	Cotton			
T ₁	Control	Control	13.06	23.24	33.41
T ₂	100 % RDF	100 % RDF	18.43	35.31	47.55
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	20.11	33.26	51.09
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	17.86	28.81	44.99
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	19.07	31.55	49.10
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	17.28	29.15	45.19
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	20.34	31.04	51.04
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	21.10	35.22	53.86
SE(m)±			0.47	0.95	1.05
CD at 5 %			1.36	2.74	3.04
(c) Interaction			NS	NS	NS

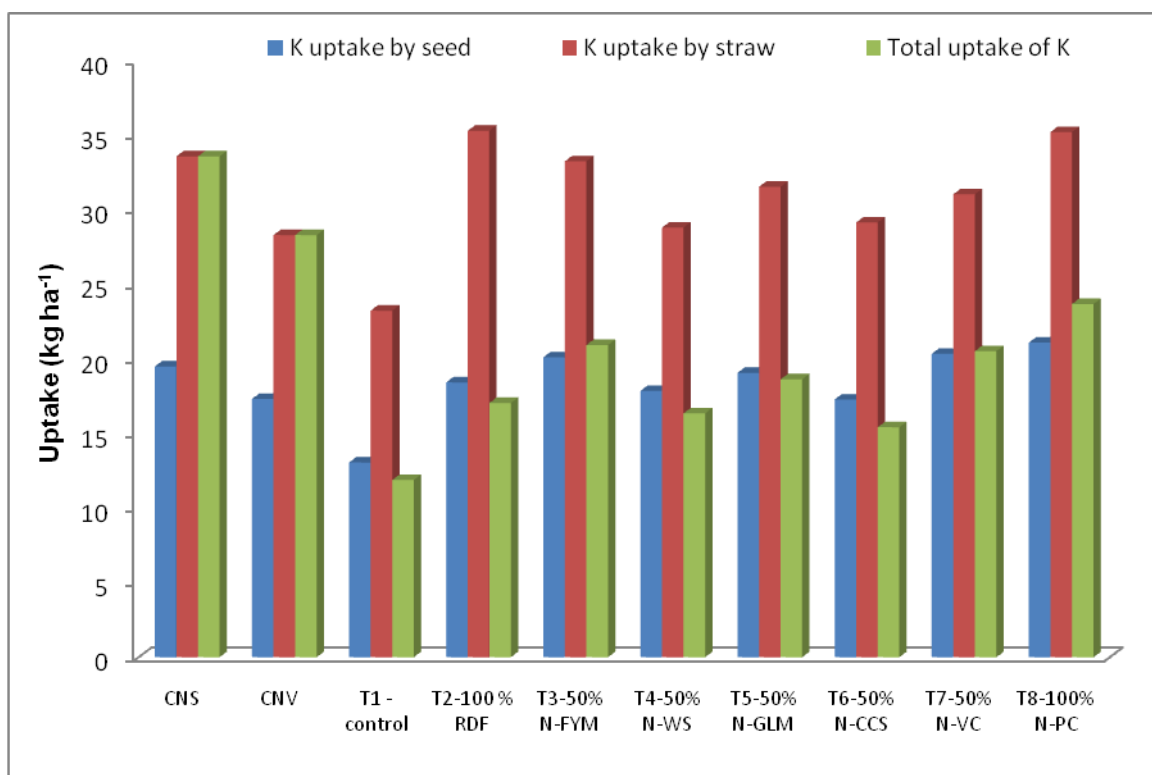


Fig. 27. Effect of tillage and IPNS on uptake of Potassium by soybean

However, the uptake of potassium by soybean straw was in ranges from 23.24 to 35.22 kg ha⁻¹. The trend of potassium uptake by straw influenced by different treatment management practices was almost similar as potassium uptake by grain.

The total uptake of potassium by soybean varied from 33.41 to 53.86 kg ha⁻¹. The significantly maximum total potassium (53.86 kg ha⁻¹) uptake by soybean was recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer which was at par with total uptake recorded with use of the 50 % N through vermicompost + remaining RD through chemical fertilizer and 50 % N through FYM + remaining RD through chemical fertilizer.

The increase in total potassium uptake was due to incorporation of decomposed material like FYM, phosphocompost, vermicompost, and glyricidia green leaf manuring along with inorganic fertilizers which can be attributed to the greater capacity of organic colloids to hold K ions on the exchange sites which enhanced the availability of potassium is responsible for more uptakes. Similar results have also been quoted by Sharma and Mishra (1997) and Sharma *et al.* (1992). There was an increasing uptake of potassium by soybean under INM treatments. The improvement in the total uptake of potassium at INM is ascribed the residual effect of organics to enhanced soil quality resulting into better availability of nutrients. Thus, the data clearly indicated that, for efficient utilization of potash, it is essential to apply organics, similar line of results were also reported by Rasool *et al.* (2008). Application of adequate levels of N, P in conjunction with crop residues improves the uptake of potassium were also reported by Chaturvedi *et al.* (2010), Arbad and Ismail (2011), Kumar *et al.* (2006) and Jadhav *et al.* (2007).

Interaction

The Interaction between tillage and IPNS on uptake of potassium by grain, straw was non significant.

4.3.2.4 Total uptake of sulphur by soybean

Sulphur has major role in improving the quality of produce. It helps in plant metabolism as well as healthy root growth. The data pertaining to sulphur uptake influenced by various treatments are presented in Table 33 and depicted in Fig 28.

Effect of tillage

The uptake of sulphur by soybean seed, straw and total uptake of soybean influenced significantly with different tillage. The uptake of sulphur by soybean seed was recorded significantly maximum (11.59 kg ha^{-1}) in conservation tillage as compared to conventional tillage (9.60 kg ha^{-1}). However, the sulphur uptake in straw of soybean was observed significantly highest (8.28 kg ha^{-1}) in the conservation tillage over the conventional tillage (6.66 kg ha^{-1}). The total uptake of sulphur was recorded significantly highest (19.87 kg ha^{-1}) in the conservation tillage over the conventional tillage (16.23 kg ha^{-1}). Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000) and He *et al.*, (2009).

Effect of integrated plant nutrient system

The effect of different nutrient management practices on uptake of sulphur by soybean seed, straw and total uptake was significantly increased. The uptake of sulphur by soybean seed was in the range of 8.22 to 12.91 kg ha^{-1} . The uptake of sulphur by seed varied phenomenally within the treatments and indicated numerical increase over control. Significantly the maximum sulphur uptake by soybean seed was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (12.91 kg ha^{-1}) followed by application of 50 % N through vermicompost + remaining RD through chemical fertilizer (12.38 kg ha^{-1}).

The uptake of sulphur by straw also influenced by various nutrient management practices and it ranges from 5.67 to 8.89 kg ha^{-1} . The significantly highest sulphur uptake by straw was recorded with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (8.89 kg ha^{-1}) followed by 50 % N through vermicompost + remaining RD through chemical fertilizer (8.68 kg ha^{-1}) and 50 % N through FYM + remaining RD through chemical fertilizer (8.56 kg ha^{-1}).

Table 33. Effect of tillage and IPNS on total uptake of sulphur by soybean under soybean-cotton rotation

	Treatments		Total S uptake (kg ha ⁻¹)		
			Seed	Straw	Uptake
	(a)Tillage				
	Set I-Conservation tillage		11.59	8.28	19.87
	Set II -Conventional tillage		9.60	6.66	16.23
	SE(m)±		0.27	0.17	0.33
	CD at 5 %		0.77	0.49	0.96
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	8.22	5.67	13.89
T ₂	100 % RDF	100 % RDF	9.89	7.16	17.05
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	11.45	8.56	20.01
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	9.59	6.76	16.35
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	11.33	7.31	18.64
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	8.98	6.44	15.42
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	12.38	8.68	21.06
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	12.91	8.89	21.80
	SE(m)±		0.53	0.34	0.66
	CD at 5 %		1.54	0.99	1.92
	(c) Interaction		NS	NS	NS

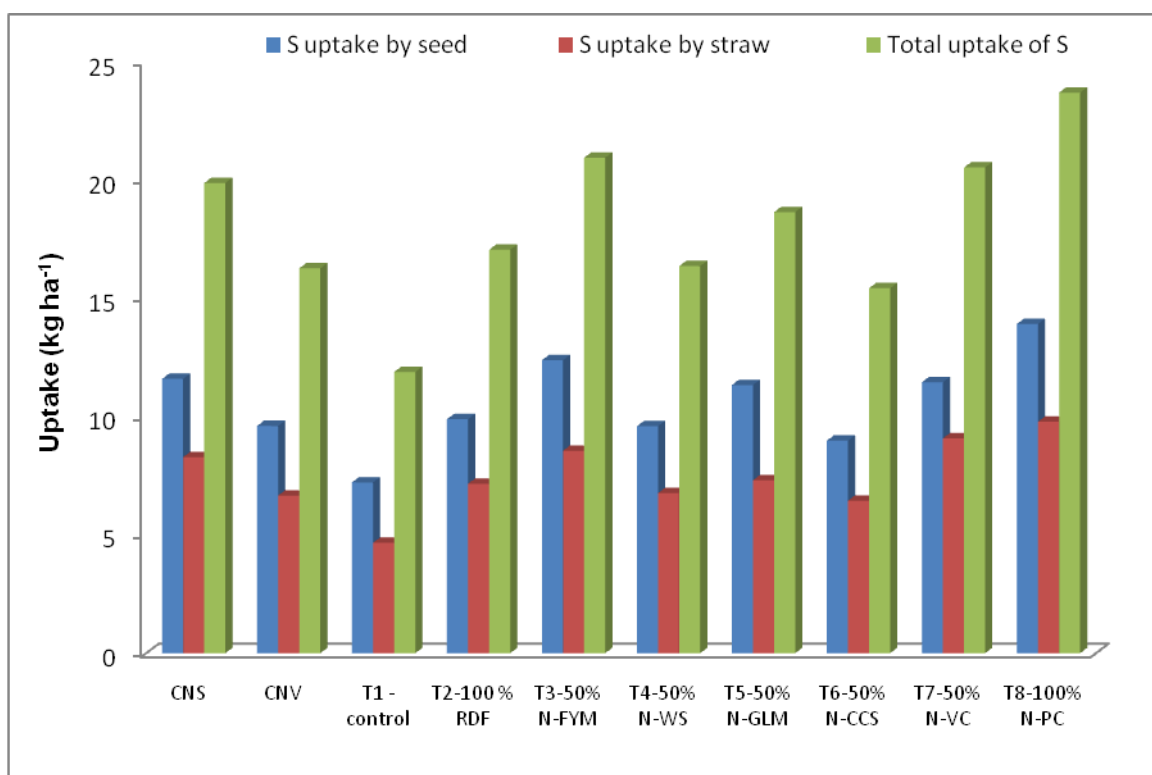


Fig. 28. Effect of tillage and IPNS on uptake of sulphur by soybean

The total uptake of sulphur by soybean varied from 13.89 to 21.80 kg ha⁻¹. The significantly maximum total sulphur uptake by soybean was recorded in application of 100 % N through phosphocompost + remaining P through chemical fertilizer (21.80 kg ha⁻¹). Application of organics which enhances the release of ions in the soil and it ultimately improves the grain yield and concentration of sulphur in plants which results into improving the total uptake of sulphur reported by Bairathi *et al.* (1974). The significantly highest uptake in respect of seed, straw and total uptake of sulphur by soybean was associated with organic and inorganic fertilizers might be attributed to better supply of nutrients throughout crop growing period. These results are conformity with those reported by Sahi *et al.*, (2013), Mathan *et al.*, (1996), Sharma and Mishra (1997), Sharma *et al.*, (1992) Bharmbe *et al.*, (1999), Jadhav *et al.*, (2007).

Interaction

The Interaction between tillage and IPNS on uptake of sulphur by soybean seed and straw was non significant.

4.4. Nutrient content and uptake by cotton

The mineral nutrition is dependent on the ability of the soil to supply the macro and micronutrients to the plant roots. The content and uptake of nutrients is interrelated with each other. In the present investigation, the effect of tillage and integrated plant nutrient management practices on nutrient content and uptake of nutrients by cotton at harvest stages were studied. The results obtained in the investigation are presented and discussed as below.

4.4.1.1 Nitrogen content in cotton

In the present investigation, the effects of different plant nutrient treatments on content of nutrients by cotton were studied. The results obtained in this regards at harvest stage of cotton are presented in annexure IV (K) and discuss below.

Effect of tillage

The data indicated that nitrogen content was ranged from 1.70 to 1.80 and 1.20 to 1.11 per cent in seed cotton and stalk of cotton

respectively at the harvest stage. However, the content of N was noticed significantly higher in conservation tillage as compared to conventional tillage at harvest stage. The content of N was observed higher in seed cotton than that of stalk of cotton. These findings are in close agreement with the results reported by Khare *et al.*, (1970), Sharma *et al.* (1993), and Taneja *et al.* (1997) and Salinas-Gracia *et al.*,(1997) .

Effect of integrated plant nutrient system

The content of nitrogen during harvest stage was influenced significantly during in kharif season 2017-18. The IPNS influenced significantly on nitrogen content by cotton. Whereas, the nitrogen content in seed cotton and stalk of cotton at harvest stage was ranged from 1.56 to 1.89, and 1.05 to 1.21 respectively.

Total nitrogen content at harvest ranged from 2.61 to 3.11 per cent and significantly higher content was observed under 50 % N through FYM + remaining RD through chemical fertilizer followed by (3.11 %) with 100 % RDF i.e. 60:30:30 NPK kg ha⁻¹ (3.06 %) and followed by the application of 100 % P through Phosphocompost + remaining N through chemical fertilizer (2.99 %). Lowest N content was observed in control (2.61 %).

Significant improvement in nitrogen content in seed cotton and stalk with increase in nutrient management level could be ascribed to the increasing availability of readily assimilable form of nitrogen with inorganic fertilizer. Similar increase in nitrogen content of different plant components with inorganic fertilizers was also reported by Fritschi *et al.* (2004).

Interaction

The Interaction between tillage and IPNS on content of N by seed cotton cotton stalk of cotton was non significant.

4.4.1.2 Phosphorus content in cotton

The data pertaining to phosphorus content in seed cotton and stalk of cotton at harvest stages as influenced by tillage and integrated plant nutrient system. The results obtained in this regards are presented in annexure IV (K) and discussed as below.

Effect of tillage

The findings showed that on content of phosphorus was ranged from 0.59 to 0.65 and 0.26 to 0.31 per cent in seed cotton and stalk of cotton respectively at the harvest stage. However, the content of P was noticed significantly higher in conservation tillage as compared to conventional tillage at harvest stage. The content of P was observed higher in seed cotton than that of stalk of cotton. These findings are in close proximity with the results reported by Dalal (1989), He *et al.* (2007), Sharma *et al.* (1993), and Taneja *et al.* (1997).

Effect of integrated plant nutrient system

The data indicated that, the phosphorus content at harvest stage ranged from 0.55 to 0.65 and 0.23 to 0.32 percent in seed cotton and stalk of cotton respectively. The content of phosphorus during harvest stage was influenced significantly during kharif season 2017-18.

Total phosphorus content at harvest ranged from 0.78 to 0.97 percent and significantly higher content was observed with application of 50 % N through FYM + remaining RD through chemical fertilizer (0.97 %) followed by use of the 100% P through Phosphocompost + remaining N through chemical fertilizer (0.96 %) and 100 % RDF (0.85 %). Lowest P content (0.78 %) was recorded in control.

Application of 50 % N through FYM + remaining N through chemical fertilizer + 100% P through Phosphocompost + remaining N through chemical fertilizer and 50% N through vermicompost + remaining N through chemical fertilizer recorded higher P content than crop residues and green manures in combination with chemical fertilizers. This can be ascribed to the immediate availability of readily assimilable form of nutrients in fertilizer treatment, while in organic treatments availability of nutrients is initially less which is released subsequently, thereby, ensured availability throughout the growing period. These results are in consonance with the findings reported by Sharma *et al.* (1993), Namdeo *et al.*, (2003), Sikka *et al.*, (2012) and Wankhade *et al.* (1997) and Mehta *et al.* (2009).

Interaction

The Interaction between tillage and IPNS on content of phosphorus in seed cotton and stalk cotton at harvest of cotton was non significant.

4.4.1.3. Potassium content in cotton

The data pertaining to potassium content in seed cotton and stalk cotton at harvest stages as influenced by tillage and IPNS treatments. The results obtained in this regards are presented in annexure IV (K) and discussed as under.

Effect of tillage

The findings showed that potassium content was ranged between 1.25 to 1.31 and 1.60 to 1.67 per cent in seed cotton and stalk respectively at the harvest stage. Perusal of the data showed that significantly higher potassium content in the treatment of conservation than conventional at harvest stage. Similar findings were reported by He et al., (2007) and Dick (1992). The potassium content was found more in seed than leaves and stem. The higher moisture content at the square initiation stages might have enhanced the decomposition of crop residues and its subsequent mineralization and availability of plant nutrients reported by Brar and Kaur (2007). Potassium content in seed cotton and stalk was significantly influenced at harvest stage during the years of investigation due to tillage practices.

Effect of integrated plant nutrient system

The data indicated that, the potassium content in seed cotton and stalk of cotton at harvest stage ranged from 1.21 to 1.32 and 1.57 to 1.67 percent respectively. The content of potassium during harvest stage was influenced significantly during kharif season 2017-18.

Total potassium content at harvest ranged from 1.78 to 2.99 percent and significantly higher content was observed with (2.99 %), 50 % N through FYM + remaining RD through chemical fertilizer followed by 100 % RDF (2.91 %), 100% P through Phosphocompost + remaining N through chemical fertilizer (2.95 %) and 50 % N through GLM + remaining RD through

chemical fertilizer (2.95 %). The lowest P content was observed in control (1.78 %). Similar observations were also recorded by Tiwari *et al.* (1994) and Ramasamy *et al.*, (2000). Wankhade *et al.* (1997) reported that, the potassium concentration in cotton at square initiation stage varied from 1.15-1.27 per cent which further decreased at boll development stage (1.08 per cent) and harvest (1.02 per cent).

Interaction

The Interaction between tillage and IPNS on content of potassium in seed cotton and cotton stalk at harvest was non significant.

4.4.1.4 Sulphur content in cotton

The data in relation to sulphur content in seed cotton and stalk at harvest stages as influenced by tillage and IPNS treatments. The results obtained in this regards are presented in annexure IV (K) and discussed as below.

Effect of tillage

The content of sulphur in seed cotton and cotton stalk at harvest of cotton was influenced significantly during kharif season 2017-18. The data showed that sulphur content was ranged from 0.56 to 0.60 and 0.26 to 0.23 per cent seed cotton and cotton stalk respectively at the harvest stage. Perusal of the data showed that significantly higher sulphur content was recorded in conservation tillage than conventional at harvest stage. The result pertaining to content due to various treatments were also reported by Khare *et al.* (1970) and Taneja *et al.* (1997).

Effect of integrated plant nutrient system

The data indicated that, the sulphur content was ranged from 0.51 to 0.64 and 0.20 to 0.30 percent in seed cotton and cotton stalk at harvest of cotton respectively.

Total sulphur content by cotton at harvest was ranged from 0.71 to 0.91 percent and significantly higher content was observed with 50 % N through FYM + remaining RD through chemical fertilizer (0.91 %) followed by 50 % N through vermicompost + remaining RD through chemical fertilizer

((0.90 %) and 100 % P through Phosphocompost + remaining N through chemical fertilizer (0.89%). Lowest sulphur content was observed in control (0.71 %).

Application of P through Phosphocompost + remaining N through chemical fertilizer and application of 50 % N through FYM + remaining RD through chemical fertilizer recorded higher sulphur content than rest of the crop residues and green manures in combination with chemical fertilizers. Similar result were reported by Mishra *et al.*, (2001) and Mishra *et al.*, (2008).

Increased in sulphur content in different plant component with increase in nutrient management level might be attributed to improvement in root growth and thus exploitation of more soil depth in conservation tillage.

Interaction

The Interaction between tillage and IPNS on content of sulphur in seed cotton and stalk at harvest of cotton was non significant.

4.4.2. Total uptake of nutrients by cotton

4.4.2.1 Total uptake of Nitrogen by cotton

The data in relation to nitrogen uptake by cotton at harvest stages are reported in the Tables 34 and it is depicted graphically in Fig 29.

Effect of Tillage

The total uptake of nitrogen by cotton was ranged between 54.43 to 45.23 kg ha⁻¹ at harvest stage. Perusal of the data showed that significantly higher nitrogen uptake was recorded conservation tillage over conventional at harvest stage. The uptake of N by seed cotton was recorded significantly highest in conservation tillage as compared to the conventional tillage. However the uptake of nitrogen by stalk was recorded significantly higher in conservation than conventional tillage. The total uptake of nitrogen was significantly increased in conservation tillage. The proper moisture content exhibits the available nitrogen under conservation tillage helped to restore high N in soil which led to improved uptake by cotton. Similar findings

were reported by Nehra (2006), Dick (1992), Patil and Sheelavantar (2000) and Tomar (2005).

The highest uptake of NPK in conservation tillage might be due to supply of required quantity of nitrogen for growth of plant were more thus it directly influences on uptake of higher nutrients in conservation tillage than conventional tillage.

Effect of integrated plant nutrient system

The effect of different IPNS on uptake of nitrogen by seed cotton and stalk and total uptake of cotton proved most effective and significantly increased total uptake at harvest stage of cotton.

The uptake of nitrogen by seed cotton was ranged from 12.83 to 25.27 kg ha⁻¹ and 16.79 to 32.90 kg ha⁻¹ cotton stalk respectively. The uptake of nitrogen by seed cotton and stalk varied phenomenally within the treatments. The uptake of nitrogen by seed cotton significantly increased with the application of application 50 % N through FYM + remaining RD through chemical fertilizer followed by 100 % P through phosphocompost + remaining RD through chemical fertilizer. Similar trend was observed in uptake of N by cotton stalk.

Total uptake of nitrogen was varied from 29.63 to 57.88 kg ha⁻¹ during the 2017-18. The significantly maximum total uptake of nitrogen was recorded with application of 100 % P through phosphocompost + remaining RD through chemical fertilizer (57.88 kg ha⁻¹) followed by application 50 % N through FYM + remaining RD through chemical fertilizer (57.73 kg ha⁻¹). It may be due to their optimum availability and complimentary interaction among themselves which help higher uptake of nitrogen. These findings are in conformity with the results reported by Ravankar and Deshmukh (1994) Wankhade *et al.* (1997) Suresh and Chellamuthu (2004) and Katkar (2006).

The significant improvement in nitrogen uptake with increase in INM treatment attributed to increase in dry matter and nitrogen concentration in different plant component. Similar findings were supported by Nawalakhe *et al.* (2010), Bhalerao and Gaikwad (2010) and Modhavadia *et al.* (2012).

Table 34. Effect of tillage and IPNS on Total uptake of nitrogen by cotton at harvest stage

	Treatments		Total N uptake (kg ha ⁻¹)		
	(a)Tillage		Seed cotton	Stalk	Uptake
	Set I-Conservation tillage		23.45	30.98	54.43
	Set II -Conventional tillage		19.99	25.24	45.23
	SE(m)±		0.33	0.52	0.63
	CD at 5 %		0.97	1.50	1.81
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	12.83	16.79	29.63
T ₂	100 % RDF	100 % RDF	24.91	27.45	52.36
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	25.27	32.46	57.73
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	19.07	27.40	46.47
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	23.16	30.93	54.09
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	19.95	26.93	46.88
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	23.58	30.03	53.61
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	24.99	32.90	57.88
	SE(m)±		0.67	0.67	1.04
	CD at 5 %		1.93	1.94	3.01
	(c) Interaction		NS	NS	NS

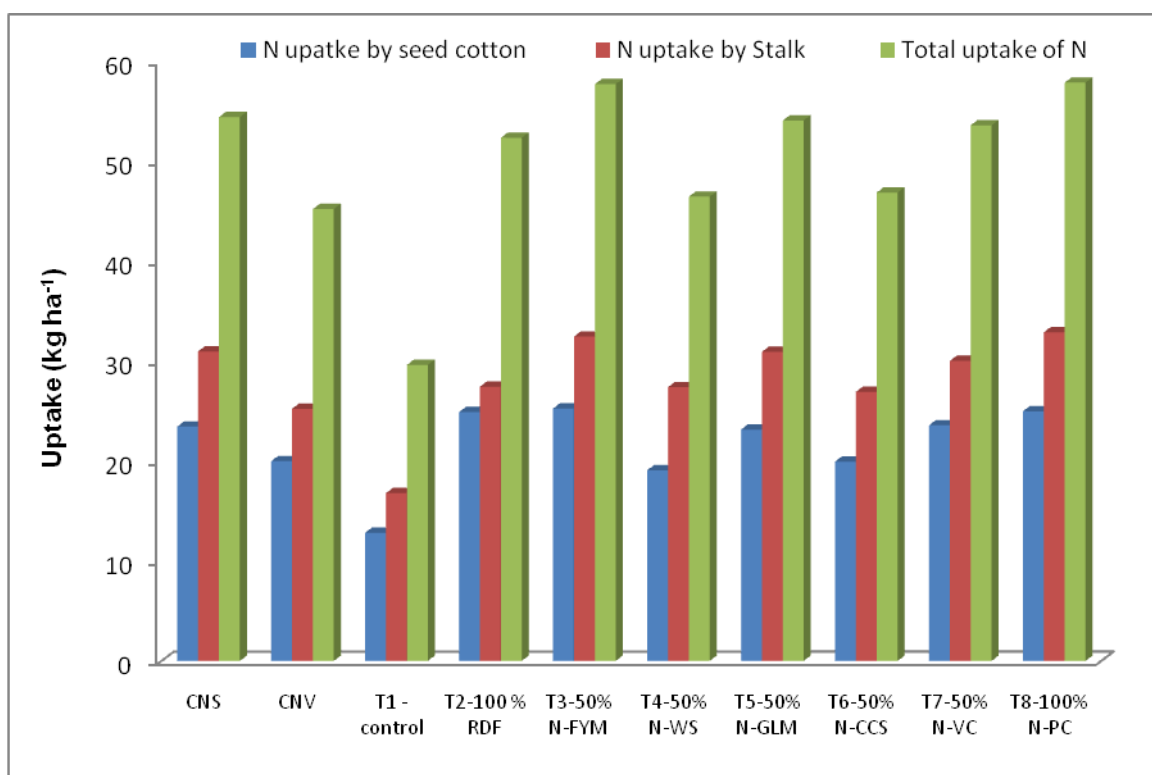


Fig. 29. Effect of tillage and IPNS on uptake of nitrogen by cotton

Interaction

The Interaction between tillage and IPNS on uptake of nitrogen in seed cotton and stalk and total uptake of nitrogen by cotton was non significant

4.4.2.2. Total uptake of Phosphorus by cotton

The data in relation to phosphorus uptake by seed cotton and stalk of cotton at harvest stages are reported in the Table 35 and Fig 30.

Effect of Tillage

The effect of tillage on uptake of phosphorus by seed cotton and stalk of cotton was found to be significant. The uptake of phosphorus by seed cotton and stalk of cotton at harvest stages of cotton was ranged from 8.50 to 6.89 and 8.01 to 5.95 kg ha⁻¹. The data showed that significantly higher phosphorus uptake of seed cotton and stalk of cotton in the conservation than conventional tillage. The uptake of phosphorus was recorded higher in seed cotton than that of stalk of cotton. Similar trend was recorded in respect of total uptake of phosphorus by cotton. The available phosphorus under conservation tillage helped to restore high phosphorus in soil which led to improved uptake by cotton. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000) and Tomar (2005).

Effect of integrated plant nutrient system

The total uptake of phosphorus was significantly increased with different plant nutrient management practices. The uptake of phosphorus by seed cotton and stalk was in the range of 4.54 to 8.85 kg ha⁻¹ and 3.65 to 8.93 kg ha⁻¹ respectively. The uptake of phosphorus by seed cotton and stalk varied within the treatments and indicated numerical increase over 100 % RDF and control. The higher phosphorus uptake by grain was recorded with application of 100 % N through phosphocompost + remaining P through chemical fertilizer (8.85 kg ha⁻¹) followed by 50 % N through vermicompost + remaining RD through chemical fertilizer (8.67 kg ha⁻¹). Similar trend was observed regarding the uptake of phosphorus by seed cotton. Further it was observed that, seed was the major contributor to the phosphorus uptake which followed by stalk.

Table 35. Effect of tillage and IPNS on Total uptake of phosphorus by cotton at harvest stage

	Treatments		Total P uptake (kg ha ⁻¹)		
	(a)Tillage		Seed cotton	Stalk	uptake
	Set I-Conservation tillage		8.50	8.01	16.51
	Set II -Conventional tillage		6.89	5.95	12.83
	SE(m)±		0.13	0.16	0.22
	CD at 5 %		0.37	0.45	0.68
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	4.54	3.65	8.19
T ₂	100 % RDF	100 % RDF	7.87	5.87	13.74
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	8.67	8.63	17.30
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	7.49	6.69	14.18
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	8.22	7.94	16.16
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	7.25	6.49	13.74
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	8.67	7.63	16.30
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	8.85	8.93	17.78
	SE(m)±		0.26	0.32	0.44
	CD at 5 %		0.75	0.99	1.29
	(c) Interaction		NS	NS	NS

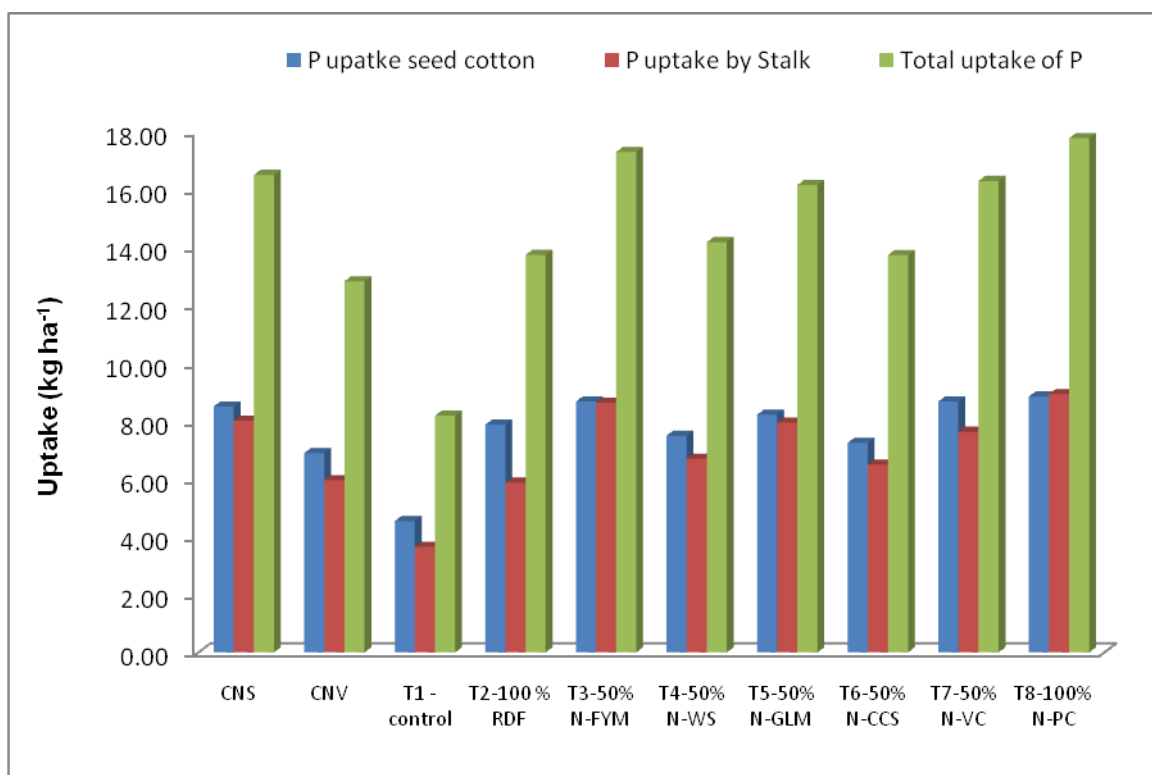


Fig. 30. Effect of tillage and IPNS on uptake of phosphorus by cotton

The total uptake of phosphorus by cotton varied from 8.19 to 17.78 kg ha⁻¹. The significantly maximum total phosphorus (17.18 kg ha⁻¹) uptake by cotton was recorded in treatment which was at par with total uptake recorded in treatments T₇ and T₃. The higher uptake of phosphorus was recorded in combined application of NPK with Phosphocompost, vermicompost, GLM, FYM and wheat straw. Katkar *et al.*, (2002) observed that P uptake by cotton mulched with greengram, glyricidia, sunhemp, FYM was found to be higher than no fertilizers. The improvement in soil physical condition caused due to addition of organics is beneficial for enhanced uptake in INM. The organics also help in enhancing nutrients available in soil by reducing fixation of phosphorus, which improves the efficient use of added phosphorus. The results are in confirmation with the findings of Ravankar *et al.* (2005), Pathak *et al.* (2005) and Tatarwal *et al.* (2011).

Application of 100 percent P through phosphocompost + remaining N through inorganic fertilizers recorded higher phosphorus uptake than other treatments, this can be ascribed to the immediate availability of readily assimilable form of phosphorus in organic with fertilizer treatment by plants. The significant increase in phosphorus uptake in different plant parts and total phosphorus uptake with nutrient management practices might be related to increase in dry matter accumulation and phosphorus content in different plant component with increase in INM treatment. Similar increase in total phosphorus uptake with increase in nutrient management treatments were also reported by Raskar (2006) and Sisodia and Khamparia (2007).

Interaction

The Interaction between tillage and IPNS on uptake of phosphorus in seed cotton and stalk of cotton was non significant.

4.4.2.3. Total uptake of Potassium by cotton

The data pertaining to potassium uptake by seed cotton and stalk of cotton at harvest stages are reported in the Tables 36 and Fig 31.

Effect of Tillage

The uptake of potassium was ranged from 16.98 to 14.61 and 42.83 to 36.41 kg ha⁻¹ in seed cotton and stalk of cotton respectively. The

data showed that significantly higher potassium uptake was recorded in conservation tillage than conventional tillage. The uptake of potassium was observed higher in reproductive parts seed cotton than that of leaves and stem stalk of cotton. The available potassium under conservation tillage helped to restore high potassium in soil which led to improved uptake by cotton. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000) and Tomar (2005).

The highest uptake of potassium in conservation tillage might be due to growth characteristics like plant height, fruiting branches, maximum number of functional leaves and bolls were higher which required more quantity of nutrients for completing their growth and development. Thus, it directly influences on uptake of maximum nutrients in conservation tillage than conventional tillage.

Effect of integrated plant nutrient system

The effect of IPNS on uptake of potassium by seed cotton, straw and total uptake of cotton proved most effective as it significantly increased uptake of potassium by seed cotton and stalk. The uptake of potassium by cotton stalk was in the range of 25.16 to 46.45 kg ha⁻¹. The significantly maximum potassium uptake by stalk was recorded over seed cotton. The uptake of potassium in stalk of cotton was recorded significantly maximum with application of 100 % N through phoshpocompost + remaining P through chemical fertilizer (46.45 kg ha⁻¹) followed by 50 % N through FYM + remaining RD through chemical fertilizer (44.75 kg ha⁻¹) and 50 % N through GLM + remaining RD through chemical fertilizer (42.93 kg ha⁻¹) which was found at par with each other at harvest stage.

However, the uptake of potassium by seed cotton was in ranges from 9.96 to 17.78 kg ha⁻¹. The trend of potassium uptake by seed cotton influenced by different integrated plant nutrient management practices was almost similar as potassium uptake by stalk.

The total uptake of potassium by cotton varied from 35.11 to 64.11 kg ha⁻¹. The significantly maximum total potassium (64.11 kg ha⁻¹) uptake by cotton was recorded with the application of 100 % N through

Table 36. Effect of tillage and IPNS on Total uptake of potassium by cotton at harvest stage

	Treatments		Total K uptake (kg ha ⁻¹)		
	(a)Tillage		Seed cotton	Stalk	Uptake
	Set I-Conservation tillage		16.98	42.83	59.81
	Set II -Conventional tillage		14.61	36.41	51.03
	SE(m)±		0.24	0.73	0.53
	CD at 5 %		0.68	2.11	1.52
	(b) Integrated plant nutrient system				
	Soybean	Cotton			
T ₁	Control	Control	9.96	25.16	35.11
T ₂	100 % RDF	100 % RDF	16.82	38.69	55.52
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	17.78	44.75	62.53
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	14.67	38.74	53.41
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	17.47	42.93	60.40
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	15.14	38.67	53.81
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	16.88	41.60	58.49
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	17.65	46.45	64.11
	SE(m)±		0.37	1.46	1.49
	CD at 5 %		1.08	4.22	4.32
	(c) Interaction		NS	NS	NS

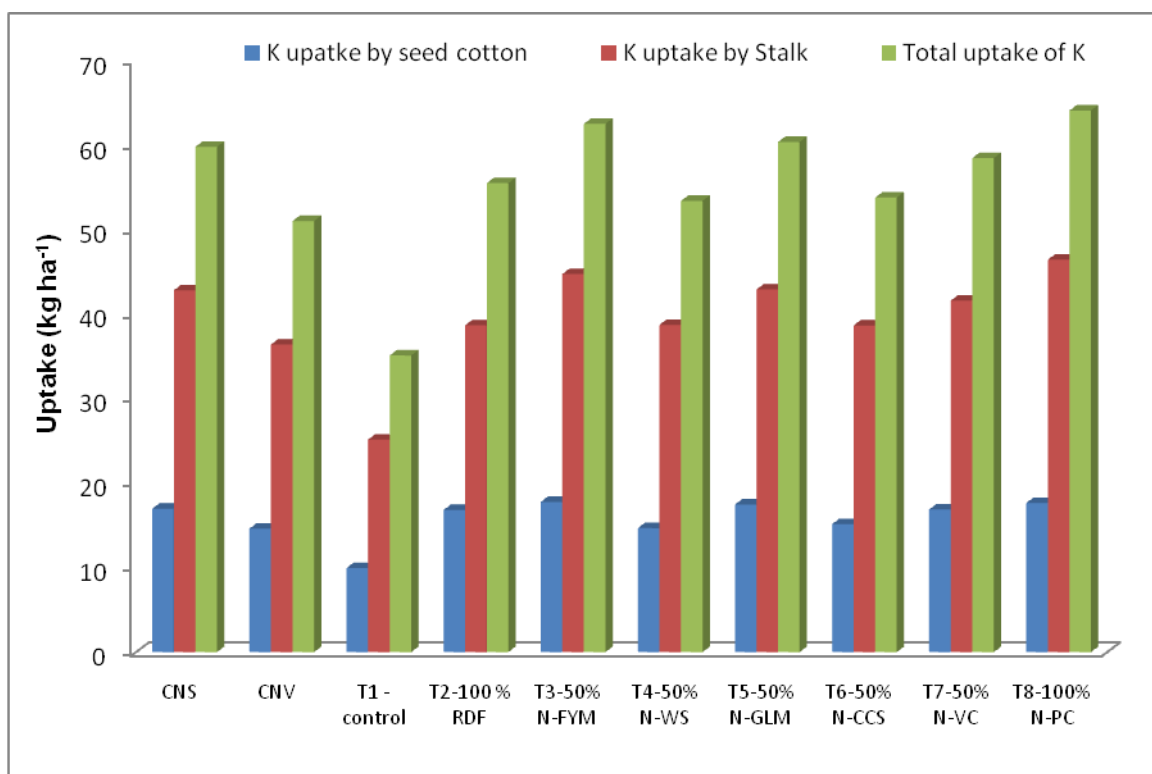


Fig. 31. Effect of tillage and IPNS on uptake of potassium by cotton

phosphocompost + remaining P through chemical fertilizer which was at par with total uptake recorded in treatments 50 % N through FYM + remaining RD through chemical fertilizer (62.53 kg ha⁻¹) and 50 % N through GLM + remaining RD through chemical fertilizer (60.40 kg ha⁻¹).

The increase in total potassium uptake was due to incorporation of decomposed material like FYM, phosphocompost, vermicompost, and glyricidia green leaf manuring along with inorganic fertilizers which can be attributed to the greater capacity of organic colloids to hold K ions on the exchange sites which enhanced the availability of potassium is responsible for more uptakes. Similar results have also been quoted by Sharma (1997) and Patil *et al.* (2002) and Sharma (1992). There was an increasing uptake of potassium by cotton under INM treatments. The improvement in the total uptake of potassium due to INM is ascribed to the residual effect of organics which enhanced soil quality resulting into better availability of nutrients. Thus, the data clearly indicated that, for efficient utilization of potash, it is essential to apply organics, similar line of results were also reported by Rasool *et al.* (2008) and Gunjal *et al.* (2010). Application of adequate levels of N, P in conjunction with crop residues improves the uptake of potassium were also reported by Chaturvedi *et al.* (2010), Arbad and Ismail (2011), Kumar *et al.* (2006) and Jadhav *et al.* (2007), Raskar (2006) and Sisodia and Khamparia (2007).

Interaction

The Interaction between tillage and IPNS on uptake of potassium in seed cotton and stalk of cotton was non significant.

4.4.2.4. Total uptake of Sulphur by cotton

The data pertaining to the sulphur uptake by cotton at harvest stages are shown in the Tables 37 and Fig. 31.

Effect of Tillage

The finding of the data observed that on uptake of sulphur by seed cotton, stalk and total uptake was in ranged from 6.63 to 7.98, 5.29 to 6.79 and 11.92 to 14.70 respectively at the harvest stage. Close observation of data showed that, significantly higher sulphur uptake was recorded in

Table 37. Effect of tillage and IPNS on total uptake of sulphur by cotton at harvest stage

Treatments			Total S uptake (kg ha ⁻¹)		
(a)Tillage			Seed cotton	Stalk	Uptake
Set I-Conservation tillage			7.98	6.79	14.77
Set II -Conventional tillage			6.63	5.29	11.92
SE(m)±			0.12	0.12	0.16
CD at 5 %			0.36	0.35	0.48
(b) Integrated plant nutrient system					
	Soybean	Cotton			
T ₁	Control	Control	4.20	3.22	7.43
T ₂	100 % RDF	100 % RDF	7.23	4.98	12.21
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	8.13	7.96	16.09
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	6.97	6.19	13.15
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	7.83	6.74	14.57
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	7.02	5.34	12.36
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	8.50	6.43	14.93
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	8.54	7.48	16.02
SE(m)±			0.25	0.24	0.33
CD at 5 %			0.73	0.70	0.96
(c) Interaction			NS	NS	NS

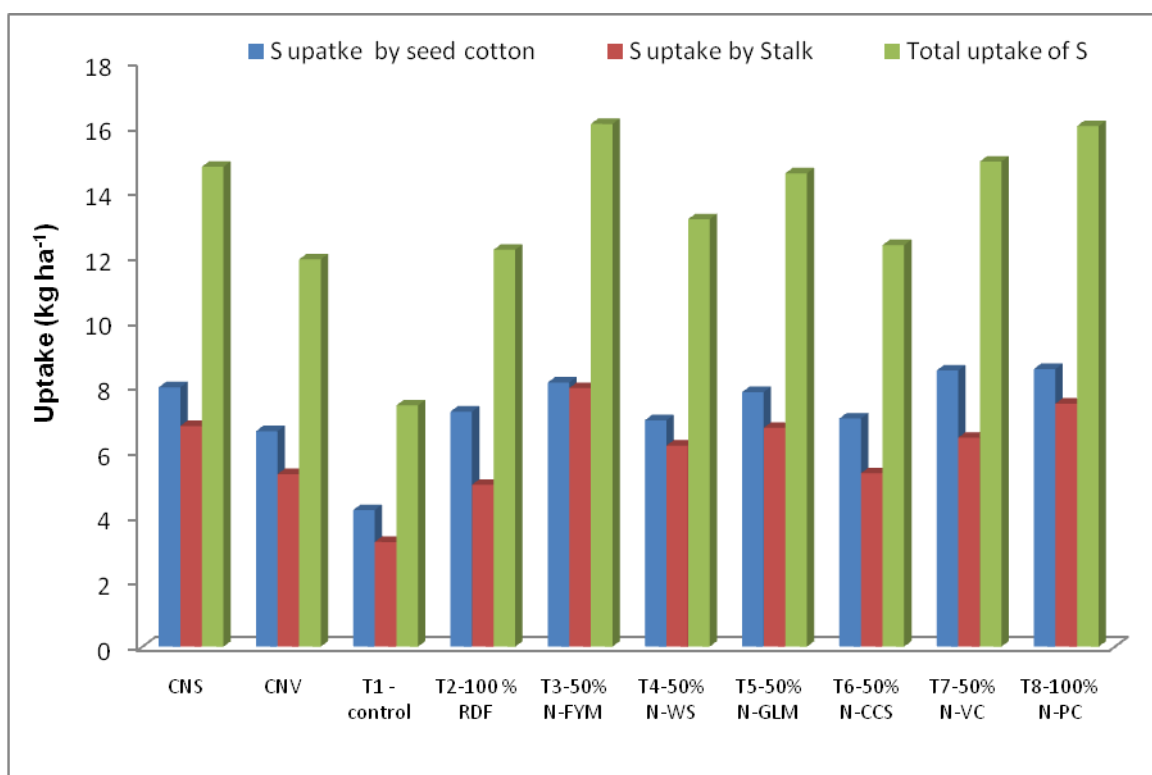


Fig. 32. Effect of tillage and IPNS on uptake of sulphur by cotton

conservation tillage than conventional. The uptake of S was observed higher in seed cotton than that of leaves and stem. Similar findings were reported by Nehra (2006), Patil and Sheelavantar (2000), Tomar (2005).

Effect of integrated plant nutrient system

Perusal of data indicated that sulphur accumulation in seed increased up to 4.20 to 8.54 kg ha⁻¹ respectively. While sulphur accumulation in stem and fruiting bodies continued to increase up to harvest during the years. The seed cotton was the major contributor to the total sulphur uptake which followed by stalk.

The findings showed that, the integrated plant nutrient management practices significantly influenced the sulphur uptake at harvest stage which was noticed in ranged from 4.20 to 8.54, 3.22 to 7.96 and 7.43 to 16.09 kg ha⁻¹ in seed cotton, stalk and total uptake of sulphur respectively. Total uptake of sulphur was observed higher in reproductive parts i.e. seed. The application of 50 percent N through FYM + remaining N through inorganic fertilizers (16.09 kg ha⁻¹) recorded higher sulphur uptake followed by 100 percent P through phosphocompost + remaining N through inorganic fertilizers (16.02 kg ha⁻¹) recorded higher total sulphur uptake than other treatments, this can be ascribed to the immediate availability of readily assimilable form of sulphur in organic with fertilizer treatment by plants. The similar results were reported by Mishra *et al.* (2008), Ravankar *et al.* (2005) and Katkar (2008).

Interaction

The Interaction between tillage and IPNS on uptake of seed and stalk of cotton was non significant.

4.5. Apparent Nutrient balance

It is desirable to calculate the apparent nutrient balance to attain the desired level of production without depleting the native reserves and ensuring the maintenance and improvement in soil fertility. Nutrient's drain has been calculated on the basis of removal by seed and straw of the soybean and removal by seed cotton and stalk of the cotton plants.

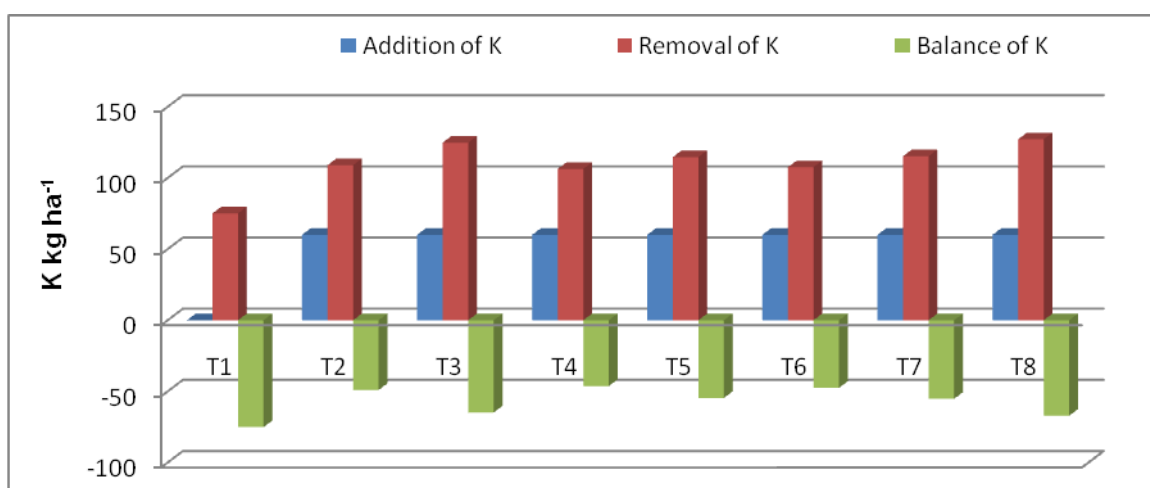
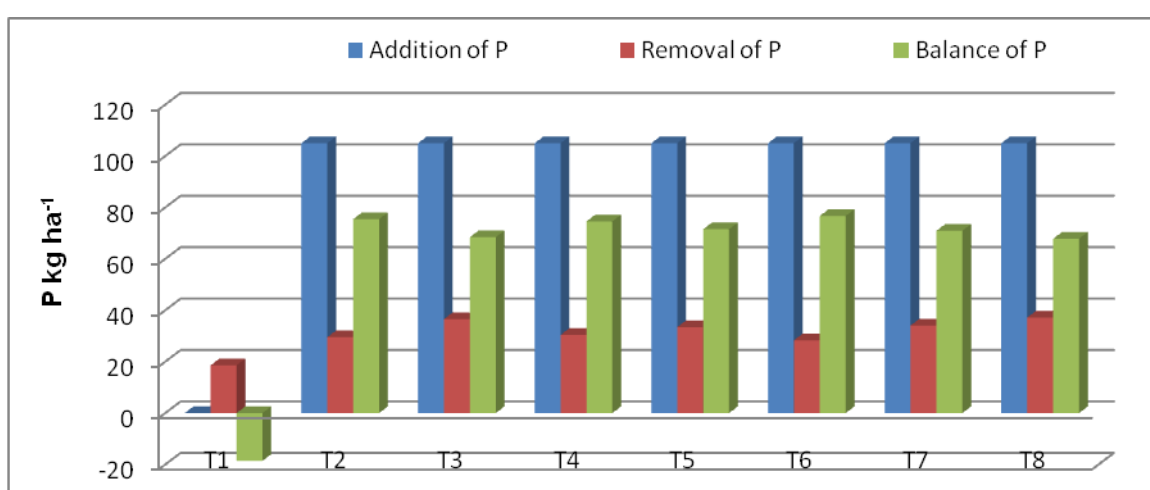
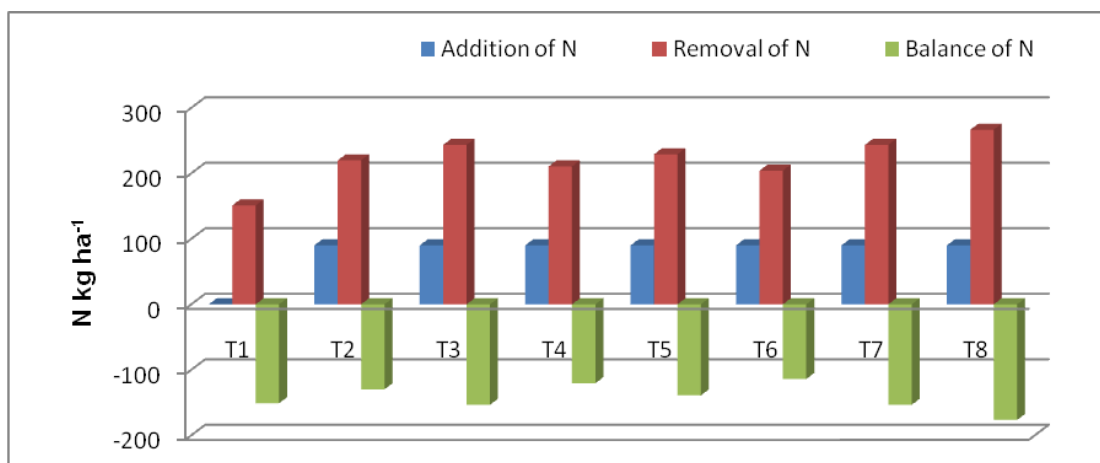


Fig. 33. Effect of IPNS on apparent nutrient balance in conservation tillage by soybean and cotton under soybean-cotton rotation

The perusal of data on inputs (nutrient applied) and output (nutrient uptake) after harvest of crops (2016-2018) under soybean - cotton rotation are presented in annexure IV (L and M). The addition of N during both the year on soybean-cotton rotation ranged between 0 to 90 kg ha⁻¹. Whereas P and K ranged between 0 to 105 kg ha⁻¹ and 0 to 60 kg ha⁻¹ respectively as against the removal of N, P and K were ranged from 151 to 267, 18.59 to 37.16 and 75.10 to 127.13 kg ha⁻¹ respectively under conservation tillage. Whereas the removal of N, P and K were ranged between 126 to 230, 14.25 to 30.32 and 67 to 109 kg ha⁻¹ under conventional tillage

It was observed that continuous addition of organics with chemical fertilizers helped in maintaining nutrient status under both soybean and cotton. The highest negative nitrogen balance was varied with -114 to -176 kg ha⁻¹ in conservation tillage practice under soybean-cotton rotation. The highest negative nitrogen balance was recorded with use of 100 % N through phosphocompost + remaining RD through chemical fertilizers under (-176 kg ha⁻¹) conservation and (-140 kg ha⁻¹) conventional tillage respectively. Similar findings were reported by Sonune *et al.*, (2003) and Thakur *et al.*, (2011).

The P is relatively immobile in soil as compared to N and K especially in swell-shrink soils; it was confined only to the upper layer of profile. Appreciable positive P balance was recorded in all the treatments. Apparent P balance increased with more the quantity of P applied from RDF, composted wheat straw and composted cotton straw treatments under conservation and conventional tillage practices. The positive P balance is because of addition of P in excess of its uptake by crops similar finding was reported by Mali *et al.*, (2012). This is possible in the present study that addition of P was appreciably excess than its removal especially in the case of soybean crop. However, most of the treatments in the present study having organics which might have help in improving the status of P and thus, occurs in the build up of P.

The critical evaluation of data indicated that on an average, there was net mining in range of -47.53 to -75.10 kg K ha⁻¹ in conservation tillage and -30.47 to -61.93 kg K ha⁻¹ in conventional tillage. The results

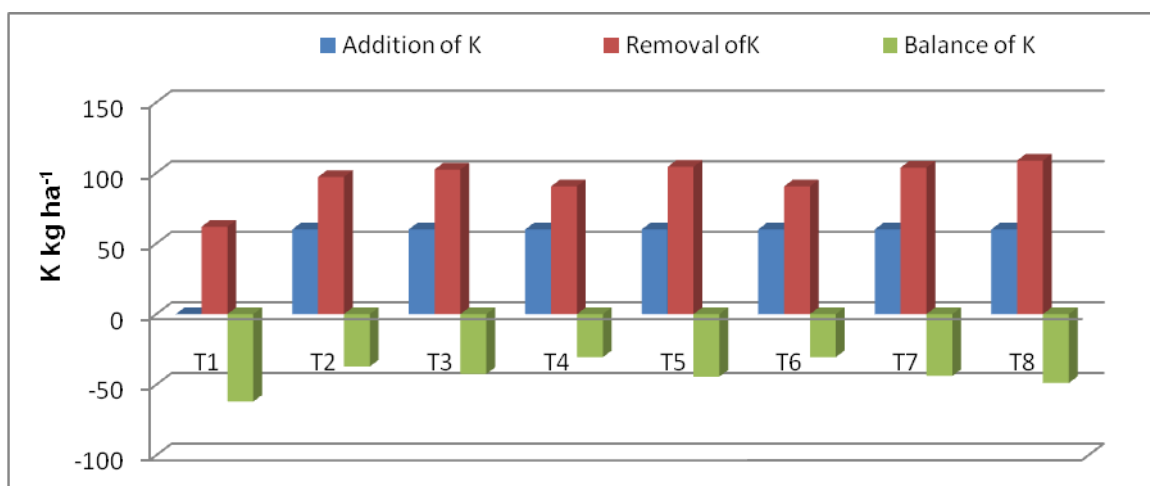
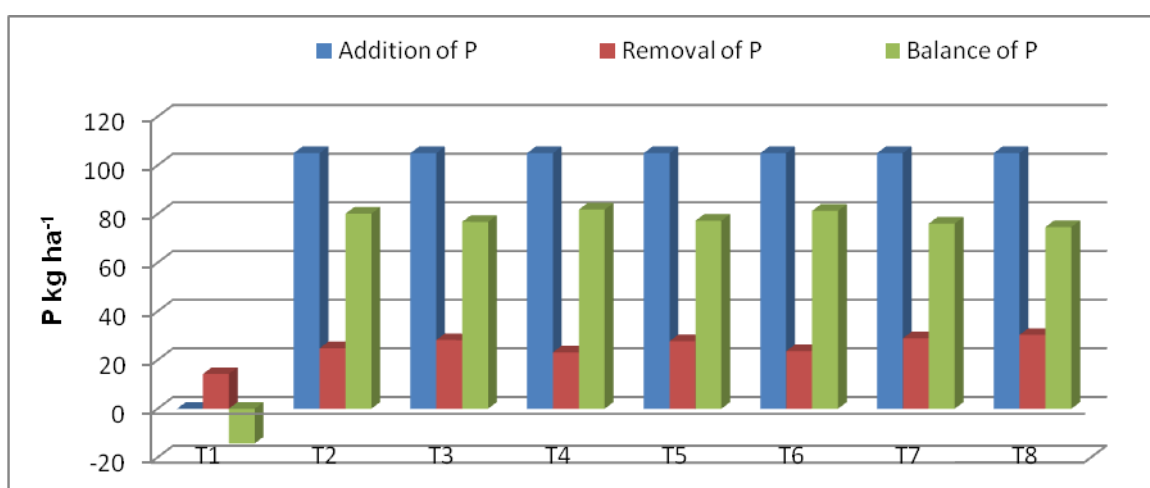
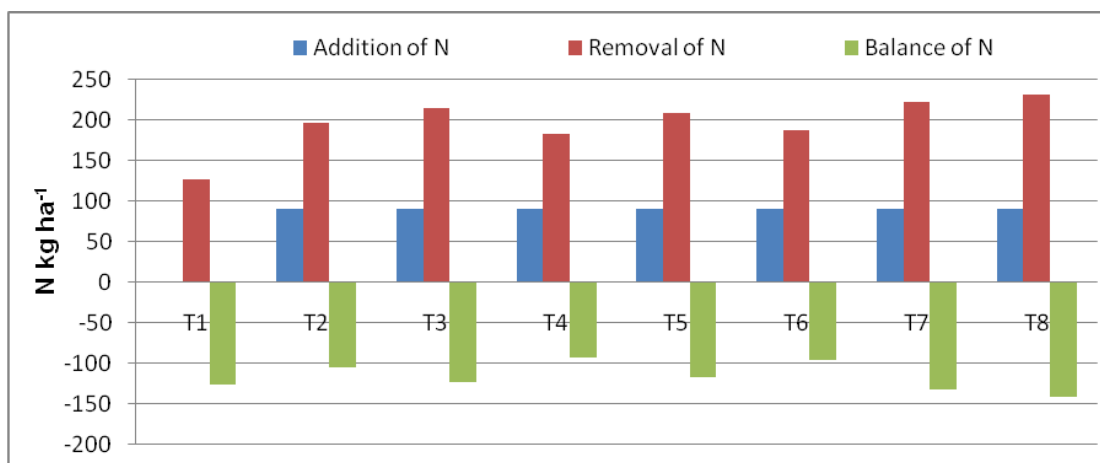


Fig. 34. Effect of IPNS on apparent nutrient balance in conventional tillage by soybean and cotton under soybean-cotton rotation

indicated that positive balance of P and negative balance of N and K was observed under best management practices for soybean-cotton rotation. Therefore, much attention is required for management of nitrogen and potassic fertilizers in order to maintain N and K status of soil and to prevent K mining of these nutrients in soils. Similar findings were reported by Sonune *et al.* (2003) and Thakur *et al.* (2011).

4.6. Soil Quality Index (SQI)

4.6.1 Principal Component Analysis (PCA):

In principal component analysis (PCA) twenty four variables were used in conservation and conventional tillage respectively. The PC1, PC2, PC3, and PC4 which explained about 10 % variability within the measured data were retained. Highest weighted variables (annexure V (N and O)) under PC1 to PC4 included BD, HC, OC, avail. N , avail. P, SMBC, DHA and CO₂ evolution. A correlation matrix for the highly weighted variable under PCs was run separately (annexure V (P)). It was assumed that, the variables having the highest correlation sum represented the best group. Thus, hydraulic conductivity (HC), organic carbon and dehydrogenase activity (DHA) were retained in the minimum data set (MDS) and regressed as independent variables with grain yields of soybean and cotton as dependent variable. The coefficients of determination (R^2) with yield of soybean, cotton were 0.602, 0.829 and 0.670 respectively (annexure V (Q)).

4.6.2 Soil Quality Index (SQI)

Soil is a key natural resource and soil quality is the integrated effect of management on most soil properties that determine crop productivity and sustainability. Good soil quality not only produces good crop yield, but also maintains environmental quality and consequently plant, animal and human health. A quantitative assessment of soil quality could provide much needed information on the adequacy of the world's soil resource base in relation to the food and fibre needs of a growing world population.

Table 38. Soil Quality Index as influenced by tillage and IPNS under soybean-cotton rotation

	Treatments		Soil Quality Index
	(a)Tillage		
	Set I-Conservation tillage		1.93
	Set II -Conventional tillage		1.69
	SE(m)±		0.01
	CD at 5 %		0.02
	(b) Integrated plant nutrient system		
	Soybean	Cotton	
T ₁	Control	Control	1.48
T ₂	100 % RDF	100 % RDF	1.59
T ₃	50 % N through FYM + remaining RD F	50 % N through FYM + remaining RDF	1.98
T ₄	50% N through WS+ remaining RD F	50% N through WS+ remaining RD F	1.88
T ₅	50% N through GLM + remaining RDF	50% N through GLM + remaining RDF	1.95
T ₆	50 % N through cotton stalk+ remaining RDF	50 % N through cotton stalk+ remaining RDF	1.79
T ₇	50 % N through vermicompost+ remaining RDF	50 % N through vermicompost+ remaining RDF	1.87
T ₈	100 % N through PC + remaining P through RDF	100 % P through PC + remaining N through RDF	1.95
	SE(m)±		0.01
	CD at 5 %		0.04
	(c) Interaction		NS

The data on Soil Quality Index as influenced by tillage and nutrient management practices is presented in Table 38 and depicted in Fig 32. Under conservation tillage the SQI recorded 1.93 which was significantly superior over conventional tillage. This indicates the conservation tillage help to improve the SQI in Vertisols. Among different IPNS treatments, the SQI ranged from 1.48 to 1.98. Addition of 50 % N through FYM + remaining RDF through chemical fertilizer and 50 % N through GLM + remaining RDF through chemical fertilizers which was significantly superior and recorded highest SQI. However, INM treatments (T₃ to T₈) recorded higher SQI over 100% RDF inorganic and control suggested that application of inorganic alone could not maintain soil quality. This indicates that overall improvement in soil

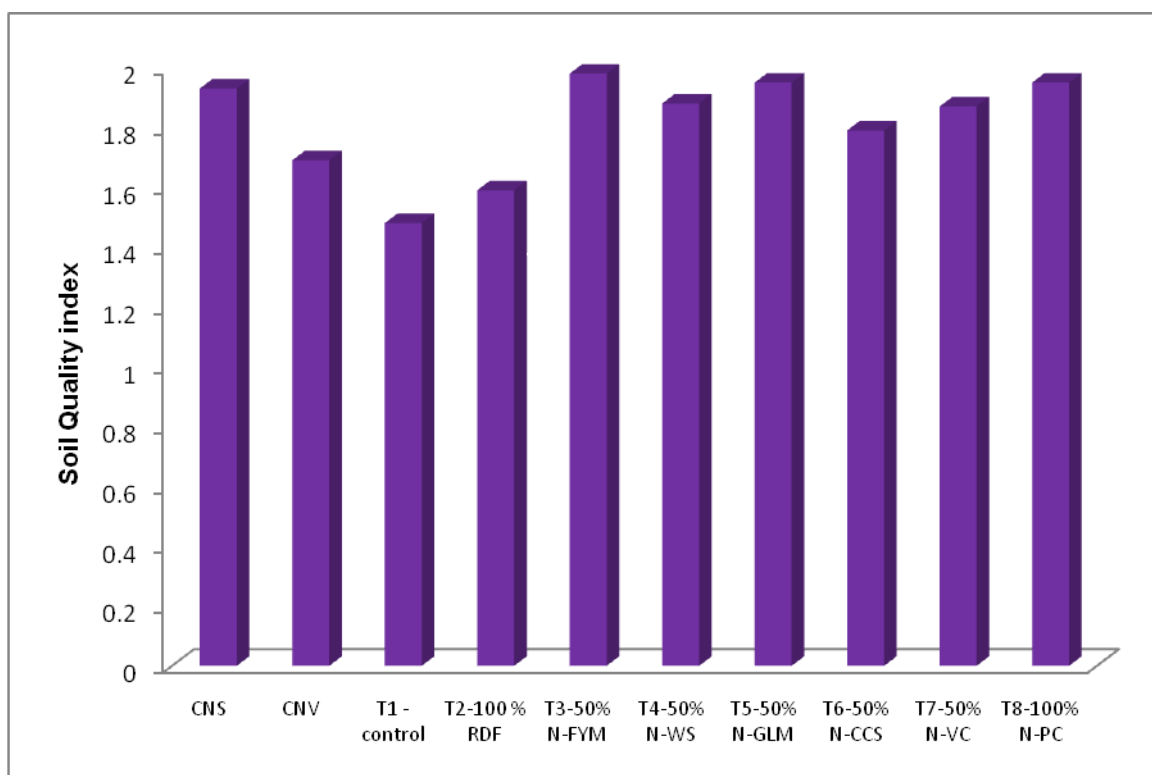


Fig. 35. Effect of tillage and IPNS on Soil Quality Index

quality in the long run is expected due to regular addition of organics in combination with chemical fertilizers. Chaudhary *et al.* (2005) concluded that the highest soil quality index was observed under use of 100% NPK + FYM followed by use of 100 % NPK, 100 % NP, 100 % N and control. The similar results were reported by Sharma *et al.*, (2011) and Masto *et al.*, (2007). Highest SQI with the addition of @10 t ha⁻¹ FYM + 100 % RDF to sorghum and only 100 % RDF to wheat under sorghum-wheat sequence grown in Vertisols reported by Kharche *et al.* (2010).

The present investigation involves the effect of different options of INM like use of FYM, GLM, phosphocompost, vermicompost and crop residues along with chemical fertilizers on the soil properties specially, the change occurring in these properties. Likewise there has been profound influence of these options on the soil properties which is reflected in soil quality index. It was highest under integration of inorganics and FYM, GLM and phosphocompost. It is interesting to note that, there has been a clear influence of only chemical fertilizers on the SQI which is likely to be reduced further during subsequent years. This justifies the soil quality index and further reveals that the identified soil quality index largely concern with the yield of soybean and cotton crops and are most sensitive to the management practices.

Table 39. Multiple regressions of total soil parameters and soil indicators

Goal/Function	R ²	
	Total Soil Parameters	Soil Indicators
Conservation Tillage		
Soybean Yield	0.87**	0.81**
Seed Cotton Yield	0.85**	0.82**
Conventional Tillage		
Soybean Yield	0.84**	0.74**
Seed Cotton Yield	0.76**	0.71**

** Denotes significance at 1% level of significance

4.6.3 Per cent contribution of key Soil Indicators in soybean and cotton seed yield and Soil Quality Index

In case of soybean seed yield, the average per cent contributions of key indicators to soybean seed yield were hydraulic conductivity (73.15 %), organic carbon (24.94 %) and dehydrogenase (1.91

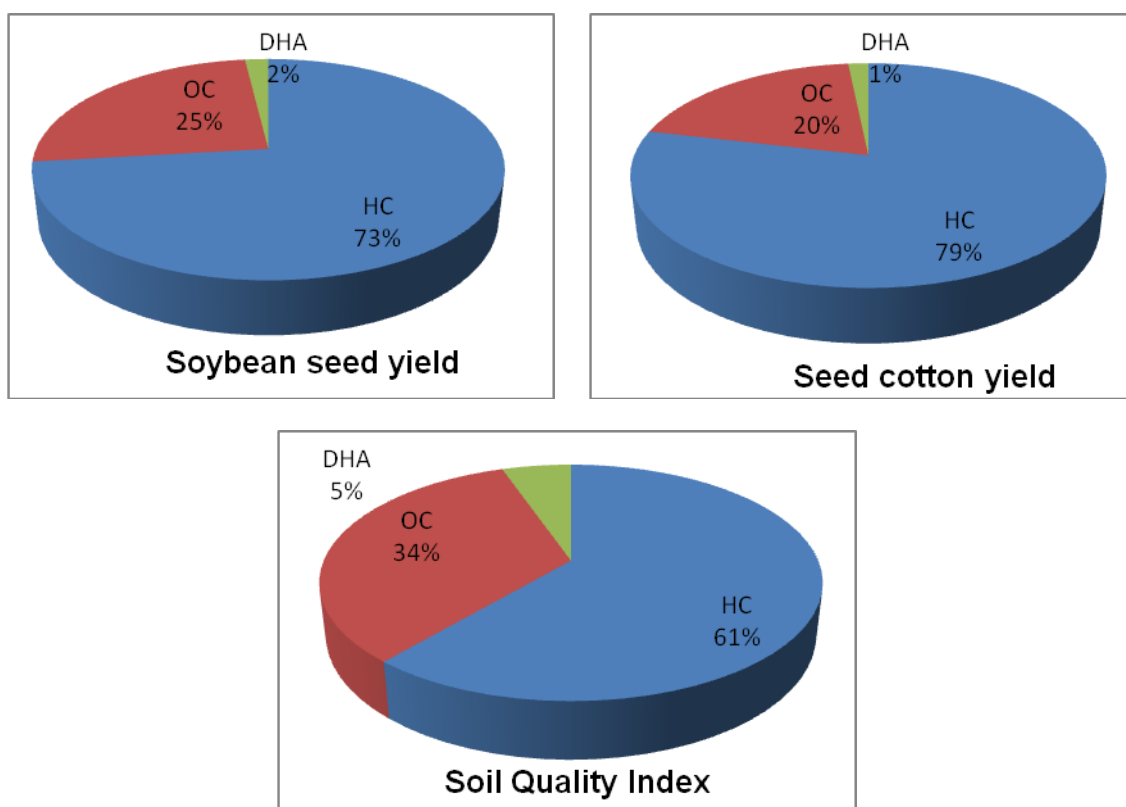


Fig. 36. Per cent contribution of key Soil Quality Indicators in Seed yield and Soil Quality Index under conservation tillage

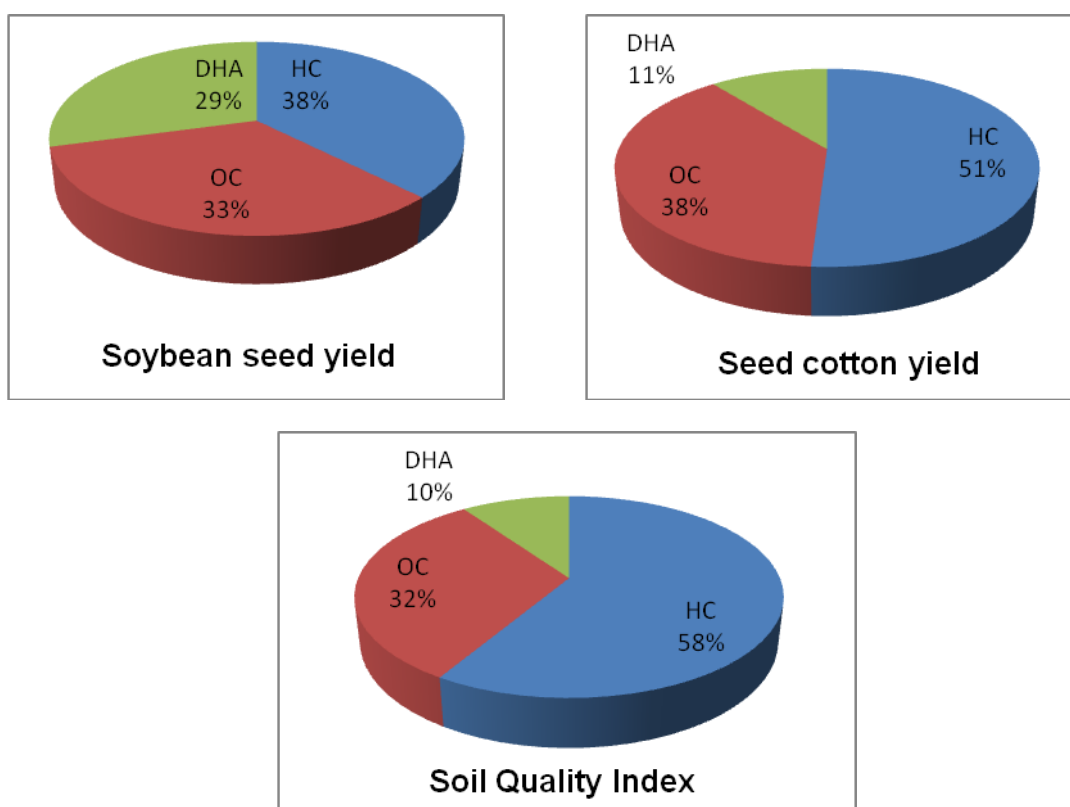


Fig. 37. Per cent contribution of key Soil Quality Indicators in Seed yield and Soil Quality Index under conventional tillage

%). The average per cent contributions of key indicators towards seed cotton yield were hydraulic conductivity (78.64 %), organic carbon (19.73 %) and dehydrogenase (1.63 %) under conservation tillage. Similar trend in per cent contributions of key indicators to soybean seed and cotton seed yield were recorded under the conventional tillage. This justifies the soil quality index largely govern the yield of these crops and are most sensitive to the nutrient management practices under conservation and conventional tillage.

The key indicators which contributed considerably to soil quality index were hydraulic conductivity, organic carbon and dehydrogenase activity. On an average, the order of relative contribution of these indicators towards soil quality index were hydraulic conductivity (61.24 %), organic carbon (33.45 %) and dehydrogenase activity (5.31%) (Table 40) under conservation tillage. Similar trend was noted under conventional tillage.

Table 40. Per cent contribution of key Soil Indicators in soybean and cotton seed yield and Soil Quality Index under conservation and conventional tillage

Sr. No.	Indicators	Contribution of key indicators (%)		
		Seed yield		Soil Quality Index
		Soybean seed	Seed cotton	
Conservation tillage				
1	Hydraulic conductivity	73.15	78.64	61.24
2	Organic carbon	24.94	19.73	33.45
3	Dehydrogenase activity	1.91	1.63	5.31
Conventional tillage				
1	Hydraulic conductivity	37.60	51.00	58.61
2	Organic carbon	33.12	38.24	31.63
3	Dehydrogenase activity	29.28	10.76	9.76

4.7. Correlation and regression studies

4.7.1. Correlation studies

The results obtained in experiment were statistically analyzed for correlation studies between soybean seed yield and seed cotton yield with different soil physical, chemical and biological parameters. Soybean seed

yield and seed cotton yield was considered as dependent variable while soil physical properties, chemical and biological properties were considered as independent variables. The correlation matrix was worked out among various soil properties and soybean seed yield and seed cotton yield under conservation and conventional tillage. The correlation studies revealed the strength of inter-relationship between the causal variables, therefore, only correlation coefficient values ('r' values) of resultant variables are presented in (annexure V (P to S)) respectively.

4.7.1.1 Soil physical properties versus soybean seed and seed cotton yield

The correlation coefficients as regards to soil physical properties like bulk density and hydraulic conductivity versus soybean seed yield and seed cotton yield are reported (annexure V (R to U)) under conservation and conventional tillage respectively.

Significant negative correlation was observed between soybean grain yield and seed cotton yield with bulk density ($r = -0.730^{**}$) and ($r = -0.609^{**}$) respectively under conservation tillage. Whereas, significant positive correlations were recorded between soybean grain yield and seed cotton yield with hydraulic conductivity ($r = 0.428^{*}$) and ($r = 0.465^{*}$) respectively under conservation tillage. In the present investigation, these soil parameters were found to be enhanced due to the application of crop residues and organics under conservation tillage. The similar results were recorded under conventional tillage practice. Similar findings were reported by Mali *et al.*, (2012), Sharma *et al.*, (2011) and Rewatkar (1998). The significant positive correlation was found in between seed cotton yield and hydraulic conductivity & available water capacity reported by Kadu *et al.* (2003).

Amongst the physical parameters, bulk density showed significant negative correlation with HC ($r = -0.474^{*}$) and ($r = -0.474^{*}$) respectively in both soybean & cotton under conservation tillage, indicating that lower the bulk density higher will be the HC. The experimental investigation was of only two years, which is in fact too shorter period to register highly significant changes in physical properties.

But this is indicative of the need to improve physical properties of soil and encourage the frequent application of crop residues and organics for enhancing the crop productivity for long term.

4.7.1.2. Soil chemical parameters versus soybean seed and seed cotton yield

The correlation coefficients in relation to soil fertility parameters and soybean seed yield and seed cotton yield are reported in correlation matrix (annexure V (R to U)). It could be seen that, soybean seed yield and seed cotton yield had recorded significant positive correlation with organic carbon ($r = 0.634^{**}$), ($r = 0.466^*$), available nitrogen ($r = 0.745^{**}$), ($r = 0.832^{**}$) and available phosphorus ($r = 0.800^{**}$), ($r = 0.731^{**}$) respectively, under conservation tillage. Similar trend was recorded in respect of conventional tillage during both the crop yield. This could be attributed that, to obtain higher soybean grain yield and seed cotton yield the nutrients should be in the available form in the soil. Available nutrients showed average positive correlation with soybean grain yield and seed cotton yield. This indicating balanced application of nutrients for their availability to crops.

4.7.1.3. Soil microbial population versus soybean seed and seed cotton yield

The correlation between soil microbial population and soybean grain and seed cotton yield was found to be positive and significant (Table 46 to 49). The soybean grain and seed cotton yield recorded significant and positive correlation with SMBC ($r = 0.801^{**}$) and ($r = 0.655^{**}$) respectively, under conservation tillage. Similar results were recorded in conventional tillage. This could be ascribed that, to obtain higher soybean grain seed cotton yield the soil microbial population should be more which enhances the decomposition of organic matter, mineralization and ultimately the availability of nutrients in the soil.

4.7.1.4. Relationship of soil physical, chemical and biological properties

The correlation coefficients amongst the soil physical, chemical and biological properties are reported (annexure V (R to U)). The significant correlation among soil physical, chemical and biological properties was noted. The hydraulic conductivity recorded significant positive correlation with chemical properties whereas, bulk density of the soil was found significant

negatively correlated with chemical properties under conservation and conventional tillage. Similar findings reported by Kausal *et al.*(1996) and Rewatkar (1998).

Bulk density recorded significant negative correlation with chemical parameters like organic carbon ($r = -0.870^{**}$), available N ($r = -0.646^{**}$), available P ($r = -0.789^{**}$) indicating the lower bulk density, favorable for physical soil condition and ultimately higher availability of nutrients. In general, bulk density showed significant negative correlation with biological parameters *viz.* CO₂ evolution ($r = -0.771^{**}$) and SMBC ($r = -0.871^{**}$) which showed the good soil physical condition essential for higher microbial population in the soil under conservation tillage similar finding was reported by Rita Patil (1999).

Soil organic carbon content showed significant negative correlation with bulk density ($r = -0.870^{**}$) and significant positive negative correlation hydraulic conductivity ($r = 0.523^{**}$) under conservation tillage. The findings are in close agreement with the results reported by Kumar *et al.* (2002). Available nitrogen and phosphorus were found to be significantly negatively correlated with bulk density ($r = -0.646^{**}$, -0.789^{**}) and significantly positive correlated with hydraulic conductivity ($r = 0.625^{**}$, 0.529^{**}) respectively, under conservation tillage.

Significant positive correlation of soil organic carbon were observed with biological parameters *viz.* SMBC ($r = 0.780^{**}$) and CO₂ evolution. ($r = 0.749^{**}$). Available nitrogen was found to be significantly positively correlated with DHA ($r = 0.728^{**}$) and CO₂ evolution ($r = 0.726^{**}$) under conservation tillage.

4.8. Cost Economic

The highest cost of cultivation was recorded with conventional tillage than conservation tillage. The integrated plant nutrient management treatments application of 50 % N through FYM + remaining RD through chemical fertiliser was recorded highest cost of cultivation, which was followed by other nutrient management treatments in decreasing order of *viz.*, FYM> phosphocompost>vermicompost>GLM>CCS>WS. Lowest COC was recorded with control treatment. (Annexure VI (V)).

Significantly highest gross monetary returns (GMR) were recorded with conservation tillage (Rs.74852 ha⁻¹) and (Rs.70048 ha⁻¹) during both soybean and cotton crops. The significantly highest GMR was recorded with application of 100 % N through phosphocompost + remaining RD through chemical fertilizer (Rs. 78302 ha⁻¹) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer and 50 % N through vermicompost + remaining RD through chemical fertilizer in soybean crop. In cotton crop the significantly highest GMR was recorded with the application of 100 % P through phosphocompost + remaining RD through chemical fertilizer (Rs.74549 ha⁻¹) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer. Statistically minimum GMR was found with control (Rs.43320 ha⁻¹). Similar finding was reported by Bhalerao *et al.*, (2007).

Significantly highest net monetary returns (NMR) were recorded with conservation tillage (Rs.29286 ha⁻¹) and (Rs.17713 ha⁻¹) in soybean and cotton crops respectively. Among the nutrient management treatments the significantly highest NMR was recorded with the application 100 % N through phosphocompost + remaining RD through chemical fertilizer (Rs.30363 ha⁻¹) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer in soybean. Similarly, the significantly higher net monetary return was recorded with the application of 100 % P through phosphocompost + remaining RD through chemical fertilizer (Rs.22146 ha⁻¹) followed by application of 50 % N through FYM + remaining RD through chemical fertilizer in cotton.

Among the tillage practices the significantly highest benefit to cost (B: C) ratio was found in conservation tillage (1.77) and (1.34) than conventional tillage during soybean and cotton crop respectively. This might be due to minimum tillage practices which involve less cost of cultivation. Significantly highest B:C ratio of (1.80) was found with application of 50 % N through FYM + remaining RD through chemical fertilizer followed by application 100 % N through phosphocompost + remaining RD through chemical fertilizer in soybean. In respect of cotton the significantly highest B:C ratio of 1.44 was found with application of 50 % N through FYM + remaining RD through chemical fertilizer followed by application of 100 % P

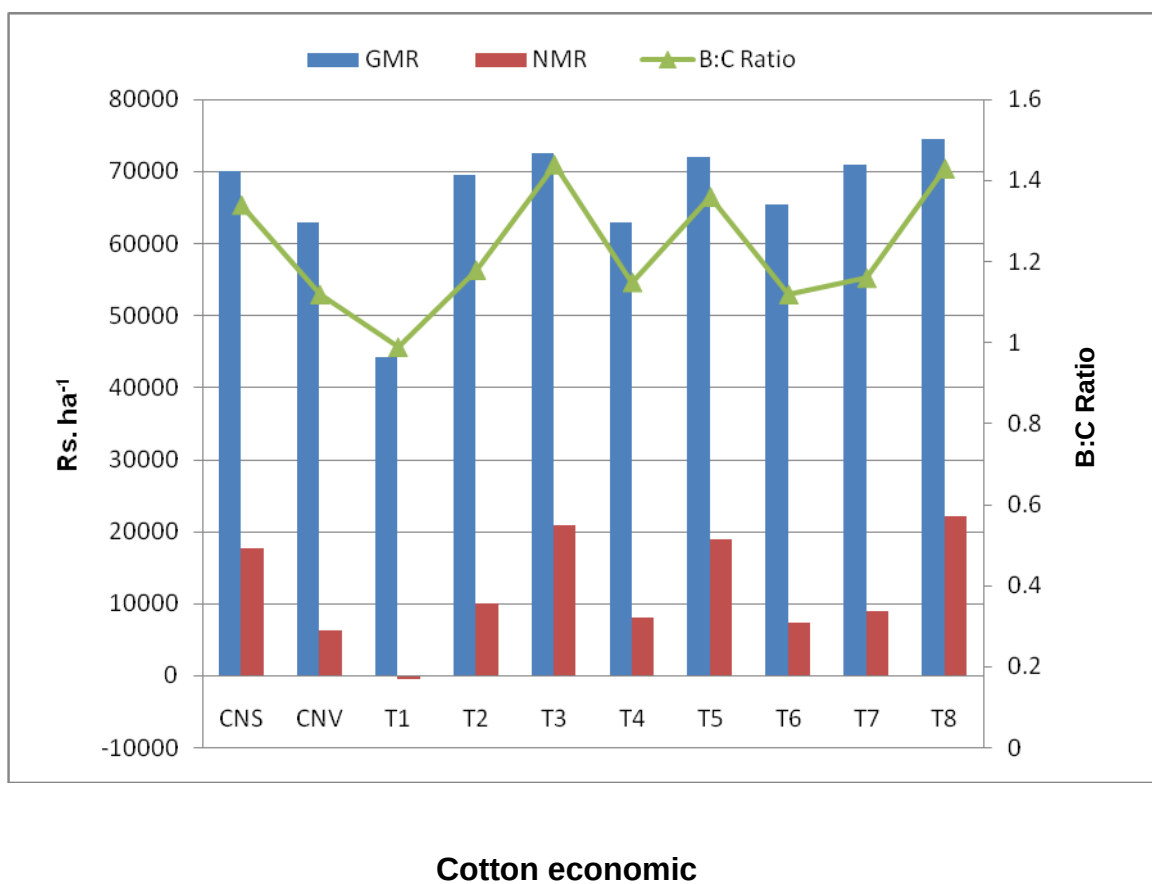
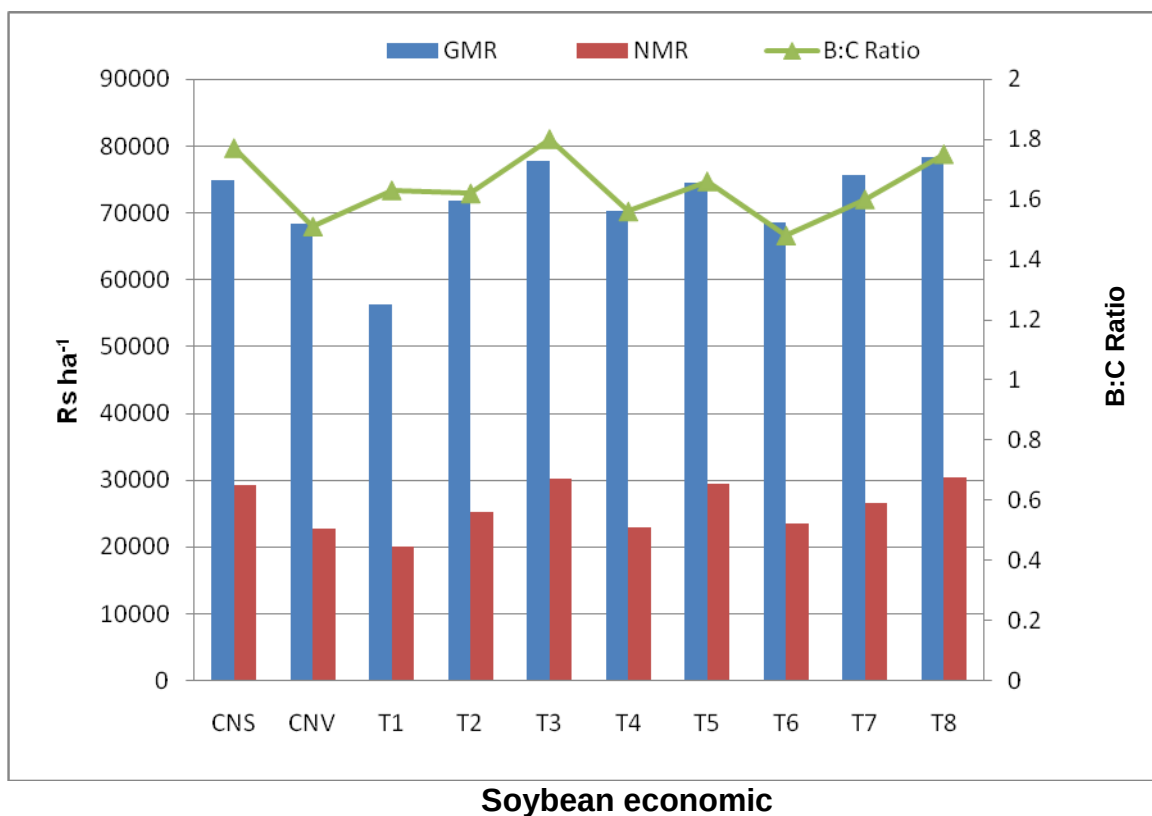


Fig. 38. Effect of tillage and IPNS on economics by soybean and cotton under soybean-cotton rotation

through phosphocompost + remaining RD through chemical fertilizer. The higher B:C ratio under integrated nutrient management practices comprising application of 50 % N through FYM + remaining RD through chemical fertilizer followed by application of 100 % P through phosphocompost + remaining RD through chemical fertilizer may be due to more economic returns in terms of GMR and NMR. Similar finding was reported by Bhalerao *et al.*, (2007).

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation was carried out to study the “Effect of tillage and integrated plant nutrient system on soil properties and uptake of nutrients and productivity of soybean - cotton rotation in Vertisol”. The experiment was conducted at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola on the same place where, cotton was grown for six years using the conservation and conventional tillage practices with various organic sources since the year 2010-11. The site has history of six year experimentation of conservation tillage with sole cotton which has added advantage of identifying the effect of various treatments on accumulated carbon and its further effect on other properties. The effect of conventional and conservation tillage was assessed along with different organic and inorganic fertilizers. The yield was not sustained after six years of experimentation hence; it was rotated with soybean as a legume to maintain residual fertility of soil and also to avoid monocropping of cotton. The results are placed considering the history of six years. The treatments defined for soybean-cotton rotation have been slightly changed to assess the effect of tillage and IPNS. Similarly the carryover effect of earlier crop and nutrient management treatments have been considered. The findings of present experiment have been compared over initial status of soil at the start of the experiment (2010-11) (Table 3). The treatment wise soil samples were collected to find out the effect of tillage and nutrient management on soil (annexure I (C)). The study was conducted in Kharif 2016-17 and 2017-18. The objectives of the study were to ascertain the impact of tillage and various nutrient management options on soil properties, nutrient uptake and crop productivity under soybean - cotton rotation.

The field experiment comprised two main treatments and eight sub treatments. The main plot involved two treatments i.e. conservation tillage (CNS) in which one harrowing and two hand weeding were followed. Conventional tillage (CNV) one ploughing (once in two year), one harrowing, two hoeing and two hand weeding operations were carried out every year.

The eight sub plot treatments of IPNS nutrient management involving control (T₁), 100 % RDF (T₂), 50 % N through FYM + remaining RD through chemical fertilizer (T₃), 50 % N through wheat straw + remaining RD through chemical fertilizer (T₄), 50 % N through GLM + remaining RD through chemical fertilizer (T₅), 50 % N through composted cotton stalk + remaining RD through chemical fertilizer (T₆), 50 % N through vermicompost + remaining RD through chemical fertilizer (T₇), 100 % N through phosphocompost + remaining P through chemical fertilizer (T₈). The treatment T₁ to T₇ were same in cotton except the treatment (T₈) i.e. 100% P through phosphocompost + remaining N through chemical fertilizer. The experimental soil was Vertisol, having montmorillonitic mineralogy, alkaline in reaction with low available N and P and high in K. The soil initial properties were ascertained and the nutrient content of each crop residue, organic manure, phosphocompost, vermicompost and green manure were estimated. Treatment wise FYM, wheat straw, composted cotton straw and GLM, phosphocompost and vermicompost were incorporated in the soil while, remaining dose of fertilizers was applied in the form of urea, SSP, and MOP for compensation. Half dose of nitrogen and full dose of P and K were applied at the time of sowing and remaining half of nitrogen was applied one month after emergence of crop and thoroughly mixed in the soil to the soybean and cotton. The three replications were undertaken in a randomized block design separately for conservation and conventional tillage.

The soil samples were collected initially at the start of the experiment and after harvest of soybean and cotton crop every year and analysed to study the effect on soil physical, chemical and biological properties of the soil. Plant samples were collected at harvest of soybean cotton and analyzed N, P, K and S content. Seed and straw yields were recorded at harvest stage of soybean crop. The treatment wise seed cotton yield and dry matter yield was recorded of cotton. The data recorded on soil properties was used for imputations of the soil quality index using Principal Component Analysis (PCA). The minimum data set was identified and contribution of key soil indicators was worked out. The salient findings on the

effect of various treatments emanated during the course of investigation are summarized and the conclusions emerged are briefly presented as under.

5.1.1 Physical Properties

Bulk density

- Bulk density was slightly reduced in conservation as compared to conventional tillage.
- The reduction in bulk density was meagre and gradually more reduction was noticed during second year indicating potential of improving soil physical condition due to addition of organics in subsequent years.
- The reduction in bulk density was recorded using of FYM, phosphocompost, vermicompost, crop residues and glyricidia green leaf manuring alongwith use of chemical fertilizers for both soybean-cotton rotations. Lower value of bulk density recorded with the application of 100 % P through phosphocompost + remaining dose through chemical fertilizer.

Hydraulic conductivity

- The hydraulic conductivity showed slight improvement under conservation tillage over conventional tillage practice.
- The highest hydraulic conductivity was recorded under conjunctive use of 50 % N through FYM + remaining RD through chemical fertilizer and 50 % N through GLM + remaining RD through chemical fertilizer .

Mean weight diameter

- MWD was found to be slightly improve under conservation than conventional tillage.
- The highest MWD was recorded with 50 % N through FYM + remaining RD through chemical fertilizer which was superior to all the remaining treatments and the lowest MWD observed in control under soybean - cotton rotation.

Available soil moisture

- The available soil moisture content was significantly enhanced due to amalgamation of use of chemical fertilizers with glyricidia green leaf manuring, FYM, phosphocompost, vermicompost and crop residues (T₃ to T₈) as compared to application of chemical fertilizers alone and in control under conservation tillage.

5.1.2 Chemical properties

pH and Electrical conductivity

- No significant differences were observed in pH and EC among the treatments with conjunctive use of organics and chemical fertilizers over a period of years under soybean-cotton rotation. However, slight decrease in pH and electrical conductivity of soil with the application of 50 % N through FYM+ remaining RD through chemical fertilizer was registered.

Organic carbon

- The higher organic carbon was found under conservation tillage as compared to conventional tillage.
- The application of the 50 % N through FYM + remaining RD through chemical fertilizer supported well in enhancement in organic carbon followed by conjoint use of 50 % N through GLM + remaining RD through chemical fertilizer under soybean crop and cotton during both the year.
- The Interaction of tillage and IPNS was found to be significant with respect to OC and highest organic carbon was recorded under application of 50 % N through FYM + remaining RD through chemical fertilizer under conservation tillage.

Available nitrogen

- Significantly higher available nitrogen was recorded under conservation tillage than conventional tillage.
- Significantly highest enhancement in available N was recorded with treatment 50 % N through FYM + remaining RD through chemical fertilizer followed by 100 % RDF, 50 % N through GLM + remaining RD through

chemical fertilizer after harvest of soybean and cotton during both the year.

- The Interaction of tillage and IPNS was significant and significantly highest available N was recorded with application of 50 % N through FYM + remaining RD through chemical fertilizer under conservation tillage.

Available phosphorus

- The highest available phosphorus was recorded in conservation tillage as compared to conventional tillage.
- Under soybean and cotton crop in IPNS the significantly highest available P was recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer and lowest in control. All treatments consist of IPNS (T₃ to T₈) showed build up in available P status than previous year.

Available potassium

- The significantly highest available potassium was noticed in conservation tillage than in conventional tillage. The application of 50 % N through FYM + remaining RD through chemical fertilizer and followed by use of 50 % N through GLM + remaining RD through chemical fertilizer registered highest available K than other treatments.

Available sulphur

- The significantly highest available sulphur was recorded in conservation tillage as compared to conventional tillage.
- The available sulphur registered highest with application of 50 % N through FYM + remaining RD through chemical fertilizer followed by in 100 % P through phosphocompost + remaining N through chemical fertilizer.

Available micronutrients

- The higher available zinc, iron, manganese, and copper were recorded under conservation tillage as compared to conventional tillage.
- The available zinc, iron, manganese and copper under soybean-cotton rotation was observed higher with use of 50 % N through FYM +

remaining RD through chemical fertilizer followed by 100 % N through Phosphocompost + remaining P through chemical fertilizer.

Nitrogen forms

- The significantly highest mineral nitrogen i.e. ammonical N and nitrate N were recorded under conservation tillage.
- The numerical higher nitrate nitrogen, ammonical nitrogen and mineral nitrogen were recorded during soybean grown under soybean-cotton rotation.
- The significantly highest nitrate nitrogen, ammonical nitrogen and mineral nitrogen were recorded with an application of 50 % N through FYM + remaining RD through chemical fertilizer followed by 50 % N through GLM + remaining RD through chemical fertilizer under soybean –cotton rotation during both the year.

5.1.3 Biological Properties

Soil Microbial Biomass Carbon (SMBC)

- The higher soil microbial biomass carbon (SMBC) was recorded in conservation over in conventional tillage.
- The SMBC was noticed higher during soybean grown under soybean-cotton rotation.
- Soil Microbial Biomass Carbon was significantly highest with. application of 50 % N through FYM + remaining RD through chemical fertilizer followed by use of 100 % P through phosphocompost + remaining N through chemical fertilizer during both the years. The lowest SMBC was observed under control.

Dehydrogenase activity

- The dehydrogenase activity (DHA) showed remarkable improvement in conservation tillage than conventional tillage during both the years.
- The application of 50 % N through FYM + remaining RD through chemical fertilizer recorded significant improvement in DHA over all the treatment and lowest value observed with control.

CO₂ Evolution

- The significantly higher CO₂ evolution was noticed in conservation tillage as compared to conventional tillage.
- The CO₂ evolution was found significantly higher with an application of 50 % N through FYM + remaining RDF through chemical fertilizer followed by 100 % N through phosphocompost + remaining P through chemical fertilizer. The lowest CO₂ evolution was identified in control during soybean-cotton rotation.

SOC Stock

- Numerically higher SOC stock was observed in conservation tillage as compared to conventional tillage in second year of experiment.
- The SOC stock was found significantly higher with application of 50% N through FYM + remaining RDF through chemical fertilizer followed by 50% N through GLM + remaining RDF through chemical fertilizer found to be at par with each other. The lowest CO₂ evolution was recorded in control during soybean-cotton rotation.

5.1.4 Crop yield

- The significantly highest soybean seed and straw yield of soybean and seed cotton yield and stalk yield of cotton were recorded in conservation than conventional tillage.
- The significantly highest soybean seed and straw yield and seed cotton yield and stalk yield were recorded with application of 100 % N through phosphocompost + remaining P through chemical fertilizer. The interaction of conservation tillage with phosphocompost and FYM was found most beneficial in achieving higher yield of both the crop.
- However, inclusions of organics like FYM, glyricidia green manuring and crop residues along with chemical fertilizers were also found beneficial in increasing the yield of soybean and cotton.

5.1.5 Nutrient uptake

- The content and total uptake of macronutrients (N, P, K and S) were recorded significantly highest in conservation tillage during both the year.

- The highest total uptake of N, P, K and S by soybean and cotton were recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizer. Lowest uptake of N, P, K and S was observed in control.

5.1.6 Apparent nutrient balance

- The removal of N was -126 to -230 kg ha⁻¹ during 2016-17 and 2017-18 as against addition of N was 90 kg ha⁻¹. However the highest negative balance of N was observed in 100 % N through N phosphocompost + remaining P through chemical fertilizers.
- The P removal was ranged 14.25 to 30.32 kg ha⁻¹ with the addition of P was 105 kg ha⁻¹ during 2016-17 and 2017-18. The positive P balance was noted under all organic treatment.
- The addition of K was 60 kg ha⁻¹ during both the year. The negative K balance was observed under all the treatments. However the high potassium mining was observed in control.

5.1.7 Soil Quality

- The highest Soil Quality Index (SQI) was computed in conservation tillage than conventional tillage.
- The highest SQI (1.98) was achieved with the application of 50 % N through FYM + remaining RD through chemical fertilizer under soybean-cotton rotation.
- The SQI under all the IPNs treatments was higher as compared to chemical fertilizers alone.
- The key soil quality indicators identified under soybean and cotton were hydraulic conductivity, OC and DHA which are the most sensitive to management and useful for monitoring the soil quality.

5.1.8 Cost economics

- The conservation tillage recorded highest GMR, NMR and B:C ratio as compared to conventional tillage.

- Among the various IPNS treatments the highest GMR, NMR was recorded with the application of 100 % N through phosphocompost + remaining P through chemical fertilizers. However the B:C ratio was highest in 50 % N through FYM + remaining RD through chemical fertilizers in soybean and cotton crop.

5.1.9 Correlation and regression

- Soybean seed yield and Seed cotton yield were recorded significantly positively correlated with hydraulic conductivity, mean weight diameter, and available nitrogen and phosphorus as well as with SMBC, DHA and CO₂ evolution.
- All the soil physical, chemical and biological properties were significantly positive correlated among themselves except that bulk density was negatively but significantly interrelationship to chemical and biological properties.

5.1.10 Best Management Practice

- The application of 50 % N through FYM + remaining RD through chemical fertilizer was found to be best combination for all the soil properties i.e. bulk density, hydraulic conductivity, mean weight diameter, organic carbon, available N,P,K,S and micronutrient, SMBC and DHA were observed the best treatment under conservation tillage. However the application of 100 % N through phosphocompost was found best in respect of yield and uptake of nutrients under soybean-cotton rotation under conservation tillage practice.

5.2 Conclusions

- Adoption of conservation tillage and application of farm yard manure and phosphocompost along with chemical fertilizers improved the soil physical, chemical and biological properties under soybean-cotton rotation in Vertisols.
- The application of phosphocompost and farm yard manure along with chemical fertilizers was found beneficial in increasing content and uptake

of nutrients by soybean and cotton under soybean-cotton rotation in Vertisols. Under conservation tillage.

- Among the organics, phosphocompost, vermicompost, FYM and glyricidia green leaf manuring found to be more efficient in increasing higher soybean seed and seed cotton yield under conservation tillage.
- The conservation tillage and integration of chemical fertilizers with organics like FYM, phosphocompost and glyricidia green leaf manuring were found beneficial for improving soil quality as compared to only chemical fertilizer under soybean-cotton rotation in Vertisols.
- It can thus be concluded that, the adoption of integrated plant nutrient system involving conservation tillage practice with the use of FYM or phosphocompost or glyricidia green leaf manuring are useful for enhancing the soil quality, crop productivity and nutrient uptake under soybean-cotton rotation in Vertisols.

5.3 Implications

Conjunctive use of FYM or phosphocompost or vermicompost or glyricidia green leaf manuring with reduced dose of chemical fertilizers under conservation tillage practices indicates the potential benefit under its long term use for maintaining soil health and soil quality. The results generated in this investigation will be helpful in improving the soybean and cotton productivity and sustaining the soil health under rainfed situation in Vertisols.

Conservation tillage practices increases organic carbon level in soil with increasing carbon sequestration and influencing majority of soil physical, chemical and biological properties.

CHAPTER VI

LITERATURE CITED

- Abdullah, S., Tahsin, S., Adin A. and E. Resat, 2008. Tillage effects on Sunflower (*Helianthus Annuus*, L.) emergence, yield, quality, and fuel consumption in double cropping system. *J. Central European Agriculture*, 9 (4):697-710.
- Abraham T. and R.B.Lal, 2004. Performance of blackgram (*Vigna munga* L.) under integrated nutrient management in a legume based cropping system for the inceptisols of NEPZ. *Indian J.Dryland agric. Res. And Dev.* 19 (1):81-87.
- Abu-Hamdeh N.H. 2004. The effect of tillage treatments on soil water holding capacity and infiltration rate on soil physical properties. *Conserving Soil and Water for Society: Sharing Solutions*. Paper No.669 pp: 1-6.
- Acharya, C L. and P.D. Sharma, 1994. Tillage and mulch effect on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisols in north-west India. *Soil & Tillage Res.* 30:291-302.
- Acharya, C.L., S.K. Bishnoi and H.S. Yaduvanshi, 1988. Effect of long term application of fertilizers and organic and inorganic amendments under continuous cropping on soil physical and chemical properties of Alfisols. *J. Indian Soc.Soil Sci.*, 58(7): 510-510.(509-516)
- Adarsha, T.S., B.C. Patil, M. Vanaja and K. Srinivas, 2004. Nitrogen and phosphorus management of cotton under different moisture regimes. In *International symposium on "Strategies for sustainable Cotton Production – A global vision"* 23-25, Nov. 2004, UAS, Dharwad : 365-365.
- Aggarwal, R.K., P. Kumar and J.F. Power, 1997. Use of crop residue and manure to conserve water and enhance nutrient availability and pearl millet yield in an arid tropical region. *Soil & Tillage Res.* 41: 43-51.
- Alvarez R, and H. S Steinbach. 2009. A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. *Soil Till Res* 104 : 1–15
- Anderson, J.P.E. 1982. Soil respiration. In A.L. Page, R.H. Miller and D.R. Keeney (ed.) *Methods of soil analysis. Part 2. Chemical and microbiological properties*, Agronomy Monograph No. 9, ASA-SSSA Publisher, Madison, Wisconsin, USA, pp. 831-871.
- Anonymous., 2016. www.cci.co.in.

- Arbad, B. K., S. Ismail and A. S. Dhawan, 2014. Influence of long term use of farmyard manure and inorganic fertilizer on grain yield and nutrient availability in Vertisols under soybean-safflower sequence cropping, *Legume Res.*, 37 (6) : 600-606.
- Arbad, B.K., and S. Ismail, 2011. Effect of integrated nutrient management on soybean (*Glycine max*) -safflower (*Carthamus tinctorius*) cropping system. *Indian J. Agron.* 56 (4):340-345.
- Awasya, H.L., P.L. Johnson, S.K. Sarawgi, H.C. Nanda and A. Kulkarni, 2006. Integrated nutrient management in upland cotton (*Gossypium hirsutum* L.) under Vertisols of Chhattisgarh. *J. Agril. Issues* 11(2): 67-70.
- Aykas, E and I. Onal, 2004. Effect of different tillage techniques on cotton yield and quality. *Asian J. Plant Sci.* 3: 403-405.
- Babhulkar, P.S., R.M. Wandile, W.P. Badole and S.S. Balpande, 2000. Residual effect of long term application of FYM and fertilizers on soil properties (Vertisols) and yield of soybean. *J. Indian Soc. Soil Sci.*, 48(1): 89-92.
- Badanur, V. P., 1990. Residual effect of nutrient management on crop yield, important properties of a Vertisol. *J. Indian Society of Soil Science*, 38 : 429-429.
- Badanur, V.P., C.M. Poleshi and B.K. Naik, 1990. Effect of organic matter on crop yield and physical and chemical properties of Vertisol. *J. Indian Soc. Soil Sci.* 38: 426-429.
- Bagal, V.T., A.J. Madane*, R.A. Gaikwad, R.R. Sisale, P.U. Lawate, V. Akhilesh and J.K. Singh 2018. Response of Cotton to Different Tillage Depth and Irrigation Levels in Southern Gujarat, India, *Int. J. Current Microbiol. App. Sci* (2018) 7(2): 602-609.
- Bahadur, L., D.D. Tiwari, J. Mishra and B.R. Gupta, 2012. Effect of integrated nutrient management on yield, microbial population and changes in soil properties under rice-wheat cropping system in sodic soil. *J. Indian soc. Sci.*, 60(3):326-329.
- Bairathi, R.C., M.M. Gupta and S.P. Seth, 1974. Effect of different legume crop residues on soil properties, yield and nutrient uptake by succeeding wheat crop. *Journal of Indian Soc. Soil sci.* 22(4): 304-307.
- Bajpai, R. K, Chitale, S., Upadhyay, S.K. and Urkurkar, J.S. 2006. Long-term studies on soil physico-chemical properties and productivity of rice-wheat system as influenced by integrated nutrient management in Inceptisol of Chhattisgarh. *J. Indian Soc. Soil Sci.* 54(1): 24-29.
- Balwindar Kumar ; R. K. Gupta and A. L. Bhandari, 2008. Soil fertility changes after long-term application of organic manures and crop residues under rice-wheat system. *J. Indian Soc. Soil Sci.* 56(1): 80-85.

- Bandopadhyay, k.k. and Ghosh,P.K. 2004 Integrated nutrient management practices in soybean (*Glycine max*) and sorghum (*Sorghum bicolor*) in sole and intercropping systems in a Vertisol. *Indian J. Agricultural Sciences* 74(2):55-63
- Bandopadhyay, k.k., Ghosh,P.K., Choudhary, R. 2003 Integrated nutrient management practices in soybean (*Glycine max*) and sorghum (*Sorghum bicolor*) in sole and intercropping systems in a Vertisol. *Indian J. of Agricultural Sciences* 75(3):65-69
- Bandyopadhyay, P.K., Subita Saha, P.K. Mani and B. Mandal, 2010. Effect of organic inputs on aggregate associated organic carbon concentration under long term rice-wheat cropping system. *Geoderma*, 154: 379-386.
- Bangar, A.R., A.N. Deshpande, B. D. Tambol and K. D. Kale, 2003. Effects of kharif legumes on yield of rabi sorghum and their economics under sequence cropping in dryland vertisols. *J. Maharashtra agric. Univ.* 28 (2): 119-122.
- Basak, B. B.,D. R. Biswas and R. K.Rattan, 2012.Comparative effectiveness of value-added manures on crop productivity, soil mineral nitrogen and soil carbon pools under maize-wheat cropping system in an Inceptisol. *J. Indian Soc. Soil Sci.* 60(4): 288-298.
- Basavanneppa, M.A. and D.P. Biradar, 2002. Effect of integrated nutrient management practices on the production of cotton-maize-bengalgram sequence under irrigated ecosystem in Tungabhadra project area. *J. Cotton Res. Dev.* 16(2) : 125-129.
- Basumatary, A. and Talukdar, M.C. 1998. Long term effect of integrated nutrient supply on fractions of N and K in an Inceptisols of Assam. *J. Ind. Soc. Soil Sci.*, 46 (3): 451-453.
- Bauer, A. and A.L.. Black, 1981. Soil carbon, nitrogen, and bulk density comparison in two crop land tillage system after 25 years in virgin grassland. *Soil Sci. Soc. of Am.* J.45:1160-1170.
- Behera U.K., A.R. Sharma and H.N. Pandey, 2007. Sustaining productivity of wheat - soybean cropping system through integrated nutrient management practices on the vertisol of India. *Plant Soil* 297:185-199.
- Belekar, D.C. 1995. Long term effect of fertilizers and manures on physical properties of black soil under sorghum-wheat cropping system M.sc. Thesis Dr. PDKV, Akola
- Bellakki, M.A. and V.P. Badanur, 1997. Long term effect of integrated nutrient management on properties of Vertisol under dryland agriculture. *J. Indian Soc. Soil Sci.* 45 (3): 438-442.

- Bellakki, M.A. and V.P. Badanur, 2000. Residual effects of crop residues in conjunction with organics, inorganic and cellulolytic organisms on chickpea grown on Vertisol. *J. Indian Soc. Soil Sci.* 48 (2): 393-395.
- Bellakki, M.A., V.P. Badanur and R.A. Setty, 1998. Effect of long term nutrient management on some important properties of Vertisols. *J. Indian Soc. Soil Sci.* 46 (2) 176-180.
- Benbi, D.K., C. R. Biswas, S. S. Bawa and K. Kumar, 1998. Influence of farmyard manure, inorganic fertilizers and weed control practices on some soil physical properties in a long term experiment. *Soil Use Manag.* 14 : 52-54.
- Bhalerao, P.D and G.G. Gaikwad, 2011. Effect of nutrient sources on productivity and sustainability of seed cotton yield under rainfed condition. *PKV Res. J.* 34 (2): 66-70.
- Bhalerao, P.D and G.S. Gaikwad, 2010. Productivity and profitability of Bt cotton (*Gossypium hirsutum*) under various plant geometry and fertilizer levels. *Indian J. Agronomy.* 55 (1): 60-63.
- Bhalerao, P.D., B.R. Patil; R.N. Katkar and P.U. Ghatol. 2007. Effect of integrated nutrient management on seed cotton yield and economics of hybrid cotton. *PKV Res. J.*, 31(2) : 259-262.
- Bhandari, A.L., K.N. Sharma; M.L. Kapur and D.S. Rana. 1989. Supplementation of N through green manuring for maize growing. *J. Indian Soc. Soil Sci.*, 37 : 483-486.
- Bharadwaj, V. and P.K. Omanwar, 1992. Impact of long term fertility treatments on bulk density water contents and microbial population of soil. *J. Indian Soc. Soil Sci.*, 40 : 553-555.
- Bharadwaj, V. and P.K. Omanwar, 1994. Long term effects of continuous rotational cropping and fertilization on crop yields and soil properties II. Effect on EC, pH, organic matter and on available nutrients of soil. *J. Indian Soc. Soil Sci.*, 42:392-397.
- Bharambe, P.R., A.S. Tajuddin, S.R. Oza and D. K. Shelke, 2002. Effect of irrigation and crop residue management on crop and soil productivity under soybean-sorghum cropping system. *J. Indian Soc. Soil Sci.*, 50(3) : 233-236.
- Bharambe, P.R., D.K. Shelke, G.S. Jadhav, V.G. Vaishnava, and S.R. Oza, 2001. Management of salt affected Vertisol with sub-surface drainage and crop residue incorporation under soybean-wheat cropping system. *J. Indian Soc. Soil Sci.* 49 :24-29.
- Bharambe, P.R., M.A. Patil, S.R. Oza and D. K. Shelke, 1999. Effect of crop residue incorporation and irrigation on sunflower yield and soil productivity under sorghum-sunflower cropping system. *J. Indian Soc. Soil Sci.*, 47(1) : 169-171.

- Bhatia, K.S. and K.K. Shukla, 1982. Effect of continuous application of fertilizers and manures on some physical properties of eroded alluvial soils. *J. Indian Soc. Sci.* 30 : 30-36.
- Bhattacharyya P., Nayak A.K., Mohanty S., Tripathi R., Shahid M., Kumar A., Raja R., Panda B.B., Roy K.S., Neogi S., Dash P.K., Shukla A.K., Rao K.S. 2013. Greenhouse gas emission in relation to labile soil C, N pools and functional microbial diversity as influenced by 39 years long-term fertilizer management in tropical rice. *Soil and Tillage Research*, 129: 93–105.
- Bhattacharyya R., S. Kundu, V. Prakash and H. S. Gupta, 2008. Sustainability under combined application of mineral and organic fertilizers in a rainfed soybean-wheat system of the Indian Himalayas. *European J. Agronomy* 28 (1): 3–46.
- *Bhattacharyya, Rajan, V. Prakash, S. Kundu, A.K. Shrivastava and H.S. Gupta, 2004. Effect of long-term manuring on soil organic carbon, bulk density and water retention characteristics under soybean wheat cropping sequence in North-Western Himalayas. *J. Indian Soc. Soil Sci.*, 52(3) : 238-242.
- Bhoite D. S. and V. K. Thombre. 2006 Integrated nutrient management in irrigated cotton. *Internat. J. agric. Sci.* Vol.2 No.2 July 2006 : (419-420)
- Bhriuvanshi, S.R. 1988. Long term effect of high doses of farm yard manure on soil properties and crop yield. *J. Indian Soc. Soil Sci.*, 36: 784-86.
- Black, C. A., D. D. Evans, J. L. White , L. K. Ensinger and F. E. Clark (1965) . *Method of soil analysis part – II* , Amer. Soc . Agron . Inc. No. 9 Madison USA , pp, 770.
- Blaise, D. 2011. Tillage and green manure effects on Bt transgenic cotton (*Gossypium hirsutum* L.) hybrid grown on rainfed Vertisols of central India. *Soil & Tillage Research*, 114: 86-96.
- Blaise, D. and C. D. Ravindran, 2003. Yield of cotton grown on a vertisol over 5 years in a semi-arid region of India. *Soil Till Res* 70:163–173
- Blake, G. R. and K.H. Hartze, 1986. In : *Methods of Soil Analysis, Part I Physical and Mineralogical Methods* by Klute, A. (Eds.), *Agronomy Monograph No. 9* (2nd edition) American Society of Agronomy and Soil Science Society of America, Madison, USA : 363-375.
- Blavins, R. L., W. W. Frye, P. L. Baldwin and S. D. Robertson, 1983. Tillage effects on sediment and soluble nutrient losses from a Maury silt loam soil. *J. Environ. Qual.* 19: 683-686.
- *Bohme, L. and F. Bohme, 2006. Soil microbiological and biochemical properties affected by plant growth and different long term fertilization. *European J. Soil Biology*, 42 : 1-12.

- Borghei, A. M., J., Taghinejad, S., Minaei, M.Karimi, and M. G. Varnamkhasti, 2008. Effect of subsoiling on soil bulk density, penetration resistance cotton yield in Northwest of Iran. *Int. J. Agri. Boi.* 10:120-123
- Bouma, T.J., K.L. Nielsen, D.M. Eissenstat and J.P. Lynch, 1997. Estimating respiration of roots in soil: interaction with soil CO₂, soil temperature and water. *Plant and Soil*, 195 : 221 - 232.
- Brar A. S. and Mandeep Kaur, 2007. Effect of Different Tillage practices on the growth and yield of cotton (*Gossypium hirsutum* L.). *J. cotton Res. Dev.* 21 (2) 212- 213.
- Bremner, J.M. 1965. Inorganic forms of nitrogen. In: Black, C.A. (ed.) *Methods of soil analysis. Part 2* American Society of Agronomy, Madison, pp 1179–1237.
- Casals, P., J. Romanya, J. Cortina, P. Bottner, M.M. Couteause and V.R. Vallejo, 2000. Soil respiration under various moisture condition. *Biogeochemistry*, 48 : 261-281.
- Chafle, B.S. D.K. Barkar., V.R. Vishwakarma, and A.N. Narkhede, 1999. Response of soybean to phosphatic fertilizer in black-cotton soil. *J. Soils and Crops*. 9 (1):127-129.
- *Chakraborty, A., K. Chakraborty, A. Chakraborty and S. Ghosh, 2011. Effect of long term fertilizers and manure application on microbial biomass and microbial activity of a tropical agricultural soil. *Boi fertile Soils*. 29(1) : 81-85.
- Chandra A., SK Guru and TC Thakur. 2017. Impact of different tillage practices on soil biochemical parameters, root and shoot growth and yield attributes of winter wheat. *Journal of Pharmacognosy and Phytochemistry* 2017; 6(5): 1915-1922
- Chandramohan, S. 2002. Studies on organic farming in cotton plus blackgram intercropping. M. Sc. (Agri.) Thesis (unpub.) TNAU, Coimbatore. PP 57-96.
- *Charjan, T.C. and D.T. Gaikwad, 2005. Efficiency of applied nitrogen on varlaxmi hybrid cotton as influenced by different agro- technique. *Indian J. Agron.* 30(3) : 305-309.
- Chaturvedi, S. and A.S. Chandel, 2005. Influence of organic and inorganic fertilization on soil fertility and productivity of soybean (*Glycin max*). *Indian J. of Agronomy*. 50(4) : 311-313.
- Chaturvedi, S., A. S.Chandel, V. C. Dhyani and A. P. Singh, 2010. Productivity, profitability and quality of soybean (*Glycine max*) and residual soil fertility as influenced by integrated nutrient management. *Indian J. of Agron.* 55 (2) : 133-137.

- Chaudhary, H.P. and S.K. Das, 1996. Effect of P, S and Mo application on yield of rainfed blackgram and their residual effect on safflower and soil water conservation in an eroded soil. *J. Indian Soc. Soil Sci.* 44(4) : 741-745.
- Chaudhary, J., U.K. Mabdai, K.L. Sharma, H. Ghosh and Mandal Biswapati, 2005. Assessing soil quality under long term rice based cropping system. *Comm. In Soil Sci. and Pl. Anal.* 36(9/10) : 1141-1161.
- Chaudhary, M.L., J.P.Singh and R.P. Narwal, 1981. Effect of long term application of P, K and FYM on some soil chemical properties. *J. Indian Soc. Soil Sci.* 29(1):81-85.
- Chaudhary, R.L., A.A. Chaudhary, V.S. Khawale, S.N. Khawale, S.N. Potkile and S.R. More, 2008. Nutrient management studies in chickpea (*Cicer arietinum*). *J. Soils and Crops*, 18(1) : 174-177.
- Chesnin, L. and C. H. Yien, 1950. Turbidimetric determination of available sulphur. *Soil Sci. Soc. Am. Proc.* 15 : 149-151.
- Chitale, S. R., R. K. Bajapai, S. K. Upadhyay and B. S. Joshi, 2003. Influence of cereal-legume, legume-cereal and cereal-cereal sequence on productivity, economics and soil fertility status. *Madras Agric. J.* 90: 733-735.
- Chittapur, B.M. 2004. Cotton based cropping systems for sustained productivity. In: International symposium on “ Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 45-55.
- Choudhary VK (2014). Tillage and Mulch Effects on Productivity and Water Use of Pea and Soil Carbon Stocks. *Archives of Agronomy and Soil Science*, Vol. 61, No. 7, 1013–1027.
- Choulwar SB, Maruthi Sankar GR, Pendke MS, Bhuibhar BW, Mishra PK, Ravindra Chary G and Ch. Srinivasa Rao (2015) “Effect of Tillage and Nutrient Management on Productivity, Soil Fertility and Profitability of Cotton+Soybean Rotated With Soybean+Pigeonpea Intercropping System Under Semi Arid Vertisols in India” *Indian J. Soil Conservation*, Vol. 43, No. 1, pp 79-91.
- Dahatonde, B. N., P.T. Kharkar and N.A. Chaube, 2004. Stability and economics of need based legume incorporated crop sequence under Vidarbha condition. *PKV. Res. J.* 28 (1): 26-29.
- Dalal, R. C. 1989. Long term effects of no tillage crop residue and nitrogen application on properties of a Vertisol. *Soil Sci. Soc. American J.* 53: 1511-1515.

- Dam, R.F. B.B. Mehdiya, M.S.E. Burgessb, C.A. Madramootooa, G.R. Mehuysa,b, I.R. Calluma, 2005. Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. *Soil & Tillage Research* 84 : 41–53
- Dangarwala, R.T., 2001. Need for sustaining balanced supply of micronutrients in soil rather than their correction. *J. Indian Soc. Soil sci.*, 49(4):647-652.
- Deshmukh, P. W., P. N. Bhoyar, P. N. Magare and S. M. Shendurse, 2010. Productivity and Economics of soybean-chickpea crop sequence under crop residue management PKV Res. J. 34(1): 49-52.
- Deshmukh, P. W., S. M. Bhoyar, P. N. Mangare and S. M. Shendurse, 2010. Productivity and economics of soybean-chickpea crop sequence under crop residue management. PKV Res. J. 34(1): 53-56.
- Deshmukh, P.A., A.S. Bonde, D.G. Padekar and S.B. Band, 2007. Long term effect of organics and fertilizers on some physical properties of soil in vertisols under sorghum-wheat sequence. *J. Soil and Crops*. 17(2) : 339-343.
- Dev, C.M. and A.G. Sarawgi, 2004. Balance sheet of nitrogen phosphorus and potassium as influenced by spacing and nutrient management in sunflower. *J. Oilseed Res.* 21(1) : 187- 188.
- Devi, K.N., Tensubam B. Singh, Herojit Singh Athokpam, Naorem Brajendra Singh and Diana Shamurailatpam. 2013. Influence of inorganic, biological and organic manures on nodulation and yield of soybean (*Glycine max* Merrill L.) and soil properties. *Australian J. Crop Science*. AJCS 7(9):1407-1415.
- Devrajan, R. and S. P. Palaniappan, 1995. Effect of zinc and molybdenum on yield and nutrition of soybean. *Madras Agric. J.*, 82(3) : 188-189.
- Dhage, S. J. and K. G. Kachhave, 2008. Effect of dual inoculation of rhizobium and PSB on yield, nutrient content availability of nutrient content and quality of soybean. *An Asian j. of Soil Sci.* 3 (2): 272-276.
- Dhawan A.S., A.S. Karle, M.S. Deshmukh and B.B. Shendge, 2006. Optimization of phosphorus management in soybean safflower cropping sequence through integrated nutrient supply in vertisol. *J. Oilseed Res.* 23(2): 340-341
- Dhillon, G.S., K.L. Chabra and S.S. Punia, 2006. Effect of crop geometry and integrated nutrient management on fibre quality and nutrient uptake by cotton crop. *J. Cotton Res. Dev.* 20(2) : 221-223.
- Dick, W.A. 1983. Organic carbon, nitrogen and phosphorus and pH in soil profiles as affected by tillage intensity. *Soil. Soc. Am. J.* 47: 102-107.

- Dick, W.A., W.M. Edwards, R.C. Stehouwer and D.J. Eckert, 1992. Maize yield and nitrogen uptake after established no tillage field are plowed..Soil and Tillage Research 24:1-10.
- Dikshit, P.R., S.K. Gauttan, O.R. Turker and S.K. Khatik, 1995. Effect of long term fertilizer application under multiple cropping sequence. J. Indian Soc. Soil Sci. 43(4) : 503-506.
- Doran, J.W. and T.B. Parkin, 1994. Defining and assessing soil quality. In J.W. Doran *et al.* (eds) "Defining soil quality for sustainable environment" Soil Sci. Soc. Am. Special Pub. 35, ASA-SSSA, Madison, Wisconsin. 3-21.
- Dwivedi C.P. and A.H. Singh, 1992. Response of soybean to phosphorus application. Indian J. Agronomy. 38 (2): 105-107.
- FAO. 1979. Yield and crop growth response, FAO Soil and Tillage Paper 32, FAO, Rome: 142.
- Fritsch, F.B., Roberts, B.A. Rains, D.W., Travis, R.L. and Hutmacher, R.B. 2004. Fate of Nitrogen-15 Applied to Irrigated Acala and Pima Cotton. American Society of Agronomy, 96 (3) 646-655.
- Gabhane V.V, B.A. Sonune and R.N. Katkar. 2014. Long Term Effect of Tillage and Integrated Nutrient Management on Soil Quality and Productivity of Rainfed Cotton in Vertisols under Semi-Arid Conditions of Maharashtra. Indian J. Dryland Agric. Res. & Dev. 2014 29(2): 71-77.
- Gaikwad, C.B. and V.S. Khuspe, 1976. Long term effect of tillage and manuring on some physical and chemical properties in black soil under rainfed cropping. J. Maharashtra Agric. Univ. 1 (2-6): 145-147.
- Gajbhiye, H. M., 2003. Effect of INM on soil fertility, yield and quality of soybean. (unpub.) M. Sc. Thesis submitted to Dr. PDKV., Akola: 30-33.
- Gandura OA, Gamal Eld-Deen Mohamed, Nouri Mosa Moumen (2017) Influence of Tillage Practices on Soil Physical Properties and Growth and Yield of Maize in Jabal al Akhdar, Libya. Open J. Soil Science, 7,118-132.
- Garcia, S., J.R., F.M. Hones and J.E. Matocha, 1997. Long term effect of tillage and fertilization on soil organic matter dynamics. Soil. Sci. Soc. Am. J. 61: 152-159.
- Gattani, P.D., S.V. Jain and S.P. Seth, 1976. Effect of continuous use of chemical fertilizer and manures on soil physical and chemical properties. J. Indian Soc. Soil Sci., 24(3):284-289.
- Gaur M. and V. Singh, 2010. Effect of phosphorus and boron on yield and uptake of nutrients by wheat. Ann. Agric. Res. 31 (3 & 4): 119-122.

- Ghatage, H.L., A.S. Mokate and P.H. Deshmukh, 2003. Fertilizer economy through phospho-compost for sequence cropping. *Madras Agric. J.* 90(1-9) : 523-524.
- Ghosh, B. N., V. Prakash and R. D. Singh, 2001. Micronutrient status in soybean-wheat cropping system in Kumaon region of Uttaranchal. *Indian J. Agric. Sci.* 71(3): 149-152.
- Ghosh, P.K., K.K.K. Bandopadhyay and A.B. Singh, 2005. Effect of integrated nutrient management in dryf matter production, water use efficiency and productivity of soybean (*Glycine max. L. Merrill*) in Vertisols of Central India. *J. Oilseed Res.* 22(2) : 289-292.
- Ghosh, P.K., P. Ramesh, K.K. Bandopadhyay, A.K. Tripathi, K.M. Mishra and C.L. Acharya, 2004. Comparative effectiveness of cattle manure, poultry manure, phospho compost and fertilizer – NPK on three cropping systems in Vertisols of semi-arid tropics. I crop yield and system performance. *Bioresource Technology.* 95 : 77-83.
- Ghuman, B.S., N.S. Suri and Kulwantlal, 1997. Effect of green manuring on soil properties and yield of wheat under dryland conditions. *J. Indian Soc. Soil Sci.*, 45(1):99-103.
- Giri, M. D, Nagdeve M D, Ganvir M M and Konde N M. 2006. Response of cotton to potassium in cotton based intercropping system. Abstract: Livelihood security through rainwater management (LSRM-2008). Organized by PDKV, Akola during 22–23 January 2008 at College of Agriculture, Nagpur.
- Gita kumari, B. Mishra, R. Kumar, B.K. Agrawal and B.P. Singh, 2011. Long term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an alfisol. *J. Indian Soc. Soil sci.* 59 (3):245-250.
- Gite. P.A., S. D .Jadhao, and D. V. Mali 2014 effect of long term manuring and fertilization to sorghum-wheat sequence on physical properties of soil. *PKV Res J.* Vol.38 (2), July 2014:75-80.
- *Gomez, K. A. and A. A. Gomez, 1984. *Statistical Procedures for Agricultural Research*, John Wiley & Sons, New York. pp 241-266.
- Goyal, S., Dalel Singh, Sunita Suneja and K. K. Kapoor, 2009. Effect of rice straw compost on soil microbiological properties and yield of rice. *Ind. J. Agric. Res.* 43 (40) : 263-269.
- Gudadhe, N.N., M.B. Dhonde, B.M. Lambade and N.M. Thete, 2011. Production potential of chickpea as influenced by residual effect of INMS in summer hybrid cotton-chickpea cropping sequence. *J. Agric. Res. Technol.*, 36 (3): 364-369.
- Guldekar, V.D., N.D. Kale, V.O. Jadhao and S.D. Jadhao, 2005. Effect of long term integrated nutrient management on yield of soybean and N fraction in vertisols. *PKV Res. J.* 29(2): 205-207.

- Guled, M. B., S. S. Gundlur, K. A. Hiremath, V. S. Surkad and Balanayounder. 2002. Influence of different *in situ* moisture conservation practices on soil properties and yield of sorghum-sunflower cropping system. Karnataka J. Agric. Sci., 15(3) : 514-517.
- Gulser, C., Candemir, Z. 2008. Prediction of Saturated Hydraulic Conductivity Using Some Moisture Constants and Soil Physical Properties. 5-7 Eylul, ODTU Ankara, p. 563-569.
- Gupta, A.P., R.S. Antil and R.P. Narwal. 1998. Effect of FYM on organic carbon, available N and P content of soil during different periods of wheat growth. J. Indian Soc. Soil Sci., 36: 269-273.
- Gupta, A.P., R.S. Antil and R.P. Narwal, 2000. Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India. Agriculture Ecosystems and Environment, 119 (2) : 127-134
- Gupta, R.D. and K.K.R. Bhardwaj, 1990. Phosphorus and urease enzymatic activities in some soil profiles of North West Himalayas, J. Indian Soc. Sci., 38 : 756-759.
- Gurav Bhavita, R. M. Deshpande and Sarika V. Sune, 2006. Nutrient management studies in Deshi Cotton (*Gossypium arborium* CV. AKA-7). J. Soil and Crops. 16 (1) : 222-226.
- Halemani, H.L., S.S. Hallikeri, S.S. Nooli, R.A. Nandagavi, and H.S. Kumar, 2004. Effect of organics on cotton productivity and physico-chemical properties of soil. In: International symposium on " Strategies for sustainable cotton production – A global vision" 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 123-129.
- Halvankar ,G.B., S.P. Taware and V.M. Raut, 1999. Response of some soybean (*Glycine max* (L.) varieties to different fertility levels. Indian J. Agron. (3): 605-608.
- Hangarge, D. S., R. S. Raut, G. R. Hanwate, G. K. Gaikwad and R. S. Dixit. 2004. Influence of coirpith compost and vermicompost application on the microbial population in Vertisols. J. Soils and Crops. 14(2) : 447-449.
- Hanway, J.J. and H. Heidel, 1952. Soil Analysis Methods, as used in Iowa State. College Soil Testing Laboratory, Iowa, Agriculture. 57 : 1-31.
- Hati, K. M., A. Swarup, A. K. Dwivedi, A. K. Mishra and K. K. Bandyopadhyay, 2007. Changes in soil physical properties and organic carbon status at the topsoil horizon of a Vertisol of central India after 28 years of continuous cropping, fertilization and manuring. Agric. Ecosyst. Environ. 119(2): 127-134.

- He,J., N.J.Kuhn, X.M. Zhang, X.R. Zhang and H.W. Li, 2009. Effect of 10 years of conservation tillage on soil properties and productivity in the farming-pastoral ectone of inner Mongolia, china. *Soil use and management* 25: 201-209.
- Hegde, D. M., 1996. Long term sustainability of productivity in an irrigated sorghum-wheat system through integrated nutrient supply. *Field Crop Res.*, 48(2&3):167-175.
- Hemlatha M., V. Thirumurugan and R. Balasubramanian, 2000. Effect of organic sources of nitrogen on productivity, quality of rice and soil fertility in single crop wetlands. *Indian J. Agronomy* 45 (3): 564-567.
- Hirekurbar, B. M., V. S. Doddamani and T. Satyanarayana, 1991. Effect of soil compaction on soil physical properties and crop growth. *J. Indian Soc. Soil Sci.* 39 (2): 348-350.
- Hongal, M.M., B.M. Chittapur and S.S. Nooli. 2004. Effect of green manures and nitrogen levels on the performance of cotton in chilli + cotton intercropping system. In : International symposium on "Strategies for sustainable cotton production – A global vision" 2. Crop Production. 23-25, Nov. 2004, UAS, Dharwad : 181-184.
- Hulihalli, U.K. and V.C. Patil, 2006^b.Effect of integrated nutrient management practices on yield and nutrient uptake by cotton. *PKV Res. J.*, 30(2):146-150.
- Indulkar, B.S. and G.U. Malewar, 1994. Response of sorghum to different Zinc sources and their residual effect on succeeding wheat. *Indian J. Agron.* 39 (3):368-372.
- Ismail, S., G.U.Malewar, V.S.Rege and N.V.Yelvikar, 1998. Influence of FYM and gypsum on soil properties and yield of groundnut grown in Vertisols. *Agropedology*. 8:73-75.
- Ismail, S., G.U. Malewar, M.N. Lomte, S. Javed Jani and A.S. Deshmukh, 2002. Impact of management practices and sorghum based cropping systems on micronutrient dynamics in Vertisols. Abstr. State level seminar on "Land Resource Management for Food Security and Permanency", Jan. 5-6, Dr.BSKKV, Dapoli (M.S.) : 103.
- Jacinthe P. and R. Lal, 2009. Tillage effects on carbon sequestration and microbial biomass in reclaimed farmland soils of southwestern Indiana. *Soil Science Society of America J.* 73(2):605-613.
- Jackson, M. L., 1973. Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi.
- Jadhao, V.O. and P.R. Bharambe, 2007. Effect of crop residue management on physical properties of soil under soybean-chickpea cropping sequence. *PKV Res. J.* 31(1) : 81-87.

- Jadhao, V.O. and P.R. Bharambe, 2007. Effect of crop residue management on physical properties of soil under soybean-chickpea cropping sequence. PKV Res. J., 31(1) : 81-87.
- Jain, V. V. Jain, S.K. Vishwakarma and R.S. Sharma, 2005. Maximization of productivity for soybean (*Glycine max*) wheat (*Triticum aestivum*) system in Kymore plateau and zone Satpura Hill of Madhya Pradesh. Indian J. of Agronomy. 50(1) : 19-21.
- Jenkinson, D.S. and D.S. Powlson, 1976. The effect of biological treatments on metabolism in soil. V. A. method for measuring soil biomass. Soil Biol. Biochem, 8 : 209-213.
- Kadu, P.R., P.H. Vaidya, S.S. Balpande, P.L. Satyavathi and D.K. Pal, 2003. Use of hydraulic conductivity to evaluate the suitability of Vertisols for deep rooted crops in semi-arid parts of central India. Soil Use & Management, 19(3) : 208-216.
- Kalaichelvi, K. C. Chinnusamyl and A. A. Swaminathan, 2006. Role of major nutrients in cotton - a critical review. Agric. Rev., 27 (4) : 308 – 312.
- Kalra, Y.P. 1998. Handbook of Reference Methods for Plant Analysis. Taylor and Francis Group, LLC, New York. PP. 1-24.
- Kanchikerimath, M. and D. Singh, 2001. Soil organic matter and biological properties after 26 years of maize-wheat-cowpea cropping as affected by manure and fertilization in a Cambisol in semiarid region of India. Agric. Ecosyst. Environ. 86 : 155-162.
- Kandeler, E., M. Stemmer and E.M. Klimanek, 1999. Response of soil microbial biomass, urease and xylanase within particle size fraction to long-term soil management. Soil Biol. Biochem, 31 : 261-273.
- Kanwar, J.S. 1997. Soil and water management: The base of the food security and sustainability. J. Indian Soc. Soil Sci., 45(3) : 417-428.
- Kanwar, K and S.S. Paliyal, 2002. Influence of phosphorus management and organic manuring on uptake and yield of chickpea (*Cicer arietinum*). Annals of Agricultural Research, 23: 642-645.
- Katkar, R. N., A. B. Turkhede, V. M. Solanke, S. T. Wankhade and M. R. Patil. 2002. Effect of integrated management of organic manures and fertilizers on soil properties and yield of cotton. J. Cotton Res. Dev. 16(1): 89-92.
- Katkar, R. N., S. D. Jadhav, V. K. Kharche, A. B. Nimkarde, D. V. Mali, A. B. Aage and S. R. Lakhe, 2014. Effect of long term manuring and fertilization on soil chemical properties and yield of sorghum in Vertisol under sorghum - wheat sequence. Agropedology, 38(2): 15-18.
- Katkar, R. N., S. T. Wankhade, A. B. Turkhede and S.P. Lambe, 2005. Effect of integrated nutrient management in cotton grown on shallow soil on growth, seed cotton yield and physico-chemical properties. PKV Res. J. 29 (2) : 210-211.

- Katkar, R.N. 2008. Effect of crop residue management and moisture regimes on soil properties, plant growth, seed cotton yield, water use efficiency and fibre quality (Ph.D thesis unpublished) Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola.
- Katkar, R.N., A., B. Turkhede, V.M. Solanke and S.T. Wankhade, 2002. Response of cotton to integrated management of various types of organic manures and fertilizers. *Crop Res.J.* 23: 194-197.
- Katkar, R.N., A.B.Turkhede and S.T. Wankhade. 2006. Residual effect of manures and inorganic fertilizers on soil properties and yield of cotton. *PKV Res. J.* 30(1) : 36-41.
- Katkar, R.N., B.A. Sonune, S.S. Rewatkar and V.K. Karche, 2010. Effect of long term nutrient management on sustainability crop productivity and soil quality under sorghum-wheat crop sequence on Vertisol. *Proceeding of national seminar on soil security for sustainable agriculture.* 28-29 February, 2010, College of Agriculture, Nagpur.
- Katkar, R.N., P.D. Bhalerao, P.U. Ghatol and B.R. Patil, 2007. Influence of organics and inorganics on soil fertility, seed cotton yield and fibre quality in Vertisol. *PKV Res. J.* 31(2): 216-222.
- Kaur K., K.K. Kapoor and A. P. Gupta, 2005. Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. *J. Plant Nutr. Soil Sci.* 168: 117-122.
- Kaur, M.,M. Kaur and A.S. Brar, 2008. Effect of NPK with and without farm yard manure on the growth and yield of hirsutum cotton (*Gossypium hirsutum* L). *J. Cotton Res. Dev.* 22(1):34-37.
- Kaur, T. and B. S. Brar, 2008.Organic matter, microbial biomass and enzyme activity of soil under maize-wheat cropping system. *J. Soil and Crops.* 18 : 24-30.
- Kausal, R., A. R. Bhandari, D. Tripathi and J. C. Sharma.1996. Soil Water retention characteristics of some soils under forests in temperate zone of the Himalayas. *J. Indian Soc. Soil Sci.*, 44(1) : 9-12.
- Kemper, W.D. and R.C. Rosenau, 1986. Aggregate stability and size distribution. In A. Klute (Ed.) *Methods of Soil Analysis Part-I.* 2nd ed. ASA and SSA, Madison, Wisconsin. Khanvilkar, S. A. and N. P. Singh.1987. Response of summer sunflower to irrigation. *J. Maharashtra Agric. Univ.*12 : 323-323.
- Khader S.E.S.A. and A. H. Prakash, 2007. Nutritional and physiological disorders of cotton. Model training course on “cultivation of long staple cotton (ELS) Dec. 15-22, 2007.
- Khambalkar Megha S., V.V. Gabhane and Shilpa V. Khambalkar. 2017. Studies on Effect of Integrated Nutrient Management on Productivity of Cotton in Rainfed Condition *Int. J.Curr. Microbiol. App. Sci* (2017) 6(8): 3639-3641.

- Khan N, Usmanb K, Yazdanc F, Dinc SU, Gull S and Khan S (2015) Impact of tillage and intra-row spacing on cotton yield and quality in wheat–cotton system. Archives of Agron and Soil Sci, 61:5, 581-597.
- Khan, N. I, A. U. Malik, F. Umer and M. Irfan Bodla. 2010. Effect of tillage and farm yard manure on physical properties of soil, International Research Journal of Plant Science (ISSN: 2141-5447) Vol. 1(4) pp. 075-82.
- Kharche, V.K., A.A. Kulkarni, S.R. Patil and R.N. Katkar, 2010. In proceeding of Vasantrao Naik agriculture seminar on soil security for sustainable agriculture, 28-29 February, 2010, College of Agriculture, Nagpur..
- *Kharche, V.K., A.A. Kulkarni, S.R. Patil and R.N. Katkar.2011. Long term integrated nutrient management for securing soil quality under intensive cropping system on vertisols of Maharashtra. Proceedings of national seminar on soil security for sustainable agriculture held at collage of agriculture, Nagpur, Dr.PDKV., Akola (M.S.) on Feb 27- 28, 2010. pp.127- 148.
- Khare, A.K., C. Singh and B.R. Ratnaparkhe. 1970. Uptake of nitrogen, its relation to yield of rainfed cotton in black cotton soils. J. Indian Soc. Soil Sci. 18:685-88.
- Khiani, K.N and D.A.More, 1984. Long term effect of tillage operation and farm yard manure application on soil properties and crop yield in Vertisol.J. Indian Soc. Soil Sci., 32: 392-393.
- Kitson, R.E. and M.G. Mellon, 1966. Colorimetric determination of phosphorus as molybdovanadate phosphoric acid. Ind. Eng. Chem. Anal. Ed. 16:379-383.
- *Klein D.A, T.C. Loh and R.L.Goulding, 1971. A rapid procedure to evaluate dehydrogenase activity of soil low in organic matter. Soil Biol. Biochem. 3: 385-387
- Klute, A. and C. Dirksen, 1986. In : Methods of Soil Analysis, Part I, Physical and Mineralogical Methods by Klute, A. (ed.), Agronomy Monograph No. 9 (2nd edition) American Society of Agronomy and Soil Science Society of America, Madison, USA : 687-732.
- Kote G.M., A.N.Giri and S.P.Kausale. 2005. Nutrient concentration and uptake of different cotton (*Gossypium hirsutum* L.) genotypes as influenced by intercrops and fertilizer level under rainfed conditions. J. Cotton Res. Dev. 19(2) : 188-190.
- Kubde, K.J. and B.A. Lakhadive, 1993.Effect of nitrogen phosphorus and spacing on yield, quality and nutrient uptake of *hirsutum* cotton.PKV. Res. J. 17(2) : 231-232.
- Kukreja N., M.M. Mishra, S.S. Dhankar, K.K. Kapoor and A.P. Gupta, 1991. Effect of long term manorial application on microbial biomass. J. Indian Soc. Soil Sci. 39 : 685-688.

- Kumar S, Jain M, Rani V, Kumar A, Kumar V and Naresh (2018) Effect of Various Tillage Practices on Soil Physical Properties. *Int.J.Curr.Microbiol.App.Sci.* 7(3): 1591-1596.
- Kumar, B., R. K. Gupta and A. L. Bhandari, 2008. Soil fertility changes after long term application of organic manures and crop residues under Rice-wheat system. *J. Indian Soc. Soil Sci.* 56(1) : 80-85.
- Kumar, K. and K.M. Gosh. 2000. Crop residues and management practices: Effects on soil quality, soil nitrogen dynamics, crop yield and nitrogen recovery. *Advances in Agronomy*, 68 : 197-319.
- Kumar, P.S.K. Pandey, B.P. Singh, S.V Singh and D.Kumar, 2007. Effect of nitrogen rate on growth, yield, economic and crop quality of Indian potato processing cultivars *Potato Research* 50:143-155.
- Kumar, R. and D.S. Yadav, 2005. Effect of zero and minimum tillage in conjunction with nitrogen management in wheat (*Triticum aestivum*) and rice (*Oryza sativa*). *Indian Journal of Agronomy*, 50 (1): 54-57.
- Kumar, Y. K. D., M. R. Ananda, H. M. A. Rehaman, A. P. Viswanath and Vitthal Navi, 2006. Nutrient uptake, availability and yield of soybean as influenced by integrated nutrient management. *Environ as ecology*. 24 S (Special 4): 1056-1058.
- Kumari, L, A. K. Veeraiah and S. R. Kumari, 2010, Long term effects of manures and fertilizers on productivity of rainfed cotton and soil fertility in vertisols. *J. Cotton Res. Dev.* 24(2) : 200-204.
- Kundu,S.,R. Bhattacharya, V. Prakash and H. S. Gupta, 2008. Carbon sequestration potential of Inceptisols under long term soybean–wheat rotation in Sub-temperate rainfed agro-ecosystem of North-Waste Himalayas . *J. Indian Soc. Soil Sci.* 56(4): 423-429.
- Kuotsu R. and A.K. Singh. 2016. Effect of integrated nutrient management on growth, yield and quality of soybean and soil fertility. *J.Soils and Crops* 26 (2) 181-1888, Dec.2016
- Laddha, K.C, and K.L. Totawat, 1997. Effect of deep tillage under rainfed agriculture on production of sorghum intercropped with green gram in western India. *Soil & Tillage Res.* 43: 241-25
- Lal R. and P.A Jacinthe, 2009. Tillage effect on carbon sequestration and microbial biomass in reclaimed farm land soils of southwestern Indiana. *Soil. Sci. Soc. Am. J.* 73: 605-613.
- Lal, R., and J. P. Bruce,1999. The potential of world cropland soils to sequester C and mitigate the greenhouse effect. *Environmental Science and Policy* 2, 177–185.

- Lal, R., T. J. Logan and N. R. Fausey, 1989. Long term tillage and wheel track effects on a poorly drained mollic ochraquatt in North West-Ocjto-1. Soil physical properties, root distribution and grain yield of corn and soybeans. *Soil and Tillage Res.* 14: 34-58.
- Lal, S. and B.S. Mathur, 1989. Effect of long term application of manures and fertilizers on the DTPA extractable micronutrients in acid soils. *J. Indian Soc. Soil Sci.*, 37: 588-590.
- Lal, R. 1989. Soil compaction and tillage effects on soil physical properties of a Mallic Ochraqualf in northwest Ohio. *J. Sustainable Agriculture*. 14, 53-65.
- Lindsay, W.L. and W.A. Norvell, 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil sci. Soc. American.* 42(3): 270-283.
- Liu X., J. Liu, B. Xing, S.J. Herbert, K.H. Meng, H. Xiaozeng and X. Zhang 2005. Effect of long term continuous cropping, tillage and fertilization on soil organic carbon and nitrogen of black soils in China. *Comm. Soil Sci plant Anal.* ;36:1229–1239.
- Lohakare V.P., 1980. Effect of long term manuring and fertilizers on micronutrients status of Vertisol. M.Sc. Thesis (Unpub.), Dr. PDKV, Akola (M.S.)
- Magar, S.S., B.P. Patil; R.H. Kadam; B.R. Patil and B.B. Patil, 1983. Use of organic amendments for improvement of infiltration in black soil. *J. Maharashtra Agric. Univ.*, 8(2):172-173.
- Mahajan and Gupta, 2009. Integrated nutrient management (INM) in a sustainable rice-wheat cropping system. Potential of Organic Resources as Plant Nutrients in India <http://link.springer.com/book/10.1007/978-1-4020-9875-8>.
- Mahapatra, S.C. and Nanda, S.S. 2007. Response of various levels of nutrient and spacing in non-Bt. Hybrid cotton (*Gossypium hirsutum*) under rainfed situation. *Res. J. Agric. Sci.* 2(1): 162-163
- Mahavishnan, K. M. Prasad and K. B. Rekha, 2008. Production potential and quality parameters of cotton (*Gossypium hirsutum* L.) as influenced by integrated nutrient management option in cotton - sunflower cropping system. *Indian J. Agric. Res.*, 42 (2) : 147 -149.
- Maheshbabu, H.M., R. Hunje, N. K. Biradar Patil And H. B. Babalad, 2008. Effect of Organic Manures on Plant Growth, Seed Yield and Quality of Soybean. *Karnataka J. Agric. Sci.*, 21(2) : 219-221.
- Maheswarappa, H.P., H.V. Najappa and M.R. Hegde, 1999. Influence of organic manures on yield of arrowroot, soil physico-chemical and biological properties when grown as intercrop in coconut garden. *Annals of Agril. Res.*, 20(3): 318-323.

- Malewar, G.U, and A.R. Hasnabade, 1995. Effect of long term application of fertilizer and organic sources on some properties of Vertisol. J. Maharashtra Agric. Univ. 20(2): 285-286.
- Malewar, G.U. S. Ismail and B.S. Indurkar, 1992. Effect of phosphorus with or without boron on yield and uptake of boron and phosphorus in cotton-groundnut cropping sequence. Ann. Agric. Res. J. 13 (3):269-270.
- Malewar, G.U., A.R. Hasnabade and S. Ismail, 1999. CO₂ evolution and microbial population in soil as influenced by organic and NPK fertilizers under sorghum-wheat system. J. Maharashtra Agric. Univ. 24(2):121-124.
- Malewar, G.U., S. Ismail and G.B. Rudraksha, 1998. Integrated nitrogen management on chilli (*Capsicum annum* L.). Bulletin of Indian Institute of Soil Science, (2), PP 156-163.
- Mali, D. V., V. K. Kharche, S. D. Jadhao, S. M. Jadhao, B. V. Saoji, P. A. Gite, A.B. Age, 2015. Soil biological health under long – term fertilization sorghum – wheat sequence on swell – shrink soil of central Asia. J. Indian Soc. Soil Sci. 63 (4) : 423-428.
- Mali, D. V., V. K. Kharche, and P. A. Gite 2014. Effect of long term fertilization and manuring to sorghum-wheat sequence on micronutrient availability and their uptake pattern in Inceptisols, PKV Res J. Vol.38 (2), July 2014:85-89.
- Mali, D.V., 2012. long-term effect of integrated nutrient management on soil quality and crop productivity under sorghum-wheat cropping sequence. Ph.D. Thesis (Unpub.) Dr. PDKV, Akola.
- Mandal, A., A.K. Patra, D. Singh, A. Swarup and R. E. Masto, 2007. Effect of long term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresour. Technol. 98(18) : 3585-3592.
- Manna, M. C., S. Kundu, M. Singh and P. N. Takkar, 1996. Influence of FYM on dynamics of microbial biomass and its turnover and activity of enzymes under a soybean - wheat system on a Typic Haplustert. J. Indian Soc. Soil Sci. 44(3): 409-412.
- Manna, M.C., A. Swarup, R.H. Wanjari, H.N. Rawankar, B. Mishra, M.N. Saha, Y.V. Singh, D.K. Sahi and P.A. Sarap, 2005. Long term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under subhumid and semi-arid tropical India. Field Crops Res. 93 : 264-280.
- Marathe, R.A. and P.R. Bharambe, 2005. Physical characteristic of Vertisol as influenced by integrated nutrient management by system under sweet orange. PKV Res. J. 29(2) : 179-182.

- Marimuthu S., U. Surendran and P. Subbian, 2014. Productivity, nutrient uptake and post-harvest soil fertility as influenced by cotton-based cropping system with integrated nutrient management practices in semi-arid tropics, *Archives of Agron. and Soil Sci.* 60(1): 87–101.
- Marinari, S., G. Masciandaro, B. Ceccanti and S. Grego, 2000. Influence of organic and mineral fertilizers on soil biological and physical properties. *Bioresour. Technol.* 72 : 9-17.
- Masto, R. E., P., K. Chhonkar, D. Singh and A.K. Patra, 2007. Soil quality response to long-term nutrient crop management on semi-arid Inceptisol. pp130-142.
- Mathan, K.K., F. Honoraj and S.P Ramanathan. 1996. Response of blackgram (*Phaseolus mungo*) to fertilization and *Rhizobium* inoculation. *Indian J. Agron.* 41(1): 71-77.
- Mathew Reji P., Yucheng Feng, Leonard Githinji, Ramble Ankumah and Kipling S. Balkcom., 2012. Impact of No-Tillage and Conventional Tillage Systems on Soil Microbial Communities. *Applied and Environmental Soil Science*
- Mathur G.M. 1997. Effect on long term application of fertilizers and manures on soil properties and yield under cotton-wheat rotation in north-west Rajasthan. *J. Indian Soc. Soil Sci.* 45(2): 288-292.
- Mehdi Abdeshari, Esfahani, Hamid RJ and Rezagolparvar A (2016) "Effect of tillage methods on growth period of spring safflower (*Carthamus tinctorius* L.) grown in Isfahan province of Iran". *Res. on Crops* 17 (3) 493-495
- Mehetre, S.S.; J.G. Thokale, A.S. Patil, R.S. Raut and S.R. Zanare, (2003). Response of cotton varieties to different fertility regimes. *J. Cotton Res. Dev.*, 17(1): 43-41.
- Mehta A.K., S.K. Thakral and H.S. Saharan, 2009. Effect of organic and inorganic sources of nutrition on yield and fiber quality of cotton (*Gossypium hirsutum*). *J. Cotton Res. Dev.* 23(2): 255-257.
- Mehta, A. K.; H. S. Saharan; S. K. Thakral and Jagdish Beniwal, 2009. Performance of Bt cotton hybrids at farmers field in Haryana. *J. Cotton Res. Dev.* 23 (2): 243-246.
- Meena, M. D. and D. R. Biswas, 2014. Changes in biological properties in soil amended with rock phosphate and waste mica enriched compost using biological amendments and chemical fertilizers under wheat-soybean rotation, *J. of Plant Nutri.* 37: 2050–2073.
- *Mikha, M. and W, R. Rice, 2004. tillage and manure effects on soil and aggregate-associated carbon and nitrogen *Soil Sci. Soc. American J.* 68 : 809-816.

- Mishra, B., A. Sharma, N.K. Roy, D.K. Shahi and J.K. Lal, 2001. Nutrient status of phosphocompost and its effect on maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system as source of phosphorus in acid alfisol of Ranchi, Jharkhand. *Indian J. Agric. Sci.* 71(12) : 749-751.
- Mishra, B.A., A. Sharma, S.K. Singh, J. Prasad and B.P. Singh, 2008. Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. *J. Indian Soc. Soil Sci.* 56(1) : 71-75.
- Modhvadia, J.M., R.M. Solanki, J.N. Nariya, K.N. Vadaria and A.D. Rathod, 2012. Effect of different levels of nitrogen, phosphorus and potassium on growth, yield and quality of Bt cotton hybrid under irrigated conditions. *J. Cotton Res. Dev.* 26(1) : 47-51.
- Mohammadi K, Rokhzadi A, Saberali SF, Byzedi M, Tahsin M and Nezhad K (2013) Tillage effects on soil properties and wheat cultivars traits, *Archives Agron and Soil Sci*, 59:12, 1625-1641.
- Mohanty, M. and D. K. Painuly, 2003. Land preparatory tillage effects on soil physical properties and growth and yield of rice in a Vertisol. *J. Indian Soc. Soil Sci.* 51 (3): 217-222.
- Mohanty, S., A.R. Rajan and N.K. Lenka, 2007. Effect of organic manures on micronutrient uptake and residual soil fertility in groundnut-corn cropping sequence. *Environment and Ecology*, 25(4) : 1180-1184.
- Mohod, M. B., S. Nemade and P. Ghadage, 2010. Effect of integrated nutrient management on growth and yield parameters of soybean. *Green Farming*, 1(3): 270-271.
- Molina Lucila González, Esaú del C. Moreno Pérez, Aurelio Baéz Pérez. 2017. Simulation of soil organic carbon changes in Vertisols under conservation tillage. *Sci. Agric.* v.74, n.3, p.235-241, May/June 2017.
- Moraes MT, Debiasi H, Carlesso R, Franchini JC, Silva YR da and Luz FB da (2016) Soil physical quality on tillage and cropping systems after two decades in the subtropical region of Brazil. *Soil and Tillage Res.* Vol. 155: 351–362.
- More, S.D and D.S. Hangarge, 2003. Effect of integrated nutrient supply on crop productivity and soil characteristics with cotton-sorghum cropping sequence in Vertisol. *J. Maharashtra Agric. Univ.* 28(1): 8-12.
- Mundra, M.C.; B.P. Singh; S.C. Gupta and S.K. Agrawal. 2002. Sustainability of pear millet wheat cropping system with integrated nutrient management. *Extended Summaries*, Vol. 1, Second International Agronomy Congress, New Delhi : 95-97.
- Muthuswamy, P, P.Santhy and , G. Ramanathan, 1990. Long-term use of fertilizers on soil fertility and yield of crops in irrigated Inceptisol. *J. Indian Soc. Soil Sci.* 38 (3): 541-542.

- Muruganandam, S, D. W. Israel, and W.P. Robarge, 2009. Activities of nitrogen-mineralization enzymes associated with soil aggregate size fraction of three tillage system. *Soil. Sci. Soc. Am. J.* 73: 751-759.
- Nagar R. K, V. V. Goud, Rajesh Kumar and Ravindra Kumar. 2016. Physical, chemical and biological properties of soil under pigeonpea based intercropping system. *International journal of farm sciences* 6(1): 101-113, 2016.
- Naidu, T. C. M. and B. K. Mahalakshmi. 2011. Reddening of Bt cotton under waterlogged conditions. *J. Cotton Res. Dev.* 25(1) : 71-73.
- Nalage, D.N., A. A. Deogikar, N.M. Konde and P.R. Damre, 2007. Performance of cotton under drip irrigation on vertisols. *J. Soil and Crops* 17 (2):299-303.
- Nambiar, K.K.M., Soni, P.N., Vats, M.R., Sehgal, K. and Mehta D.K.(1992)Annual Report 1987-88 / 1988-89. All India Co-ordinated Research Project on Long-term Fertilizer Experiments, ICAR, New Delhi.
- Namdeo, S. L., B. B. Parmar and K. S. Bangar, 2003. Preparation of phosphorus enriched compost and its effect on yield and phosphorus uptake by soybean grown in vertisols. *Indian J. agric. Sci.* 73 (9): 490-493.
- Naphade, K.T., V.N. Deshmukh, S.S. Rewatkar and B.U. Solanke, 1993. Grain yield and nutrient uptake by irrigated wheat grown on Vertisol under various nutrient levels. *J. Indian Soc. Soil Sci.* 41: 370-371
- Narayana, E., K. Hema, K. Srinivasulu, N.V.V.S.D. Prasad and N.H.P. Rao. 2011. Agronomic evaluation of *Gossypium hirsutum* hybrids for varied spacings and nitrogen levels in vertisols under rainfed conditions. *J. Cotton Res. Dev.*, 21, 197-200
- Narkhede, P. L. and R. V. Ghugare.1987. Organic recycling in drylands - II : Effect of organic recycling of subabul on yield, nutrient uptake and moisture utilization by winter sorghum. *J. Indian Soc. Soil Sci.*, 35 : 417-420.
- Navale, K. B., C. B. Gaikwad and B. D. Tamboli, 2000. Effect of integrated nutrient management on yield, nutrient availability and uptake of nutrients by soybean. *J. Mah. Agric. Univ.*, 25 (1): 105 - 107.
- Naveen Kumar B.T and H.B. Babalad, 2017. Effect of Different Conservation Agricultural Practices under Rainfed Situations. *Int.J.Curr.Microbiol.App.Sci* 6(11): 2279-2286.
- Nawlakhe, S.M and D.D. Mankar, 2010. Effect of integrated nutrient management on growth and yield of cotton and greengram under cotton+greengram intercropping. *PKV Res. J.* 34 (2):.198-200.

- Nazmus Salahin, Md. Khairul Alam, Md. Monirul Islam, Laila Naher and Nik M. Majid, 2013. Effects of green manure crops and tillage practice on maize and rice yields and soil properties. *Aus.J.Crop.Sci.*, 7 (12):1901-1911.
- Nehra P.L, 2006. Effect of tillage and residue management practices on growth and yield of cotton wheat cropping system of north western Rajasthan. *J. Cotton Res. Dev.* 20 (1) 71-76.
- Nehra, A.S. and I.S. Hooda, 2002. Influence of integrated use of organic manures and inorganic fertilizers on wheat yield and soil properties. *Res. on Crops*, 3(1) : 11-16.
- Nehra, P.L., K.C. Nehra and P.D. Kumawat, 2004. Impact of nutrient supply on cotton production, fibre quality and soil health. In International symposium on “ Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 31-39.
- Nelson, D. W. and L. E. Sommer, 1982. Total carbon, organic carbon and organic matter. In : *Methods of Soil Analysis Part-II*. Page, A.L. (Ed.). Am. Soc. of Agron. Inc. Soil Sci. Soc. Am. Madison, Wisconsin, USA, pp 539-577.
- Nilam, M. Kanse, 2010. Effect of nutrient management on crop productivity, quality, residual soil fertility and uptake of nutrients under soybean – sunflower cropping system. Ph.D. Thesis (Unpub.) Dr. PDKV, Akola
- Nimje, P.M., and Jagdish Seth, 1988. Effect of phosphorus and farmyard manure on nutrient uptake by soybean, *Indian J. Agron.* 33(2): 139-142.
- Nivelle Elodie, Julien Verzeauxa, Hazzar Habbiba, Yakov Kuzyakovb,c, Guillaume Decocqa, David Rogera, Jérôme Lacoux, Jérôme Duclercqa, Fabien Spichera, Jose-Edmundo Nava-Saucedoa, Manuella Catteroua, Frédéric Dubois, Thierry Tetua. 2016. Functional response of soil microbial communities to tillage, cover crops and nitrogen fertilization. *Applied Soil Ecology* 108 (2016) 147–155.
- Novak, J.M., J.R. Frederick, P.J. Bauer, and D.W. Watts, 2009. Rebuilding organic carbon content in coastal plain soils using conservation tillage systems. *Soil. Sci. Soc. Am. J.* 73: 622-629.
- Ogundare SK, Aduloju MO, Ayodele FG, Olorunfemi SD (2015) Effect of Tillage Methods and Foliar Fertilization (Boost Extra™) on Soil Physical Properties, Weed Dry Matter and Grain Yield of Sorghum in Ejiba, Kogi State, Nigeria. *Natural Science*; 7, 338-345.
- Ogunwole, J.O., S. O. Alabi and I. Onu. 2003. Evaluation of three long staple lines of cotton to levels of fertilizer under moisture stressed and unstressed conditions. *Crop Res.*, 25(1): 50-57

- Ojha Ramesh Babu, Shree Chand Shah, K. R. Pande and D.D. Dhakal.2014. Soil properties and earthworm population dynamics influenced by organic manure in winter and spring seasons at Rampur, Nepal. *Int. J. Appl Sci. Biotechnol*, vol. 2(2): 193-198.
- Ozpinar S and Ozpinar A (2015) Tillage effects on soil properties and maize productivity in western Turkey. *Archives of Agron and Soil Sci* 61:7, 1029-1040.
- Pagaria, T.M., H.N. Ravankar, H.W. Khonde, R.P. Gawande and S. Laharia. 1995. Effect of FYM with and without fertilizers on the yield and chemical composition of cotton under *rainfed* condition. *PKV Res. J.* 19 (1): 87-88.
- Parihar, CM, Jat SL, Yadav MR, Singh AK, Kumar B, Pradhan S, Chakraborty D, Jat ML, Jat RK, Saharavat YS and Yadav OP 2016. Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. *Soil and Tillage Res.* Vol. 161: 116–128.
- Parvin N, Parvage MM and Etana (2014) Effect of mouldboard ploughing and shallow tillage on sub-soil physical properties and crop performance. *Soil Sci and Pl Nutr*, 60:1, 38-44.
- Paslawar, A.N., Gawande., R.P., Shingrup. R.P., Sonali Thakare P. V. and Mali, D.V. 2007. Use of organic, inorganic and bio-fertilizer in pigeonpea + soybean intercropping system and its effect on yield, protein and physico-chemical properties of soil. *J. Annals of Plant Physiology*. 21(1), 96-98.
- Pathak, S.K; S.B. Singh; R.N. Jha and R.P. Sharma, 2005. Effect of nutrient management on nutrient uptake and changes in soil fertility in maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system. *Indian J. Agronomy* 50(4): 269-273.
- Patil, M. A. 1994. Effect of crop residue incorporation and irrigation management under sorghum-sunflower cropping sequence M. Sc. (Agri.) Thesis unpubl. Marathwada Agril. University, Parbhani.
- Patil, M.B., V.C. Patil, and B.S. Hulgur, 1993. Critical period of weed management in different crops. *Pestology* 17, 16–18.
- Patil, N. B., G. L. Ingole, P. D. Raut and S. T. Dangore, 2002. Impact of manuring and fertilization on yield, quality and nutrient uptake of soybean. *Ann. Plant Physiol.* 16(2) : 166-169.
- Patil, R.B. and R.B. Puranik, 2001. Microbial biomass C and N as influenced by cropping systems and nutrient management. *PKV Res. J.* 25(2): 73-77.
- Patil, S. L. and M. N. Sheelavantar, 2000. Effect of cultural practices on soil properties, moisture conservation and grain yield of winter sorghum (*Sorghum bicolor* L. Monech) in semiarid tropics of India. *Agri. Water Management*. 64:49-67.

- Patil, S. L., M. N. Sheelavantar and V. S. Surkod, 2000. Grain yield and economics of rabi sorghum as influenced by in situ moisture conservation practices and integrated nutrient management in semi-arid Vertisols. *Indian J. Dryland Agric. Res and Dev.* 15(2); 98-103
- Patil, K.D., Anita R. Ranjun, Dipti S. Waghare and S.R. Patil, 2008. Effect of conjoint use of manures and fertilizer on yield and quality of soybean grains. *An Asian J. Soil Sci.* 3 (1):4-7
- Patnaik, S., Pandya, D. Kara. S. and R.N. Dash, 1989. Long term fertilizer experiments with wetland rice. *Fertilizer News*, 34 : 47-52.
- Patrick M. Carr, Greta G. Gramig and Mark A. Liebig (2013). Impacts of Organic Zero Tillage Systems on Crops, Weeds and Soil Quality. *Sustainability* 2013, 5, 3172-3201.
- Pattanayak, S. K, K. N. Mishra, M. K. Jena and R. K. Nayak. 2001. Evaluation of green manure crops fertilized with various phosphorus sources and their effect on subsequent rice crop. *J. Indian Soc. Soil Sci.* 49 : 285-291.
- Pawar, K.P. and A.S. Jadhao, 1996. Influence of sorghum based cropping systems on physico-chemical properties of soil. *J. Mah. Agri. Univ.* 21 (1): 30-33.
- *Pettigrew, W.T. 2004. Moisture deficit effects on cotton lint yield, yield components, and boll distribution. *Agronomy J.*, 96(2) : 377-383.
- Pharande, A.L. and K.R. Sonar, 1996. Depthwise distribution of different forms of potassium in important Vertisol soil series of Maharashtra. *J. Pot. Res.* 12 (2) : 127 – 134.
- Pinjari, S.S., Pawar, P.P. and Mhasker, M.V. 2006. Response of irrigated cotton (JLH-168) to different levels and sources of fertilizer. *J. Crop. Prot. Prod.* 2(2): 120-121.
- Piper, C.S. 1966. Soil and plant analysis. Asian Reprint, Hans Publication Bombay, India.
- Poongothai, S. and T. Chideshwari, 2003. Response of black gram to multi micronutrients. *Madras Agric. J.* 90(7-9) : 442-443.
- Powlson, D.S., P.C. Brooks, B.T. Christensen, 1987. Measurement of soil microbial biomass provide an early indication of changes in total soil organic matter due to straw incorporation. *Soil Biol. Biochem.* 19 : 159-164.
- Prabhakaran, N.K. and A. Christopher Lourduraj. 2003. Nutrient management in soybean. *Agric. Rev.* 24 (3):223-228.
- Praharaj, C.S., T.P. Rajendran and K. Sankaranarayanan, 2004. Studies on the incorporation of various organic sources to soil on the performance of hirsutum cotton. In International symposium on “ Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 130-132.

- Prakash Ram, M. Prasad and D. K. Pachauri. 2001. Effect of nitrogen, chlormequate and FYM on growth, yield and quality of cotton. *Annual Res.* 22(1): 107-110.
- Prakash, Y.S., P.B.S. Bhadoria and A. Rakshit, 2002. Comparative efficacy of organic manures on the changes in soil properties and nutrient availability in an Alfisol. *J.Indian Soc.Soil.Sci.* 50(2):219-221.
- Prasad, A., N.G. Totey, P.M. Khatri, and A.K. Bhowmik, 1991. Effect of added tree leaves on the composition of humus and availability of nutrient in soil. *J. Indian Soc. Soil Sci.* 39: 429-434.
- Prasad, B and A.P.Singh. 1980. Changes in soil properties with long term use of fertilizers, lime and farm yard manure. *J. Indian Soc. Soil Sci.*, 28(4):465-68.
- Prasad, B and S.K. Sinha, 2000. Long-term effects of fertilizers and organic manures on crop yields, nutrient balance and soil properties in rice – wheat cropping system in Bihar. Rice -Wheat Consortium Paper Series 6. New Delhi, India: Rice – Wheat Consortium for the Indo-Gangetic Plains. : 105-119.
- Prasad, R. and J.F. Power, 1991. Crop residues management. *Advances in Soil Science*, Springer - Verlag, New York., 15 : 205-251.
- Puli, M. R., R.N. Katkar, Jayalakshmi, M., and Burla S. R. 2013\ Influence of long term fertilization on labile carbon and N-mineralization of soil in sorghum-wheat cropping system. *International J. Applied Biology and Pharmaceutical Technl.*, 4 (4): 420-423.
- Puranik, R. B., D. K. Ballal and N. K. Barde, 1978. Studies on nitrogen forms as affected by long term manuring and fertilization in Vertisols. *J. Indian Soc. Soil Sci.* 26:169.
- Puri, G and S.A. Jaipurkar, 2000. Nutrient requirement utilization and economic phosphorus (P) requirement for *G. hirsutum* cotton in Vertisols. *J. Indian Soc. Cotton Improve.* 153-160.
- Qamar R, Ehsanullah, Saqib M, Javeed HMR, Rehman A, Rehman A and Ali A (2015) Influence of tillage and mulch on soil physical properties and wheat yield in rice-wheat system. *West African J Applied Ecology*, vol. 23(1), 21–38.
- Rajarajan, P. K. Janaki, K. Appavu and A. Vadivel. 2005. Effect of Fertilizer NPK and FYM on Yield, uptake of Cotton and Nutrient Status in Black Soil. *Madras Agric. J.* 92(4-6) : 266-270
- Rajendran A.L. M.V.Venugopalan, C.S.Paharaj (2005) Cotton research towards sufficiency to Indian industry. *Indian Journal of Agricultural Sciences* 75(11):699-708.
- Rajkanan, B., C.S. Balasundaram, A. Basker and D. Selvi, 2001. Impact of tillage and organics on soil physical properties at different depths and growth stages of sorghum in a TypicHaplustalf with sub soil hardpan. *J. Indian Soc. Soil .Sci.*, 49(4): 740-743.

- Ramasamy, M., K. Shrinivasan and N. Sankaran, 2000. Effect of 'P' mobilizers and different levels of phosphorus on growth and yield of soybean. *Madras Agric. J.* 87 (10/12): 674-675.
- Ramesh, K Sathiya, P K Padmanaban and G J Martin.2009. Optimization of nitrogen and suitable weed management practice for aerobic rice. *Madras Agric J* 96: 344-348 (2009).
- Rao S and A.D. Janwade, 2009. Influence of integrated nutrient management practices on physico-chemical properties of cotton growing soils. *J. Cotton Res. Dev.* 23(1): 60-63.
- Rao S and R.A. Setty, 2007. Integrated nutrient management practices in cotton based cropping systems in Tungabhadra project area of Karnataka. *J. Cotton Res. Dev.* 21(2): 174-177.
- Rao, A. V. and Richa Tak. 2001. Influence of organic amendments on the growth of different trees and nutrient uptake in gypsum minespoils. *J. Indian Soc. Soil Sci.*, 49(2) : 386-390.
- Rao, S. 2007. Microbial biomass and activity in salt affected soils under arid conditions. *Applied soil Ecology* 35 (2): 319-328.
- Rao, S. and A. D. Janawade, 2009. Nutrient uptake and fibre quality parameters as influenced by integrated nutrient management practices in irrigated hybrid cotton. *J. Cotton Res. Dev.* 23(2) : 237-239
- Rashidi, M. and F, Keshavarzpour, 2007. Effect of different tillage methods on soil physical properties and crop yield of watermelon (*Citrullus Vulgaris*) *ARPN J. Agric. and Biological Science.* 2 (6): 2007.
- Raskar, B.S. 2006. Effect of irrigation methods, fertilizer levels and green manuring on yield and nutrient balance in summer cotton. *J. Cotton Res. Dev.* 18(2) :180-183.
- Raskar, B.S., 2004.Effect of irrigation method, fertilizer levels and green manuring on yield and nutrient balance in summer cotton. *J.Cotton Res. Dev.*18 (2):180-183
- Rasool, R., S. S. Kukal and G. S. Hira, 2008. Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize–wheat system. *Soil Till. Res.* 101(1-2): 31-36.
- Rathod, K. S., R. K. Pannu and S. S. Dahiya, 2012. Effect of nitrogen management on soil fertility and NPK uptake in soybean. *J. Food Legumes*, 25(2): 237-239.
- *Rattan, R.K., S. Neelan and S.P. Datta, 1999. Micronutrient depletion in Indian soils: extent, causes and remedies. *Fertl. News.* 44(2):35-50.
- Ravankar, H.N. and V.A. Deshmukh, 1994. Study on nutrient uptake pattern in H-4 cotton under different agronomic management. *PKV Res. J.*, 18(1): 60-62.

- Ravankar, H.N. R.T. Patil and S.S. Hadole. 2003. Final report of Adnoc project on nutrient management in cotton under drip irrigation system. Department of Agril. Chemistry and Soil Science. Dr. PDKV, Akola center.
- Ravankar, H.N., N.N. Gajbhiye and P.A. Sarap, 2005. Effect of organic manures and inorganic fertilizers on yield and availability of nutrients under sorghumwheat sequence. *Indian J. Agric. Res.*, 39(2): 142-145.
- Ray, S.S and R.P. Gupta, 2001. Effect of green manuring and tillage practices on physical properties of puddle loam soil under rice-wheat cropping system. *J. Indian Soc. Soil. Sci.* 49(4): 670-678.
- Reddy C. V., Alok Tiwari, K. Tedia, Anil Verma and R. R. Saxena. 2017. Effect Long term fertilizer experiments on Bulk Density, Crack Volume, Soil Organic Carbon stock and Carbon sequestration rate Rice crop. *Int. J. Pure App. Biosci.* 5 (4): 1051-1057.
- Reddy, G.B. and S. Reddy, 1998. Effect of organic manures and nitrogen levels on soils available nutrients status in maize - soybean-cropping system. *J. Indian Soc. Soil Sci.* 46(3) : 474-476.
- Reddy, G.R., G.U. Malewar; and B.G. Karle, 2002. Effect of crop residue incorporation and tillage operations on soil properties of Vertisol under rainfed agriculture. *Indian J. Dryland Agric. Res. and Dev.* 17(1): 55-58.
- Reddy, G.R. 1997. Management of swell shrink soils through tillage, intercropping and crop residues. Ph. D. Thesis (unpub.), Marathwada Agril. University, Parbhani, (M.S.).
- Rewatkar, S.S. 1998. Investigation on the effect of soil amendments and land treatments on soil characteristics and productivity of cotton grown in salt affected Vertisols. Ph. D. Thesis (unpub.), Dr. PDKV, Akola, (M.S.).
- Rita Patil, 1999. Dynamics of soil nitrogen as influenced by cropping systems and nutrient management. Ph. D. (Agri.) Thesis (unpub.), Dr. PDKV, Akola.
- Rudrappa, L., T.J. Purkhasthya, S. Dhyan and S. Bhadraray, 2006. Long term manuring and fertilization effects on soil organic carbon pools in typic Haplustept of semi arid subtropical India. *Soil and Tillage Res.* 88(1-2) : 180-192.
- Saini, V.K., S.C. Bhandari, S.K. Sharma and J.C. Tarafdar, 2005. Assessment of microbial biomass under integrated nutrient management in soybean-winter maize cropping sequence. *J. Indian Soc. Soil Sci.*, 53(3) : 346-351.
- Sainju, U.M., J.D. Jabro and T.C. Tonthat, 2009. Carbon and nitrogen fraction in dryland soil aggregates affected by long-term tillage and cropping sequence. *Soil. Sci. Soc. Am. J.* 73:1488-1495.
- Salahin M, Khairul A, Abu Taher Mohammad Anwarul Islam Mondol, Mahammad Shariful Islam, Md. Harunur Rashid and Muhammad Azizal Hoque (2017) Effect of Tillage and Residue

Retention on Soil Properties and Crop Yields in Wheat-Mungbean-Rice Crop Rotation under Subtropical Humid Climate. Open Journal of Soil Science, 2017, 7, 1-17.

- Salians-Garcia J.R., F.M. Hones and J.E. Matocha, 1997. Long term effect of tillage and fertilization on soil organic matter dynamics. Soil. Sci. Soc. Am. J. 61: 152-159.
- Sanjay Kumar, Subash Chand and B.P.S.Gautam, 2015. Enhance the soil health, nutrient uptake and yield of crops under rice –wheat cropping system through green manuring. Int. Journal of Tropical Agriculture, 33(3):2075-2079.
- Santhy, P., P. Muthuvel, V.Murugappan and D. Selvi, 1998. Long-term effect of continuous cropping and fertilization on crop yield and soil fertility status. J. Indian Soc. Soil Sci. 46(3):391-395.
- Santhy, P., J. Sreesanker, P. Muthavel and D. Selvi, 1999. Long term fertilizer experiment status on N, P and K fraction in soil. J. Indian Soc. Soil Sci. 46(3): 395 -398.
- Sarode, S.S., B.N. Dahatonde, N.K. Patke, S.K. Lawale and Shilpa Dahatonde, 2003. Studies on growth and yield of pre monsoon hybrid cotton in response to moisture regimes, planting patterns and intra-row distances under drip irrigation. Res. on Crops. 4(1) : 131-132.
- Sekhon K.S., G.S. Battar, B.S. Sidhu and S. Singh, 2011. Tillage and nitrogen fertilization affects on yield and water expense efficiency of Bt Cotton hybrid. J. Cotton Res. Dev. 25(1): 55-58.
- Selvi, D. P., P. Santhy and M. Dhakshinamoorthy, 2005. Effect of inorganics alone and in combination with farmyard manure on physical properties and productivity of Vertic Haplusteps under long-term fertilization. J. Indian Soc. Soil Sci. 53(3): 302-307.
- *Selvi, D., P. Santhy and M. Dhakshinamoorthy, 2003. Efficacy of long term integrated plant nutrient management on important soil properties of an Inceptisol. Madras Agric. J. 90(10-12) : 656-660
- Sethi, H.N. 1988. Studies on biomass production and water use efficiency of cotton varieties as influenced by intercrops and irrigation levels. Ph. D. Thesis, (unpub.), Dr. PDKV, Akola.
- Shah, M. S. and R.I.Verma, 2012. Integrated nutrient management in *hirsutum* cotton. J. Cotton Res. Dev. 26(2): 202-203.
- Shahi S.K., 2013. Effect of organic manures, inorganic fertilizers and biofertilizers addition on soil properties and productivity under onion (*Allium cepa* L.). Plant Archives., 13(1):381-387.
- Shalini, P. P., Geethakumari V. L., Rebecca, I. S. 2007. Balance-sheet of soil nitrogen in rice (*Oryza sativa*) - based cropping systems under integrated nutrient management. Indian J. Agronomy. 52 (1) 16-20.

- Sharma R. A. and O.R. Misra, 1997. Crop residues, FYM and fertilizer use in relation to growth, yield and nutrient uptake by soybean. *Crop Res.* 13(1):51-57.
- Sharma, A. R., R. Singh, S.K.Dhyani and R.K. Dube, 2010. Tillage and legume mulching effects on moisture conservation and productivity of rainfed maize- wheat cropping system. *Indian J. Agron.* 55(4): 245-252.
- Sharma, A.P., A.D. Taneja; B.P.S. Lather and R.D. Kaushik. 1993. Chemical composition of healthy and drying plant. *J. Cotton Res. Dev.*, 7(1): 95-100.
- Sharma, C. 2006. Impact of puddling and tillage practices on soil physical properties and crop productivity under rice-wheat cropping system in Alfisol. Unpublished Ph. D. thesis Dept. of Soil Science, Indira Gandhi Krishi Vishwavidyala, Raipur, 76-78.
- Sharma, C.P., B.R. Gupta and P.D. Bajpai, 1986. Residual effect of leguminous crops on some chemical and microbiological properties of soil. *J. Indian Soc. Soil Sci.* 34:206-208.
- Sharma, H. H., R. P. R. Sharma and S. S. Mishra. 1992. Fertilizer management in legume and cereal based cropping system. *Indian J. Pulses Res.*, 4(1) : 40-44.
- Sharma, J. C., A. D. Taneja, A. P. Sharma and M. S. Kairon, 1988. Effect of phosphorus application on yield and uptake of nutrients in different parts of cotton plant at different stages of crop growth. *J. Cotton Res. Dev.* 17 : 3-8.
- Sharma, K.L., K. Subbaiah, D. Jawahar, U. Solaiappan, V. Subramanian, P.K. Mishra, B. Venkateswarlu, J. Kusuma Grace, G.R. Korwar, G. Maruthi Sankar, G. Ravindra Chary, Pravin N. Gajbhiye, M. Madhavi, U.K. Mandal, K. Srinivas, Ch. Srinivasarao, Kausalya Ramachandran and K. Usha Rani, 2009. Soil quality assessment under long-term soil and nutrient management practices in Vertisols of Kovilpatti. *Indian J. Dryland Agric. Res. & Dev.* 24(1): 8-19.
- Sharma, K.L., J. Kusuma Grace., P.K. Mishra, B. Venkateshwaralu, M.B. Nagdeve, V.V. Gabhane, G. Maruti Shankar, G.R. Korwar, G. Ravindra Chary, C. Srinivasarao, P.N. Gajbhiye, M. Madhavi, U. K. Mandal, K.Srinivas and K. Ramchandran, 2011. Effect of Soil and Nutrient-Management Treatments on Soil Quality Indices under Cotton-Based Production System in Rainfed Semi-arid Tropical Vertisol. *Communication in Soil Science and Plant Analysis*. Vol. 42(11):1298-1315.
- Sharma, M.P. and J.P. Gupta, 1998. Effect of rainfed soybean (*Glycine max*)-safflower (*Carthamum tictoriosis*) sequence to nitrogen and sulphur fertilization in vertisols. *Indian J. Agric Sci.* 68(11) : 715-717.
- Sharma, M.P., S.V. Bali and D.K. Gupta, 2000. Crop yield and properties of Inceptisol as influenced by residue management under rice-wheat cropping sequence. *J. Indian Soc. Soil Sci.* 48(3) :506-509.

- Sharma, R.A., 1992. Efficient water use and sustainable production of rainfed soybean and safflower through conjunctive use of organics and fertilizer. *Crop Res.* 5(2): 181-194.
- Sharma, R.A., 1997. Influence of conjunctive use of organics and fertilizer nutrient on nutrient uptake and productivity of soybean-safflower cropping sequence in Typic chromusterts. *Crop Res.* 13(2): 321-325.
- Sharma, S.K. and S. Singh, 2007. Yield, yield attributes and quality of cotton as influenced by foliar application of potassium. *Cotton Res. Dev.* 21(1):51-54.
- Sharma, U., and S. K. Subehia, 2014. Effect of long-term integrated nutrient management on rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) productivity and soil properties in north-western Himalaya, *J. Indian Soc. Soil Sci.* 62 (3): 248-254.
- *Sheeba, S. and S. Chellamuthu, 1999. Long-term influence of organic and inorganic fertilization on the macronutrient status of Inceptisol. *J. Indian Soc. Soil Sci.* 47(4): 803-804.
- Shekhawat K, Rathore S.S, Premi O.P, Singh D and Chauhan B.S (2016) Effect of establishment method on productivity, soil health and economics of mustard under various cropping systems. *Soil and Tillage Research*, 158: 137-146.
- Shete, M.R., 2005. Effect of integrated nutrient supply on yield, nutrient uptake and quality of soybean. M.Sc. Thesis, Dr. PDKV, Akola, pp 36-39.
- Shirale, S. T. and L.E. Khating, 2009. Effect of organic and inorganic nutrients on yield, nutrient uptake and balance in different cropping systems in Vertisol. *Ann Pl. Physiology*, 23(1):83-85.
- Shivakumar, B. G. and I. P. S. Ahlawat, 2008. Integrated nutrient management in soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system *Indian J. of Agronomy* 53(4): 273-278.
- Shokati B and A. G. Ahangar, 2014. Effect of conservation tillage on soil fertility factors: review. *International J. Biosciences*. Vol. 4, No. 11, p. 144-156.
- Shuman L. M. and W. L. Hargrove, 1984. Effect of Tillage on the Distribution of Manganese, Copper, Iron, and Zinc in Soil Fractions. *Soil Science Society of America J.* 49 (5) :1117-1121
- Sikka, R., D. Singh and J.S.Deol.2012 Productivity and nutrient uptake by soybean as influenced by integrated nutrient and some other agronomic management practices. *Legumes Res.*, 36(6):545-551.
- Simon T., M. Javurek, O. Mikanova and M. Vach, 2009. The influence of tillage systems on soil organic matter and soil organic matter and soil hydrophobicity. *Soil Till. Res.* 105:44–48.

- Singaram P. and K. Kamalakumari, 1995. Long-term effect of FYM and fertilizers on enzyme dynamics of soil. *J. Indian Soc. Soil Sci.* 43 (3): 378-381.
- Singh ,A. K., A. K. Sarkar and B. Mishra, 2009. Long term effect of residue incorporation on crop yield, nutrient uptake and availability of plant nutrient in an acid soil. *Indian J. Agric. Sci.* 79(1) : 70-72.
- Singh M., and Narendra Kumar. 2012. Effect of FYM, vermicompost, vermiwash and NPK on growth, microbial biomass and yield of soybean. *Soybean Res.* 10:60-66.
- Singh P.K, S.P. Tomar and P.R. Singh. 1991. Effect of tillage, seed rates and irrigation on growth, yield and quality of lentil. *Indian J. Agron.* 36 (2):143-147.
- Singh Y., Singh, B., Ladha, J.K., Khind, C.S., Gupta, R.K., Meelu, O.P. and Pasuquin, E. 2004. Long-term effects of organic inputs on yield and soil fertility in the rice – wheat rotation. *Soil Sci. Soc. Am. J.* 68: 845-853.
- Singh, J., K.S. Bhaskar, D. Blaise and G. Mujumdar, 2002. Effect of crop residue incorporation on yield of cotton and wheat in irrigated sandy loam soils. In: *Extended summaries Vol 2 of 2nd Interl. Agronomy Congress*, Nov. 26-30, 2002, New Delhi : 360-361.
- Singh, K, K. Singh, H.R. Garg, and P. Rathore, 2006. Effect of nutrients on productivity of seed cotton yield and other ancillary parameters in American Cotton. *J. Cotton Res. Dev.* 20(2): 216-218.
- Singh, M., B.S. Azad and A. S Bali, 2001. Effect of in- situ crop residue management techniques on productivity of rice-wheat cropping system. *Environment and Ecology* 23(Spl-4): 673–676.
- Singh, R. and R.K. Rai, 2009. Yield attributes, yield and quality of soybean as influenced by integrated nutrient management. *Indian J. Agron.* 49(4) : 271-274.
- Singh, S. R. and G. R. Najar and Ummed Singh, 2007. Productivity and nutrient uptake of soybean (*Glycine max*) as influenced by bio-inoculants and farmyard manure under rainfed conditions. *Indian J. of Agron.* 52 (4): 325-329.
- Singh, Y. V., D. W. Dhar and B. Agarwal, 2011. Influence of organic nutrient management on Basmati rice (*Oryza sativa*)-wheat (*Triticum aestivum*)-greengram (*Vigna radiata*) cropping system. *Indian J. of Agron.* 56(3): 169-175.
- Singh, H., G. Singh and J.S. Deol, 2010. Nodulation and uptake of nitrogen and potassium by grain and straw of soybean (*Glycine max* (L.) Merrill) as affected by potassium and nitrogen. *Legumes Res.*, 33 (4): 249-255.
- Singh, V. K. and R.P. Bajpai, 1990. Effect of phosphorus and potash on growth and yield of rainfed soybean. *Indian J. Agron.* 35 (3):310-311.

- Sisodia, R. I. and S. K. Khamparia, 2007. American cotton varieties as influenced by plant densities and fertility levels under rainfed conditions. *J. Cotton Res. Dev.* 21(1): 35-40.
- Solaiappan, U., D. Krishnadas and S. Senthivel, 1999. Influence of legume biomolecule on seed cotton yield and change in physic-ochemical properties of soil in rainfed Vertisols. *Indian. J. Agric. Res.* 33(2) :119-124.
- Solunke, P.S., and S.U. Fatak, 2011. Influence of organic and inorganic sources of nutrients on production of desi cotton under different plant protection measures. *J. Cotton Res. Dev.* 25(1): 42-45.
- Sonune B. A., V.V. Gabhane, S.S. Rewatkar and M.S. Sawangikar, 2013. Productivity of rainfed cotton and soil health as influenced by tillage and integrated nutrient management in Vertisol under semi-arid agro-ecosystem of Maharashtra. *Indian. J. Dryland Agric. Res. & Dev.* 27(1):10-17.
- Sonune, B. A, K.B. Tayade, V.V. Gabhane and R.B. Puranik, 2003. Long-term effect of manuring and fertilization on fertility and crop productivity of Vertisols under sorghum-wheat sequence. *Crop Res.* 25 (3):460-467.
- Sonune, B. A., V.V. Gabhane, S.S. Rewatkar and M.S. Sawangikar, 2012. Productivity of rainfed cotton and soil health as influenced by tillage and integrated nutrient management in Vertisol under semi-arid agro-ecosystem of Maharashtra. *Indian J. Dryland Agric. Res. & Dev.* 27(1):10-17.
- Sonune, B. A; K.B. Tayade; V.V. Gabhane and R.B. Puranik, 2005. Long-term effect of manuring and fertilization on fertility and crop productivity of Vertisols under sorghum-wheat sequence. *Crop Res.* 25(3):460-467
- Srikanth, K., C.A. Srinivasamurthy, R. Siddaramappa and V.R.R. Parama, 2000. Direct and residual effect of enriched composts, FYM, vermicompost and fertilizers on properties of an Alfisols. *J. Indian Soc. Soil Sci.* 48(3):496-499.
- Sriramachandrasekharan, M. V., G. Ramanathan and M. Ravichandran, 1997. Effect of different organic manures on enzyme activities in a flooded rice soil. *Oryza* 34 : 39-42.
- Subbiah, B.V and G. L. Asija, 1956. A rapid procedure for the determination of available nitrogen in soil. *Curr. Sci.* 25:259-260.
- Subehia S.K. and Swapana sepehya, 2012. Influence of long term nitrogen substitution through organics on yield, uptake and available nutrients in a rice-wheat system in an acidic soil. *J. Indian soc. Sci.*, 60(3):213-217.
- Subramanian, S., M. Rajeswari and T. Chitdeswari. 2000. Effect of organic fertilizers on soil moisture conservation in rainfed Vertisol. *Madras Agril. J.* 87(4-6): 345-347.

- Sudhir, K., S.M.M. Gowda, K.Srikanth and R.Siddaramappa, 1998. Long term fertility management through integrated plant nutrient supply system in an Alfisol under finger millet-hybrid maize sequence. Bulletin of Indian Institute of Soil Science (2). pp 136-140.
- Sujata Pothare, P.K. Rathod, H.N. Ravankar, Y.G. Patil, A.C. Yewale and Dhammadina Pothare, 2007. Effect of long term fertilization in Vertisols on soil properties and yield of sorghum-wheat sequence. Asian J. Soil Sci., 2(1) : 74-78.
- Surekha, K. and K. V. Rao, 2009. Direct and residue effects of organic sources on rice productivity and soil quality of Vertisols. J. Indian Soc. Soil Sci., 37(1) : 53-57.
- Surekha, K., M. N. Reddy, K.V. Rao and P.C. S. Cruz, 2004. Evaluation of crop residue management practices for improving yields, nutrient balance and soil health under intensive rice-rice system. J. Indian Soc. Soil Sci. 52(4):448-453.
- Suresh, P. and V. Chellamuthu, 2004. Seed cotton yield and uptake of nutrients by cotton cultivars as influenced by different fertilizer levels under irrigated condition in the coastal region of Karaikal. In : International symposium on “ Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 98-102.
- Suresh, S., S. Subramanian, and T. Chitdeswari, 1999. Effect of long term fertilizers and manures in Vertisol. Under dry farming and soil properties. J. Indian Soc. Soil. Sci. 47 (2): 272-276.
- *Surya, J.N., R.B.Puranik, S.D.Zadode and S.D.Deshmukh, 2000.Effect of wheat straw incorporation on yield of green gram and wheat, soil fertility and microbiota.J. Maharashtra Agric. Univ. 25(2):158-160.
- Swarup, A. 1991. Effect of Gypsum, Green manure, farm yard manure and zinc fertilization on the zinc, iron and manganese nutrition of wetland rice on a sodic soil. J. Indian Soc. Soil. Sci. 39 : 530-536.
- Swarup, A., 1984. Effect of micro-nutrients and farm yard manure on the yield and micro-nutrient content of Rice and Wheat grown on a sodic soil. J. Indian Soc. Soil Sci. 32:397-399.
- Swarup, A., 2010. Integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity. J. Indian Soc. Soil. Sci. 58 (1): 25-31.
- Tabassum, S. Reddy, K. Sammi, Vaishya, U.K., Singh, Muneshwar and Biswas, A.K. 2010. Changes in Organic and Inorganic Forms of Nitrogen in a Typic Haplustert under Soybean-Wheat System due to Conjoint Use of Inorganic Fertilizers and Organic Manures Journal of the Indian Society of Soil Science, 58, (1), pp 76-85.
- Tailakov, N and K. Meredov. 1984. Effect of organic manures on agrochemical properties of soil and cotton yield. Biologicheskikh Nauk. 4 : 59-62.

- Talati, P. K., 2004. Effect of inorganic and organic sources of nitrogen on summer soybean (*Glycine max.* (L.) Merrill) under South Gujarat condition, M.Sc. (Agri.) Thesis, submitted to N.A.U. Navsari.
- Taneja, A.D., A.P. Sharma, D.P. Singh and B.S. Chhabra, 1997. Biochemical composition of different genotypes of *hirsutum* and *arboreum* cotton. J. Cotton Res. Dev. 11(1): 37-43.
- Tanwar, S.P.S. and M.S. Shaktawat, 2003. Influence of phosphorus sources, levels and solubilizers on yield, quality and nutrient uptake of soybean (*G. max.*)- wheat (*T. aestivum*) cropping system in Southern Rajasthan. Indian J. Agric. Sci. 13(1) : 3-7.
- Tetarwal, J.P; Baldev Ram and D.S. Meena, 2011. Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rainfed maize (*Zea mays*). Indian J. of Agron. 56(4): 373-376
- Thakur, K.C., R.G. Sahay and A.S. Sarkar, 1990. Nutrient balance in acid sedentary soil (Haplusterts) of Randu as influenced by crop response. J. Indian Soc. Soil Sci. 48(2) : 233-236.
- Thakur, R., S. D. Sawarkar, U. K. Vaishya and M. Singh, 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. J. Indian Soc. Soil Sci. 59 (1): 74-81.
- Tiwari, A., A.K. Dwivedi and P.R. Dikshit, 2002. Long term influence of organic and inorganic fertilization on soil fertility and productivity of soybean-wheat system in Vertisol. J. Indian Soc. Soil Sci. 50(4) : 472-475.
- Tiwari, R.J., K. Dwivedi and S.K. Verma, 1994. Effect of gypsum application on nutrient content in cotton leaves grown on sodic Vertisol. Crop Res. 7 (2): 193-196.
- Tiwari, K.L., Upadhyaya, Vishwakarma, S.K., V.B. and Sharma, R.S. 2001. Integrated nutrient management in rice-wheat cropping system. In *Extended Summaries: 2nd International Agronomy Congress*, Vol. 1 held at New Delhi, India from November 26–30, pp. 65–67.
- Tomar, R.S., 2005. Productivity of upland cotton (*Gossypium hirsutum*) genotypes under different levels of fertility and spacing. Indian J. Agron. 45(4): 776-777.
- Tripathi, P.N. and S.D. Sawarkar, 2007. Morphology, physical-chemical properties and classification of some Vertisol of kymore plateau. J. Soil and crops 12(2): 237-240.
- Tyagi, V.V. and V. Bhardwaj. 1994. Effect of continuous cropping and fertilization on the status of available nitrogen, phosphorus, and potassium in Mollisol. J. Pot. Res., 10(4): 384-391.

- Umesh, U.N., Kumar, V., Prasad, R.K., Singh, K. D. N. and Singh, A.P. 2014. Effect of Integrated Use of Inorganic and Organic Materials on the Distribution of Different Forms of Nitrogen in Soil and their Influence on Sugarcane Yield and Nutrient Uptake. *J. Indian Soc. Soil Sci*, 62 (3): 209-215.
- Vasanthi, D and K. Kumaraswamy, 1999. Efficiency of vermicompost to improve soil fertility and rice yield. *J. Indian Soc. Soil Sci.*, 47(2):268-272.
- Venkateshwaralu, J., 1984. Residue management. *Advances in Soil Science*, 7 : 192-204.
- Verma A, V. Nepalia and P.C. Kanthaliya, 2005. Effect of continuous cropping and fertilization on crop yields and nutrient status of a Typic Haplustept. *J. Indian Soc. Soil Sci*. 53(3): 365-368.
- Verma, G., A.K. Mathur, S.C. Bhandari and P.C. Kanthaliya, 2010. Long term effect of integrated nutrient management on properties of a Typic Haplustept under maize-wheat cropping system. *J. Indian Soc. Soil Sci.*, 58(3) : 299-302.
- Verma, S.M. and N.T.Singh, 1974. Effect of some indigenous organic materials on soil aggregation. *J.Indian Soc.Soil.Sci*. 22(3):220-225.
- Verma,G. and A.K. Mathur, 2009. Effect of integrated nutrient management on active pools of soil organic matter under maize-wheat system of TypicHaplustept.*J. Indian Soc. Soil Sci.*, 57(3):317-322.
- Vidyavathi, G. S., Dasog, H, B. Babalad, N. S. Hebsur, S. K. Gali, S. G. Patil and A.R. Alagawadi, 2011. Influence of nutrient management practices on crop response and economics in different cropping systems in a Vertisol. *Karnataka J. Agric. Sci.*, 24 (4): 455-460.
- Vineela, C, S.P. Wani, C. Srinivasarao, B. Padmaja and K.P.R. Vittal, 2008. Microbial properties of soils as affected by cropping and nutrient management practices in several long term manurial experiments in the semi-arid tropics of India. *Appl. Soil Ecol*. 40 : 165-173.
- Vipin Kumar and A.P. Singh.2010. Long term effect of green manuring and farm yard manure on yield and soil fertility status in rice-wheat cropping system. *J. Indian Soc. Soil Sci*. 58 (4):409-412.
- Waghmare Y.M.,N.K.Kalegore ,D.N.Gokhale and D.A.Chavan,2012.Effect of integrated nutrient management on yield attributes ,yield and quality of soybean. *J.Soils and Crops* 22 (2):321-326
- Wani, S.P., C.H. Srinivasrao, T.J. Rego, G. Parthasarthi, Somnath Roy, 2007. On farm nutrient depletion and buildup in Vertisols under soybean based cropping system in semi arid central India. *Indian J. Dryland Agric*. 22(1): 69-73.
- Wankhade, S.T., A.B. Turkhede, R.N. Katkar, V.M. Solanke and B.A. Sakhare, 2001.a.Effect of bio-mulching and fertilizers on growth and yield of cotton. *J. Crop Res*. 21 (1) : 34-37.

- Wankhade, S.T., V.M. Solanke, A.B. Turkhede, S.D. Malvi and R.N. Katkar. 2001.b. Effect of bio-fertilizer on growth and yield of *Arboreum* cotton (AKA-8401). *Crop Res.* 21(1): 38-40.
- Watanabe, F.S. and Olsen, S.R. 1965. Test of ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts of soils. *Proc. Soil Sci. Soc. Am.*, 29: 677-678.
- Yadav G. S., R. Datta, S. I. Pathan, R. Lal, R. s. Meena, S. Babu, A. Das, S. N. Bhowmik, M. Datta, P. Saha and P. K.Mishra 2017 . Effects of Conservation Tillage and Nutrient Management Practices on Soil Fertility and Productivity of Rice (*Oryza sativa* L.)–Rice System in North Eastern Region of India. *Sustainability* 2017, 9, 1816.
- Yaduvanshi N.P.S. and D.R. Sharma , 2007. Use of wheat residue and manures to enhance nutrient availability and rice – wheat yield sodic soil under sodic water irrigation . *J. Indian Soc. Soil Sci.*, 55 (3) : 330-334.
- Yaduvanshi N.P.S., D.R. Sharma and A. Swarup , 2013. Impact of integrated nutrient management of soil properties and yield of rice and wheat in a long term experiment on a reclaimed sodic soil. *J. Indian Soc. Soil Sci.*,61(3) : 188 - 194
- Yaduvanshi, N.P.S, 2003. Substitution of inorganic fertilizers by organic manures and effect on soil fertility in a rice-wheat rotation on reclaimed sodic soil in India. *J. Agricultural Sciences.* 140, 161-168.
- Zang, J., Qin, J., Yao, W., Bi1, L. , Lai, T., Yu, X. 2009. Effect of long-term application of manure and mineral fertilizers on nitrogen mineralization and microbial biomass in paddy soil during rice growth stages. *Plant Soil Environ.*, 55(3): 101–109.
- Zibilske, L. M. and J. M. Bradford, 2007. Soil aggragation aggregate carbon and nitrogen and moisture retention induced by conservation tillage. *Soil Sci. Soc American J.* 71(3): 793-802.

*** Original not seen**

V I T A

1. Name of the student : **ASHOK BHAGWAN AGE**
2. Date of Birth : 26/06/1982
3. Name of the University : Dr. Panjabrao Deshmukh Krishi Vidyapeeth
Akola
4. Residential address : Flat No. 10, Lalji terrace, Balaji nager,
Near Gorkshan Road, Akola (444004)
5. Phone No. : 07588073040
6. Academic qualifications:

Sr. No.	Name of degrees awarded	Year in which obtained	Division/ class	Name of awarding University	Subjects
1.	HSC	1999	I	HSC Board, Aurangabad	Physics, Chemistry, Maths, Biology
2.	B.Sc. (Agri.)	2003	II	VNMAU, Parbhani	Agriculture
3.	M.Sc. (Agri.)	2006	I	VNMAU, Parbhani	Soil Science and Agricultural Chemistry

7. Professional Experience : **10 years in teaching, research and extension**
8. Memberships of Professional societies : 06
9. Award /Recognitions : 03
10. Publications :
 - Research : 21
 - Scientific : 46
 - Extension : 20
 - Technical Bulletins : 03

Place: Akola

Date: 22 /02/2019

Signature of student

Ashok Bhagwan Age

Weekly Weather data for the year 2016 recorded at Meteorological Observatory, Department of Agronomy Dr. PDKV., Akola

TOTAL RFJanuary to Dec

B (i). Weekly distributed rainfall during 2017-18

Weekly Weather data for the year 2017-2018 recorded at Meteorological Observatory , Department of Agronomy Dr. PDKV., Akola																				
Weeks	Dates	Actual				2017								Normal				1971-2000		
		T MAX (°C)		T MIN (°C)		BSH (hrs)		WS (km/hr)		RH I (%)		RH II (%)		Evap (mm)		RF (mm)		CRF (mm)	Rainy Days	
		N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
1	1-7 Jan	29.0	29.5	10.3	9.3	8.7	8.1	4.9	0.5	78	82	30	33	4.2	3.5	1.7	0.0	0.0	0.2	0.0
2	8-14	29.2	27.3	11.3	8.4	8.6	7.6	6.3	0.6	71	84	30	40	4.5	3.3	3.4	0.0	0.0	0.2	0.0
3	15-21	29.9	29.3	11.6	12.2	8.9	5.8	5.4	0.8	69	79	28	36	4.8	3.8	0.9	0.0	0.0	0.1	0.0
4	22-28	30.8	31.3	11.8	13.8	9.1	7.7	5.5	1.4	67	77	27	35	5.2	5.1	1.1	0.0	0.0	0.2	0.0
5	29-4 Feb	31.1	31.6	12.1	11.8	9.3	8.8	5.8	0.8	61	80	25	27	5.6	4.8	2.8	0.0	0.0	0.2	0.0
6	5-11	31.3	32.5	11.9	14.2	9.1	8.5	5.6	1.7	59	72	23	27	5.9	5.7	4.9	0.0	0.0	0.4	0.0
7	12-18	32.5	33.2	13.4	16.4	9.4	7.7	6.1	2.2	56	74	22	27	6.6	6.2	0.1	0.5	0.5	0.0	0.0
8	19-25	33.0	35.1	13.8	14.8	9.5	9.4	6.5	2.9	57	59	22	14	7.3	8.3	3.3	0.0	0.5	0.5	0.0
9	26-4 Mar	34.7	36.4	14.8	15.6	9.6	9.2	7.0	1.4	50	42	17	12	8.1	8.0	3.4	0.0	0.5	0.3	0.0
10	5-11	36.1	34.7	16.7	17.4	9.6	9.0	6.8	4.2	44	46	18	16	9.0	9.5	2.1	0.0	0.5	0.3	0.0
11	12-18	37.3	34.2	17.5	16.0	9.6	8.3	6.9	3.5	42	42	17	14	9.5	9.1	2.5	0.0	0.5	0.3	0.0
12	19-25	38.5	37.7	18.3	18.9	9.6	9.1	6.9	2.7	37	35	13	13	10.5	10.0	0.3	0.0	0.5	0.1	0.0
13	26-1 Apr	39.0	42.4	19.7	22.5	9.6	9.0	7.6	1.8	36	32	15	11	11.3	10.6	2.9	0.0	0.5	0.3	0.0
14	2-8 Apr	40.1	40.7	21.1	26.2	9.8	9.1	7.9	6.4	36	33	15	15	11.7	13.6	0.6	0.0	0.5	0.1	0.0
15	9-15	40.8	41.9	22.5	20.0	9.9	9.5	9.3	2.3	34	27	12	8	13.4	11.3	0.3	0.0	0.5	0.1	0.0
16	16-22	41.7	43.9	23.5	27.7	10.2	10.0	9.1	8.3	34	25	14	6	13.7	17.6	0.3	0.0	0.5	0.0	0.0
17	23-29	42.1	41.1	24.8	25.5	10.1	10.1	10.2	8.3	37	35	14	10	14.4	14.9	0.0	0.0	0.5	0.1	0.0
18	30- 6 May	42.7	42.2	26.0	26.7	9.9	9.3	11.4	3.5	38	28	14	14	15.4	13.2	0.3	0.0	0.5	0.2	0.0
19	7-13	42.6	43.5	26.5	27.7	10.1	8.7	12.7	3.7	43	30	17	15	16.4	13.8	0.3	0.3	0.8	0.1	0.0
20	14-20	42.6	43.8	27.3	30.4	9.7	9.2	14.6	10.2	48	37	18	17	17.3	17.5	1.8	0.0	0.8	0.2	0.0
21	21-27	42.4	43.6	27.4	30.1	9.8	8.9	15.7	9.2	50	41	20	18	17.0	17.3	4.1	0.0	0.8	0.5	0.0
22	28-3 Jun	41.9	40.5	27.6	28.9	9.7	7.3	16.2	8.2	56	58	23	31	16.3	13.7	5.7	0.8	1.6	0.5	0.0
23	4-10	39.0	38.0	25.8	25.5	8.0	7.1	14.9	10.0	62	74	30	41	13.4	10.9	18.3	24.6	26.2	1.2	1.0
24	11-17	38.2	35.6	25.5	23.8	7.5	5.2	15.4	6.3	71	80	42	51	11.1	7.4	43.3	45.4	71.6	2.0	4.0
25	18-24	35.3	37.4	24.9	26.3	7.1	8.9	15.1	11.0	76	67	50	36	9.1	11.5	52.3	5.7	77.3	2.2	1.0
26	25-1Jul	34.1	34.8	24.2	25.0	5.3	5.1	13.4	7.7	80	75	55	48	7.3	8.6	38.2	10.5	87.8	2.3	2.0
27	2-8	33.5	33.2	24.4	24.3	5.2	3.8	12.9	11.3	81	79	58	51	6.8	7.5	34.7	37.6	125.4	2.4	1.0
28	9-15	32.3	33.9	23.7	24.9	3.8	3.7	12.0	12.6	84	77	62	51	5.5	9.3	52.2	10.8	136.2	2.8	2.0
29	16-22	32.0	29.8	23.9	23.8	3.3	0.6	11.2	6.9	84	88	65	72	5.6	4.2	58.6	101.1	237.3	2.6	4.0
30	23-29	31.7	30.5	23.3	23.0	4.3	2.3	11.9	8.2	85	88	64	65	5.3	4.1	44.2	35.8	273.1	2.6	4.0
31	30-5 Aug	31.1	31.9	23.1	23.6	3.6	6.8	11.7	6.3	88	85	66	58	4.6	6.9	49.3	10.0	283.1	2.5	2.0
32	6-12	30.2	30.7	22.9	24.1	3.5	2.9	11.6	6.0	87	80	69	63	4.2	5.8	59.9	4.4	287.5	2.9	1.0
33	13-19	30.5	32.9	22.8	23.8	4.4	5.4	11.7	7.1	86	83	66	58	4.5	6.2	40.6	18.9	306.4	2.2	1.0
34	20-26	30.5	29.1	22.6	23.4	4.3	2.0	11.0	5.9	88	92	66	76	4.3	2.8	46.7	25.3	331.7	2.0	4.0
35	27-2 Sep	30.4	30.5	22.7	23.3	4.4	3.8	10.6	2.5	86	88	64	68	4.2	3.7	47.1	70.2	401.9	2.4	4.0
36	3-9	31.1	32.3	22.5	23.8	5.7	6.5	9.1	2.7	85	89	61	62	4.7	5.0	28.5	9.7	411.6	1.5	1.0
37	10-16	32.2	31.8	22.4	23.8	7.1	2.6	9.0	0.8	85	93	56	69	5.1	3.5	18.9	27.9	439.5	1.1	3.0
38	17-23	33.4	30.8	22.3	23.0	7.2	2.5	8.5	2.5	83	92	53	69	5.3	3.2	24.6	12.5	452.0	1.4	2.0
39	24-30	33.7	33.8	21.9	22.8	7.6	8.4	5.4	1.6	83	89	50	50	4.9	5.1	24.4	4.1	456.1	1.5	1.0
40	1-7 Oct	33.9	35.6	20.2	21.1	8.1	8.0	7.5	1.2	81	81	45	42	5.5	6.5	21.8	0.0	456.1	1.1	0.0
41	8-14	34.1	31.9	18.7	20.0	4.2	4.3	4.1	0.7	76	91	40	64	5.3	4.2	16.0	57.5	513.6	0.9	4.0
42	15-21	33.9	33.7	18.1	20.5	8.4	6.9	4.4	0.8	74	83	36	43	5.5	5.7	3.1	0.0	513.6	0.4	0.0
43	22-28	33.1	33.9	18.5	16.6	8.4	8.5	4.1	0.6	73	77	36	29	5.3	5.8	10.0	4.5	518.1	0.6	1.0
44	29-4 Nov	33.0	32.7	15.8	14.4	8.7	8.5	4.7	0.6	72	82	31	26	5.3	5.9	2.3	0.0	518.1	0.3	0.0
45	5-11	32.4	31.6	14.8	14.7	8.6	8.5	4.5	1.0	70	81	30	28	5.2	5.4	3.7	0.0	518.1	0.3	0.0
46	12-18	31.7	31.0	13.7	13.7	8.6	7.9	4.6	0.4	70	79	30	37	4.9	4.9	1.1	0.0	518.1	0.2	0.0
47	19-25	31.0	31.8	13.1	17.9	8.6	5.3	4.4	0.9	71	84	30	40	4.6	4.6	10.1	0.0	518.1	0.3	0.0
48	26-2 Dec	30.3	30.6	12.4	11.2	8.8	8.2	4.6	0.9	71	79	31	23	4.3	5.4	6.8	0.0	518.1	0.3	0.0
49	3-9	29.8	29.7	11.2	14.5	8.7	5.6	4.7	1.5	70	78	29	38	4.3	4.8	1.3	0.0	518.1	0.2	0.0
50	10-16	29.4	31.2	10.3	13.7	8.8	7.6	4.5	0.8	70	74	27	27	4.2	5.3	1.3	0.0	518.1	0.2	0.0
51	17-23	29.5	29.7	10.6	10.4	8.7	6.6	4.7	0.8	69	80	29	25	4.3	4.6	0.9	0.0	518.1	0.1	0.0
52	24-31	29.2	29.4	10.7	8.7	8.6	8.2	4.8	1.0	70	72	31	22	4.3	4.3	2.6	0.0	518.1	0.2	0.0
														TOTAL RF January to Dec			518.1			43
														Total RF June to Dec			517.3			43

B (ii). Weekly distributed rainfall during 2017-18

Weekly Weather data for the year 2018 recorded at Meteorological Observatory Department of Agronomy Dr. PDKV., Akola																				
Weeks	Dates	Actual				2018								Normal				1971-2000		
		T MAX (oC)		T MIN (oC)		BSH (hrs)		WS (km/hr)		RH I (%)		RH II (%)		Evap (mm)		RF (mm)		CRF (mm)	Rainy Days	
		N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
1	1-7 Jan	29.0	29.5	10.3	9.4	8.7	7.5	4.9	0.8	78	74	30	23	4.2	3.8	1.7	0.0	0.0	0.2	0.0
2	8-14	29.2	29.6	11.3	12.3	8.6	7.7	6.3	1.2	71	58	30	23	4.5	5.9	3.4	0.0	0.0	0.2	0.0
3	15-21	29.9	31.3	11.6	12.1	8.9	7.9	5.4	1.3	69	68	28	20	4.8	6.4	0.9	0.0	0.0	0.1	0.0
4	22-28	30.8	29.8	11.8	10.0	9.1	8.3	5.5	1.7	67	57	27	20	5.2	7.3	1.1	0.0	0.0	0.2	0.0
5	29-4 Feb	31.1	32.4	12.1	10.9	9.3	8.7	5.8	1.0	61	58	25	15	5.6	6.7	2.8	0.0	0.0	0.2	0.0
6	5-11	31.3	32.3	11.9	16.0	9.1	5.8	5.6	1.9	59	48	23	20	5.9	7.4	4.9	0.0	0.0	0.4	0.0
7	12-18	32.5	29.9	13.4	14.9	9.4	6.1	6.1	3.9	56	70	22	35	6.6	6.6	0.1	0.7	0.7	0.0	0.0
8	19-25	33.0	35.5	13.8	17.9	9.5	8.0	6.5	1.7	57	48	22	18	7.3	7.4	3.3	0.0	0.7	0.5	0.0

C. Plot wise soil fertility status during the year 2015-16 before start of the present experiments

	BD	HC	MWD	pH	EC	OC	N	P	K	S	Zn	Fe	Mn	Cu
	(Mgm ⁻³)	(cmhr ⁻¹)	(mm)		(dSm ⁻¹)	(g kg ⁻¹)	(kg ha ⁻¹)			(mg kg ⁻¹)				
CNS	1.35	0.72	0.67	8.11	0.32	5.86	224.6	14.27	365.2	12.00	0.50	6.91	9.13	1.98
CNV	1.35	0.70	0.64	8.17	0.34	5.74	217.1	14.19	357.3	10.61	0.48	6.56	8.71	1.84
T₁	1.37	0.65	0.61	8.19	0.36	5.20	202.4	13.07	346.6	10.03	0.45	6.08	8.29	1.69
T₂	1.36	0.69	0.63	8.18	0.35	5.53	230.1	14.03	391.4	10.50	0.47	6.57	8.73	1.72
T₃	1.36	0.76	0.70	8.04	0.31	6.17	235.7	15.50	366.8	12.08	0.53	7.06	9.15	2.16
T₄	1.36	0.74	0.64	8.17	0.33	5.74	219.8	14.99	381.2	11.05	0.48	6.83	8.87	1.90
T₅	1.34	0.74	0.66	8.12	0.32	5.95	213.7	14.45	360.7	11.23	0.47	6.69	8.78	1.78
T₆	1.36	0.70	0.65	8.15	0.35	5.68	220.2	13.66	361.0	11.84	0.50	6.92	8.93	2.06
T₇	1.34	0.70	0.67	8.18	0.34	5.84	217.9	14.05	358.8	11.36	0.51	6.93	8.92	2.03
T₈	1.31	0.69	0.68	8.15	0.31	5.73	217.9	14.09	346.6	11.58	0.51	6.79	8.88	1.92
Initial (2010-11)	1.38	0.66	0.61	8.10	0.29	5.40	212.5	14.34	347.8	9.61	0.51	5.80	8.42	1.64

Annexure-II

Table D. Quantity of chemical fertilizers and organic manures, crop residues, green manures and applied (kg plot⁻¹) 2016-17

	Urea	SSP	MOP	FYM	Wheat straw	Glyricidia	Composted Cotton stalk	Vermicompost	Phosphocompost
T ₁	-	-	-	-	-	-			
T ₂	0.210	1.51	0.162	-	-	-			
T ₃	0.105	1.39	0.071	9.20	-	-			
T ₄	0.105	1.35	0.058		12.0				
T ₅	0.105	1.50	0.098			2.02			
T ₆	0.105	1.36	0.058				10.33		
T ₇	0.105	1.33	0.101					4.01	
T ₈	-	0.160	0.017						12.78

Table E. Quantity of chemical fertilizers and organic manures, crop residues, green manures and applied (kg plot⁻¹) 2017-18

	Urea	SSP	MOP	FYM	Wheat straw	Glyricidia	Composted Cotton stalk	Vermicompost	Phosphocompost
T ₁	-	-	-	-	-	-			
T ₂	0.422	0.605	0.162		-	-			
T ₃	0.211	0.295	-	19.83					
T ₄	0.211	0.289	-		5.64				
T ₅	0.211	0.556	0.053			3.73			
T ₆	0.211	0.329	-				20.25		
T ₇	0.211	0.227	0.040					7.90	
T ₈	0.152	-	0.097						5.61

F. Quantity of chemical fertilizers and organic manures, crop residues, green manures and applied (kg ha⁻¹) 2016-17

	Urea	SSP	MOP	FYM	Wheat straw	Glyricidia	Composted Cotton stalk	Vermicompost	Phosphocompost
T ₁	-	-	-	-	-	-			
T ₂	65.21	468	50	-	-	-			
T ₃	32.60	433	13.02	28.30	-	-			
T ₄	32.60	422	18.06	-	37.50	-			
T ₅	32.60	468	30.41		-	6.25			
T ₆	32.60	420	18.1				31.91		
T ₇	32.60	410	31.41					12.39	
T ₈	-	49.43	26.83						39.47

G. Quantity of chemical fertilizers and organic manures, crop residues, green manures and applied (kg ha⁻¹) 2017-18

	Urea	SSP	MOP	FYM	Wheat straw	Glyricidia	Composted Cotton stalk	Vermicompost	Phosphocompost
T ₁	-	-	-	-	-	-			
T ₂	130.43	187	50	-	-	-			
T ₃	65.21	91.18	37.33	61.22					
T ₄	65.21	89.31	-		71.42				
T ₅	65.21	171.0	16.38			11.53			
T ₆	65.21	101.56	--				62.50		
T ₇	65.21	70.12	12.81					24.39	
T ₈	102.17	--	30.0						17.34

Annexure-III

H. Soil moisture content at critical growth stages of soybean as influence by tillage and IPNS under soybean-cotton rotation

Treatments			Soil moisture content (%)					
(a)Tillage			At sowing	Nodulation	Flowering	Pod development	Physiological maturity	At harvest
Set I-Conservation tillage			24.62	22.19	25.23	26.36	21.93	19.74
Set II –Conventional tillage			23.63	20.65	22.90	23.87	20.86	18.85
SE(m)±			0.39	0.17	0.19	0.26	0.35	0.22
CD at 5 %			1.13	0.50	0.54	0.74	1.01	0.63
(b) Integrated plant nutrient system								
	Soybean	Cotton						
T ₁	Control	Control	23.69	20.62	23.24	24.58	22.21	19.02
T ₂	100 % RDF	100 % RDF	23.78	20.88	23.28	24.67	22.28	19.10
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	24.65	22.61	24.86	25.58	23.67	19.70
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	23.93	21.25	24.12	24.75	22.83	19.19
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	24.32	21.58	24.55	25.49	23.38	19.55
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	24.08	21.43	24.29	25.29	23.13	19.24
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	24.13	21.31	23.85	25.16	23.07	19.18
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	24.51	21.48	24.33	25.39	23.22	19.39
SE(m)±			0.78	0.34	0.38	0.51	0.70	0.44
CD at 5 %			NS	1.00	1.08	NS	2.02	NS
(c) Interaction effect			NS	NS	NS	NS	NS	NS

I. Soil moisture content at various growth stages of cotton as influence by tillage and IPNS under soybean-cotton rotation

Treatments			Soil moisture content (%)					
(a)Tillage			Sowing	Square formation	Flowering	Boll develop	50% Boll bursting	At last picking
Set I-Conservation tillage			22.68	21.94	21.15	23.67	23.10	18.88
Set II –Conventional tillage			21.38	19.18	19.53	21.50	21.47	16.12
SE(m)±			0.20	0.26	0.39	0.32	0.21	0.21
CD at 5 %			0.57	0.76	1.13	0.93	0.61	0.62
(b) Integrated plant nutrient system								
Soybean		Cotton						
T ₁	Control	Control	21.63	17.91	19.02	20.37	21.90	16.80
T ₂	100 % RDF	100 % RDF	21.64	20.36	19.77	22.56	21.94	17.66
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	22.74	22.01	21.29	23.57	23.11	17.83
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	21.89	20.26	21.15	23.03	22.09	17.45
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	22.21	20.78	21.16	23.29	22.76	17.44
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	22.00	20.62	20.06	22.27	21.96	17.50
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	22.10	20.74	20.00	22.19	22.36	17.56
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	22.66	21.79	20.26	23.16	22.90	17.78
SE(m)±			0.39	0.52	0.78	0.65	0.42	0.43
CD at 5 %			NS	1.52	2.25	1.87	NS	NS
(c) Interaction effect			NS	NS	NS	NS	NS	NS

Annexure-IV

J. Effect of tillage and IPNS on nutrients content by soybean under soybean-cotton rotation

Treatments			N content (%)		P content (%)		K content (%)		S content (%)	
(a)Tillage			Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Set I-Conservation tillage			5.73	0.76	0.40	0.14	0.79	0.95	0.47	0.25
Set II -Conventional tillage			5.64	0.75	0.38	0.12	0.76	0.93	0.42	0.23
SE(m)±			0.07	0.01	0.004	0.002	0.006	0.005	0.009	0.004
CD at 5 %			NS	NS	NS	NS	0.017	0.014	0.025	0.011
(b) Integrated plant nutrient system										
	Soybean	Cotton								
T ₁	Control	Control	4.99	0.67	0.32	0.10	0.70	0.84	0.41	0.21
T ₂	100 % RDF	100 % RDF	5.55	0.75	0.39	0.13	0.78	0.93	0.46	0.25
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	5.88	0.78	0.41	0.15	0.80	0.97	0.47	0.26
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	5.58	0.70	0.38	0.11	0.77	0.92	0.41	0.23
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	5.72	0.77	0.40	0.14	0.78	0.95	0.45	0.24
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	5.53	0.74	0.38	0.12	0.77	0.93	0.40	0.22
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	5.97	0.79	0.42	0.15	0.79	0.96	0.49	0.26
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	6.26	0.86	0.43	0.16	0.81	0.98	0.50	0.28
SE(m)±			0.13	0.03	0.009	0.002	0.012	0.009	0.017	0.008
CD at 5 %			0.38	0.07	0.025	0.012	0.035	0.027	0.050	0.022
(c) Interaction effect			NS	NS	NS	NS	NS	NS	NS	NS

K. Effect of tillage and IPNS on nutrients content by cotton under soybean-cotton rotation

Treatments			N content (%)		P content (%)		K content (%)		S content (%)	
(a)Tillage			Seed	Stalk	Seed	Stalk	Seed	Stalk	Seed	Stalk
Set I-Conservation tillage			1.80	1.20	0.65	0.31	1.31	1.67	0.61	0.26
Set II -Conventional tillage			1.70	1.11	0.59	0.26	1.25	1.60	0.56	0.23
SE(m)±			0.023	0.010	0.010	0.003	0.011	0.012	0.008	0.004
CD at 5 %			0.067	0.030	0.030	0.009	0.032	0.033	0.022	0.010
(b) Nutrient management										
	Soybean	Cotton								
T ₁	Control	Control	1.56	1.05	0.55	0.23	1.21	1.57	0.51	0.20
T ₂	100 % RDF	100 % RDF	1.91	1.15	0.60	0.25	1.29	1.62	0.56	0.21
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	1.89	1.21	0.65	0.32	1.32	1.67	0.61	0.30
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	1.65	1.17	0.64	0.29	1.27	1.65	0.60	0.26
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	1.74	1.18	0.62	0.30	1.31	1.64	0.59	0.26
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	1.65	1.13	0.60	0.27	1.25	1.63	0.58	0.22
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	1.79	1.19	0.66	0.30	1.28	1.65	0.64	0.26
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	1.82	1.17	0.64	0.32	1.29	1.66	0.62	0.27
SE(m)±			0.046	0.020	0.020	0.007	0.022	0.023	0.015	0.007
CD at 5 %			0.134	0.028	0.029	0.019	0.063	0.067	0.045	0.021
(c) Interaction effect			NS	NS	NS	NS	NS	NS	NS	NS

L. Effect of IPNS on apparent nutrient balance in conservation tillage by soybean and cotton under soybean-cotton rotation

	Integrated plant nutrient system		N			P			K		
	Soybean	Cotton	Addition	Removal	Balance	Addition	Removal	Balance	Addition	Removal	Balance
T ₁	Control	Control	0	151	-151	0	18.59	-18.59	0	75.10	-75.10
T ₂	100 % RDF	100 % RDF	90	219	-130	105	29.54	75.46	60	108.99	-48.99
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	90	243	-153	105	36.56	68.44	60	124.81	-64.81
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	90	210	-121	105	30.41	74.59	60	106.26	-46.26
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	90	229	-139	105	33.47	71.53	60	114.67	-54.67
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	90	204	-114	105	28.29	76.71	60	107.53	-47.53
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	90	243	-153	105	34.06	70.94	60	115.25	-55.25
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	90	267	-176	105	37.16	67.84	60	127.13	-67.13

M. Effect of IPNS on apparent nutrient balance in conventional tillage by soybean and cotton under soybean-cotton rotation

	Integrated plant nutrient system		N (kg ha ⁻¹)			P (kg ha ⁻¹)			K (kg ha ⁻¹)		
	Soybean	Cotton	Addition	Removal	Balance	Addition	Removal	Balance	Addition	Removal	Balance
T ₁	Control	Control	0	126	-126	0	14.25	-14.25	0	67	-61.93
T ₂	100 % RDF	100 % RDF	90	195	-105	105	24.84	80.16	60	97	-37.13
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	90	213	-123	105	28.21	76.79	60	102	-42.44
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	90	182	-92	105	23.17	81.83	60	90	-30.54
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	90	207	-117	105	27.73	77.27	60	104	-44.32
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	90	186	-96	105	23.68	81.32	60	90	-30.47
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	90	222	-132	105	28.92	76.08	60	103	-43.80
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	90	230	-140	105	30.32	74.68	60	109	-48.80

Annexure-V

N. Principal Components Analysis (PCA) based on 24 soil parameters under conservation tillage

Sr. No	Soil parameters	PC1	PC2	PC3	PC4
1	Bulk density	0.873	0.291	0.017	0.142
2	Hydraulic Conductivity	0.823	0.050	0.268	0.286
3	Mean Weight Diameter	0.764	0.044	0.264	0.133
4	Soil Moisture at square formation stage	0.685	0.247	0.065	0.043
5	Soil Moisture at Flowering	0.792	0.214	0.159	0.047
6	Soil Moisture at boll development	0.821	0.279	0.110	0.202
7	pH	0.268	0.306	0.272	0.793
8	Electrical conductivity	0.618	0.299	0.316	0.039
9	Organic carbon	0.863	0.396	0.077	0.174
10	Available N	0.836	0.204	0.416	-0.007
11	Available P	0.842	0.470	0.260	0.153
12	Available K	0.749	0.371	0.340	0.100
13	Available S	0.559	0.038	0.070	0.073
14	Available Zn	0.817	0.101	0.271	0.302
15	Available Fe	0.766	0.082	0.163	0.009
16	Available Mn	0.788	0.092	0.068	0.027
17	Available Cu	0.670	0.234	0.522	0.232
18	AMMo. N	0.918	0.071	0.011	0.038
19	Nitrate N	0.832	0.334	0.316	0.119
20	MINER N	0.940	0.199	0.142	0.078
21	SMBC	0.904	0.029	0.247	0.029
22	DHA	0.920	0.159	0.079	0.258
23	CO ₂ evolution	0.873	0.091	0.132	0.112
24	SOC	0.583	0.494	0.209	0.155

Note -Extraction Method: Principal Component Analysis four components were extracted.

O. Principal Components Analysis (PCA) based on 24 soil parameters under conventional tillage

Sr. No	Soil parameters	PC1	PC2	PC3	PC4
1	Bulk density	0.889	0.252	0.022	0.151
2	Hydraulic Conductivity	0.839	0.197	0.078	0.075
3	Mean Weight Diameter	0.744	0.043	0.252	0.001
4	Soil Moisture at square formation stage	0.740	0.059	0.279	0.040
5	Soil Moisture at Flowering	0.648	0.386	0.277	0.175
6	Soil Moisture at boll development	0.748	0.148	0.190	0.152
7	pH	0.048	0.110	0.234	0.785
8	Electrical conductivity	0.457	0.575	0.107	0.176
9	Organic carbon	0.943	0.499	0.303	0.152
10	Available N	0.871	0.022	0.049	0.127
11	Available P	0.756	0.111	0.060	0.127
12	Available K	0.893	0.134	0.064	0.104
13	Available S	0.369	0.226	0.733	0.076
14	Available Zn	0.849	0.067	0.054	0.267
15	Available Fe	0.428	0.664	0.230	0.100
16	Available Mn	0.572	0.163	0.153	0.570
17	Available Cu	0.748	0.492	0.253	0.122
18	AMMo. N	0.888	0.074	0.244	0.083
19	Nitrate N	0.937	0.010	0.263	0.021
20	MINER N	0.942	0.030	0.263	0.041
21	SMBC	0.925	0.089	0.247	0.130
22	DHA	0.950	0.069	0.049	0.049
23	CO ₂ evolution	0.895	0.201	0.090	0.167
24	SOC	0.461	0.623	0.332	0.067

Note -Extraction Method: Principal Component Analysis four components were extracted.

P. Correlation matrix (Pearson's coefficients) under PC's with high factor loadings under conservation tillage

Variables	BD	HC	OC	AN	AP	SMBC	DHA	CO ₂
BD	1.000	0.474	0.870	0.646	0.789	0.814	0.664	0.771
HC	0.474	1.000	0.525	0.626	0.530	0.478	0.671	0.562
OC	0.870	0.525	1.000	0.654	0.689	0.783	0.632	0.749
AN	0.646	0.626	0.654	1.000	0.778	0.638	0.728	0.726
AP	0.789	0.530	0.689	0.778	1.000	0.786	0.767	0.785
SMBC	0.814	0.478	0.783	0.638	0.786	1.000	0.780	0.856
DHA	0.664	0.671	0.632	0.728	0.767	0.780	1.000	0.885
CO₂	0.771	0.562	0.749	0.726	0.785	0.856	0.885	1.000
Correlation sum	6.026	4.867	5.900	5.796	6.124	6.135	6.127	6.333

Q. Correlation matrix (Pearson's coefficients) under PC's with high factor loadings under conventional tillage

Variables	BD	HC	OC	AN	AP	SMBC	DHA	CO ₂
BD	1.000	0.635	0.812	0.792	0.821	0.762	0.825	0.766
HC	0.635	1.000	0.566	0.670	0.804	0.725	0.823	0.761
OC	0.812	0.566	1.000	0.605	0.677	0.652	0.745	0.595
AN	0.792	0.670	0.605	1.000	0.837	0.724	0.818	0.783
AP	0.821	0.804	0.677	0.837	1.000	0.820	0.894	0.872
SMBC	0.762	0.725	0.652	0.724	0.820	1.000	0.865	0.794
DHA	0.825	0.823	0.745	0.818	0.894	0.865	1.000	0.825
CO₂	0.766	0.761	0.595	0.783	0.872	0.794	0.825	1.000
Correlation sum	6.412	5.984	5.652	6.228	6.726	6.342	6.794	6.396

R. Relationship between soil properties and Soybean grain (n= 24) under conservation tillage

	Soybean seed yield	BD	HC	OC	AN	AP	SMBC	DHA	CO₂
Soybean seed yield	1.000								
BD	-0.730**	1.000							
HC	0.428*	-0.474*	1.000						
OC	0.634**	-0.870**	0.523**	1.000					
AN	0.745**	-0.646**	0.625**	0.654**	1.000				
AP	0.800**	-0.789**	0.529**	0.689**	0.778**	1.000			
SMBC	0.801**	-0.812**	0.471*	0.780**	0.632**	0.782**	1.000		
DHA	0.641**	-0.664**	0.675**	0.631**	0.728**	0.767**	0.778**	1.000	
CO₂ evolution	0.728**	-0.771**	0.563**	0.749**	0.726**	0.785**	0.854**	0.885**	1.000

* Significant at 5% level , ** Significant at 1% level

S. Relationship between soil properties and seed cotton yield (n= 24) under conservation tillage

	Seed cotton yield	BD	HC	OC	AN	AP	SMBC	DHA	CO₂
Seed cotton yield	1.000								
BD	-0.609**	1.000							
HC	0.465*	-0.474*	1.000						
OC	0.466*	-0.870**	0.523**	1.000					
AN	0.832**	-0.646**	0.625**	0.654**	1.000				
AP	0.731**	-0.789**	0.529**	0.689**	0.778**	1.000			
SMBC	0.655**	-0.812**	0.471*	0.780**	0.632**	0.782**	1.000		
DHA	0.612**	-0.664**	0.675**	0.631**	0.728**	0.767**	0.778**	1.000	
CO₂ evolution	0.603**	-0.771**	0.563**	0.749**	0.726**	0.785**	0.854**	0.885**	1.000

* Significant at 5% level , ** Significant at 1% level

T. Relationship between soil properties and Soybean grain (n= 24) under conventional tillage

	Soybean seed yield	BD	HC	OC	AN	AP	SMBC	DHA	CO₂
Soybean seed yield	1.000								
BD	-0.728**	1.000							
HC	0.661**	-0.644**	1.000						
OC	0.386 *	-0.815**	0.572**	1.000					
AN	0.792**	-0.792**	0.674**	0.605**	1.000				
AP	0.736**	-0.824**	0.811**	0.677**	0.836**	1.000			
SMBC	0.567**	-0.766**	0.728**	0.651**	0.721**	0.821**	1.000		
DHA	0.654**	-0.830**	0.827**	0.745**	0.818**	0.894**	0.864**	1.000	
CO₂ evolution	0.804**	-0.765**	0.759**	0.595**	0.783**	0.872**	0.793**	0.825**	1.000

* Significant at 5% level , ** Significant at 1% level

U. Relationship between soil properties and seed cotton yield (n= 24) under conventional tillage

	Seed cotton yield	BD	HC	OC	AN	AP	SMBC	DHA	CO₂
Seed cotton yield	1.000	-0.750**							
BD	-0.750**	1.000							
HC	0.489*	-0.644**	1.000						
OC	0.462*	-0.815**	0.572**	1.000					
AN	0.725**	-0.792**	0.674**	0.605**	1.000				
AP	0.679**	-0.824**	0.811**	0.677**	0.836**	1.000			
SMBC	0.590**	-0.766**	0.728**	0.651**	0.721**	0.821**	1.000		
DHA	0.606**	-0.830**	0.827**	0.745**	0.818**	0.894**	0.864**	1.000	
CO₂ evolution	0.813**	-0.765**	0.759**	0.595**	0.783**	0.872**	0.793**	0.825**	1.000

* Significant at 5% level , ** Significant at 1% level

Annexure-VI

V. Effect of tillage and IPNS on economics by soybean and cotton under soybean-cotton rotation

			Soybean			Cotton		
	(a) Tillage		GMR	NMR	B:C Ratio	GMR	NMR	B:C Ratio
	Set I-Conservation tillage		74852	29286	1.77	70048	17713	1.34
	Set II -Conventional tillage		68445	22879	1.51	63009	6342	1.12
	SE(m)±		668	668	0.015	566	566	0.011
	CD at 5 %		1929	1929	0.044	1637	1637	0.032
	(b) Integrated plant nutrient system							
	Soybean	Cotton						
T ₁	Control	Control	56345	20056	1.63	44320	-430	0.99
T ₂	100 % RDF	100 % RDF	71829	25234	1.62	69541	10041	1.18
T ₃	50 % N through FYM + remaining RD through chemical fertilizer	50 % N through FYM + remaining RD through chemical fertilizer	77813	30299	1.80	72544	21014	1.44
T ₄	50% N through WS+ remaining RD through chemical fertilizer	50% N through WS+ remaining RD through chemical fertilizer	70224	23005	1.56	62884	8100	1.15
T ₅	50% N through GLM + remaining RD through chemical fertilizer	50% N through GLM + remaining RD through chemical fertilizer	74407	29418	1.66	71993	18921	1.36
T ₆	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	50 % N through composted cotton stalk+ remaining RD through chemical fertilizer	68583	23621	1.48	65406	7383	1.12
T ₇	50 % N through vermicompost+ remaining RD through chemical fertilizer	50 % N through vermicompost+ remaining RD through chemical fertilizer	75686	26665	1.60	70989	9046	1.16
T ₈	100 % N through phoshpocompost+ remaining P through chemical fertilizer	100 % P through phoshpocompost+ remaining N through chemical fertilizer	78302	30363	1.75	74549	22146	1.43
	SE(m)±		1336	1336	0.030	1133	1133	0.022
	CD at 5 %		3859	3859	0.087	3275	3275	0.064
	(c) Interaction effect		NS	NS	NS	NS	NS	NS