

**INFLUENCE OF CONSERVATION AND
CONVENTIONAL TILLAGE ON BIOLOGICAL
DYNAMICS OF SOIL AND ROOTING
BEHAVIOUR OF COTTON IN VERTISOL**

THESIS

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Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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IN
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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretations of the Thesis entitled **“INFLUENCE OF CONSERVATION AND CONVENTIONAL TILLAGE ON BIOLOGICAL DYNAMICS OF SOIL AND ROOTING BEHAVIOUR OF COTTON 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.

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CERTIFICATE

This is to certify that thesis entitled **“INFLUENCE OF CONSERVATION AND CONVENTIONAL TILLAGE ON BIOLOGICAL DYNAMICS OF SOIL AND ROOTING BEHAVIOUR OF COTTON IN VERTISOL”** submitted in partial fulfilment of the requirements for the degree of **“Master of Science in Agriculture (Soil Science and Agricultural Chemistry)”** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is a record of bonafide research work carried out by **GOPNARAYAN MRUNALI DILIP** under my guidance and supervision.

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(D)**Abbreviations**

%	-	per cent
/	-	Per
@	-	at the rate of
AICRP	-	All India Coordinated Research Project
BD	-	Bulk density
°C	-	Degree Celsius
CD	-	Critical difference
cm	-	Centimeter
DAS	-	Days after sowing
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
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
t ha ⁻¹	-	tonne per hectare
µg	-	Microgram
<i>viz.</i>	-	<i>videlicet</i> (namely)
yr ⁻¹	-	per year

(F)**THESIS ABSTRACT**

- a. Title of the thesis : **INFLUENCE OF CONSERVATION AND CONVENTIONAL TILLAGE ON BIOLOGICAL DYNAMICS OF SOIL AND ROOTING BEHAVIOUR OF COTTON IN VERTISOL.**
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ABSTRACT

The present investigation was conducted during 2017-18 with a view to study the “Influence of conservation and conventional tillage on biological dynamics of soil and rooting behavior of cotton in Vertisols” at Research farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2017-18 with object to assess the influence of conservation and conventional tillage on

biological dynamics and rooting behavior of cotton in Vertisols and to study the influence of conservation and conventional tillage on seed cotton yield.

The experiment was carried out with main plot comprises two treatments i.e. conservation tillage (one harrowing and two weeding) and in conventional tillage (one ploughing and one harrowing, two hoeing and two hand weeding) and eight sub plot treatments of integrated nutrient management 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, green leaf manuring, cotton straw, vermicompost and phosphocompost) and remaining N was applied through chemical fertilizer were given.

The soil samples were collected initially at the start of experiment and after harvest of cotton and analyzed for chemical and biological properties of the soil. Plants were uprooted and analyzed for root length and root volume. The treatment wise seed cotton yield was recorded

The use of organics *viz.* FYM, glyricidia, vermicompost and phosphocompost in conjunction with chemical fertilizers recorded improvement in chemical properties *viz* soil organic carbon, available macro and secondary nutrients like N, P, K, and S under conservation tillage. The biological properties *viz.* SMBC, SMBN, CO₂ evolution and DHA were improved under INM treatments comprising use of FYM, phosphocompost and vermicompost in combination with 50 % RDF as compared to chemical fertilizers alone and control under conservation tillage. Highest seed cotton yield was recorded under conservation tillage in phosphocompost and vermicompost in conjunction with chemical fertilizers.

The rooting behavior of cotton was also studies and found significant under conservation tillage with INM treatments of FYM, phosphocompost and vermicompost.

Therefore, it can be concluded that combined use of FYM, phosphocompost and vermicompost along with 50% recommended dose of inorganic fertilizers was indispensable to improve the efficiency of applied organics and fertilizers, thereby enhancing various properties and microbial activity in soil and productivity of crops in long run.

CHAPTER I

INTRODUCTION

1.1 Background Information

Conservation agriculture (CA), disturbing the soil as little as possible, keeping the soil covered, mixing and rotating crops, is been discussed to be a potential remedy to soil degradation. Soil quality improvement by conservation agriculture is an important determinant of soil fertility, productivity and sustainability. It is a useful indicator of soil quality. Residue retention and reduced tillage are both CA management options that may enhance soil organic carbon (SOC) stabilization. CA aims to address the problems in soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil (Giller et al., 2009). No-till improves soil quality (soil function), carbon, organic matter, aggregates, protect the soil from erosion, evaporation of water and structural breakdown (Araya et al., 2012). Reduction in tillage possess helps to prevent compaction of soil. Recently, researchers found that no-till farming makes soil much more stable than ploughed soil (Li et al., 2011). In addition, No-till stores more carbon in the form of organic matter, it is a key factor in holding soil particles together. The crop residue left on the soil surface limits evaporation, conserving water for plant growth (Thierfelder and Wall, 2009). Attaining food security for a growing population and alleviating poverty while sustaining agricultural systems under the current scenario of depleting natural resources, negative impacts of climatic variability, spiraling cost of inputs and volatile food prices are the major challenges before most of the Asian countries. In addition to these challenges, the principal indicators of non-sustainability of agricultural systems includes: soil erosion, decline in soil organic matter, salinization. These are mainly caused by: (i) intensive tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, (ii) insufficient return of organic material, and (iii) monocropping. Therefore, a paradigm shift in farming practices through eliminating unsustainable parts

of conventional agriculture (ploughing/tilling the soil, removing all organic material, monoculture) is crucial for future productivity gains while sustaining the natural resources. Conservation agriculture (CA), a concept evolved as a response to concerns of sustainability of agriculture globally, has steadily increased worldwide to cover about ~8% of the world arable land (124.8 M ha) (FAO, 2012). CA is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition (Abrol and Sangar, 2006). It stresses the very beneficial impacts of a conservative way of cultivation on the global environment (soil, air, water and biodiversity), compared to traditional agriculture (Derpsch et al., 2010; Derpsch et al., 2011).

CA promotes soils to have a richer bioactivity and biodiversity, a better structure and cohesion and a very high natural physical protection against weather (raindrops, wind, dry or wet periods). Soil erosion is therefore highly reduced, soil agronomic inputs transport slightly reduced, while pesticide bio-degradation is enhanced. It protects surface and ground water resources from pollution and also mitigates negative climate effects. It is an efficient alternative to traditional agriculture, attenuating its drawbacks.

Cotton Scenario

Cotton is one of the most important cash crops and accounts for around 25% of the total global fibre production. Cotton is also one of the most important commercial crops cultivated in India. In the raw material consumption basket of the Indian textile industry, the proportion of cotton is around 59%. It plays a major role in sustaining the livelihood of an estimated 5.8 million cotton farmers and 40- 50 million people engaged in related activities such as cotton processing and trade. India also has the distinction of having the largest area under cotton cultivation in the world i.e. about 11 million hectares.

Production & Consumption:

India is the country to grow all four species of cultivated cotton *Gossypium arboreum* and *herbaceum* (Asian cotton), *G. barbadense* (Egyptian cotton) and *G. hirsutum* (American Upland cotton). *Gossypium hirsutum* represents 88% of the hybrid cotton production in India and all the current Bt cotton hybrids are *G. hirsutum*. In India, majority of the cotton production comes from nine major cotton growing states, which are grouped into three diverse agro-ecological zones, Northern zone comprising states of Punjab, Haryana and Rajasthan, Central zone comprising the states of Gujarat, Maharashtra and Madhya Pradesh and Southern zone comprising the states of Telangana, Andhra Pradesh and Karnataka. Besides this, cotton is also grown in the States of Tamil Nadu and Orissa. Cotton cultivation has also gained momentum in small areas of non-traditional states such as Uttar Pradesh, West Bengal, Tripura, etc. Production and productivity of cotton in India have improved significantly during the past decades. India is the largest producer and 2nd largest exporter of cotton in the World. India is also leading consumer of cotton. The details of production of cotton during the last 5 years is (in lakh bales) : 2011-12 – 367, 2012-13 – 370, 2013-14 – 398, 2014-15 – 386, 2015-16 – 338, and in 2016-17 – 351 (provisional as estimated by Cotton Advisory Board).

India got 1st place in the world in cotton acreage with around 118.77 lakh hectares under cotton cultivation i.e. around 39% of the world area. Approximately 62% of India's Cotton is produced on rain-fed areas and 38% on irrigated lands. In terms of productivity, India ranks poor compared to USA & China. During 2016-17, India's productivity of cotton was 568.29 kg/ha.

However cotton production is maximum in rainfed areas Maharashtra, Vidarbha is the largest cotton growing region of Maharashtra accounting for 12.37 lakh ha with production of 35 lakh bales. In Vidarbha, cotton is grown predominantly as a rainfed crop. In Vidarbha region about 89 per cent cultivable land is under rainfed farming and rainfed cotton crop production has direct bearing on the agrarian economy of the region.

The stagnation in the production and productivity of different crops for the last few years has become a matter of concern and is posing a serious threat to our national food security. Soil health degradation has emerged as a major factor responsible for stagnation in agricultural production. The degradation of soil health in many cultivated areas is manifested in terms of loss of soil organic matter, depletion of native soil fertility due to imbalanced and unscientific use of fertilizer which is now one of the major constraints in improving crop productivity. The burgeoning population, shrinking 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. Intensive cropping with increased use of NPK fertilizers have not only increased food production, but also resulted in the depletion of soil nutrients and reduction in soil productivity. The high yielding varieties / hybrids 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.

Most of the soils in India and Maharashtra are poor in nitrogen and organic matter. Particularly the soils of the cotton growing areas are low in organic carbon, nitrogen and available phosphorus (Rattan *et. al.*1999). Increase in production and productivity can be achieved only through enhanced soil fertility which can be sustained if the nutrients removed from soil are replenished by way of addition. Supplying the entire quantity of nutrients required for cotton through fertilizer may not be possible, hence nutrient requirement of cotton would have to be met through organic sources in combination with inorganic fertilizers.

Vertisols is an important soil order in semi-arid dryland agriculture because in this environment they are amongst the most productive soils. The major factor contributing to the productivity of Vertisols in semi-arid environments is their high-water holding capacity. However, low organic matter has been always the constraint in these soils.

Indian agriculture entering into a new phase. The major research and development efforts in the green revolution era focused on enhancing productivity of selected food grains and few other crops.

It is essential to develop strategies for utilizing all available organic resources and to develop crop management system for sustainable crop production. The soil and crop productivity are directly influenced by physical, chemical and biological properties. It is essential to evaluate basic soil characteristics for planning better land use.

1.2 Importance and need of study

The systematic study of soil physical, chemical and biological properties of soil under conservation and conventional tillage practices is necessary to create an evidence for evaluating the impact of these practices on soil quality and rooting behaviour of crop. The plant roots are normally hidden underground and performs various functions which are essential for growth and development. Roots provide anchorage and support such that plants are more resistant to toppling during storms.

In recent years conservation tillage concept has come in vogue, 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 rainfed production system. 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, 1989). Conservation tillage can rebuild organic carbon levels in soil and increases the carbon sequestration in soil (Novak *et al.*, 2009).

With the introduction of high yielding varieties and use of high analysis fertilizer in intensified agriculture resulted in green revolution in our country but continuous use of chemical fertilizers in indiscriminate manner without assessing soil also had adverse effect on productivity and environment. Under such situation integrated nutrient management and conservation tillage not only reduce the nutrient gap between addition and

removal, soil erosion, soil quality, degradation but also ensure high nutrient use efficiency, sustainability of the system and minimize environmental pollution.

Integrated nutrient management is an intelligent use of optimum combination of organic, inorganic and biological nutrient sources so as to achieve and sustain optimum crop yield and improve soil physical, chemical and biological properties. Adoption of integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity is extremely important for food and nutritional security in Indian agriculture. Many factors influence the complex chemical, physical and biological processes which govern soil fertility and productivity. Under such condition integrated plant nutrient supply and management is best future strategy for enhancing soil quality and crop productivity (Swarup, 2010).

The supplementary and complementary use of organic residues improves physico-chemical properties of soil and also 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. FYM improves, physical, chemical and biological environment thereby increasing the crop yield. 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. The fertility of the soil needs to be maintained through organic manure, crop residue incorporation with supplemental application of chemical fertilizer.

It is essential to develop strategies for utilizing all available organic resources and to develop crop management system for sustainable crop production. The soil and crop productivity are directly influenced by physical, chemical and biological properties. It is essential to evaluate basic soil characteristics for planning better land use. Efficient use of water and fertilizer is highly critical to sustain agricultural production and will continue

to occupy a dominant place in future to meet a projected growing demands matching with rapidly swelling population, more particularly in the context of declining per capita land, water availability, pollution, degradation and increasing fertilizer cost etc.

In this context, the present investigation has been planned to study the influence of conservation and conventional tillage on biological dynamics and rooting behaviour of cotton in Vertisol during 2017-18.

1.3 Objectives:

The present investigation was therefore conducted to study the **“Influence of conservation and conventional tillage on biological dynamics of soil and rooting behaviour of cotton in Vertisol”** with the following objectives:

- To assess the influence of conservation and conventional tillage on biological dynamics and rooting behavior of cotton in vertisol.
- To study the influence of conservation and conventional tillage on seed cotton yield.

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.* bulk density, particle density, hydraulic conductivity increases with the application of crop residues along with fertilizers, whereas bulk density decreases. The chemical properties namely organic carbon content, available nutrients enhances with the application of crop residues supplemented with chemical fertilizers. The biological properties are improved due to organics and helps in nutrient transformations useful for good soil health.

Conservation tillage increases organic carbon content in soil with increasing carbon sequestration and influencing majority of soil physical, chemical and biological properties. Soil structure improved due to minimum disturbance and also improvement in soil aggregation. The biological properties like SMBC, DHA and SMBN increase along with the use of FYM, crop residue and green manuring in conservation tillage.

It is essential to build up the organic matter status of the soil 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 long term soil fertility and crop productivity is by integrated use of inorganic and organic sources of plant nutrients and adoption of conservation tillage.

1.5 Scope and limitation

The conservation tillage and integrated nutrient management in Vertisols has wide scope. This practice has scope for build-up of soil organic matter and ultimately augmenting the soil fertility and soil quality. It will also be useful in conserving moisture and reducing soil erosion and nutrient loss there by sustain the crop yields as well as soil health. It reduces time, labour and machine operation as well as conserving moisture, reducing soil erosion and nutrient loss there by sustaining the crop yields as well as soil health.

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.

The continuous addition of chemical fertilizers possess problems like toxicity due to high amount of salts as a residues of fertilizers, deterioration of physical properties of soil, impacting the aeration and soil water relationship which results in decreased production. Available evidences indicated that, balanced use of chemical fertilizer alone cannot improve the soil productivity under continuous cropping whereas, inclusion of organic manure or bio manures as well as micronutrients improves the quality, yield and physical status of soil.

Conservation tillage entails a systems approach to farming and involves techniques for management of various multidisciplinary strategies.

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 and enhancing crop yields. The conservation agriculture practices although have been found very useful elsewhere in the light texture soils, the intensity of tillage needs to be systematically studied in heavy black soils. A comparison made in the present study between conventional tillage and conservation tillage practices is most appropriate platform to develop database in this regard.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made to review which are described under the “Influence of conservation and conventional tillage on biological dynamics and rooting behaviour of cotton in Vertisol” following appropriate heads.

- 2.1 Effect of tillage and nutrient management on soil properties
 - 2.1.1 Chemical properties
 - 2.1.2 Biological properties
- 2.2 Effect of tillage and nutrient management on root growth contributing characters
- 2.3. Effect of tillage and nutrient management on nutrient content of soil.
- 2.4 Effect of tillage and nutrient management on seed cotton yield.

2.1 Effect of tillage and nutrient management on soil properties

2.1.2 Chemical properties

2.1.2.1 Tillage

2.1.2.2 Integrated nutrient management

Sharma et al. (2000) studied on crop yield and properties of Inceptisol as influenced by residual management under rice-wheat cropping sequence and reported that, decreased in pH of soil was recorded in residues and FYM incorporated treatments. The effect was more pronounced with the application of FYM.

Babhulkar et al. (2000) studied on residual effect of long term application of FYM and fertilizers on soil properties and reported that, the content of organic carbon (6.2 g kg^{-1}), total nitrogen (0.056 per cent), available phosphorus (21.21 kg ha^{-1}) and available potassium (390 kg ha^{-1})

were higher in treatment receiving 15:30 NP + 7.5 t FYM ha⁻¹ after harvest of soybean crop. It might be due to addition of FYM which help to stimulate the growth activity of microorganisms. This effect was further enhanced by addition of N and P resulting in the improvement in root and shoot growth. Higher production of biomass might have increased the organic carbon content. Amongst the cropping sequence soybean followed by gram was superior sequence with respect to organic carbon (5.5 g kg⁻¹), available phosphorus (17.81 kg ha⁻¹) and available potassium (355 kg ha⁻¹).

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.

Bellakki and Badanur (2000) observed that the soil pH and EC were not influenced significantly with the incorporation of sorghum stubbles alone or in combination with cellulolytic organisms A and B and other treatments whereas, He also 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. He further noticed significantly highest organic carbon content in stubbles + leuceana loppings @ 5 t ha⁻¹ which was at par with sorghum stubbles @ 5 t ha⁻¹ , sorghum stubbles @ 5 t ha⁻¹ + 30 kg N and sorghum stubbles @ 5 t ha⁻¹ + cellulolytic organisms A. In another set of experiment,.

Lal *et al.* (2000) revealed that mineralization of organic sulphur due to decomposition of organic material also resulted in enhanced availability of sulphate sulphur in soil.

Ghosh *et al.* (2001) noted that there was a drop in pH in NPK treatment due to acid equivalent in the inorganic fertilizer in soybean-wheat cropping systems from last five years average .He also reported that organic carbon was maintained in NPK treated plots or slightly increased due to huge biomass / leaf fall of soybean. Organic carbon has increased significantly in FYM treated plot in last five years average in soybean-wheat cropping system.

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. also found slight reduction in CaCO₃ content of Vertisol with organic manure in combination with inorganic fertilizer over control.

Reddy *et al.* (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 for experimentation and 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. He observed that organic carbon content increased from 5.73 to 7.53 per cent due to addition of organic manures alone and from 6.92 to 9.52 per cent in combination with fertilizers as compared with RDF.

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.

Bharambe *et al.* (2002) reported that the effect of crop residue management in improving the soil characteristics persist increase organic carbon after the harvest of second crop in a soybean-sorghum

sequence. He also reported that the crop residue improved the soil properties such as increased per cent stable aggregates >0.25 mm, infiltration rate, and available potassium in soil at the harvest of second crop in soybean-sorghum sequence.

Prakash *et al.* (2002) reported an increase in pH from 5.5 to 6.2 in acid laterite soil through treatment with farmyard manure.

Ismail *et al.* (2002) reported significant buildup of Fe, Zn, Mn and Cu in Vertisol in the treatment receiving 50 per cent RDF + 5 Mg FYM ha⁻¹ as compared to application of RDF or FYM alone, whereas depletion of the micronutrient content was noticed in control.

More and Hangarge (2003) reported decrease in pH from 8.00 to 7.85 with application crop residue under cotton-sorghum rotation and application of crop residue as source of nutrient increases the organic carbon (0.75 %) in soil as compared to other nutrient sources.

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 increase in CEC, organic carbon and total N content of soil due to incorporation of organic with inorganics. There was no marked changes in soil pH and EC due to various treatments.

Bangar *et al.* (2003) reported that in different cropping sequences available N was highest under cowpea (166 kg ha⁻¹). 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).

Rathod *et al.* (2003) reported that the pH of the sodic soil was reduced significantly by application of FYM at 5 tonnes per ha which was on par with the pH value that had been reduced by 50 per cent gypsum

requirement. Similarly electrical conductivity was also found to be reduced significantly by application of the FYM.

Tolanur and Badanur (2003 a) reported that the organic carbon content, available N, P and K were significantly influenced by the use of 50 per cent N through organic manure in conjunction with 50 per cent RDF through chemical fertilizer under pearl millet- pigeon pea cropping systems in Inceptisol. They further (Tolanur and Badanur, 2003b) reported that the organic carbon and available N status declined with the application of fertilizer N alone and increased with conjunctive use of fertilizer N and organic manure. The combined application of organic and inorganic N sustained the productivity. Soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizers alone.

Guled *et al.* (2003) conducted field experiment at Regional Research Station, Bijapur on Typic Chromustert for four years from 1998-2002, to know the influence of organic and inorganic fertilizer on rabi sorghum - sunflower yearly rotational cropping system. Results of two years indicated that application of FYM @ 5 t ha⁻¹ with inorganic fertilizer and *in situ* incorporation of sunhemp with inorganic fertilizer significantly increased the uptake of sulphur. The highest uptake of sulphur (3.44 kg ha⁻¹) in haulm of sorghum was obtained with FYM @ 5t ha⁻¹ application. The uptake pattern of nutrients is an indication of grain yield vis-a-vis crop productivity

Kademani *et al.* (2003) conducted research in Vertisol at Water Management Research Center, Belavatagi in Malaprabha Command during rabi 1999-2000 to study the integrated effect of organic and inorganic sources of nutrients on uptake of nutrients by sunflower and their availability after harvest. The organic sources included were maize residue, cotton stock, FYM each @ 5 t ha⁻¹ and vermicompost @ 2 t ha⁻¹. S in soil at harvest of crop was highest with application of vermicompost @ 2 t ha⁻¹ followed by FYM 5 t 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.

Halemani *et al.* (2004)^a recorded significantly higher soil organic carbon content with the application of FYM alone @ 10 t ha⁻¹ followed by FYM + crop residues and FYM + in situ green manuring as compared to fertilizer application and control. Further, they reported that the application of FYM @ 10 t ha⁻¹ resulted in significantly highest organic carbon followed by FYM @ 5 t + crop residues 2.5 t ha⁻¹

Murillo *et al.* (2004) conducted experiment in a wheat-sunflower crop rotation established in 1991 under rainfed conditions in south-west Spain, correspond to the years 2001 (sunflower) and 2002 (wheat). The results show that, under studied conditions, Conservation tillage (CT) improved soil quality by reaching a greater SR (> 2) than that in traditional tillage (TT) (< 2) (SR > 2 indicates better soil quality), decreasing the loss of CaCO₃ and increasing the P and K contents at the soil surface (0-5 cm and 5-10 cm). Crop performance was in general better under CT than under TT. Long-term CT was effective in improving soil fertility as compared to TT. The mean soil organic matter (SOM) in 0-10cm soil layer for CT was 21.7% and 10.5% higher than for TT in Linfen (after 16 years) and Beijing (after 8 years). In Wuchuan, the mean SOM in the 0-10cm layer was 16.5g/kg for CT after 10 years, which was significantly greater than the 13.4g/kg observed on TT. The SOM difference between CT and TT declined in the deeper layers, but were still significant at 20cm depth. The SOM increases resulting from conservation tillage are attributed to the greater straw input and reduced biological oxidation associated with less soil disturbance. Tillage-induced changes in soil organic N are directly related to changes in soil organic C. In Beijing, total N (TN) in 0-10cm and

10-20cm layers was 24.3% and 18.6% higher for CT than for TT after 8 years.

Surekha *et al.* (2004) noticed 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. The available K increased significantly with incorporation of straw or its ash (440-519 kg ha⁻¹) over control (377 kg ha⁻¹) with no significant change in available N and P. The soil organic carbon (SOC) content and soil respiration rate increased significantly in all the crop residue treatments over control with maximum values in straw + GM treatment.

Verma *et al.* (2005) conducted field experiments during 2000-01 and 2001-02 on clay loam at Udaipur to assess the effect of nutrient application through different sources in maize-wheat cropping sequence. A marked build-up of available P and S 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.

Chaturvedi and Chandel (2005) studied the 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 terms 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.

Soniya Thakare *et al.* (2005) conducted long-term field experiment after 15th cycle for long-term changes in soil properties and nutrient availability under sorghum-wheat cropping sequence at Dr. PDKV, Akola since 1988. Amongst the various treatments, the treatment of 100

per cent NPK + 10 t FYM ha⁻¹ recorded a build up in organic carbon, available and total N and P and S content in soil after 14th cycle. The next superior treatment is 150 per cent NPK, hence the fertilizer dose along with FYM proved superior in built of organic carbon content and nutrient availability in the soil.

Pathak *et al.* (2005) noticed that all the organic sources were instrumental in improving pH and aggregation of soils. 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.

Varalakshmi *et al.* (2005) recorded significant increase in the organic carbon content after groundnut and finger millet crops in treatments where FYM applied along with inorganic fertilizers. The highest organic carbon content was recorded in the treatment of 100% RDF + 7.5 t ha⁻¹ after the harvest of groundnut (9.5 g kg⁻¹) and after the harvest of finger millet (10.4 g kg⁻¹). The significantly highest available N and P were recorded in the treatment of package of practices where 100 % recommended dose of fertilizer along with 7.5 t ha⁻¹ FYM after finger millet and groundnut. In respect of available K, the STCR approach recorded highest available potassium content in soil after groundnut (394 kg ha⁻¹) and after finger millet (399 kg ha⁻¹) followed by the treatment of package of practices.

Verma *et al.* (2005) conducted field experiments during 2000-01 and 2001-02 on clay loam (TypicHaplustept) at Udaipur to assess the effect of nutrient application through different sources in maize-wheat cropping sequence. After two years of experimentation, the application of 100% NPK through FYM 10 t ha⁻¹ and fertilizers, 100% NPK + FYM 10 t ha⁻¹

¹ and FYM 20 t ha⁻¹ significantly improved the organic carbon content of soil. A marked buildup 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.

Kaur *et al.* (2005) conducted the experiment initiated in 1994 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.

Borie *et al.* (2006) reported that soil pH was slightly higher under NT and RT than under CT at the first sampling. The greater pH observed in CTB compared with CTS may have been due to alkalinity produced by burning. Similar trends occurred at the second sampling, but differences were less significant. Total soil P range from 1.867 mg kg⁻¹ for CTB to 2.384 mg kg⁻¹ for RT being mainly inorganic in nature in comparison with that P bound to humic and fulvic acids which together after wheat harvest, represented 34, 43, 25 and 36% for NT, RT, CTS and CTB, respectively. The higher amounts of total P found in NT and RT compared with CT could be explained by soil mixing with CT that diluted the upper soil layers. Positive effects of RT and NT on soil chemical and mycorrhizal characteristics was demonstrated. Such effects can be summarized as greater soil C, N, S and P levels and AM fungal propagules left in the soil under NT than under CT.

Benito and Sombrero (2006) revealed that the nitrogen content showed highly significant differences between tillage systems at the 0-10 and 10-20 cm depths, with higher values in NT plots, followed by

minimum tillage. At the 20-30 cm depth, the values of this parameter were similar in the three tillage systems, following the same tendency observed for the SOM content. The phosphorus content presented significant differences in the first 10 cm of soil with higher values in MT and NT compared to CT. Likewise, there were significant differences between tillage systems in soil potassium with the following trend: NT>MT>CT. Considering the 0-30 cm depth, results indicated that the contents of organic matter, nitrogen, phosphorus and potassium were significantly different between tillage systems, with higher values under NT and MT than under CT as a consequence of the differences observed in the first centimetres of soil.

Jessika *et al.* (2006) reported that conservation tillage increased available phosphorus but redistributed potassium from the subsurface to the surface by accumulating organic matter at the soil surface and not remixing it with tillage. Nitrate accumulated at the surface as well.

Gal *et al.* (2007) reported that in the 0–5 cm depth interval, differences due to tillage in OC and total N concentrations between the no-till and plow treatment were highly significant; indeed, no-till resulted in 33% higher OC and 32% higher total N concentration than plow.

Katkar *et al.* (2007) reported that pH and electrical conductivity was decreased with application of FYM (10 t ha⁻¹) than chemical fertilizer. 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.

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.

Singh *et al.* (2008) stated that soil pH was around 5.0 under pigeon pea-rice and it ranged from 4.77 to 4.85 in black gram-rice and rice-rice sequence at the end of four years of rotation. Decrease the pH from the initial value was the highest under blackgram-rice followed by rice-rice because of incomplete and slower rate of decomposition.

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

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.

Carter *et al.* (2009) concluded that Improvements in the level of SOC at the surface depth would be potentially beneficial for both the protection of the soil resource from erosive forces and enhancing soil water-holding capacity. After 6-yr of tillage and mulch treatments, the SOC

level had appeared to reach equilibrium in the 3-yr conservation tillage system.

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.

He *et al.* (2009) reported that conservation tillage increases the soil organic carbon (18.8 g kg⁻¹) as compared to traditional tillage (14.3 g kg⁻¹).

Surekha and Rao (2009) reported increase in available nitrogen, phosphorus and potassium with application of paddy straw (5 t ha⁻¹).

Lal and Jacinthe (2009) reported that organic C concentration in the 0-5 cm soil depth were significantly greater under no tillage (16.3 g kg⁻¹) compared with conventional tillage (8.8 g kg⁻¹).

Nawlakhe and Mankar (2009) conducted field experiment during the *kharif* seasons of 2000-2001 and 2001-2002 under rainfed condition at AICRP for Dryland Agriculture, CRS, Dr. PDKV, Akola (M.S.) The treatment 25 kg N+25 kg P₂O₅ ha⁻¹ inorganic fertilizer + 25 kg N ha⁻¹ through farmyard manure (T₇) recorded the highest improvement in organic carbon (from initial 0.701% to 0.894%) and the same treatment also recorded significant improvement in available N, P₂O₅ and K₂O status.

Venugopalan *et al.* (2010) reported that, sustainability of organic cotton (*Gossypium hirsutum* L.) based on production system *vis-a-vis* non-organic system under low input, semi-arid pedo-climatic conditions was evaluated during 2001 through 2005 on farmers fields in Yavatmal district, Maharashtra. Results showed that, organic carbon content was significantly higher under organic system. All the soils were calcareous but the proportion of organic to total carbon was higher in organic system and between sampling periods, this increased from 54.5 to 57.5%.

Sornpoon and jayasuriya (2013) concluded that the mean of soil EC at 15 days after planting were found significantly affected by the four tillage treatments against no-tillage (ST, CT1, CT2, CT3 and NT of 113.9a, 110.1a, 110.1a, 106.1a, and 82.4b mS m⁻¹ respectively, and before tillage the corresponding values were 78.3, 76.4, 77.9, 77.7 and 75.1, no significantly different) however, there was no significant effect on EC due to the residue management method and also no interaction was observed between tillage methods and corn residue management methods. The results indicated that ploughed soil, which had the high volume of macro pores, would have resulted in the higher rate of soil EC.

Sonune *et al.* (2003) reported that, the highest OC (6.33 g/kg) was observed in 50% RDF + FYM @ 15 tonnes ha⁻¹ followed by 50% RDF + FYM @ 10 tonnes ha⁻¹ (6.03 g/kg) 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 depend upon the type and quality of organic matter and also stage of decomposition.

Tadesse *et al.* (2013) conducted research on effects of Farmyard Manure and Inorganic Fertilizer Application on Soil Physico-Chemical Properties and Nutrient Balance in Rainfed Lowland Rice Ecosystem. The results showed that, highest organic matter being recorded for the highest (15 t·ha⁻¹) FYM application. Application of 15 t·ha⁻¹ FYM increased the soil organic matter and available water holding capacity by about 2.16% and 17.6%, respectively, while it reduced the soil bulk density by 0.31 g·cm⁻³.

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.

Gholami A. *et al.* (2014) found that by changing tillage system from conventional tillage to no tillage, the no tillage had the highest electrical conductivity (1.78 dS). In the case of the conventional tillage system, the lowest electrical conductivity (1.19 dS) was observed. Results indicate a significant difference between the mean of three tillage systems such that the lowest pH level corresponds to the no tillage system while the highest belongs to the conventional tillage.

Oja *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) 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 OC (6.33 g/kg) was observed in 50% RDF + FYM @ 15 t/ha followed by 50% RDF + FYM @ 10 t/ha (6.03 g/kg) 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.

Carvalho *et al.* (2015) reported that, sunhemp seems to be more efficient in the improvement of chemical properties. The higher values reported for soil P and K content in plot with sunhemp (*Crotalaria Juncea*) are due to decomposition of the green manure, which presents high content of P and K in its composition and contributes for the releasing of these elements to the soil.

Babatunde *et al.* (2016) found Significant difference in soil organic matter, nitrogen, phosphorus while, soil pH and potassium were not significantly affected. pH range from 6.0 to 6.2, Soil Organic Matter range from 6.2 to 6.0 and P range from 3.39 to 3.98mg/kg.K ranges from 0.39cmol/kg in Plough and Harrow to 0.41cmol/kg in PHR and ZT. Calcium was between 1.8 cmol/kg and 2.3cmol/kg in ZT and PHR. Magnesium was between 1.3cmol/kg in MT and 1.8cmol/kg in PH. The result for sodium range from 0.13 and 0.07cmol/kg.

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 NH_4^+ -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 NH_4^+ - 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 ($336.5 \text{ kg ha}^{-1} \text{ year}^{-1}$), 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 $1.2 \text{ Mg ha yr}^{-1}$.

C. V. 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) followed by 100% NPK+FYM (12.87 t/ha) and the lower values were recorded in Control (9.43 t/ha) followed by 100% N (9.93 t/ha).

2.1.3 Biological properties

2.1.3.1 Tillage

2.1.3.2 Integrated nutrient management

Surya *et al.* (2000) reported that application of $\text{N}_{20} + \text{P}_{40} + 6 \text{ Mg}$ wheat straw per ha 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 reduce 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.

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 Goh (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.

Bationo *et al.* (2000) found that bacteria, fungi and actinomycetes population increased in the rhizosphere with the incorporation of the 4 t ha⁻¹ crop residues in conjunction with fertilizers as compared to their application alone and in control.

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. Higher values were observed under sorghum-chickpea-groundnut sequence and monocropping with legumes. The maximum SMBC (soil microbial biomass carbon) and SMBN (soil microbial biomass nitrogen) were observed under 100 per cent NPK + 10 t FYM in sorghum-wheat crop sequence. So also the application of recommended dose of fertilizers increased their amount over control. FYM, wheat straw and green manuring application to soybean-wheat increased the SMBC and N content in soil.

Kanchikerimath and 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.

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.

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.

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.

Patil and Raut (2002) reported significantly higher amount of phosphate solubilizing bacteria with the application of PSB culture as well as PSB culture + FYM. The results also confirmed that inoculated PSB was multiplying well in soil and they maintained their efficiency to multiply in presence of FYM.

Rita Thakare and Gupta (2003) studied effect of cropping system and nutrient management on microbial population. Maximum fungal, actinomycetes and bacterial population were recorded under irrigated condition. Application of FYM, wheat straw and green manuring greatly boosted the fungal population while FYM in combination with NPK fertilizer found to be most promising in enhancing actinomycetes and bacterial population. Highest fungal count was noted under sorghum-

chickpea-Groundnut followed by sorghum-wheat green gram cropping system.

Singh (2003) observed that high status of soil microbial biomass carbon in the NPK and FYM treated plot followed by NPK and control in Vertisols due to improvement of water soluble fraction in these treatments under continuous cropping of sorghum- wheat sequence while continuous application of fertilizer N and P rather alone or in combination did not improve active pools of nutrient.

Gawai (2003) studied soil microbial population in a field experiment on sorghum-chickpea sequence with INM treatments and reported that the microbial population of bacteria, fungi and actinomycetes in soil was on higher side due to application of FYM with both the levels *i.e.* 100 and 75 per cent RDF.

Thakur and Sharma (2004) studied on long term effect of fertilizers and farm yard manure on microbiological properties and total productivity in acid soils. As regards the microbial population and microbial biomass, highest values were recorded under FYM + 100% NPK ($71 \text{ cfu} \times 10^{-6} \text{ g}^{-1}$ soil of bacteria and fungi $62 \times 10^{-6} \text{ g}^{-1}$ of soil) as compared to use of 100% NPK ($5 \times 10^{-6} \text{ g}^{-1}$ and $3.4 \times 10^{-6} \text{ g}^{-1}$ of soil bacteria and fungi, respectively).

Selvi *et al.* (2004) studied on microbial population and biomass in rhizosphere as influenced by continuous intensive fertilization and concluded that bacteria, fungi and actinomycetes proliferated well under continuous application of FYM and NPK. Among the microbes bacterial population was the highest compared to fungi and actinomycetes in the soil after cowpea and finger millet cropping sequence. The application of 100% N alone and control recorded lower values of microbial population. Application of 100% NPK + FYM recorded significantly highest biomass. The organic material coupled with NPK fertilization exerted a stimulating influence on the preponderance of bacteria in soil. It was observed that NPK fertilizer helped in the built up of microbial population which might be due to the proliferation of root exudates and addition of crop residues including more root biomass thus helped in providing the

increased carbon substrate for microbial growth, nitrogen fertilization stimulating the growth of fungi.

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.

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.

Selvi *et al.* (2004) revealed that the bacterial population in soil ranged from 22 to 72, 14 to 60 and 22 to 76 $\times 10^6 \text{ g}^{-1}$ of soil after finger millet, maize and fodder cowpea, respectively. The application of FYM @ 10 t ha^{-1} to finger millet annually along with 100 per cent NPK recorded the highest bacterial counts at the end of rotation followed by 150 per cent NPK. The control recorded significantly lower values of microbial count.

Halemani *et al.* (2004^b) reported significantly highest population of bacteria ($76.66 \times 10^6 \text{ cfu g}^{-1}$ soil), fungi ($40.22 \times 10^4 \text{ cfu g}^{-1}$ soil) and actinomycetes ($54.77 \times 10^3 \text{ cfu g}^{-1}$ soil) with the application of FYM alone @ 10 t ha^{-1} followed FYM @ $5 \text{ t} + \text{CR } 2.5 \text{ t ha}^{-1}$ and FYM @ $5 \text{ t} + \text{VC } 1.25 \text{ t ha}^{-1}$. Significantly lowest microbial population was noticed in control.

Kaur *et al.* (2005) conducted the experiment initiated in 1994 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.

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 TypicHaplustept 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.

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 and Rajasthan in Typic Haplocambid 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.

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.

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.

Carter *et al.* (2009) studied influence of long term conservation tillage and revealed that the Conservation tillage was associated with significant positive effects on soil biota and biological properties, 3-yr conservation tillage treatment has found increased in

concentration of SOC, Total Nitrogen, Particulate Organic Matter-C and Particulate Organic Matter -N, also significant result for Microbial Biomass Carbon concentration under the 3-yr conservation tillage over conventional tillage treatments.

Lal *et al.* (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}).

Khosro 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.

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.

Nivelle *et al.* (2016) A 5-yr 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.

2.2 Effect of tillage and nutrient management on root growth contributing characters.

Root distribution is controlled by soil properties, such as porosity, compaction, water content and concentration of organic matter, which in turn are affected by the system of soil management.

Singh *et al.* (2002) reported that up to depth of 15 cm the root density of wheat was significantly less (637.7 g/m³) in zero tillage than conventional tillage. But below 15 cm soil depth there was non-significant effect on root density. Under zero tillage, total moisture content in soil profile was higher than reduced and conventional tillage throughout the crop growth stages. So, it is concluded that the rooting density was less in surface soil of zero tillage as compared to conventional system but recorded almost similar in deeper soil layers.

Lampurlanes and Cantero Martinez (2003) concluded that root length density profiles sometimes showed greater values for no tillage than for the other tillage systems, revealing a good soil condition for root growth under no tillage. Therefore, an increase in soil strength is observed under no tillage in the first year after its introduction and doesn't greatly affect root growth in well-structured soils.

Kusnarta *et al.* (2003) A field study on root distribution was conducted in the second year of an experiment on a rice-based (*Oryza sativa*) cropping system on rainfed Vertisols, in the wet season of 2002-

2003 at Indonesia. The treatments were rice, grown on: a) raised beds with no tillage, not flooded (M1), b) raised beds with tillage not flooded (M2), c) flat land with no tillage flooded (M3) and d) flat land with tillage, flooded (M4). The root distribution (by volume) at each depth was not significantly different between treatments, with mean: $0.15 \text{ cm}^3 \text{ root/cm}^3 \text{ soil}$ at 0–5 cm depth, and $0.14 \text{ cm}^3 \text{ root/cm}^3 \text{ soil}$ at each of 5–10 cm, 10–15 cm, and 15–20 cm depth. However, Figures 1 to 4 show that the concentration of roots was higher at a depth of 0–5 cm than that at 15–20 cm in three of the four treatments (M1, M2, M3). Throughout the season, penetrometer resistance was not significantly different between the treatments. At 10, 20, 40 and 60 cm depth, mean penetrometer resistance was 232, 392, 612 and 1098 k Pa respectively. So should not have restricted roots.

Barrios *et al.* (2006) concluded that during periods of normal precipitation, total root activity was greater under the CT conditions. However, during periods of water deficit, such as that experienced during the maize growth period, DS allowed greater root activity.

Tomar *et al.* (2006) found that root volume of wheat grown either after puddled and direct seeded rice was significantly affected by tillage systems as well as by moisture regimes and the interactions were significant. Significantly higher root volume was observed under direct seeded (31.2 cc) compared to puddled (27.4 cc) condition indicating the adverse effect of puddling.

Martinez *et al.* (2008) concluded that for the top 5 cm of soil, root length was greater under NT than under CT. This trend was found during the two leaves, flowering, and grain filling stages, with average root length values for NT of 3.43, 14.30, and 9.53 cm cm_3 , and 1.34, 6.70, and 5.22 cm cm_3 for CT, respectively. The continuous addition of crop residues have increased soil organic carbon, particularly in the topsoil. This increase in SOC have created a new topsoil environment with better and more stable aggregates that may favour, at least indirectly, root development in time. However, soil compaction, particularly of the deeper soil layers may have caused a significant decrease of root length in depth. From 5–15 cm depth, the effects of management treatment and years

under management were not clear. Soil compaction of deeper soil layers under NT may impeded the optimal development of roots, decreasing then differences between management treatments.

Guan *et al.* (2015) revealed from their study that the root length density (RLD) under Plow Tillage was much higher than that under No tillage across the 0–110 cm soil profile at the tillering stage during the two growing seasons. At the flowering stage, RLD under PT was higher at the 0–110 cm (except for 20–50 cm) soil depth in 2011–2012 and at the 0–40 cm soil depth in 2012–2013 than that under NT. At ripening stage, RLD under NT was higher than that under PT at the 0–10 cm soil depth in both growing reasons, but less than that under PT at the 10–20 cm soil depth. Moreover, RLD values showed no significant difference between PT and NT at 30–110 cm soil depth.

Chou-su (2015) studied the effect of three tillage treatments (no-till, NT; rotary till, RT; and conventional till, CT) and two crop residue management practices (straw mulch, ML; and non-straw mulch, NML) on stand establishment, root growth, and grain yield of wheat. Found straw mulching resulted in more soil water content and root length density (RLD) at most of the growth stages and soil depths. The maximum RLD, root surface area density and root dry matter density were obtained under NT.

Esser (2016) reported that the numbers of large roots under conservation tillage tended to be higher than under conventional tillage. The ratios of *root distribution indices* for large roots under conservation tillage versus conventional tillage do not show any indication of large roots having a greater tendency of growing deeper under conservation tillage than under conventional tillage. Maize roots under conservation tillage were higher than under conventional tillage for a couple of the soil squares.

Yeboah *et al.* (2017) conducted experiment and studied the effect of conventional tillage with straw removed (T), no tillage with straw removed (NT), no tillage with straw retained on the soil surface (NTS) and conventional tillage with straw incorporated (TS) on soil moisture, root growth and straw yield under rain-fed conditions. They concluded that compared with T and NT, root length, root surface area, root diameter and

root volume at 0-50 cm soil depth under straw treated soils, especially with no tillage were significantly increased. NTS could enhance spring wheat and field pea yield and water uptake via stimulating root growth, and therefore a practical way to improve crop productivity.

Chandra *et al.* (2017) studied effect of tillage, zero tillage (ZT), reduced tillage (RT) and deep tillage (DT) on shoot and root growth of winter wheat. And found that the root surface area did not differ among the treatments at 0- 10, 20-30, and 30-40 cm soil depths. It was lower at 0-10 cm soil depth which ranged between 0.16-0.20 m². At 10-20 cm there were significant differences in the root surface area among the treatments. The DT had the highest surface area (0.65 m²) whereas ZT and RT recorded a surface area of 0.42- 0.47 m². The root surface area density did not differ among the treatments at 0-10, 20-30, and 30-40 cm soil depths. It was lower at 0-10 cm soil depth which ranged between 0.43-0.53 cm² / cm³. At 20-40 cm soil depth root surface area density was higher than 0-10 cm depth. Highest surface area density (0.17 cm²/ cm³ soil) was observed under DT whereas ZT and RT recorded a surface area of 0.13 and 0.12 cm²/ cm³ soil respectively. At 0-10 cm depth, root length ranged from 27.8 m in RT to 37.9 m in DT. At 20-40 cm soil depth root volume density was higher than 0-10 cm depth. It ranged between 0.53-0.96 mm³ / cm³. At 10-20 cm there was significantly higher root volume density under DT than ZT or RT.

2.3 Effect of tillage and nutrient management on nutrient content of soil.

Katkar *et al.* (2002) used the FYM, glyricidia foliage loppings, greengram mulching either alone or in combination with chemical fertilizers for experimentation and 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.

Singh *et al.* (2002) observed that application of wheat residue at the rate of 4 t/ha along with recommended dose of Nitrogen and Phosphorus enhanced the availability of nutrients in the soil.

More and Hangarge (2003) reported that combined application of organic and inorganic source recorded maximum availability of nitrogen, phosphorus and potassium under cotton-groundnut cropping system.

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.

Bharambe and Tomar (2004) reported that application of NPK fertilizers with FYM significantly increased the available phosphorus content in soil over no FYM and treatment combination 100 per cent NPK + FYM was found as the optimum for increasing available P contents.

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.

Varlakshmi *et al.* (2005) observed the significantly highest available N and P in the treatment of package of practices where 100% recommended dose of fertilizer along with 7.5 t ha⁻¹ FYM after finger millet and groundnut.

Katkar *et al.* (2007) 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.

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. They reported that 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 and K in soil over chemical fertilizers alone.

Nawlakhe and Mankar (2009) carried out a field experiment under rainfed condition at AICRP for Dryland Agriculture CRS, Dr. PDKV, Akola and reported that addition of pure organic or in combination with inorganic fertilizers increased the available potassium content of soil as compared with exclusive chemical fertilizer treatment and control.

Rao and Janawade (2009) conducted a field experiment to study the effect of green manures, organic manures and fertilizer on soil fertility of a medium black soil. The results indicated that the application of FYM @ 10 t ha⁻¹ among organic manures influenced these parameters favourably and green manure sunhemp was found highly beneficial in improving the status of organic carbon, available N, P₂O₅ and K₂O. Increase in fertilizer level from 50 to 100 per cent RDF increased the fertility status of the soil.

Praharaj *et al.* (2010) conducted a field experiment during 2004–07 in 'Surabhi' upland cotton (*Gossypium hirsutum* L.) at Coimbatore (Tamil Nadu) under irrigated condition to explore the suitability of locally available and low-cost plant wastes, *viz.* neem, grass, weed and cotton residues vis-à-vis farmyard manure. They reported that significantly higher level of organic carbon and available N were analyzed in 0-15 cm soil samples under neem leaves, amended plots over both control and NPK alone.

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, 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 (NPK) as well as micronutrients for longer period in medium black soil.

Sharma *et al.* (2011) analyzed the soil quality assessment studies on long-term experiment from Akola Centre (Maharashtra) of All-India Coordinated Research Project for Dryland Agriculture (AICRPDA). They reported that application of 25 kg P₂O₅ ha⁻¹ + 50 kg N ha⁻¹ through leuceana (T₆) recorded the significantly greatest available N (191.3 kg ha⁻¹), available P (36.0 kg ha⁻¹) and available K (395.3 kg ha⁻¹) followed by 25 kg N + 25 kg P₂O₅ ha⁻¹ + 25 kg N ha⁻¹ through FYM (T₅).

Sonune *et al.* (2012) conducted a field experiment during 2005-06 and 2007-08. The treatments consisted of tillage (conventional and minimum), nutrient management viz., 100% RDF, 50% RDF with graded doses of FYM and green manuring (Dhaincha). Significantly highest OC (6.05 g kg⁻¹) was observed in treatment 50% RDF + FYM @ 15 t ha⁻¹ followed by 50% RDF + FYM @ 10 t ha⁻¹ (5.88 g kg⁻¹) which were at par with each other. Highest available N (238.74 kg ha⁻¹) and K (392.40 kg ha⁻¹) were recorded in treatment 50% RDF + FYM @ 15 t ha⁻¹.

Tamboli *et al.* (2013) conducted a field experiment during the *rabi* season 2007-08 to 2011-12. They reported that maximum values of available N (138 kg ha⁻¹) was recorded under FYM @ 5 t ha⁻¹ + recommended dose of fertilizer (50 kg N + 25 kg P₂O₅ ha⁻¹ + Zn @ 10 kg ha⁻¹ as ZnSO₄) while, soil available P (17.11 kg ha⁻¹), available K (661 kg ha⁻¹) and DTPA extractable Zn (0.78 mg kg⁻¹) were maximum under soil test (75 kg N + 31 kg P₂O₅ ha⁻¹ + Zn @ 15 kg ha⁻¹ as ZnSO₄) treatment.

Marimuthu *et al.* (2014) conducted a field experiment during 2006-08 at the Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore. They reported that among the different cropping systems, cotton + dhaincha (M₂) recorded maximum soil N (197.53; 186.15 kg N ha⁻¹) and Olsen P (11.74; 9.53 kg ha⁻¹) in 2007 and 2008, respectively, followed by cotton + green gram (M₃) system. The least soil N (166.47; 158.42 kg N ha⁻¹) and Olsen P (10.10; 8.68 kg ha⁻¹) were recorded by the sole crop of cotton (M₁) in 2007 and 2008, respectively.

Sankar *et al.* (2014) analysed the soil quality assessment studies on long-term experiment from Akola Centre (Maharashtra) of All India Coordinated Research Project for Dryland Agriculture (AICRPDA). They reported that 25 kg N (FYM) + 25 kg N (urea) + 25 kg P ha⁻¹(T₅) was found to be the higher soil available N of 254 kg ha⁻¹, soil P of 33.4 kg ha⁻¹, and soil K of 369 kg ha⁻¹ over years in these semi-arid Vertisol soils.

Odyuo *et al.* (2015) analysed physico-chemical properties and potassium fractions in surface (0-20cm) and sub-surface (20-40cm) soils of SASRD research farm of Nagaland University. They reported that the available K content of surface and subsurface soils varied from 149 to 197 and 145 to 193 mg kg⁻¹ with a mean value of 171 and 165 mg kg⁻¹.

2.4 Effect of tillage and nutrient management on seed cotton yield

The accumulation of dry matter per plant and height are the best index of growth put forth by crop and it reflects in yield contributing parameters and ultimately in yield.

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.

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.

Ogunwole *et al.* (2003) observed 4 t ha⁻¹ seed cotton yield under unstressed conditions and 1.5 t/ha under moisture stress conditions. However, under adequate moisture conditions, NPK at 90:39:39 and 60:26:26 kg/ha resulted in the highest yields. This indicates that soil nutrition can only be a constraint under moisture stress conditions.

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.

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.

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) concluded that combined application of RDF + FYM gave 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.

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). Patil *et al.* (2004) also found significantly higher seed cotton yield, number of bolls and boll weight per plant under irrigation as compare to rainfed condition.

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, Halemani *et al.* (2004) studies 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 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.

Praharaj *et al.* (2004) revealed that maximum seed cotton yield (18.6 q ha⁻¹) was recorded with the combined application of FYM @ 5 t ha⁻¹ + *in situ* incorporation of sunhemp green manure followed crop residue @ 5 t ha⁻¹ + *in situ* incorporation of sunhemp green manure.

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.

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 (*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 value were recorded with 100% RDF.

Bhoite and Thombre (2006) reported 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 ball 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.

Hulhalli 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).

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.

Rao and Janawade (2009) studied integrated nutrient management in irrigated hybrid cotton and found higher seed cotton yield

with 100 per cent RDF over 50 and 75 per cent RDF was associated with higher yield components like number of harvested bolls plant⁻¹ and boll weight.

Singh *et al.* (2006) indicate that among various nutrient combinations, it was observed that 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 N, P, recommended NPK, recommended NPKS and recommended N, P, K, S, Zn 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.

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.

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.

Mahavishnan *et al* (2006) Field experiments were conducted during *kharif* and *rabi* seasons 2002-03 and 2003-04, respectively to investigate the response of cotton to integrated nutrient management in cotton –sunflowercropping 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.

Mehta *et al.* (2009) reported that the application of recommended dose of chemical fertilizer has achieved statistically higher seed cotton yield (20.40 q ha^{-1}).

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.

Nawlakhe and Mankar (2010) reported that in 25 kg N through fertilizer + 25 kg N through FYM + 25 kg P₂O₅ 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 kg P₂O₅ ha⁻¹ inorganic fertilizer i.e. 100 % RDF treatment.

Sonune *et al.* (2012) conducted the experiment in medium deep soil (Inceptisols) 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.

Lalitha Kumari *et al.* (2010) reported that the pooled mean yield of cotton kapas 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).

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.

Solankhe 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) reported that Transgenic Bt cotton hybrids, in India, now constitute more than 90% of the cotton area. Conservation tillage systems such as reduced tillage (RT) improve soil health and crop productivity. Field experiments were conducted to study the response of Bt cotton hybrids to the tillage methods in a split plot design for three years (2005–2006 to 2007–2008) 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. Averaged over seasons, 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 + N100 and GM + N80 (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.

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).

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 @ 10t/ha, Recommended dose (RD) of NPK, RD of N alone, RD of N and P, RD of NPK + 5t/ha FYM, 50 percent RD of NPK + 10 t/ha FYM, 50 per cent Rd of NPK + 10 t/ha FYM + 2% urea, RD of NPK + 10 t/ha FYM and RD of NPK + sun hemp @ 15 kg/ha. Application of RD of NPK + 10 t/ha FYM (T9) recorded highest seed cotton yield during all the three years of experimentation (1924, 1723 and 2010) kg/ha, respectively. Lowest seed cotton yield was record with absolute control.

Thimareddy *et al.* (2013) reported that, different in-situ green manures, sunnhemp in-situ green manuring (2231.33 kg ha⁻¹) recorded significantly higher seed cotton yield per hectare and was on par with dhaincha in-situ green manuring (2225.72 kg ha⁻¹).

Gabhane *et al.* (2014) studied and concluded that the pooled results indicated that the application of 50% RDF + FYM @ 15 t/ha recorded significantly highest seed cotton yield (16.04 q/ha) which was at

par with the application of 50% RDF + FYM @ 10 t/ha (14.89 q/ha). The seed cotton yield obtained in treatment 100% RDF (13.58 q/ha) and 50% RDF + green manuring (12.60 q/ha) were statistically at par with each other and superior over only 50% RDF. The increase in the yield due to 50% RDF + FYM @ 15 t/ha was 7.72 and 18.11% higher over 50% RDF + FYM @ 10 t/ha and 100% RDF, respectively.

Schwab (2014) revealed that In 5 yr experiment seed cotton yield from all conservation tillage treatments were greater than or equal to conventional tillage yields.

Gudadhe *et al.* (2015) conducted an experiment at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri a representative place for the vertisols of Deccan plateau of India to study the effect of organic and inorganic fertilizers on crop yield and soil physical, chemical and biological properties in the cotton-chickpea cropping sequence. Application of Recommended Dose of Fertilizer (RDF) according to Soil Test Crop Response (STCR) equation recorded significantly higher seed cotton yield and cotton equivalent yield, however it was at par with 10 t Farm Yard Manure (FYM) ha⁻¹ + RDF. Chickpea registered significantly higher seed yield in 10 t FYM ha⁻¹ + RDF and it was at par with 100% RDN through vermicompost. 100% RDF registered significantly superior seed chickpea seed yield and cotton equivalent yield.

Vora *et al.* (2015) revealed that, seed cotton yield was significantly affected due to different treatments during all the years and pooled results Significantly highest seed cotton yield was recorded under T₉ (80 kg ha⁻¹+ 10 t compost ha⁻¹ +500 kg castor cake ha⁻¹+bio-fertilizer (*Azotobacter*+PSM) in the individual year and also in pooled as compared to remaining treatments but it was at par with T₈, T₇, T₆, T₅, T₄ and T₃. The highest seed cotton yield resulted in treatment T₉ (80 kg ha⁻¹+10 t compost ha⁻¹+ 500 kg castor cake ha⁻¹ + bio-fertilizer (*Azotobacter* + PSM) on account of balance supply of nutrients through organic and inorganic sources which improve physical and chemical properties of soil.

Hemlata Chitte *et al.* (2016) conduct a field experiment during kharif season of 2013-14. The experiment was conducted with three

nitrification inhibitors viz., neem cake @ 300 kg ha⁻¹ (N₁), karanj cake @ 300 kg ha⁻¹ (N₂) and control (N₃). The result showed that various all growth attributes were higher in F₃ over F₁ and which at par with F₂. In case of yield attributes and yield were significantly higher in F₃ over F₂ and F₁. Uptake of NPK kg ha⁻¹ after harvest of cotton crop was significantly higher in F₃ over F₂ and F₁.

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

bolts 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 bolts.

CHAPTER III

MATERIAL AND METHODS

The field experiment was carried out to study the “Influence of conservation and conventional tillage on biological dynamics of soil and rooting behavior of cotton in Vertisol” at Akola during 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 chemical properties
 - 3.2.2.2 Soil biological properties
- 3.3 Rooting behaviour
- 3.4 Seed cotton yield
- 3.5 Statistical analysis
- 3.6 Location, duration and season of experiment

3.1 Material required

3.1.1 Climate and weather conditions

Akola is situated in sub-tropical region between 22° 42' N latitude and 77° 02' E longitudes. The altitude of the place is 304.42 m above mean sea level. The climate of Akola is semi-arid and characterized by three distinct season viz., hot and dry summer from March to May, warm humid rainy season from June to October and mild cold winter from November to February. Average annual precipitation on the basis of last fifteen years is 515.8 mm. The experimental rainfed cotton crop was sown

Table.1 Weekly weather data for the year 2017-18 recorded at meteorological Observatory, Dr. PDKV, Akola. (Work period from 28June 2017 to 3 March 2018)

Dates	Week	T MAX (°C)	TMIN (°C)	BSH(hrs)	WS (km/hr)	RH I (%)	RH II (%)	Evap (mm)	RF (mm)
23-29 Jul 2017	30	30.5	23.0	2.3	8.2	88	65	4.1	35.8
30-5 Aug	31	31.9	23.6	6.8	6.3	85	58	6.9	10
6-12	32	30.7	24.1	2.9	6.0	80	63	5.8	4.4
13-19	33	32.9	23.8	5.4	7.1	83	58	6.2	18.9
20-26	34	29.1	23.4	2.0	5.9	92	76	2.8	25.3
27-2 Sep	35	30.5	23.3	3.8	2.5	88	68	3.7	70.2
3-9	36	32.3	23.8	6.5	2.7	89	62	5.0	9.7
10-16	37	31.8	23.8	2.6	0.8	93	69	3.5	27.9
17-23	38	30.8	23.0	2.5	2.5	92	69	3.2	12.5
24-30	39	33.8	22.8	8.4	1.6	89	50	5.1	4.1
1-7 Oct	40	35.6	21.1	8.0	1.2	81	42	6.5	0.0
8-14	41	31.9	22.0	4.3	0.7	91	64	4.2	57.5
15-21	42	33.7	20.5	6.9	0.8	83	43	5.7	0.0
22-28	43	33.9	16.6	8.5	0.6	77	29	5.8	4.5
29-4 Nov	44	32.7	14.4	8.5	0.6	82	26	5.9	0.0
5-11	45	31.6	14.7	8.5	1.0	81	28	5.4	0.0
12-18	46	31.0	13.7	7.9	0.4	79	37	4.9	0.0
19-25	47	31.8	17.9	5.3	0.9	84	40	4.6	0.0
26-2 Dec	48	30.6	11.2	8.2	0.9	79	23	5.4	0.0
3-9	49	29.7	14.5	5.6	1.5	78	38	4.8	0.0
10-16	50	31.2	13.7	7.6	0.8	74	27	5.3	0.0
17-23	51	29.7	10.4	6.6	0.8	80	25	4.6	0.0
24-31	52	29.4	8.7	8.2	1.0	72	22	4.3	0.0
1-7 Jan 2018	01	29.5	9.4	7.5	0.8	74	23	3.8	0.0
8-14	02	29.6	12.3	7.7	1.2	58	23	5.9	0.0
15-21	03	31.3	12.1	7.9	1.3	68	20	6.4	0.0
22-28	04	29.8	10.0	8.3	1.7	57	20	7.3	0.0
29-4 Feb	05	32.4	10.9	8.7	1.0	58	15	6.7	0.0
5-11	06	32.3	16.0	5.8	1.9	48	20	7.4	0.0
12-18	07	29.9	14.9	6.1	3.9	70	35	6.6	0.7
19-25	08	35.5	17.9	8.0	1.7	48	18	7.4	0.0
26-4 Mar	09	37.3	18.5	8.1	1.7	40	15	7.6	0.0

in the 25 MW (20 June, 2017) and harvested in 51MW (Last picking). The total rainfall received during the crop growth period was 591.3 mm in 26 rainy days. The temperature data reported maximum (day) temperature 38°C in 41 MW during the crop growth period and minimum temperature during (night) time was ranged from 12.1°C in 49 MW. Dry spell was in 39 MW which hampered the growth of the crop during flowering stage and thereafter it was well distributed up to 51MW, which ultimately reflected on the significant improvement in the yields of the rainfed cotton under the various manural treatments.

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 2. Initial physical and chemical properties of experimental site

Sr. No.	Particulars	Depth (0-30 cm)
	Mechanical analysis	
	Sand	0.68
	Silt	30.21
	Clay	60.11
	Texture :	Clay
	Order :	Vertisols
	Subgroup	Typic Haplusterts
A.	Physical properties	
1.	Bulk density (Mg m ⁻³)	1.38
2.	Hydraulic conductivity (cm h ⁻¹)	0.66
3.	Free lime (%)	8.12
4.	Mean weight diameter	0.61
B.	Chemical properties	
1.	pH (1:2.5)	8.11
2.	EC (dS m ⁻¹)	0.29
3.	Organic carbon (g kg ⁻¹)	5.4
4.	Available nitrogen (kg ha ⁻¹)	206.4
5.	Available phosphorus (kg ha ⁻¹)	13.07
6.	Available potassium (kg ha ⁻¹)	323.3

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 year 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 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 3.

Table 3. 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

The present experiment was started during 2016-17 with soybean. While , the present investigation was conducted in Kharif 2017-18 with cotton as a test crop. The initial composite soil sample was collected and analyzed for various soil properties (Table 2). The experiment was started in 2010-11. The initial data of soil placed Table 2 is of at the initiation of an experiment i.e year 2010-11.

Experimental details

1. Location : Research farm of Department of SSAC
2. Year of start of experiment : 2010-11
3. Year of study : 2017-18
4. No. of treatments : 08
5. No. of replications : 03
- Design of experiment : RBD (Two set of condition)
6. Set I - Conservation tillage
Set II - Conventional tillage
7. Crop : Cotton (*kharif*) 2017 -18
8. Variety : AKH 9916
- Plot size : Gross: 6.0 X 5.4 m²
9. : Net: 5.4 X 4.8 m²
10. Total number of plot : 48
11. Soil : Vertisols
12. Seed rate : 12 kg ha⁻¹
13. Fertilizer Dose : 60:30:30 (Rainfed cotton)
14. Spacing : 60x30 cm
15. Method of sowing : Dibbling

Date of sowing and picking of cotton. :

Date of sowing : 03-07-2017

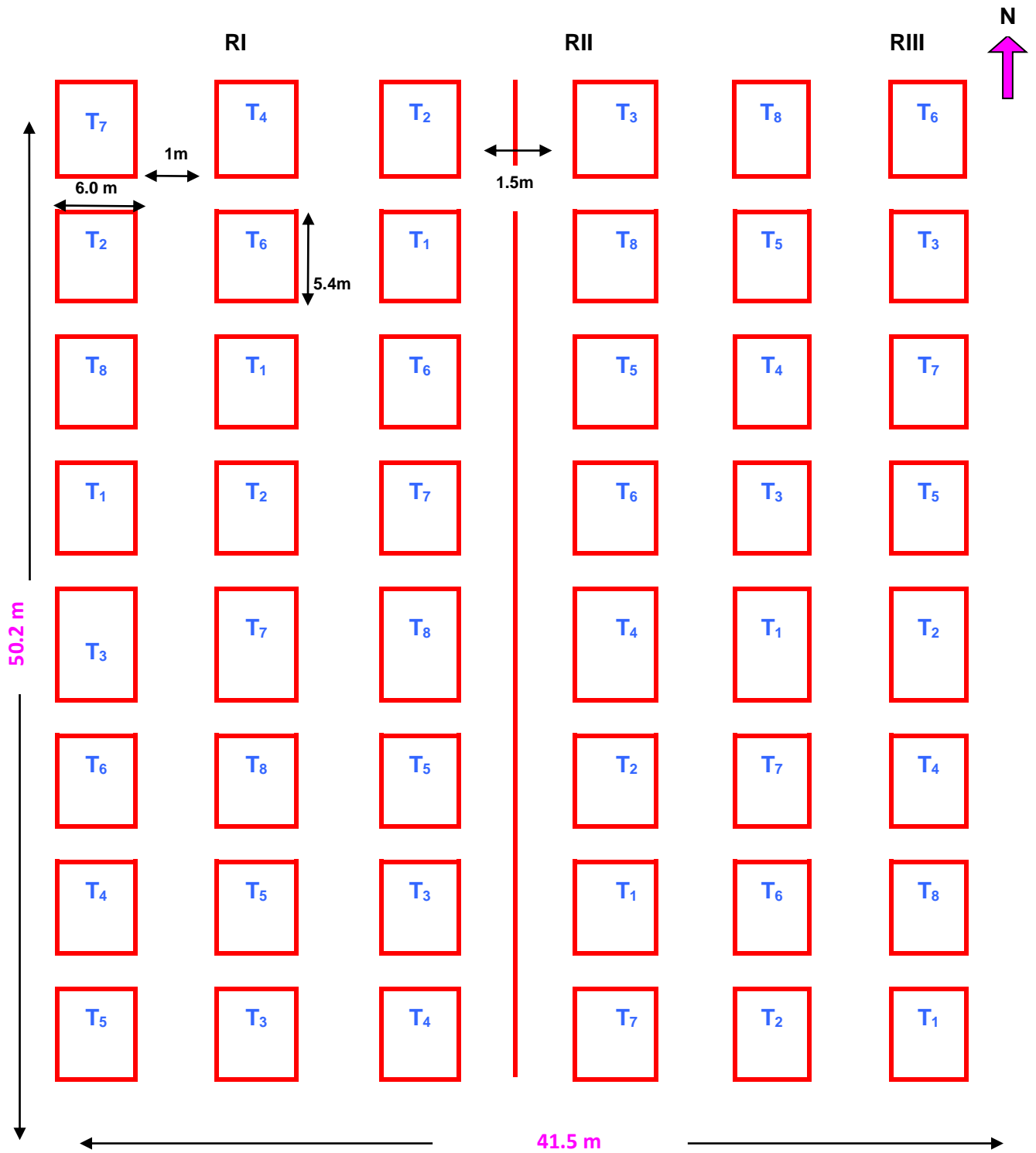
Date of picking

Cotton picking 1st : 05-12-2017

Cotton picking 2nd : 18-12-2017

Cotton picking 3rd : 11-01-2018

Cotton picking 4th : 22-02-2018



Design : RBD Replications : 3
 Treatment combination : 16 Plot size : 6.0 x 5.4 m²

Fig. 1 Plan of layout

Table 4. Treatment details

The details of treatments under taken in the experiment are as follows:

A : Tillage

CNS: Conservation tillage (CNS)

CNV: Conventional tillage (CNV)

B : Integrated nutrient management

Tr.	Cotton
T ₁	Control
T ₂	100% RDF
T ₃	50% N through FYM+ remaining RD through chemical fertilizer
T ₄	50% N through wheat straw + remaining RD through chemical fertilizer
T ₅	50% N through GLM + remaining RD through chemical fertilizer
T ₆	50% N through composted cotton stalk + remaining RD through chemical fertilizer
T ₇	50% N through vermicompost + remaining RD through chemical fertilizer
T ₈	100% P through phosphocompost + remaining N through chemical fertilizer

A) Tillage

The two separate experiments each in conservation and conventional tillage were conducted on same site and same 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.

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,



Plate 1. Overview of field experiment

composted cotton stalk, green manuring (glyricidia), vermicompost and phosphocompost). 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.

3.1.3.3 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 of cotton, thoroughly mixed in the soil. The crop residues were decomposed by PDKV decomposer. FYM, wheat straw, composted cotton stalk, vermicompost and phosphocompost 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 cotton crop and thoroughly mixed in the soil. Simultaneously the crop residue samples were collected and analysed for nutrient composition.

Table 5. Chemical composition of organics added in soil.

Particulars	N (%)	P (%)	K (%)
FYM	0.49	0.25	0.61
Wheat straw	0.42	0.22	0.53
Glyricidia (oven dried)	2.60	0.22	1.75
Shraded cotton stalk	0.49	0.18	0.57
Vermicompost	1.27	0.79	0.92
Phosphocompost	0.74	1.73	0.63

Table 6. Sources and quantity of fertilizers and manures added in soil.

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 phosphocompost + remaining N and K through chemical fertilizer	47.17	-	18.73	phosphocompost	12.83	29.99	11.27	1734	5.61

3.1.3.4 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.

3.2 Methods adopted

3.2.1 Collection and processing of soil samples

The treatment wise initial surface soil samples (0-20 cm) before sowing in *kharif* (2016-17) from experimental site and after harvest of *kharif* were collected. 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. Soil samples for biological parameters will be collected during peak growth stages of crop and immediately analysed.

3.2.3 Soil chemical analysis

3.2.3.1 Soil reaction (pH)

Hydrogen ion activity expressed as pH was measured with pH meter using 1:2.5 soil-water suspension (Jackson, 1973).

3.2.3.2 Electrical conductivity

The clear supernatant extract obtained from soil-water suspension used for pH was utilized for the EC measurement using a conductivity bridge (Jackson, 1973).

3.2.3.3 Organic carbon

Walkley and Black method as described by Jackson, 1973 was used to determine organic carbon content of soil.

3.2.2.2.5 Available nutrients

3.2.2.2.5.1 Nitrogen

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

3.2.2.2.5.2 Phosphorus

Available phosphorus was determined by Olsen's method using 0.5 M sodium bicarbonate pH (8.5) as an extractant using UV based double beam spectrophotometer (Watanabe and Olsen, 1965).

3.2.2.2.5.3 Potassium

Available potassium was determined by neutral normal ammonium acetate method using flame photometer (Knudsen and Peterson, 1982).

3.2.2.2.5.4 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 Biological properties

3.2.2.2.1 Soil microbial biomass carbon (SMBC)

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

3.2.2.2.2 Soil microbial biomass nitrogen (SMBN)

SMBN was estimated using chloroform fumigation extraction method by Jenkinson and Powlson (1976)

3.2.2.2.3 Dehydrogenase activity (DHA)

DHA was estimated by TTC method by Klein (1971).

3.2.2.2.4 CO₂ evolution

CO₂ evolution was estimated using Alkali trap method by Anderson (1982).

3.3 Root studies

Above studies were carried out at the boll development stage of the crops. The soil samples with root mass were kept in water over night and then, roots were made free from soil by gentle washing with a fine jet of water. The roots were collected on sieves and observations on following parameters were made: The method selected for analysis of rooting behaviour was line intersection method, but due to some changes during experimentation it has been changed to manual methods i.e. root length by scale measurement and root volume by water displacement method.

3.3.1 Root length (cm)

The fresh root samples belonging to different treatments were placed on a hard sheet in stretched condition followed by measurements of their tap root maximum lengths using a meter scale.

3.3.2 Root volume (cm³)

Root volume was determined by displacement method. About 900 ml of water was poured into a 1000 ml measuring cylinder and roots belonging to the given treatment were transferred to it and change in water volume reading were recorded.

3.4 Seed cotton yield

Seed cotton was picked from net plots in all the replications and yield per plot and yield per hectare was calculated.

3.5 Statistical analysis

Experimental data were analysed by adopting standard statistical methods of analysis of variance as given by Panse and Sukhatme (1985). The field experiment was conducted at Research Farm, Department of Soil Science and Agricultural Chemistry. The performances of eight treatments on nutrient management were separately analysed for conservation and conventional tillage using RBD. To compare the interaction effect of tillage with treatments on nutrient management, the data was analysed using FRBD design.

3.6 Location, duration and season of experiment

The experiment on “Influence of conservation and conventional tillage on biological dynamics of soil and rooting behaviour of cotton in Vertisol” carried out on the Research farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2017-18.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the field experimentation entitled “Influence of conservation and conventional tillage on biological dynamics of soil and rooting behaviour of cotton in Vertisol” conducted on the Research Farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season of 2017-18. The findings are presented and discussed under the following heads.

- 4.1 Effect of tillage and nutrient management on soil properties
 - 4.1.1. Chemical properties
 - 4.1.1.1 pH
 - 4.1.1.2 Electrical conductivity
 - 4.1.1.3 Organic carbon
 - 4.1.1.4 Available nutrients (N, P, K,S)
 - 4.1.2 Biological properties
 - 4.1.2.1 Soil microbial biomass carbon
 - 4.1.2.2 Soil microbial biomass nitrogen
 - 4.1.2.3 CO₂ evolution
 - 4.1.2.4 Dehydrogenase activity
- 4.2 Effect of tillage and nutrient management on rooting behaviour of cotton
 - 4.2.1 Root length
 - 4.2.2 Root volume
- 4.3 Effect of tillage and nutrient management on seed cotton yield

4.1 Effect of tillage and nutrient management on soil properties

4.1.1 Chemical properties of soil

4.1.1.1 Soil pH

Data pertaining to soil pH under different treatments are presented in Table 7 and graphically depicted in Fig. 2.

Tillage

The effect of tillage on pH of soil was non-significant. Lower value of pH was observed in conventional tillage (8.07) compared to conservation tillage (8.11). Lal (1997) reported a significantly higher soil pH in NT plots compared to those in tilled plots. Conversely, the lower pH in zero tillage was attributed to accumulation of organic matter in the upper few centimeters (Rhoton, 2000). Therefore, tillage may not directly affect soil pH but its effects on pH will depend on the prevailing climatic conditions, soil type and management factors.

Integrated nutrient management

The effect of integrated nutrient management on pH of soil was non-significant. The pH of soil varied from 7.96 to 8.16. The lower pH (7.96) of soil was observed in T₃, with the application of 50% N through FYM + remaining RD through chemical fertilizers followed by treatment T₅ (50% N through GLM + remaining RD through chemical fertilizers) and 8.10 in T₆ where 50% N through composted cotton stalk + remaining RD through chemical fertilizers. The results were on par with each other. It might be due to conjoint use of organic manures and inorganic fertilizers. As organic manures and crop residues contain large amount of organic nitrogen such as protein and amino acids, which mineralizes to nitrate in soil producing protons during nitrification and hence acidifying the soil. Singh *et al.* (2014) reported decrease in pH of soil under farmyard manure, which might be due to the activation of Al³⁺ and continuous release of basic cation upon its decomposition and gravitational movement of those cations into lower horizons of soil. The similar result also noted by Guled *et al.* (2002) who has reported that application of organic manures and inorganic fertilizers decreases the pH of soil.

These results are also in conformity with Mandal *et al.* (2010). The identical result was observed by Rathod *et al.* (2003) that the pH of the soil was reduced significantly by application of FYM at 5 tons per ha.

Table 7. Effect of tillage and nutrient management on soil pH

Treatments	pH (1:2.5)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	8.09	8.07
Set II : Conservation tillage	8.13	8.11
SE (m) ±	0.18	0.08
CD at 5 %	0.51	0.23
b. Nutrient management		
T1: Control	8.18	8.16
T2: 100% RDF	8.11	8.09
T3: 50% N through FYM+ remaining RD through chemical fertilizer	8.01	7.96
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	8.13	8.11
T5: 50% N through GLM + remaining RD through chemical fertilizer	8.06	8.05
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	8.12	8.10
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	8.14	8.11
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	8.14	8.15
SE (m) ±	0.35	0.16
CD at 5 %	1.01	0.45
c. Interaction effect	NS	NS

Interaction effect

The interaction effect between tillage and integrated nutrient management on soil pH was found to be non-significant during the experimentation. The pH was increased in conservation tillage as compare with conventional tillage. Considering nutrient management, the 50 % N through FYM + compensation of RDF recorded lowest pH (7.96).

4.1.1.2 Soil EC

The data on electrical conductivity affected by tillage and different nutrient management treatments is presented in Table 8 and graphically depicted in Fig. 3.

Tillage

It was observed that, the electrical conductivity among different tillage systems were found non-significant. The electrical conductivity recorded under conservation tillage was 0.34 dSm^{-1} and with conventional tillage it was 0.32 dSm^{-1} . These results are in accordance with the findings of Gholami *et al.* (2014), who stated that no tillage has more electrical conductivity than conventional tillage system.

Integrated nutrient management

The effect of integrated nutrient management on electrical conductivity of soil was non-significant. The values of electrical conductivity ranged from 0.27 to 0.35 dS m^{-1} . The numerically higher electrical conductivity of soil was observed with the application of 100% P through phosphocompost + remaining N through chemical fertilizer (0.35) and 50% N through composted cotton stalk + remaining RD through chemical fertilizer (0.34). The lower (0.27) value observed with the application of 50% N through FYM+ remaining RD through chemical fertilizer.

The organic manures release organic acid in the soil during decomposition, it may help to reduce electrical conductivity of soil. The results are conformity with the Guled *et al.* (2002). Slight decrease in EC was recorded with application of FYM as compared to no FYM treatment by Katkar *et al.* (2005).

Interaction effect

The interaction effect between tillage and integrated nutrient management was found non-significant in respect of electrical conductivity of soil.

Table 8. Effect of tillage and nutrient management on electrical conductivity

Treatments	EC (dS m ⁻¹)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	0.31	0.32
Set II : Conservation tillage	0.33	0.33
SE (m) ±	0.01	0.01
CD at 5 %	0.03	0.02
b. Nutrient management		
T1: Control	0.30	0.31
T2: 100% RDF	0.33	0.34
T3: 50% N through FYM+ remaining RD through chemical fertilizer	0.29	0.27
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	0.30	0.31
T5: 50% N through GLM + remaining RD through chemical fertilizer	0.34	0.33
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	0.34	0.34
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	0.33	0.34
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	0.34	0.35
SE (m) ±	0.02	0.01
CD at 5 %	0.07	0.04
c. Interaction effect	NS	NS

4.1.1.3 Organic carbon

The results on organic carbon content in soil after harvest of cotton are presented in Table 9 and graphically depicted in Fig. 4.

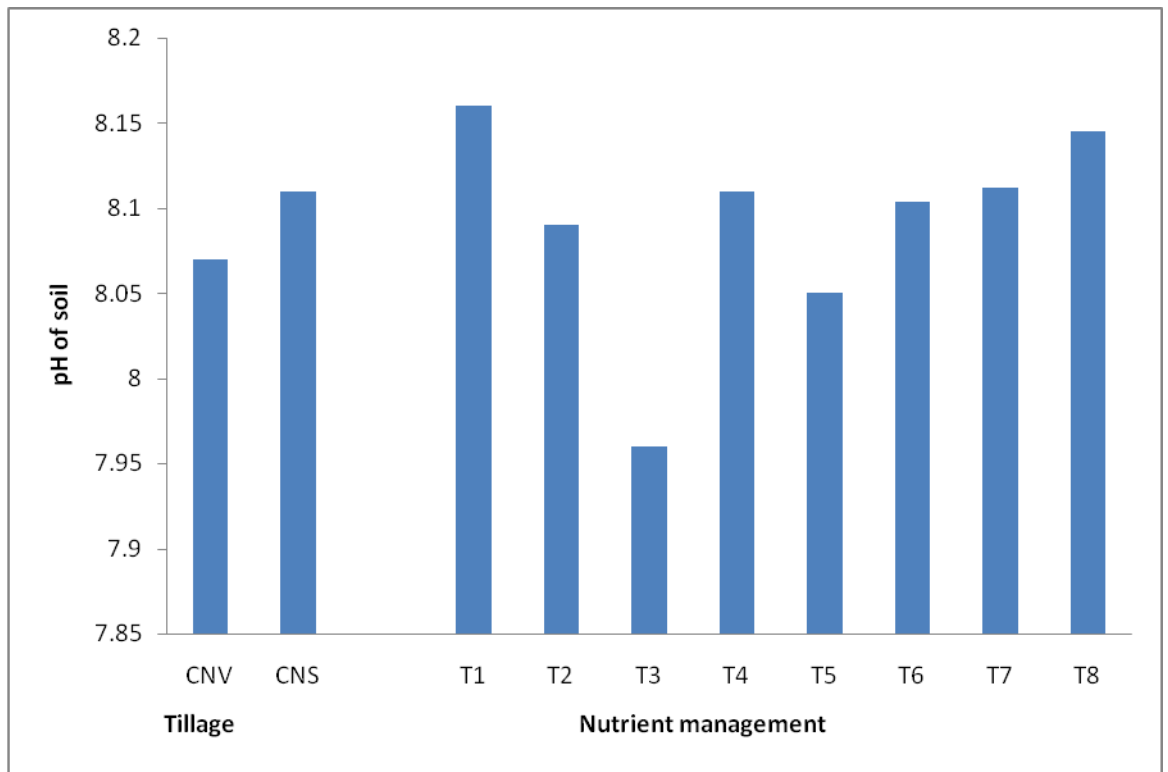


Fig. 2 pH of soil as influenced by various treatments

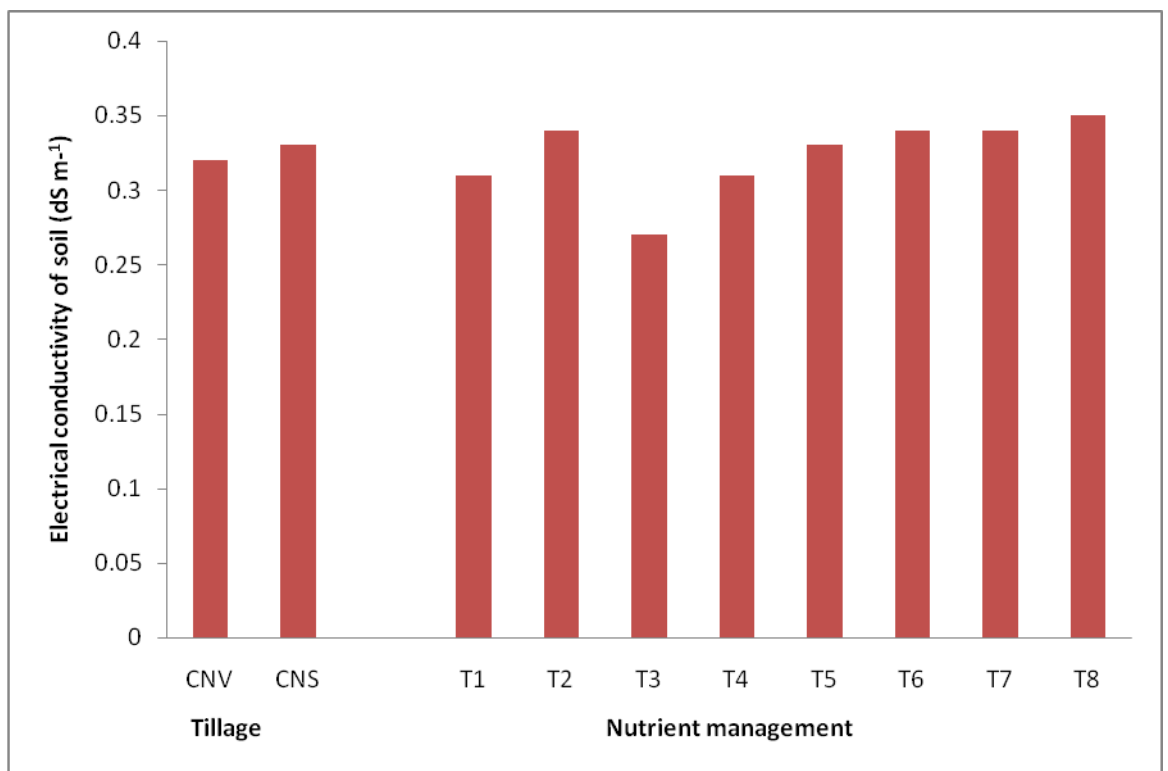


Fig. 3 Electrical conductivity of soil as influenced by various treatments

Table 9. Effect of tillage and nutrient management on organic carbon content

Treatments	Organic Carbon (g kg ⁻¹)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	5.80	5.83
Set II : Conservation tillage	5.91	5.99
SE (m) ±	0.20	0.12
CD at 5 %	0.57	0.35
b. Nutrient management		
T1: Control	5.54	5.57
T2: 100% RDF	5.60	5.65
T3: 50% N through FYM+ remaining RD through chemical fertilizer	6.27	6.29
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	5.93	5.94
T5: 50% N through GLM + remaining RD through chemical fertilizer	6.07	6.10
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	5.77	5.79
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	5.83	5.95
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	5.85	5.97
SE (m) ±	0.39	0.29
CD at 5 %	1.14	0.83
c. Interaction effect	NS	NS

Tillage

The organic carbon in soil was significantly influenced due to the effect of tillage. The organic carbon status under various tillage and nutrient management treatments were assessed and presented in Table 9. Significantly higher value of organic carbon was observed under conservation tillage (5.99 g kg⁻¹) as compared to conventional tillage (5.83 g kg⁻¹). This could be attributed due to accumulation of biomass in soil and favorable biological environment. Similar results were reported by Wagh *et al.*

(2016) who found slightly higher values of organic carbon in conservation tillage as compared to conventional tillage. These results are in accordance with Novak *et al.* (2009) they reported that conservation tillage increases the soil organic carbon as compared to disc tillage system. Sainju *et al.* (2009) also noted that no tillage increases organic carbon in soil as compared to tilled plot.

Lal and Jacinthe (2009) reported that organic C concentration in the 0-5 cm soil depth were significantly greater under no tillage (16.3 g kg⁻¹) compared to conventional tillage (8.8 g kg⁻¹). Similar results recorded by Sonune *et al.* (2012), and stated that, that higher organic carbon under minimum tillage as compared to the conventional tillage in Vertisols.

Integrated nutrient management

Based on observation taken, it was observed that the effect of integrated nutrient management on organic carbon of soil was non-significant. Numerically higher value of organic carbon (6.29 g kg⁻¹) was observed in a treatment T₃ 50% N through FYM + remaining RD through chemical fertilizers followed by T₅ 50% N through GLM + remaining RD through chemical fertilizers (6.13 g kg⁻¹). The lowest value of organic carbon (5.57 g kg⁻¹) was found in control.

The increase in organic carbon in treatment T₃ was 13.12% over treatment T₁ where no external inputs were applied. Gabhane *et al.* (2014) noted that 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. Hati *et al.* (2007) reported that increase in organic carbon with integrated application of FYM and NPK in a long-term fertilizer experiment conducted on a Vertisol. Similar results were also reported by Singh *et al.* (2014) and Mali *et al.* (2015).

Interaction effect

The interaction effect between tillage and nutrient management was non-significant in respect of organic carbon. However, the improvement in organic carbon under conservation tillage is attributed to minimum soil disturbance and consequent sequestration of more carbon

in soil. Similarly balanced integration of organic and inorganic inputs supports to enhance organic carbon in soil.

4.2. Effect of tillage and nutrient management on residual fertility of soil.

The available nutrients status of soil was recorded at harvest of cotton. The treatment wise samples were taken and analyzed for available nitrogen, phosphorous and potassium to assess the effect of various treatments on fertility status of soil.

4.2.1 Available nitrogen

The data in respect of available nitrogen compiled during the experimentation and presented in Table 10 and graphically depicted in Fig. 5.

Table 10. Effect of tillage and nutrient management on available nitrogen in soil

Treatments	Available Nitrogen (kg ha ⁻¹)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	220.7	224.82
Set II : Conservation tillage	232.3	238.32
SE (m) ±	2.7	3.82
CD at 5 %	7.9	11.09
b. Nutrient management		
T1: Control	203.0	204.57
T2: 100% RDF	236.8	240.13
T3: 50% N through FYM+ remaining RD through chemical fertilizer	238.2	245.22
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	221.5	226.35
T5: 50% N through GLM + remaining RD through chemical fertilizer	232.8	239.95
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	223.7	226.36
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	227.7	234.53
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	227.7	235.47
SE (m) ±	5.5	7.65
CD at 5 %	15.9	22.08
c. Interaction effect	NS	NS

Tillage

Perusal of data (Table 10) indicates that the available nitrogen content increased over the initial in both tillage treatments. The data in respect of available nitrogen as influenced by tillage was found to be significant. The significantly higher value of available nitrogen was recorded in conservation tillage (238.32 kg ha⁻¹) as compared to conventional tillage (224.82 kg ha⁻¹). Improved nitrogen status after harvest of crop was due to addition of biomass which was stayed large period under conservation tillage. Benito and Sombrero (2006) revealed that the nitrogen content showed highly significant differences between tillage systems at the 0-10 and 10-20 cm depths, with higher values in No tillage than conventional tillage. Chandra *et al.* (2017) found that nitrogen content in soil was highest in zero tillage than in tilled plots. These result are in accordance with the findings of Borie *et al.* (2006).

Integrated nutrient management

Treatment T₃ receiving 50% N through FYM + remaining RD through chemical fertilizers recorded higher available nitrogen (245.22 kg ha⁻¹). Among the treatments, highest values of available nitrogen was registered in T₃ and in T₅ (239.95 kg ha⁻¹) which received 50% N through GLM + remaining RD through chemical fertilizers and T₈ (235.47 kg ha⁻¹) which received 100% P through phosphocompost + remaining N through chemical fertilizer. This increase in available nitrogen might be due to the direct addition of the N through FYM, green manuring to the available pool of soil. The lower value of nitrogen was recorded in treatment T₁ (204.57 kg ha⁻¹).

Increase in the available nitrogen content over control with the application of 50% N through FYM + remaining RD through chemical fertilizers, 50% N through GLM + remaining RD through chemical fertilizers and 100% P through phosphocompost + remaining N through chemical fertilizer over control was 19.87%, 17.29% and 15.10% respectively. This increase is due to the effect of balanced fertilization of organic manures along with chemical fertilizers. Such a response can be ascribed to direct addition of nitrogen through the organics or inorganics due to higher soil

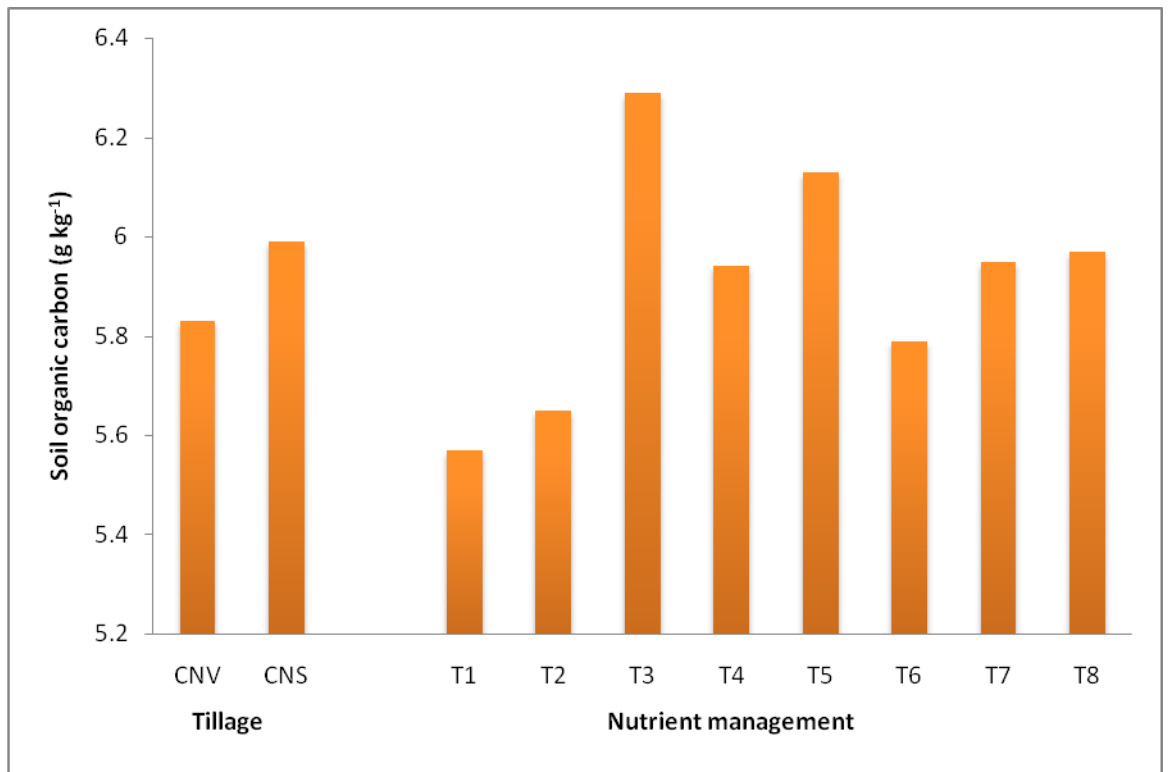


Fig. 4 Soil organic carbon as influenced by various treatments

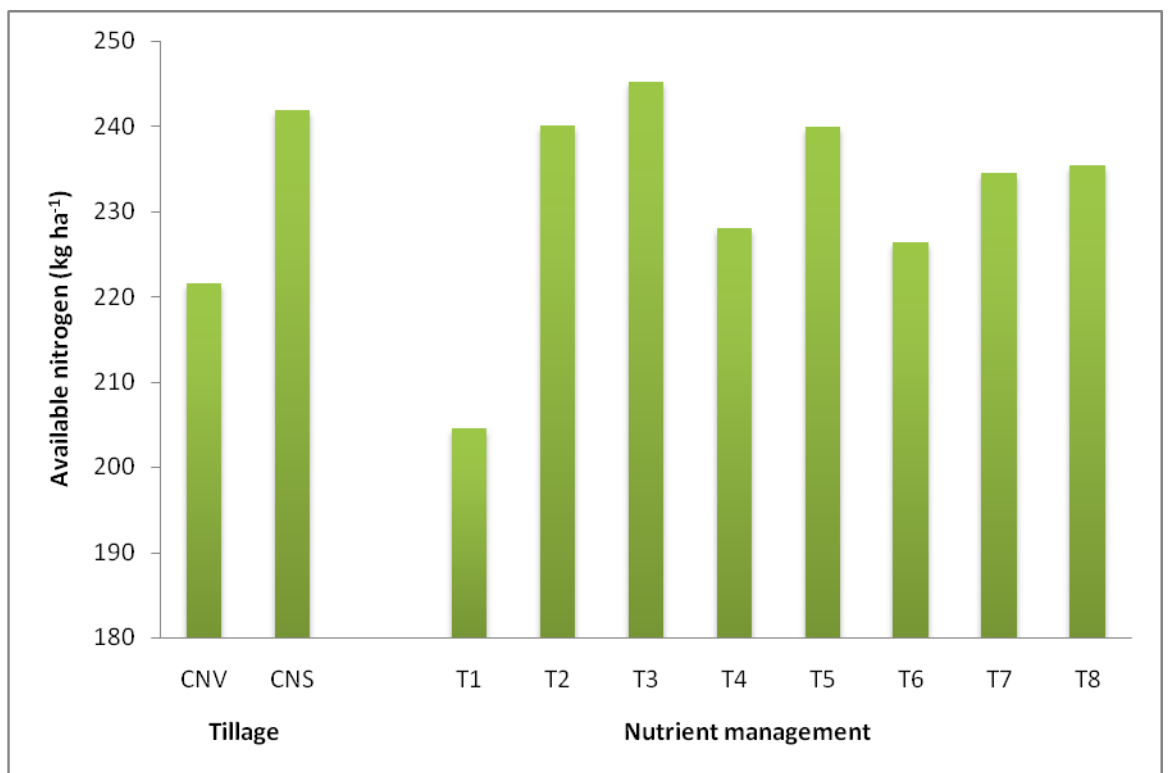


Fig. 5 Available nitrogen as influenced by various treatments

microbial activity, which converted immobilized organically bound nitrogen into an inorganic form.

Reddy and Malewar (2002) observed that the significantly higher available nitrogen content of soil was obtained with incorporation of crop residues. Tolanur and Badanur (2003) noted that available N status increased with conjunctive use of fertilizer and organic manure. Similar higher availability of nitrogen was also recorded by Selvi *et al.* (2003).

Kumar *et al.* (2008) revealed that application of crop residues along with FYM and green leaf manure significantly increased the available nitrogen content of soil over 100 per cent NPK alone treatment. These results are in agreement with the findings of Singh *et al.* (2014).

Interaction effect

The interaction effect between tillage and integrated nutrient management on available nitrogen was non-significant.

4.2.2 Available phosphorus

The findings on available phosphorus in soil after harvest of cotton are presented in Table 11 and depicted in Fig.6.

Tillage

The data on available phosphorus influenced by different tillage treatments is presented in Table 11. The data revealed that available phosphorus content of soil was significantly influenced by tillage treatments. Highest value of available phosphorus was observed in conservation tillage (23.26 kg ha⁻¹) as compared to conventional tillage (19.67 kg ha⁻¹). Benito and Sombrero (2006) revealed that the content of phosphorus was significantly different between tillage systems, with higher values under no tillage and minimum tillage than under conventional tillage as a consequence of the differences observed in the first centimeters of soil. Jessika *et al.* (2006) reported that conservation tillage increased available phosphorus. Positive effects of reduced tillage and no tillage on soil chemical characteristics was demonstrated, such effects summarized as greater available phosphorus levels left in the soil under no tillage than under conventional tillage (Borie *et al.*, 2006).

Table 11. Effect of tillage and nutrient management on available phosphorus in soil

Treatments	Available Phosphorus (kg ha ⁻¹)	
	Initial	Post harvest
a. Tillage		
Set I : Conventional tillage	19.86	19.67
Set II : Conservation tillage	21.26	23.26
SE (m) ±	0.43	0.32
CD at 5 %	1.25	0.92
b. Nutrient management		
T1: Control	14.46	14.78
T2: 100% RDF	18.35	19.87
T3: 50% N through FYM+ remaining RD through chemical fertilizer	21.82	22.39
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	21.07	21.93
T5: 50% N through GLM + remaining RD through chemical fertilizer	21.51	21.80
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	21.34	21.77
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	22.13	23.83
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	23.82	25.37
SE (m) ±	0.86	0.64
CD at 5 %	2.49	1.85
c. Interaction effect	Sig	Sig

Table 11 b. Interaction effect of tillage and nutrient management on available phosphorus in soil

Tillage	CNV	CNS	Mean
Nutrient management			
T1: Control	11.81	17.75	14.78
T2: 100% RDF	17.11	22.62	19.86
T3: 50% N through FYM+ remaining RD through chemical fertilizer	21.58	23.20	22.39
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	21.80	22.06	21.93
T5: 50% N through GLM + remaining RD through chemical fertilizer	21.15	22.45	21.8
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	19.32	24.21	21.76
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	22.52	25.58	24.05
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	22.10	28.63	25.36
Mean	19.67	23.26	---
SE (m) ±	0.91		
CD at 5 %	2.62		

Integrated nutrient management

The available phosphorus in soil after harvest of cotton was differ among various treatments. The significantly highest available P (25.37 kg ha⁻¹) was observed in treatment T₈ receiving 100% P through phosphocompost + remaining N through chemical fertilizer followed by T₇ (23.83 kg ha⁻¹) where 50% N through vermicompost + remaining RD through chemical fertilizer and T₃ (22.39 kg ha⁻¹) receiving 50% N through through FYM+ remaining RD through chemical fertilizer. The values were on par with each other. Increase in available P in these treatments might be

due to the effect of mineralization of organic sources or through solubilization of nutrients from the native sources during the process of decomposition. Lowest value was recorded in treatment T₁ (14.78 kg ha⁻¹).

The increase in available phosphorous in soil in treatment T₈ (25.37 kg ha⁻¹) was 71.65% over treatment T₁. Similarly it was also observed that where organic sources were used, the available phosphorous was remarkably increase in soil. The similar result also noted by Surekha *et al.* (2004), they had reported that the application of organic manures and inorganic fertilizers resulted in increase in available phosphorous content in soil. These results are in agreement with the findings of Chaturvedi and Chandel (2005), Verma *et al.* (2005) and Singh *et al.* (2014).

Interaction effect

The interaction effect between tillage and integrated nutrient management on soil available P was found significant. In respect of tillage treatments the highest value of available phosphorus was observed in conservation tillage (23.26 kg ha⁻¹) as compared to conventional tillage (19.67 kg ha⁻¹).

4.2.3 Available potassium

Tillage

On examination of data, it is noticed that, the effect of tillage on available potassium was significant. The same has been presented in table 12 and depicted in Fig. 7. Highest value of soil available potassium was observed in conservation tillage (393.61 kg ha⁻¹) as compared to conventional tillage (372.14kg ha⁻¹).

Table 12. Effect of tillage and nutrient management on available potassium in soil

Treatments	Available Potassium (kg ha ⁻¹)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	368.6	372.14
Set II : Conservation tillage	379.6	393.61
SE (m) ±	2.9	2.75
CD at 5 %	8.3	7.95
b. Nutrient management		
T1: Control	314.1	313.24
T2: 100% RDF	358.5	360.12
T3: 50% N through FYM+ remaining RD through chemical fertilizer	399.9	400.82
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	378.1	379.37
T5: 50% N through GLM + remaining RD through chemical fertilizer	393.0	401.22
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	382.6	384.75
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	385.5	401.62
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	381.1	393.86
SE (m) ±	5.8	5.51
CD at 5 %	16.6	15.91
c. Interaction effect	NS	NS

Integrated nutrient management

The data in Table 12 indicated available potassium content of soil. It was changed significantly from 313.24 to 401.62 kg ha⁻¹ indicating that the soil was very high in available potassium content. It was observed that the availability of potassium was significantly influenced because of various treatment. Significantly higher available potassium (401.62 kg ha⁻¹) was recorded in treatment T₇ receiving 50% N through vermicompost + remaining RD through chemical fertilizer closely followed by treatment T₅ receiving

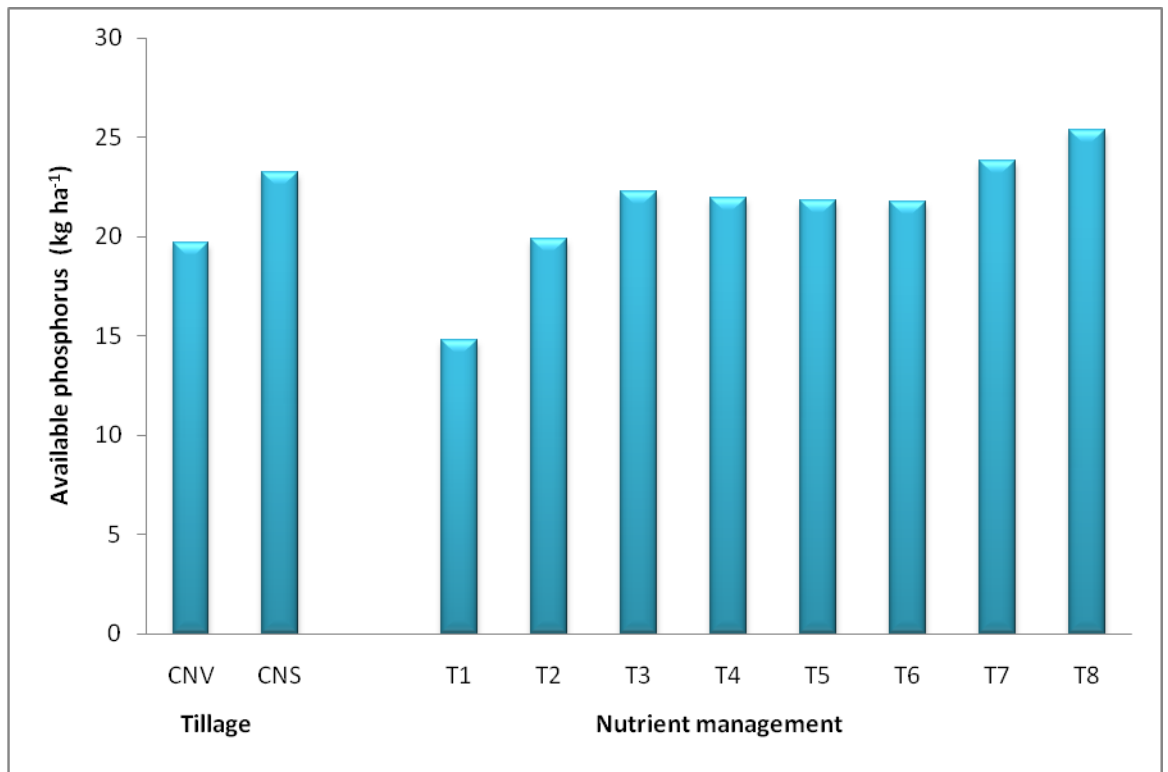


Fig. 6 Available phosphorus as influenced by various treatments

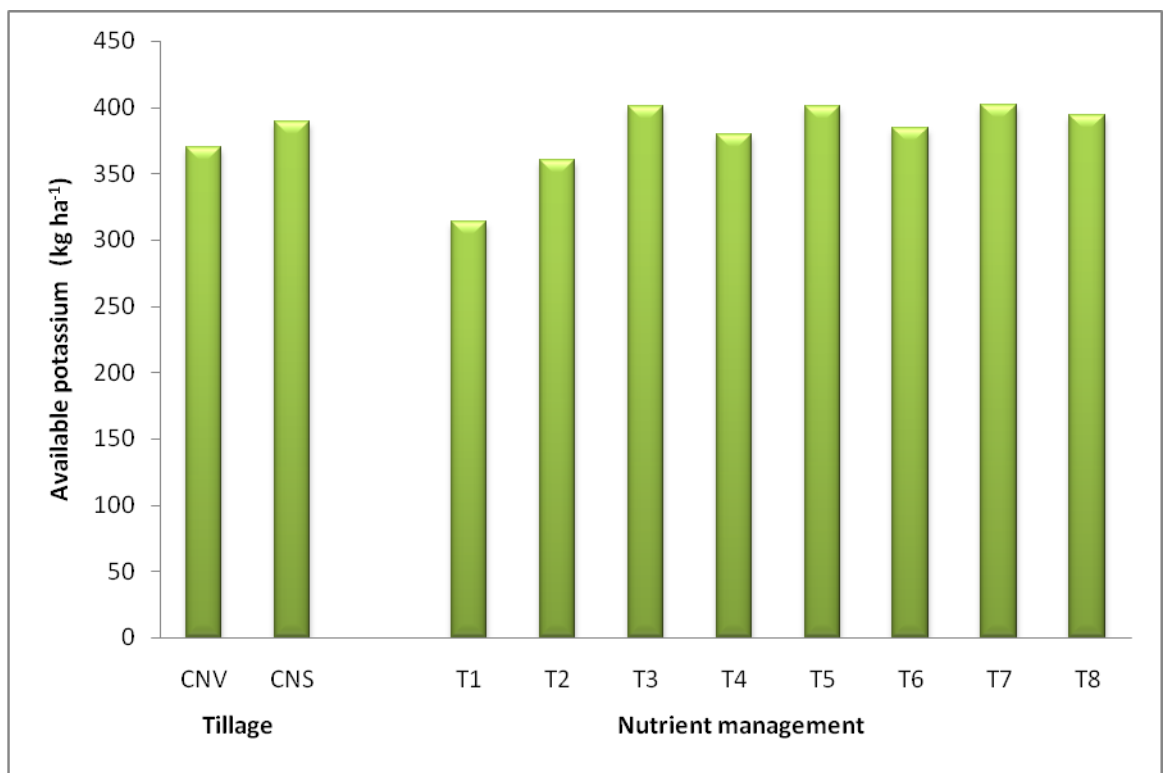


Fig. 7 Available potassium as influenced by various treatments

50% N through GLM + remaining RD through chemical fertilizers (400.65 kg ha⁻¹) and T₃ where 50% N through FYM + compensation of RDF (400.22 kg ha⁻¹) through chemical fertilizer. The treatments T₇, T₅ and T₃ were on par with each other and significantly superior over rest of treatments. The increase in potassium can be attributed to direct addition of potassium through application of FYM to the available pool in the soil and also. And also the interaction of organic matter added through FYM and other sources with clay reduce potassium fixation and releases potassium in soil. The increase in the available potassium in treatment T₇ was found to be 28% more over control.

The combined use of crop residue, organic amendments and chemical fertilizers significantly increased the availability of K in soil over chemical fertilizers alone. The result is in conformity with Surekha *et al.* (2004), Katkar *et al.* (2007) and Kumar *et al.* (2008).

Interaction effect

The interaction effect between tillage and integrated nutrient management on available potassium was found non-significant.

4.2.4 Available sulphur

Data in respect of available sulphur as influenced by different treatments are presented in Table 13 and depicted in Fig. 8

Tillage

The examination of data indicates that, the effect of tillage on available sulphur was found to be significant. Significantly higher available sulphur (13.31 mg kg⁻¹) was observed in conservation tillage as compared to conventional tillage (10.69 mg kg⁻¹). The increased availability of sulphur might be due to enhanced 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 influence on improvement of chemical properties which alters the availability of native sulphur in the soil. The results corroborates with the findings of Bharambe *et al.* (2002).



Application of FYM



Application of green leaf manure



Application of phosphocompost



Application of vermicompost



Application of cotton stalk



Application of wheat straw

Plate 2. Addition of organic sources

Table 13a. Effect of tillage and nutrient management on available sulphur in soil

Treatments	Available Sulphur (mg kg ⁻¹)	
	Initial	After harvest
a. Tillage		
Set I : Conventional tillage	10.97	10.69
Set II : Conservation tillage	12.18	13.31
SE (m) ±	0.08	0.16
CD at 5 %	0.24	0.45
b. Nutrient management		
T1: Control	10.16	10.10
T2: 100% RDF	10.99	11.34
T3: 50% N through FYM+ remaining RD through chemical fertilizer	12.87	13.11
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	11.68	12.19
T5: 50% N through GLM + remaining RD through chemical fertilizer	11.57	12.30
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	11.89	12.18
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	11.48	12.19
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	11.93	12.57
SE (m) ±	0.17	0.31
CD at 5 %	0.49	0.90
c. Interaction effect	Sig	Sig

Table 13b. Interaction effect of tillage and nutrient management on available sulphur in soil

Tillage			
Nutrient management	CNV	CNS	Mean
T1: Control	9.34	10.86	10.1
T2: 100% RDF	10.34	12.34	11.34
T3: 50% N through FYM+ remaining RD through chemical fertilizer	10.95	15.28	12.81
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	10.38	14.00	12.19
T5: 50% N through GLM + remaining RD through chemical fertilizer	10.65	13.96	12.30
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	12.04	12.33	12.18
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	10.63	13.76	12.19
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	11.22	13.92	12.57
Mean	10.69	13.31	---
SE (m) ±	0.66		
CD at 5 %	1.91		

Integrated nutrient management

The available sulphur varied from 10.10 to 13.11, where it was found significant. The available sulphur was found significantly higher (13.11 mg kg⁻¹) in the treatment where 50% N through FYM + 50% RDF was given, followed by, 100% P through phosphocompost + remaining N through chemical fertilizer (12.57 mg kg⁻¹) and 50% N through GLM + remaining RD through chemical fertilizer (12.30 mg kg⁻¹) these treatment

were found at par with each others. The lowest available sulphur (10.10 mg kg⁻¹) was recorded in unfertilized control plots. Available sulphur was influenced significantly due to integrated nutrient management. This was apparently due to the supply of sulphur through organic sources which exceeded that supplied through fertilizers as impurities.

The increase in the available sulphur was found 29.80%, 24.78% and 24.45% over unfertilized control plots, in the treatments T₃, T₅ and T₈ where organic manures were applied along with chemical fertilizers. Kademani (2003) observed that content of sulphur in soil increased due to application of organic manures. Verma *et al.* (2005) also revealed that long term application of organic manures and crop residues increased availability of sulphur in soil over chemical fertilization alone. Similar results were reported by Sujata Pothere *et al.* (2007).

Interaction effect

Interaction effect between tillage and nutrient management was found significant. Significantly higher values of available sulphur (15.28 mg kg⁻¹) were observed in conservation tillage with 50% N through FYM + 50% RDF. It was on par with T₅, T₈ and T₇ treatments. The lowest value was observed in treatment T₁. Hence conservation tillage along with integrated nutrient management practices was found beneficial for providing nutrients.

4.1.2 Influence of tillage and nutrient management on biological properties of soil

4.1.2.1 Soil microbial biomass carbon

The soil microbial biomass carbon is an important component of soil organic matter and comprises 1-3 per cent of total organic carbon in soil, but it has a rapid turnover rate and represents a labile reservoir of nutrients. Due to its dynamic character, microbial biomass responds to agricultural management practices. Soil microbial biomass through the process of immobilization and mineralization controls the flow of C, N and P in terrestrial ecosystems (Jenkinson and Ladd, 1981; Dick *et al.* 1992).

Table. 14 a. Influence of tillage and nutrient management on soil microbial biomass carbon

Treatments	Soil microbial biomass carbon ($\mu\text{g g}^{-1}$ soil)
a. Tillage	
Set I : Conventional tillage	238.16
Set II : Conservation tillage	260.68
SE (m) \pm	1.69
CD at 5 %	4.87
b. Nutrient management	
T1: Control	217.44
T2: 100% RDF	229.81
T3: 50% N through FYM+ remaining RD through chemical fertilizer	270.80
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	240.74
T5: 50% N through GLM + remaining RD through chemical fertilizer	255.02
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	253.62
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	264.28
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	267.01
SE (m) \pm	3.37
CD at 5 %	9.73
c. Interaction effect	Sig

Tillage

The close examination of data, indicated that the effect of tillage and nutrient management on soil microbial biomass carbon was found to be significant. The data placed in Table 14 and depicted in Fig. 9. Significantly higher soil microbial biomass carbon was observed under conservation tillage ($260.68 \mu\text{g g}^{-1}$ soil) as compared to conventional tillage ($238.16 \mu\text{g g}^{-1}$ soil). 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 are in consonance with the findings of Murugandam *et al.* (2009) they reported that no-till practices increases soil microbial biomass C as compared to chisel plough and mould board plough.

Table 14b. Influence of tillage and nutrient management on soil microbial biomass carbon

Tillage Nutrient management	CNV	CNS	Mean
T1: Control	215.44	219.43	217.43
T2: 100% RDF	225.11	234.51	229.81
T3: 50% N through FYM+ remaining RD through chemical fertilizer	261.14	280.46	270.8
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	230.91	250.57	240.74
T5: 50% N through GLM + remaining RD through chemical fertilizer	241.00	269.05	255.02
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	233.81	273.43	253.62
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	253.11	275.45	264.28
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	244.78	289.23	267.00
Mean	238.16	260.68	----
SE (m) ±	4.17		
CD at 5 %	13.77		

Carter *et al.* (2009) revealed that the conservation tillage was associated with significant positive effects on soil biota and biological properties, the three years conservation tillage treatment has found increased in concentration of SOC and significant result for Microbial Biomass Carbon concentration. The results are in conformity with Lal *et al.*

(2009), reported that no-till increases the soil microbial biomass carbon as compared to conventional tillage.

Integrated nutrient management

Soil microbial biomass carbon was influenced significantly due to integrated nutrient management. Soil microbial biomass carbon was found significantly highest ($270.80 \mu\text{g g}^{-1}$ soil) in treatment where 50% N through FYM + 50% RDF through chemical fertilizers was given, while it was at par with 100% P through phosphocompost + remaining N through chemical fertilizer ($267.01 \mu\text{g g}^{-1}$ soil) and 50% N through vermicompost + remaining RD through chemical fertilizer ($264.28 \mu\text{g g}^{-1}$ soil). It might be due to the supply of readily available and mineralizable carbon by the addition of organic matter resulted in high microbial activity and it turns in the increase of microbial biomass carbon. This indicates that, system with high organic matter inputs tend to have higher microbial biomass carbon and activities because they are preferred energy sources for microorganisms. The lowest soil microbial biomass carbon ($217.44 \mu\text{g g}^{-1}$ soil) was recorded in control (T_1).

The increase in soil microbial biomass carbon was 24.54 % more in treatment 50% N through FYM + 50% RDF through chemical fertilizers over treatment T_1 . These findings corroborated with the findings of Gabhane *et al.* (2014), who noted that among the various nutrient management treatments, significantly highest improvement in SMBC was noticed under the plots receiving 50% RDF + FYM @ 15 t/ha which was superior over rest of the treatments. Nagar *et al.* (2016) observed that significantly higher values of SMBC with application of phosphocompost and FYM.

Interaction effect

Interaction effect between tillage and nutrient management was found significant. Highest values were found in conservation tillage in treatment T_3 ($280.46 \mu\text{g g}^{-1}$ soil) and under conventional tillage ($261.14 \mu\text{g g}^{-1}$ soil) followed by treatment T_8 . The lowest values found in control.

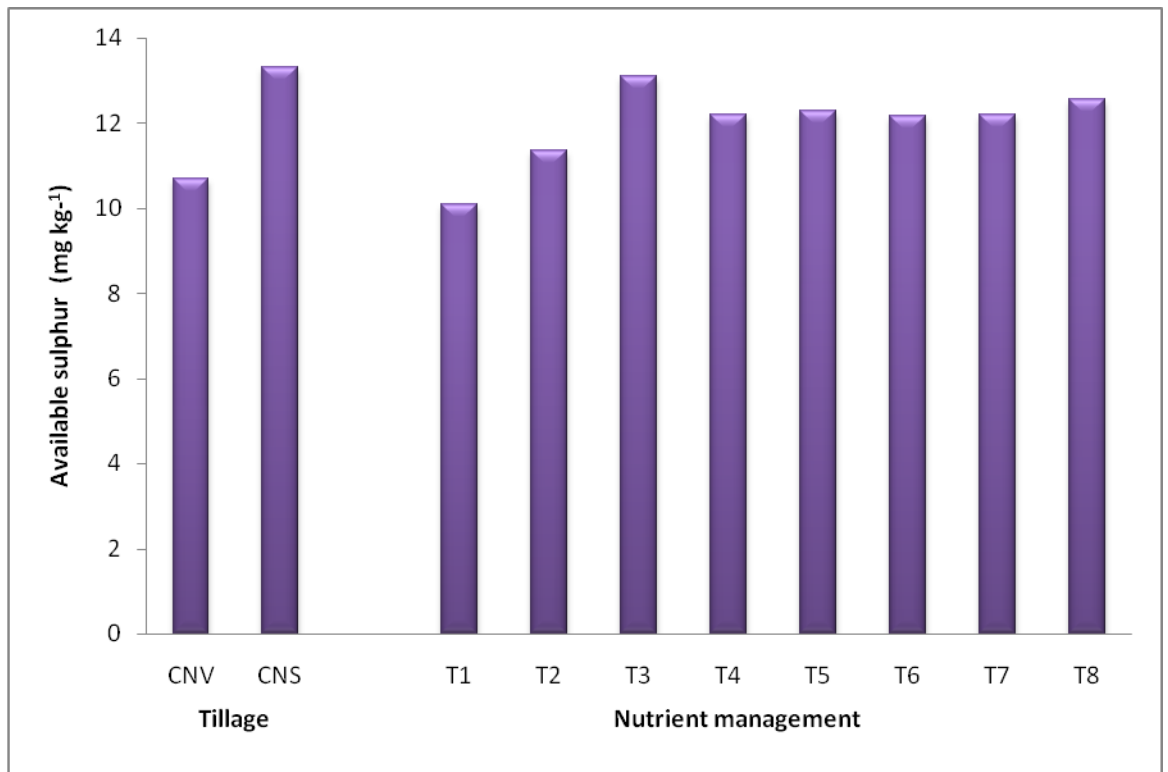


Fig. 8 Available sulphur as influenced by various treatments

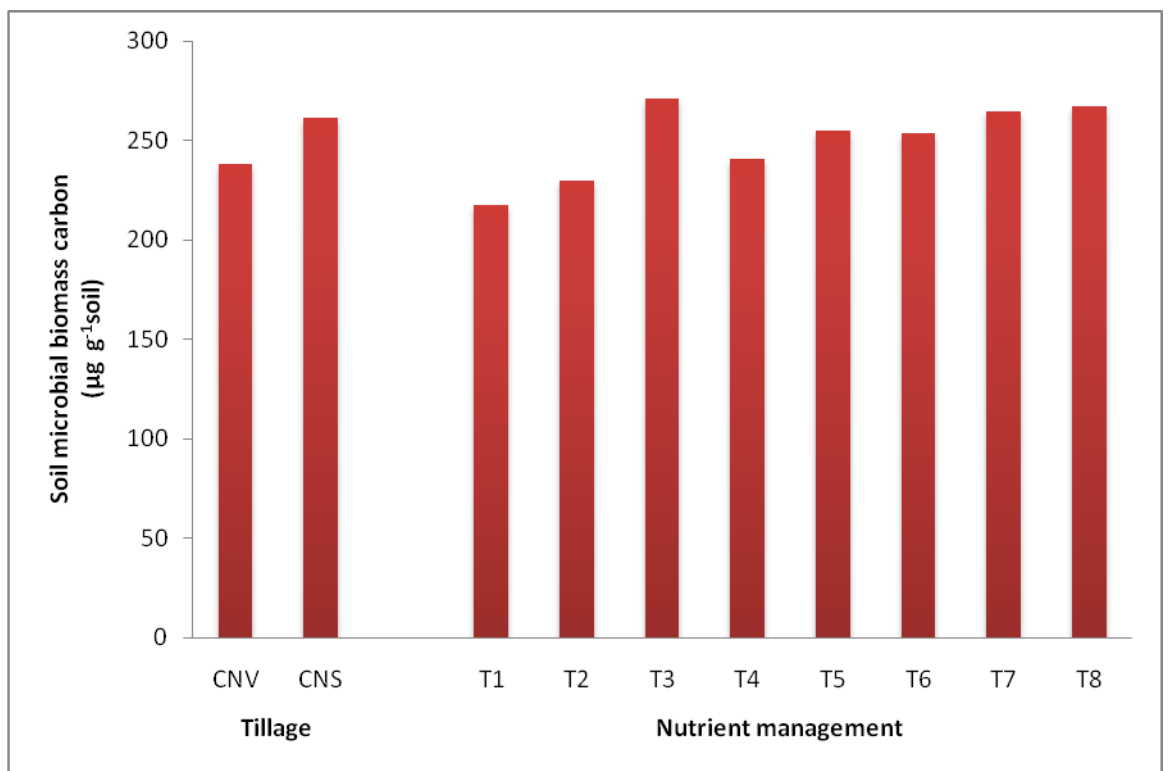


Fig. 9 Soil microbial biomass carbon as influenced by various treatments

Therefore conservation tillage along with integrated nutrient management favors microbial activity and soil fertility.

4.1.2.4 Soil microbial biomass nitrogen

The data in respect of soil microbial biomass nitrogen as influenced by tillage and nutrient management is presented in Table 15 and depicted in Fig 10.

Table 15. Effect of tillage and nutrient management on soil microbial biomass nitrogen

Treatments	Soil microbial biomass nitrogen ($\mu\text{g g}^{-1}$ soil)
a. Tillage	
Set I : Conventional tillage	39.27
Set II : Conservation tillage	42.64
SE (m) \pm	0.25
CD at 5 %	0.71
b. Nutrient management	
T1: Control	36.02
T2: 100% RDF	40.01
T3: 50% N through FYM+ remaining RD through chemical fertilizer	43.90
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	42.35
T5: 50% N through GLM + remaining RD through chemical fertilizer	43.25
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	40.52
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	41.56
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	40.04
SE (m) \pm	0.49
CD at 5 %	1.43
c. Interaction effect	NS

Tillage

Conservation tillage practices showed higher accumulation of microbial biomass content mainly in the upper layers. Amplitude of disturbance determines the distribution and microbial biomass content. No tillage is known to have greater potential than conservation tillage to improve soil physico chemical properties, soil organic carbon, and crop yield. Therefore, soils under no tillage generally contain more organic C, organic N and microbial biomass than soils under conservation tillage. Tillage caused significant spatial variation in microbial C, N and P content in the topsoil more than that of the bottom layer. Significantly higher soil microbial biomass nitrogen was recorded in conservation tillage ($42.64 \mu\text{g g}^{-1}$ soil) as compared to conventional tillage ($39.27 \mu\text{g g}^{-1}$ soil).

Integrated nutrient management

The significantly higher (43.90 mg kg^{-1}) soil microbial biomass nitrogen recorded in treatment 50% N through FYM+ remaining RD through chemical fertilizer, followed by in 50% N through GLM + remaining RD through chemical fertilizer (43.25 mg kg^{-1}) and 50% N through wheat straw + remaining RD through chemical fertilizer (42.35 mg kg^{-1}). All these treatments were on par with each other. The lowest soil microbial biomass nitrogen was obtained in treatment ($36.02 \text{ .mg kg}^{-1}$ soil) where plots were unfertilized.

The percent increase in soil microbial biomass nitrogen was about 21.87%, 20.07% and 17.57% in 50% N through FYM+ remaining RD through chemical fertilizer, 50% N through GLM + remaining RD through chemical fertilizer and 50% N through wheat straw + remaining RD through chemical fertilizer over control.

The similar results also quoted by Patil and Puranik (2001), who has reported that application of FYM, wheat straw and green manuring in soybean-wheat cropping system resulted in increased in soil microbial biomass nitrogen content in soil. Similar results were observed by Kumari *et. al.* (2011).

Interaction effect

Interaction effect between tillage and nutrient management was found non-significant.

4.1.2.3 CO₂ evolution (mg 100 g⁻¹ soil)

The CO₂ evolution is an index of microbial activity and rate of decomposition of organic matter in soil. Soil respiration is an evaluation of soil biological activity and extent of organic matter decomposition. The data in respect of CO₂ evolution is compiled in the Table 16 and depicted in Fig. 11.

Table 16. Effect of tillage and nutrient management on CO₂ evolution

Treatments	CO ₂ evolution
a.Tillage	
Set I : Conventional tillage	53.12
Set II : Conservation tillage	64.44
SE (m) ±	2.04
CD at 5 %	5.90
b.Nutrient management	
T1: Control	38.52
T2: 100% RDF	50.08
T3: 50% N through FYM+ remaining RD through chemical fertilizer	62.86
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	56.92
T5: 50% N through GLM + remaining RD through chemical fertilizer	64.67
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	59.77
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	68.38
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	69.21
SE (m) ±	4.08
CD at 5 %	11.80
c. Interaction effect	NS

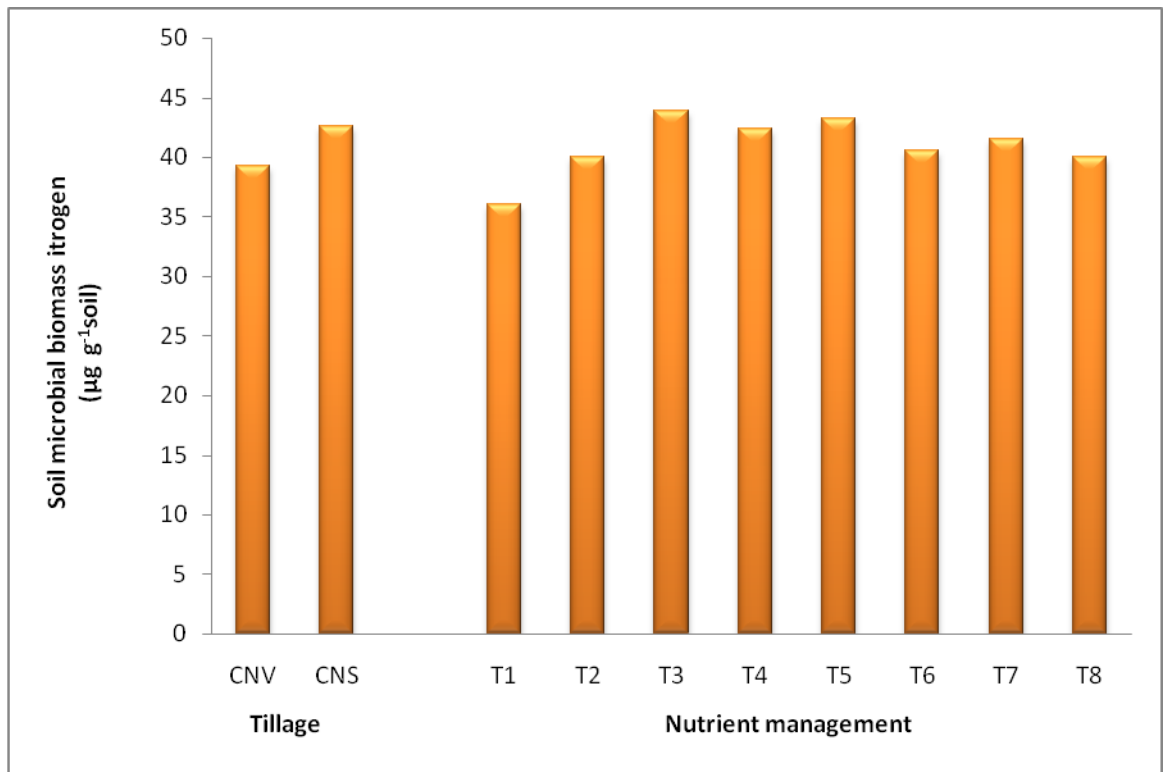


Fig. 10 Soil microbial biomass nitrogen as influenced by various treatments

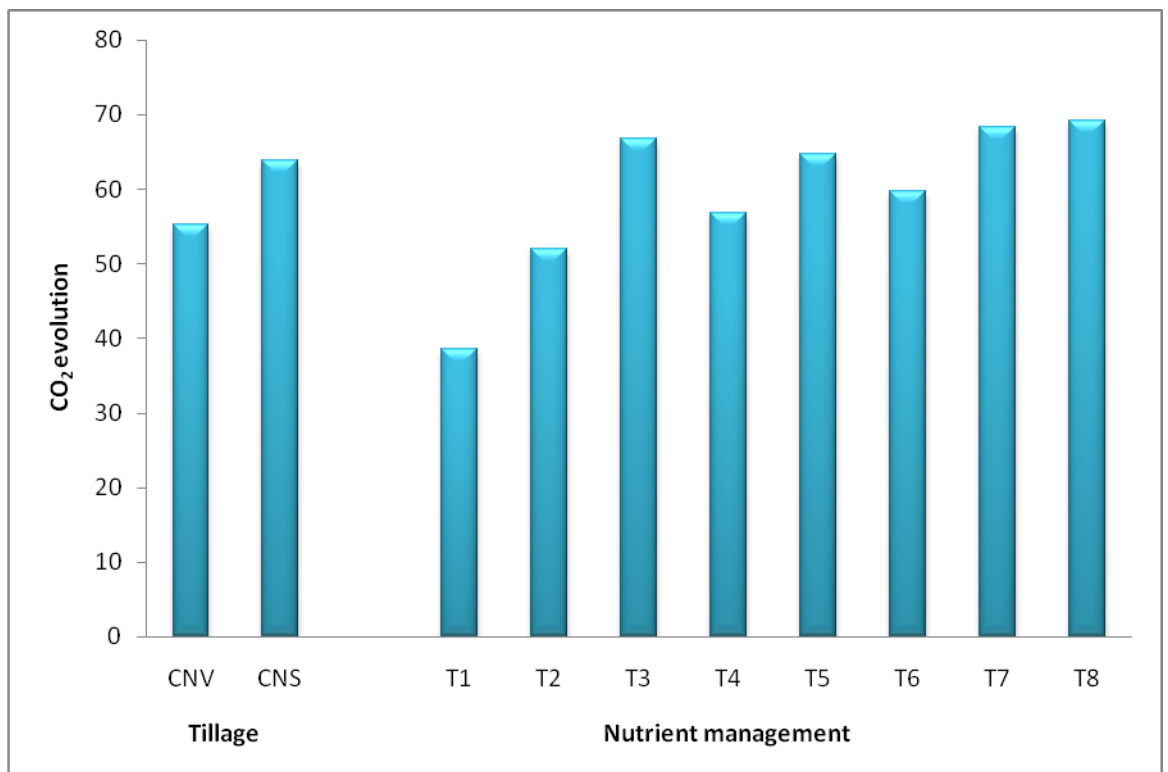


Fig. 11 CO₂ evolution as influenced by various treatments

Tillage

Significantly higher CO₂ evolution was observed in conservation tillage (64.44 mg 100 g⁻¹ soil) as compared to conventional tillage (53.16 mg 100 g⁻¹ soil). Under conventional ploughing, macro aggregates are readily broken down prior to micro-aggregate formation. This leads to a reduction in the proportion of carbon that is more protected in micro-aggregates and thus to the loss of recalcitrant SOC (Six et al., 2000; Chivenge et al., 2007). Hernanz et al., (2002) and Martinez et al., (2008) revealed that differences in aggregate stability are very large when conservation tillage as compared to soil subjected to mouldboard ploughing. Same findings were noted by Tisdall & Oades (1982), they stated that improved aggregate stability under CT management results from greater biological activity in these soils and a reduction in the breakdown of surface soil aggregates. Similar findings reported by Jacinthe and Lal (2009).

Integrated nutrient management

CO₂ evolution was influenced significantly due to integrated nutrient management. CO₂ evolution was found significantly higher (69.21 mg 100 g⁻¹ soil) in the treatment of 100% P through phosphocompost + remaining N through chemical fertilizer followed by treatments, 50% N through vermicompost + remaining RD through chemical fertilizer (68.38 mg 100 g⁻¹ soil) and 50% N through FYM+ remaining RD through chemical fertilizer (62.86 mg 100 g⁻¹ soil) which were found at par with each other. The lowest (38.52 mg 100 g⁻¹ soil) CO₂ evolution was recorded control. Similar findings were reported by Kaur *et al.* (2005) and Surekha and Rao (2009).

Interaction effect

Interaction effect between tillage and nutrient management was found non-significant.

4.1.2.2 Dehydrogenase activity ($\mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$)

Dehydrogenase is considered to play an important role in initial stages of the oxidation of soil organic matter by transferring hydrogen and electron from substrates to acceptors. Dehydrogenase enzyme is

known to oxidize soil organic matter by transferring protons and electrons from substrates to acceptors. These processes are part of respiration pathways of soil microorganisms and closely related to the type of soil. The activity of dehydrogenase enzyme in the soil system is very important as it may give indications of potential of soil to support biochemical processes which are essential for maintaining soil fertility (Joachim *et al.*, 2008). The soil enzyme activity was found to be influenced by native soil eco-system and fertilizer application and soil dehydrogenase activity, as an indicator of total soil microbial activity, reflects the fertility of soils (Rautaray, 2005).

Table 17. Effect of tillage and nutrient management on dehydrogenase activity

Treatments	Dehydrogenase activity ($\mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$)
a. Tillage	
Set I : Conventional tillage	49.77
Set II : Conservation tillage	57.67
SE (m) \pm	1.96
CD at 5 %	4.65
b. Nutrient management	
T1: Control	35.98
T2: 100% RDF	42.56
T3: 50% N through FYM+ remaining RD through chemical fertilizer	62.55
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	57.98
T5: 50% N through GLM + remaining RD through chemical fertilizer	57.75
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	56.13
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	60.58
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	60.24
SE (m) \pm	3.22
CD at 5 %	9.30
c. Interaction effect	NS

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.

Tillage

Data presented in Table 17 and depicted in Fig. 12, showed that significantly highest value dehydrogenase activity was recorded in conservation tillage ($57.67 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) as compared to the conventional tillage was ($49.77 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$). These results may be attributed due to enhanced microbial activities as undisturbed soil condition which promotes microbial growth and there by enzymatic activities. 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 and hence improved enzyme activity in soil Mathew *et al.* (2012).

Integrated nutrient management

The dehydrogenase activity was influenced significantly due to integrated nutrient management. The highest dehydrogenase activity ($62.55 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) was found in the treatment with 50% N through FYM + 50% RDF through chemical fertilizers followed by, 50% N through vermicompost + remaining RD through chemical fertilizer ($60.58 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) and 100% P through phosphocompost + remaining N through chemical fertilizer ($60.24 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$). These treatments were found to be at par with each other. The lowest dehydrogenase activity ($35.98 \mu\text{g TPF g}^{-1} 24 \text{ h}^{-1}$) was recorded in control.

The dehydrogenase activity was 73.84%, 68.37 and 67.42% more with the application of FYM, Vermicompost and Phosphocompost along with chemical fertilizers over control. The results are in conformity with the findings of Mandal *et al.* (2010).

Interaction effect

Interaction effect of tillage and integrated nutrient management was non-significant.

4.2 Effect of tillage and nutrient management on rooting behavior of cotton

4.2.1 Root length

Data regarding the effect of tillage and nutrient management on rooting behavior of cotton at boll development stage is presented in Table 18 and depicted in Fig.13.

Tillage

Based on assessment of data, it was noticed that the effect of tillage on root length was found to be significant. The findings indicated that the root length at boll development stage of cotton was 51.73 cm in conventional tillage and 55.83 in conservation tillage. The root length was greater under no tillage than under conventional tillage. This is attributed due to the continuous addition of crop residues which supported to increased soil organic carbon, particularly in the topsoil. This increase in SOC supported to develop favorable environment through proper manipulation of soil that may favors root development in time. (Martinez *et al* 2008).

These results are in accordance with Esser (2016), showed that the numbers of large roots under conservation tillage tended to be higher than under conventional tillage.

Nutrient management

The results indicated that the root length at boll development stage was significant. It was ranged from 39.97 to 61.27 cm. Highest (61.27 cm) root length was recorded with the treatment T₃ where 50% N through FYM+ remaining RD through chemical fertilizer was applied, followed by T₇ (60.88 cm) and T₈ (60.82 cm).

Interaction effect

Interaction effect of tillage and nutrient management was found significant.

4.2.2 Root volume

The effect of tillage and nutrient management on rooting volume of cotton at boll development stage, was found significant. The same is presented in Table 18 and depicted in Fig.14.

Table 18a. Effect of tillage and nutrient management on rooting behavior of cotton

Treatments	Root length (cm)	Root volume (cm ³)
a.Tillage		
Set I : Conventional tillage	55.52	7.08
Set II : Conservation tillage	58.09	7.63
SE (m) ±	0.39	0.10
CD at 5 %	1.12	0.30
b.Nutrient management		
T1: Control	39.97	5.68
T2: 100% RDF	51.90	6.25
T3: 50% N through FYM+ remaining RD through chemical fertilizer	61.27	8.27
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	60.40	7.48
T5: 50% N through GLM + remaining RD through chemical fertilizer	59.48	7.68
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	59.75	7.63
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	60.88	7.92
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	60.82	7.93
SE (m) ±	0.77	0.21
CD at 5 %	2.24	0.60
c. Interaction effect	Sig	Sig

Table 18b. Interaction effect of tillage and nutrient management on root length of cotton

Tillage Nutrient management	CNV	CNS	Mean
T1: Control	37.63	42.30	39.96
T2: 100% RDF	50.97	52.83	51.9
T3: 50% N through FYM+ remaining RD through chemical fertilizer	60.47	62.07	60.39
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	60.20	60.59	59.48
T5: 50% N through GLM + remaining RD through chemical fertilizer	57.33	61.63	59.75
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	55.47	64.03	60.88
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	60.83	60.93	60.81
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	59.20	62.43	
Mean	55.52	58.09	
SE (m) ±	1.09		
CD at 5 %	3.16		

Tillage

Significantly higher values of root volume (7.63 cm³) was recorded due to conservation tillage as compared to conventional tillage.

Effect of nutrient management

Based on the data compiled for root volume, it was observed that the significantly higher root volume (8.27 cm³) recorded in treatment T₃ receiving 50% N through FYM+ remaining RD through chemical fertilizer

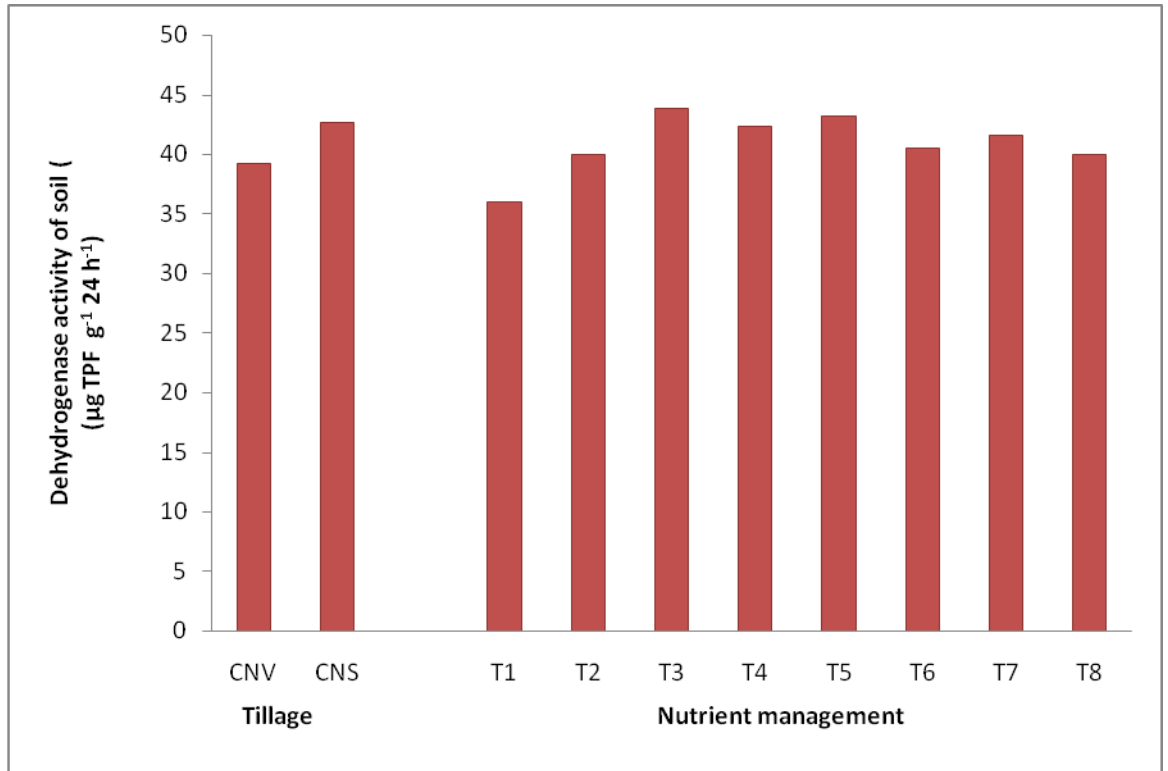


Fig. 12 Dehydrogenase activity of soil as influenced by various treatments

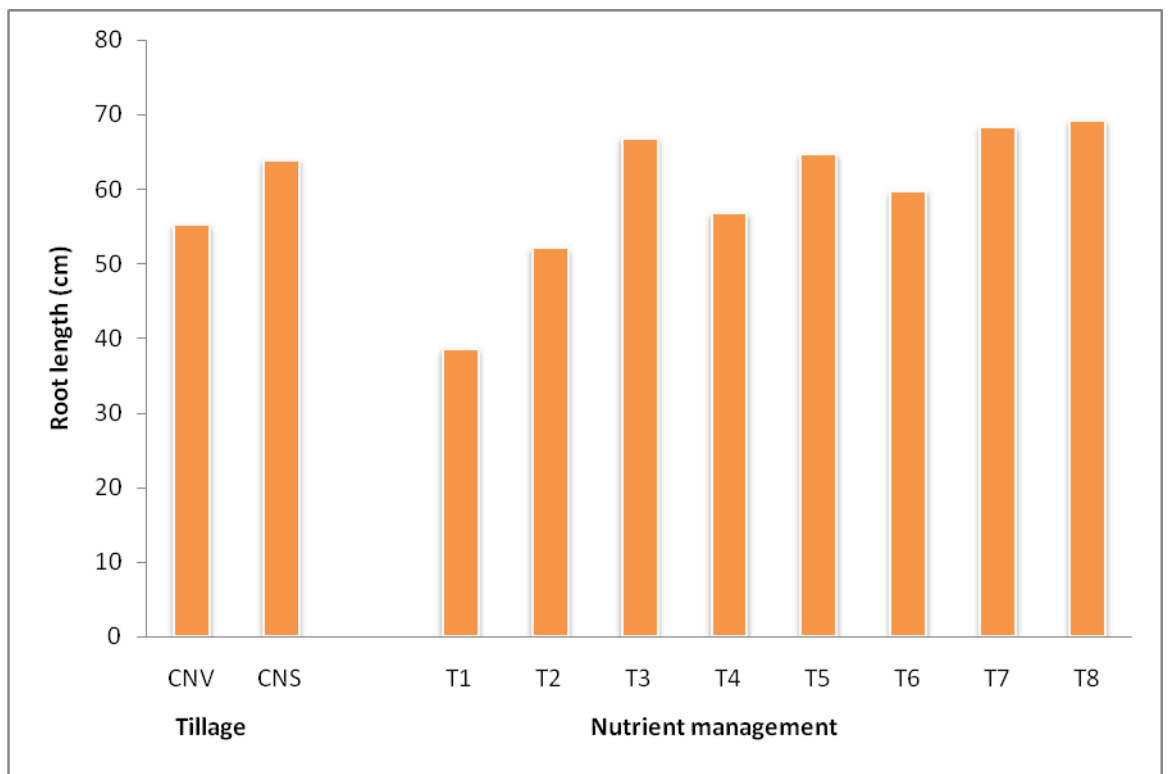


Fig. 13 Root length as influenced by various treatments

and it was at par with T₈, T₇ and T₅ treatments. The lowest value of root volume was noted in treatment T₁ (5.68 cc).

Table 18 c. Interaction effect of tillage and nutrient management on root volume of cotton

Tillage Nutrient management	CNV	CNS	Mean
T1: Control	5.20	6.17	11.37
T2: 100% RDF	6.20	6.30	12.5
T3: 50% N through FYM+ remaining RD through chemical fertilizer	8.03	8.50	16.53
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	7.00	7.97	14.97
T5: 50% N through GLM + remaining RD through chemical fertilizer	7.30	8.07	15.37
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	7.53	7.73	15.26
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	7.67	8.17	15.84
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	7.73	8.13	15.86
Mean	7.08	7.63	
SE (m) ±	0.29		
CD at 5 %	1.84		

The root volume obtained in treatment T₃ was 45% more over control. This root growth was might be due to combined effect of organic and inorganic inputs that favors root growth by providing beneficial microbial activity and timely nutrient support.

Interaction effect

Interaction between tillage and integrated nutrient management was found significant. The highest root volume was observed (8.50 cc) under conservation tillage and (8.03 cc) under conventional tillage with same treatment T₃, followed by treatment T₅.

4.3 Effect of tillage and nutrient management on seed cotton yield

Tillage

The data regarding seed cotton yield presented in Table 19 and depicted in Fig. 15. The seed cotton yield as influenced by tillage was significant. Maximum value of seed cotton yield (13.79 q ha⁻¹) was obtained with conservation tillage as compared to conventional tillage (12.49 q ha⁻¹). Schwab *et al.* (2014) examined the trend of seed cotton yield under five years experimentation and claimed that, the seed cotton yield was greater or equivalent to yield in conventional tillage.

Naveen kumar and Babalad (2017) revealed that 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 seed cotton yield (1,756 and 1,743 kg ha⁻¹, respectively) over conventional tillage. Blaise (2011) also noted that reduced tillage has significant value of seed cotton yield than conventional tillage.

Conventional tillage

Conservation tillage



T₁– Control



T₂– 100% RDF

Plate 3a. Performance of cotton under conventional and conservation tillage

Conventional tillage

Conservation tillage



T₃ – 50% N (FYM) + RD



T₇ – 50% N (VC) + RD



T₈ – 50% N (PC) + RD

Plate 3b. Performance of cotton under conventional and conservation tillage

Table 19a. Influenced of tillage and nutrient management on seed cotton yield

Treatments	Seed cotton yield (q ha⁻¹)
a.Tillage	
Set I : Conventional tillage	12.49
Set II : Conservation tillage	13.79
SE (m) ±	0.35
CD at 5 %	1.01
b.Nutrient management	
T1: Control	8.76
T2: 100% RDF	13.87
T3: 50% N through FYM+ remaining RD through chemical fertilizer	14.27
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	12.35
T5: 50% N through GLM + remaining RD through chemical fertilizer	14.21
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	12.91
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	14.35
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	14.42
SE (m) ±	0.70
CD at 5 %	2.01
c. Interaction effect	Sig

Integrated nutrient management

The results revealed that the seed cotton yield was significantly influenced by integrated nutrient management. The significantly highest seed cotton yield (14.42 q ha⁻¹) was observed in 100% P through phosphocompost + remaining N through chemical fertilizers,

followed by application of 50% N through vermicompost + remaining RD through chemical fertilizer (14.35 q ha⁻¹), 50% N through FYM + remaining RD through chemical fertilizer (14.27 q ha⁻¹) and 50% N through GLM + remaining RD through chemical fertilizers (14.21 q ha⁻¹) which were at par with each other. The lowest seed cotton yield was observed in unfertilized plot (8.76 q ha⁻¹). The increase in seed cotton yield due to integrated use of organic manures and chemical fertilizers attributed to efficient utilization of nutrient from soil. Inclusion of phosphocompost, crop residues and green manure in cropping system improves fertility status of soil and helps in increasing the yield of crop. The similar results are also corroborated with the findings of solankhe and Fatak (2011), Shah and Verma (2012) and Gabhane *et al.* (2014).

Table 19 b. Interaction effect of tillage and nutrient management on seed cotton yield

Nutrient management	Tillage		
	CNV	CNS	Mean
T1: Control	8.20	9.32	8.76
T2: 100% RDF	12.83	14.92	13.87
T3: 50% N through FYM+ remaining RD through chemical fertilizer	13.29	15.25	14.27
T4: 50% N through wheat straw + remaining RD through chemical fertilizer	10.70	13.99	12.34
T5: 50% N through GLM + remaining RD through chemical fertilizer	14.03	14.38	14.20
T6: 50% N through composted cotton stalk + remaining RD through chemical fertilizer	12.87	12.96	12.91
T7: 50% N through vermicompost + remaining RD through chemical fertilizer	14.35	14.36	14.35
T8: 100% P through phosphocompost + remaining N through chemical fertilizer	13.67	15.17	14.42
Mean	12.49	13.79	---
SE (m) ±	0.99		
CD at 5 %	2.85		

Interaction effect

Interaction effect of tillage and integrated nutrient management was significant on seed cotton yield. Highest seed cotton yield was (13.79 q ha^{-1}) recorded under conservation tillage against conventional tillage (12.49 q ha^{-1}). The conservation tillage and 50% N through FYM and remaining RD through chemical fertilizers recorded significantly high (15.25 q ha^{-1}) and it was closely followed by T₈ i.e. 100% P through phosphocompost + remaining N through chemical fertilizers. Both the treatments were at par with all the treatments except control.

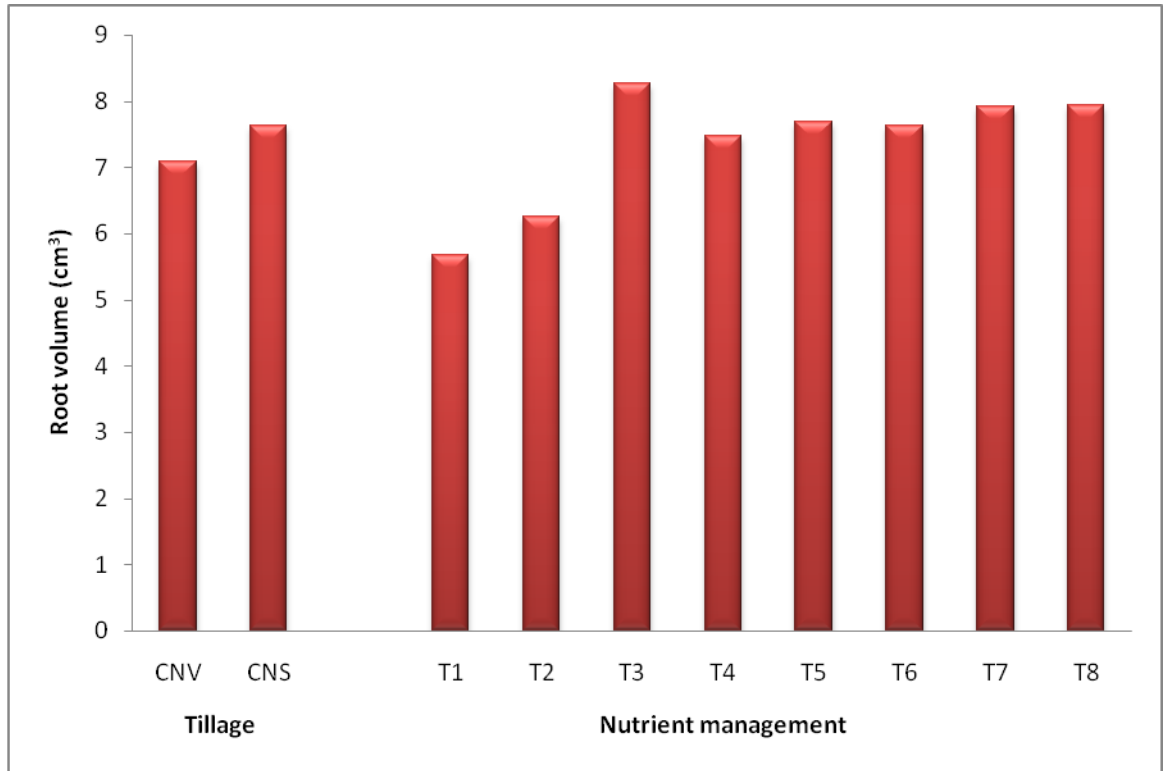


Fig. 14 Root volume as influenced by various treatments

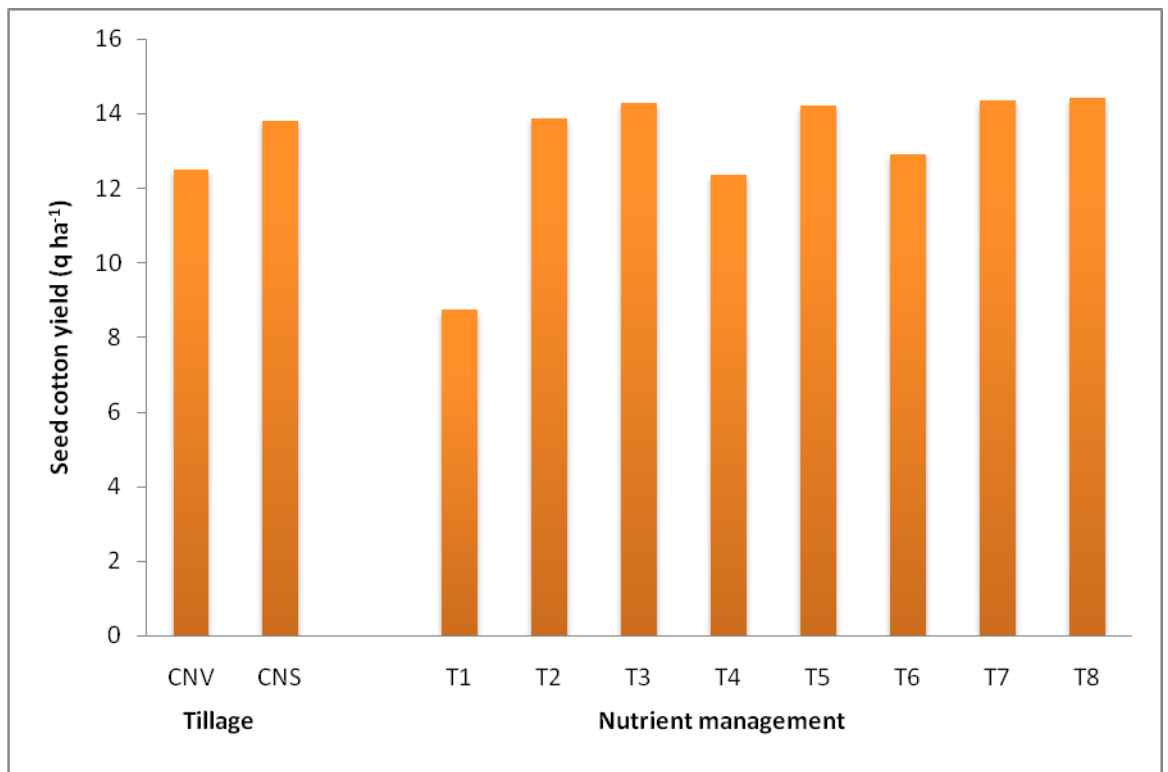


Fig. 15 Seed cotton yield as influenced by various treatments

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

The field experiment on cotton was conducted on Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. PDKV Akola during 2017-18 in order to study the “Influence of tillage and nutrient management on biological dynamics of soil and rooting behavior of cotton in Vertisols” The main treatments comprised of conservation tillage and conventional tillage while the sub treatments were integrated nutrient management practices. The integrated nutrient management treatments consist of FYM, wheat straw, glyricidia, cotton stalk, vermicompost and phosphocompost and their combinations. The treatments thus involved two main treatments and eight sub treatments. The three replications were under taken with a randomized block design.

The treatment wise soil samples were collected at harvest of cotton and analyzed for various properties. The salient findings of the present investigation are summarized below.

5.1.1 Chemical properties

pH and Electrical conductivity

- The pH of soil was not influenced significantly under tillage as well as nutrient management practices.
- The slight decrease in electrical conductivity of soil was registered with application of FYM and fertilizers. While no specific trend was observed due to various treatments.

Organic carbon

- The higher organic carbon was recorded under conservation tillage. Relatively higher organic carbon was recorded with the conjoint use of chemical fertilizers and FYM followed by treatments where integration of chemical fertilizers with green leaf manuring glyricidia and phosphocompost was given.

- The higher organic carbon (5.99 g kg^{-1}) was found under conservation tillage as compared to conventional tillage (5.75 g kg^{-1}) in respect of tillage operations.
- The highest organic carbon content (5.83 g kg^{-1}) was recorded with the integrated use of chemical fertilizers and FYM.
- Conjoint use of chemical fertilizers with organics like FYM, GLM, phosphocompost, vermicompost, cotton stalk and wheat straw were found beneficial for maintaining organic carbon content compared to the use of only chemical fertilizers.
- While, the interaction effect of tillage and integrated nutrient management was non-significant however highest organic carbon was recorded with combined effect of FYM under conservation tillage.

Available nitrogen

- Significantly higher available nitrogen was recorded under conservation tillage than conventional tillage. The significantly highest available nitrogen in soil was recorded by integration with FYM and chemical fertilizers.
- The highest available nitrogen ($241.92 \text{ kg ha}^{-1}$) was registered under conservation tillage as against conventional tillage ($221.64 \text{ kg ha}^{-1}$). Furthermore, the highest available nitrogen was noted with application of 50% N through FYM+ remaining RD through chemical fertilizer.
- Interaction effect between tillage and nutrient management was found non-significant. The highest available nitrogen was found with integration of FYM under conservation tillage, followed by phosphocompost and vermicompost.
- The lowest values of available nitrogen ($202.77 \text{ kg ha}^{-1}$) were observed in control under conventional tillage.

Available phosphorus

The highest available phosphorus was recorded under conservation tillage (23.26 kg ha⁻¹) as compared to conventional tillage (19.67 kg ha⁻¹). Whereas, the highest available phosphorus (25.37 kg ha⁻¹) was noted with application of 100% P through phosphocompost + remaining N through chemical fertilizer.

- Interaction effect between tillage and nutrient management was found significant. The highest available phosphorus (26.63 kg ha⁻¹) was found with integration of phosphocompost under conservation tillage. The lowest available phosphorus (11.81 kg ha⁻¹) was recorded in control under conventional tillage.

Available potassium

- The significantly highest available potassium was noticed in conservation tillage (393.61 kg ha⁻¹) than in conventional tillage (365.14 kg ha⁻¹). Furthermore, the highest available potassium (401.62 kg ha⁻¹) was noted with application of 50% N through vermicompost + remaining RD through chemical fertilizer.
- Interaction effect between tillage and nutrient management was found non-significant. The highest available potassium (403.65 kg ha⁻¹) was found with integration of vermicompost under conservation tillage and under conventional tillage (399.59 kg ha⁻¹) in same treatment T₇. The lowest available potassium (305.50 kg ha⁻¹) was recorded in control under conventional tillage.

Available sulphur

- The significantly highest available sulphur was (13.31 kg ha⁻¹) registered under conservation tillage as against conventional tillage (10.69 kg ha⁻¹). In respect of nutrient management highest sulphur was observed in 50% N through FYM+ remaining RD through chemical fertilizer (13.11 kg ha⁻¹) followed by The application 100% P through phosphocompost + remaining N through chemical fertilizer (12.57 kg ha⁻¹).

- Considering interaction effect, the highest available sulphur was noted under conservation tillage (15.28 kg ha⁻¹) and conventional (12.04 kg ha⁻¹) in same treatment T₃ where integration of FYM and chemical fertilizers was given.

5.3 Biological properties

- The highest SMBC was recorded under 50% N through FYM followed by phosphocompost and vermicompost along with chemical fertilizers.
- The SMBC in CNS (261.52 µg g⁻¹ soil) and in CNV (238.16 µg g⁻¹ soil).
- The highest SMBC was registered in 50% N through FYM+ remaining RD through chemical fertilizer (270.80 µg g⁻¹ soil).
- The SMBN in CNS (42.64 µg g⁻¹ soil) and in CNV (39.27 µg g⁻¹ soil).
- The highest SMBN was recorded in 50% N through FYM+ remaining RD through chemical fertilizer (43.90 µg g⁻¹ soil).
- Profound influence of integrated nutrient management treatments comprising of phosphocompost, vermicompost, and FYM with chemical fertilizers was noticed on soil respiration over chemical fertilizer treatments.
- The dehydrogenase activity (DHA) showed significant improvement due to FYM along with chemical fertilizers over only chemical fertilizers.
- The 50% nutrients through organics also recorded significant improvement in DHA. The highest value of dehydrogenase activity was recorded with the treatment T₃ (62.55 µg TPF g⁻¹ 24 h⁻¹).
- In respect of CO₂ evolution, highest values were recorded under conservation tillage against conventional tillage. FYM in conjunction with chemical fertilizers recorded the highest CO₂ evolution followed by treatments T₇ and T₈ receiving vermicompost and phosphocompost respectively.

5.4 Rooting behaviour

- Influence of conservation tillage on root growth of cotton was found significant against conventional tillage.
- The significantly highest root length (58.09 cm) was registered under conservation tillage as against conventional tillage (55.52 cm). In respect of nutrient management highest root length was observed in 50% N through FYM+ remaining RD through chemical fertilizer (61.27 cm) followed by the application 100% P through vermicompost + remaining N through chemical fertilizer (60.88 cm).
- The highest value of root volume observed under conservation tillage. In respect of nutrient management highest value (8.27 cc) was recorded in treatment T₃ where 50% N through FYM + remaining RD through chemical fertilizers was applied.
- Furthermore, the highest root length and root volume in an interaction effect, was noted under conservation tillage and conventional in same treatment T₃ where integration of FYM and chemical fertilizers was given.

5.5 Seed cotton yield

- The seed cotton yield was slightly higher under conservation tillage as compared to conventional tillage and highest seed cotton yield under conservation tillage (13.79 q ha⁻¹) over conventional tillage (12.49 q ha⁻¹).
- Highest seed cotton yield was recorded in the treatment receiving application 100% P through phoshpocompost + remaining N through chemical fertilizer (14.42 q ha⁻¹) followed by 50% N through vermicompost + remaining RD through chemical fertilizer (14.35 q ha⁻¹).

5.6 Conclusions

- Based on the observation recorded during the course of investigation, it was observed that, the nutrient management under conservation tillage as compare to conventional tillage shown remarkable changes in various properties of soil. The conservation tillage supported well to enhance biological dynamics of soil by enhancing soil microbial biomass carbon and CO₂ evolution over conventional tillage. The rooting behaviour was also significantly enhanced under conservation tillage along with application of 50% nitrogen through FYM or vermicompost or 100% P through phosphocompost and remaining recommended dose through chemical fertilizers.
- The seed cotton yield was improved significantly under conservation tillage with the application of 50% nitrogen through FYM or vermicompost or 100 % P through phosphocompost and remaining recommended dose through chemical fertilizers under rainfed agriculture

5.3 Implications

The combined use of FYM or vermicompost or phosphocompost and reduced dose of chemical fertilizers under conservation tillage indicates the potential benefit under its long term use for maintaining soil health. The results generated in this investigation is beneficial in improving the cotton productivity and sustaining the soil health under rainfed situation in Vertisols with modified tillage system.

CHAPTER VI

LITERATURE CITED

- Abrol, I. P. and Sangar, S. (2006). Sustaining Indian agriculture-conservation agriculture the way forward. *Current Science*, 91(8), 1020-2015.
- Adarsha, T.S., B.C. Patil, M. Vanaja and K. Srinivas., 2004. Nitrogen and phosphorus management of cotton under different moisture regimes. International Symposium on "Strategies for sustainable cotton production - A global Vision" 23rd to 25th November, 2004. UAS, Dharwad. pp 365-365.
- Anderson, J.P.E. 1982. Soil respiration. p. 831–853. In A.L. Page et al. (ed.) *Methods of soil analysis. Part. 2. Chemical and microbiological properties.* 2nd ed. ASA and SSSA. Madison, WI.
- Araya T. 2012. Medium term effect of conservation agriculture based cropping systems for sustainable soil and water management and crop productivity in the Ethiopian highlands. *Field crops. Re.* 132., 53-62.
- 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.
- Babatunde I. J, B. S. Ewulo, S. O. Agele and S. K. Ogundare, 2016. Reduced Tillage Effect on Soil Physico-Chemical Properties, Growth and Yield of Maize in Gleysol and Ultisol of Kogi State, Nigeria. *American Research Journal of Agriculture (ARJA)* ISSN (Online): 2378-9018, Volume 2016, 11 pages.
- 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.
- Bablad, H.B and C.J. Itnal. 2004. Integrated nutrient management in cotton and soybean intercropping system on vertic Inceptisols under rainfed condition. In: International symposium on "Strategies for sustainable, 2. Crop Production – A global vision" 23-25, Nov. 2004, UAS, Dharwad : 92-97.
- 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.CurrMicrobiol.App.Sci*(2018) 7(2): 602-609.
- Bangar, A. R., A. N. Deshpande, B. D. Tamboli and K. D. Kale, 2003. Effects of *kharif* legumes as yield of *rabi* sorghum and their

economics under sequence cropping in dryland Vertisols. *J. Maharashtra Agri. Univ.* 28(2): 119-122.

- Barrios M. B., A. A. Bozzo, S. P. Debelis, A. M. Pereyra and A. Buján. 2006. Soil physical properties and root activity in a soybean secondcrop/maize rotation under direct sowing and conventional tillage. *spanish journal of agricultural research.* 4(4), 355-362
- 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.
- Bationo, A., S.P. Wani; C.L. Biielders; P.L.G. Vlek and A.U. Mokwunye. 2000. Crop residue and fertilizer management to improve soil organic carbon content, soil quality and productivity in the desert margin of west Africa. In: *Advances in Soil Science, Ch. 6. Global climate change and tropical ecosystem* Eds. R. Lal, J.M. Kimbel and B.A. Stewarts: 117-145.
- Bellakki, M.A. and V.P. Badanur, 2000. Redidual 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.
- Benito A. and A. Sombrero, (2006). Changes in soil chemical properties under three tillage systems in a long-term experiment. Third Mediterranean meetings of direct seeding, Zaragoza, Spain. Zaragoza: Mediterranean Option. Seminars Mediterranean. 69 :155-159
- 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., 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.
- Bharambe, A.P. and Tomar, A. 2004. Direct and residual effect of FYM and inorganic nutrients on rice-wheat cropping system in vertisol. *PKV Res. J.*, 28: 47-52.
- 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.
- Bhattacharya Ranjan, Ved Prakash, S. Kundu, B.N. Ghosh and H.S. Gupta., 2008. Potassium availability as influenced by farmyard manure application under continuous soybean-wheat cropping in Typic Haplaquept. *J. Indian Soc. Soil Sci.*, 56(2): 182-185.

- Bhoite D. S and V. K. Thombre, 2006. Integrated nutrient management in irrigated cotton. *Int. J. Agric. Sci.* Vol.2: 419-420.
- Blaise D, 2011. Tillage and green manure effect on Bt transgenic cotton grown on rainfed vertisol of central India. *Soil Till. Res.* 114: 86-96.
- Blaise, D. and Ravindran, C.D. 2003. Influence of tillage and residue management on growth and yield of cotton grown on a Vertisol over 5 years in a semi-arid region of India. *Soil Till Res.* 70: 163-173.
- Borie, F., Rubio, R., Rouanet, J.L., Morales, A., Borie, G., and Rojas, C. 2006. Effects of tillage systems on soil characteristics, glomalin and mycorrhizal propagules in a Chilean Ultisol. *Soil Till. Res.* 88, 253-261.
- Brar, A.S. and Kaur, M. (2007). Effect of different tillage practices on the growth and yield of cotton (*Gossypium hirsutum* L.). *Journal of Cotton Research and Development*, 21(2): 212-213.
- Carter M. R., R. D. Peters, C. Noronha, and J. Kimpinski. Influence of 10 years of conservation tillage on some biological properties of a fine sandy loam in the potato phase of two crop rotations in Atlantic Canada. *Can. J. Soil. Sci.* 2009. 89: 391-402
- Carvalho N. S, Antonio Bruno Bitencourt Oliveira, Maristella Moura Calação Pessoa, Vicente Paulo Costa Neto, Ricardo Silva de Sousa, Joao Rodrigues da Cunha, Arthur Goncalves Coutinho, Vilma Maria dos Santos and Ademir Sergio Ferreira de Araujo. (2015). Short-term effect of different green manure on soil chemical and biological properties. *African journal of agri. Research* Vol. 10(43) pg. 4076-4081.
- Casals P., Cristina Gimeno, Arnaud Carrara, Luis Lopez-Sangil, Ma Jose Sanz. 2000. Soil CO₂ efflux and extractable organic carbon fractions under simulated precipitation events in a Mediterranean Dehesa. *Soil Biology & Biochemistry*. 1-8
- 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.
- Chaturvedi, Sumit and A.S. Chandel, 2005. Influence of organic and inorganic fertilization on soil fertility and productivity of soybean (*Glycinmax*). *Indian J. of Agronomy*, 50(4): 311-313.
- Chesin L and Yien C. H. (1950) turbidimetric determination of available sulphur. *Soil.Sci.Soc. of America. Proceedings*, 950, 28:149-151

- Chittpur, 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.
- Chivenge, P.P., Murwira, H.K., Giller, K.E., Mapfumo, P. & Six, J. 2007. Long-term impact of reduced tillage and residue management on soil carbon stabilization: implications for conservation agriculture on contrasting soils. *Soil & Tillage Research*, 94, 328–337.
- Chou-su Li., Li Jin-gang, Tang yong-lu, Wu ioa-li, Wu chun, Huang Gang, Zeng Hui. 2015. Stand establishment, root development and yield of winter wheat as affected by tillage and straw in the water deficit hilly region of southwestern China. *Journal of Integrative Agriculture Advances Online Publication* 2015. Doi: 10.1016/s2095-3119(15)61184-4
- Derpsch, R., Friedrich, T., Kassam, A. & Li, H.W. (2010). Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*, 3, 1-25.
- Derpsch, R., Friedrich, T., Landers, J. N., Rainbow, R., Reicosky, D. C., Sa´, J. C. M., Sturny, W. G., Wall, P., Ward, R. C. & Weiss, K., (2011). About the necessity of adequately defining no-tillage – a discussion paper. In Proc. 5th World Congr. Conserv. Agric., 26-29 September 2011, Brisbane, Australia.
- 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.
- Esser K. B., 2016. Hardpan and maize root distribution under conservation and conventional tillage in agro-ecological zone iia, Zambia. *African crop science journal*, vol. 24, no. 3, pp. 267 – 287
- FAO. (2012). Food and Agriculture Organization of the United Nations, 2012. Available online at <http://www.fao.org/ag/ca/6c.html>.
- 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.
- Gal Anita, Tony J. Vyn , Erika Micheli , Eileen J. Kladvko , William W. (2007). McFee Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zonesampling depths. *Soil & Tillage Research* 96 (2007) 42–51.
- Gawai, P. P. 2003. Effect of integrated nutrient management system in sorghum-chickpea cropping sequence, Ph.D. Thesis, (unpub.) MPKV, Rahuri (M.S.).

- Gholami A., H. R. Asgari, and Z. Saeidifar. 2014. Short-term effect of different tillage systems on soil salinity, density and nutrients in irrigated wheat. *International journal of Advanced Biological and Biomedical Research* Volume 2, Issue 5, 2014: 1513-1524.
- Ghosh, P. K., 2001, ISCI Silver Jubilee Lecture Series – Lecture on “Genetically modified crops in India with special reference to Bt cotton”. *Journal of Indian Society of Cotton Improvement*, pp. 106-107.
- Giller K. E., E. Witter, M. Corbeels, P. Tittonell, 2009. Conservation agriculture and smallholder farming in Africa: the heretics. *Field Crops Res.* 114: 23-34.
- Giri, A. N., M.N.Deshmukh and S.B.Gore, 2006. Nutrient Management in cotton. *Indian J. Agron.* 51(2): 116-118.
- Gormus, O., 2005. Interactive effect of nitrogen and boron on cotton yield and fiber quality. *Turk. J. Agric.* 29 51-59.
- Guan Dahai, Yushi Zhang, Mahdi M, Al-Kaisi, Oingyan Wang, Mincai Zhang, Zhaohu Li. 2015. Tillage practices effect on root distribution and water use efficiency of winter wheat under rainfed condition in the North China Plain. *Soil & Tillage Research.* 146 (2015)- 286-295.
- Gudadhe Nitin, M.B. Dhonde and N.A. Hirwe. 2015. Effect of integrated nutrient management on soil properties under cotton chickpea cropping sequence in vertisols of Deccan plateau of India. *Indian J. Agric. Res.*, 49 (3) 2015: 207-214
- 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.
- 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.
- Halemani, H.L., S. S. Hallikeri; R.A. Nandagavi; S.S. Nooli and G. Mohan Kumar. 2004^b. Influence of organics, inorganics and their combinations on soil properties and crop productivity in cotton based cropping system. In: International symposium on “Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 174-180.
- Halemani, H.L., S.S. Hallikeri, S.S. Nooli, R.A. Nandagavi, and H.S. Harish Kumar, 2004^a. 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.

- 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.
- Hati K. M., Swarum, A. K. Dwivedi, A. K. Mishra and K. K. Bandopadhyay, 2007. Changes in soil physical properties and organic carbon status at top soil horizon of a Vertisol of Central India after 28 years of continuous cropping, fertilization and manuring. Agric. Ecosystem 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.
- Hemlata Chitte, Anita Chorey, V.M. Bhale and Bharti Tijare, 2016. Productivity and nutrient uptake of cotton as influenced by application of organic nitrification inhibitors and fertilizers. <http://waste.org/abstract-52818>.
- Hernanz, J.L., L_opez, R., Navarrete, L. & S_anchez-Gir_on, V. 2002. Long-term effects of tillage systems and rotations on soil structural stability and organic carbon stratification in semiarid central Spain. Soil & Tillage Research, 66, 129–141.
- 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, 2004. Response of rainfed cotton cv. Jaydhar to NPK levels and organic manures. In: International symposium on “Strategies for sustainable cotton production – A global vision” 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 163-168.
- Hulihalli, U.K. and V.C. Patil, 2006^a. Effect of in-situ moisture conservation practices and organic manures on yield and quality of cotton grown on Vertisol. PKV Res. J.30(2):135-140.
- 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.
- Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall Publication Pvt. Ltd., New Delhi, India, pp. 452.

- Jackson, M.L., 1973. Soil Chemical Analysis. Prentice Hall Publication Pvt. Ltd., New Delhi, India.
- Jenkinson D. S and Ladd J. N (1981) Measurement of microbial biomass in intact soil cores and in sieved soil. *Soil Bio and Biochem.* Vol.12. pg. 579-581.
- Jenkinson, D. S and Powlson D. C (1976) A method for measuring soil biomass. *Soil Bio. And Biochem.* 8: 209-213.
- 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.
- Jessika. V. J., William R. Horwath, Jeffrey P. Mitchell and Daniel S. Munk.2006. Conservation tillage and cover cropping influence soil properties in San Joaquin Valley cotton-tomato crop. *California Agriculture* .Vol. 60, No.3.
- Joachima, H.J. R., Makoil and Patrick, A Ndakidemi. 2008. Selected soil enzymes,
- Kademani, M.B., Radder, B. M. and Hebsur, N.S., 2003, Effect of organic and inorganic fertilizers on availability and uptake of nutrients by sunflower in vertisols of Malaprabha command. *Karnataka. journal of Agricultural Sciences*, 16 (1): 48-53.
- Kanchikerimatha, M and Singh, D. 2001. Soil organic matter and biological properties after 26 years of maize-wheat-cowpea cropping as affected by manure and fertilization in semi arid region of India . *Agriculture Ecosystems and Environment.*86: 155-162.
- Katkar, R.N., A.B. Turkhede and S.T. Wankhede, 2006. Residual effect of manures and inorganic fertilizer on soil properties and yield of cotton. *PKV Res. J.*, 30(1): 36-41.
- Katkar, R.N., A.B. Turkhede, V.M. Solanke, S.T. Wankhede and M.R. Patil, 2002. Effect of organic manures and fertilizers on soil properties and yield of cotton. *J. Cotton Res. Dev.*, 16(1): 89-92.
- 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.
- Katkar, R.N., S.T. Wankhede, A.B. Turkhede and S.P. Lambe, 2005. Effect of integrated nutrient management in cotton grown on shallow soil on growth, seed yield and physio-chemical properties. *PKV Res. J.*, 29(1): 210-214.
- Kaur Kulvinder; Krishan K. Kapoor and Anand 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.

- Khaddar, V.K. and Shivaji Yadav, 2006. Effect of integrated nutrient management practices on soil microbial population in soybean-wheat cropping sequence. *J. Environmental Research and Development*, 1(2).
- 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
- Khosro Mohammadi., 2011. Soil Microbial Activity and Biomass as Influenced by Tillage and Fertilization in Wheat Production *J. Agric. & Environ. Sci.*, 10 (3): 330-337
- Klein. D.A., T.C. Loh and R.L. Goulding, 1971. A rapid procedure to evaluate dehydrogenase activity of soils low in organic matter, *Soil Biology & Biochemistry*. 3: (1971), pp. 385–387.
- Knudsen D. A and G. A. Peterson. Lithium, sodium and potassium. 225-246. In A.L. Page (ed.). *Method of Soil Analysis Agronomy Monogram No. 9. J. Am. Soc. Agron. Incl. Soil Sci.*, Am. Publ. Madison, USA, 1982.
- Kumar P, Kathju, S., Panwar, J., Saini, V.K. and Tarafdar, J.C. 2007. Dehydrogenase and phosphatase activities in soil under arid ecosystems as influenced by tillage, soil depth and crop rotation. *Journal of the Indian Society of Soil Science* 55(4): 488-492.
- 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. Goh. 2000. Crop residues and management practices: effects on soil quality, soil nitrogen dynamics, crop yield and nitrogen recovery. *Adv. Agron.* 68, 197.
- Kumar., 2015. Impact of resource conservation technologies on
- Kumari, G., B. Mishra, R. Kumar, B.K. Agarwal and B.P., 2011. Singh 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. of Indian Soc. Soil Science*, Vol. 59, No. 3, PP. 245-250.
- Kusnarta I.G.M., J. Tisdall, Sukartono, Mahrup, M. Mashum, J. S. Gill and Don Van Cooten. 2003. Rice root distribution under various systems of soil management on rainfed Vertisols in Southern Lombok, Eastern Indonesia. www.regional.org.au/asa/2004/poster/1/41216-sukartonov.htm
- Lal J. K., B. Mishra and A. K. Sarkar. 2000. Effect of plant residues incorporation on specific microbial group and availability of some plant nutrients in soil. *J. Indian. Soc. Sci.* (48) (1) 67-71

- 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. (1997). Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. I. Crop yield and soil physical properties. *Soil and Tillage Research*, 42, 145–160.
- Lal, R. 2009. Challenges and opportunities in soil organic matter research. *Eur. J. Soil. Sci.* 60, 158-169.
- Lal, R., 1989. Soil compaction and tillage effects on soil physical properties of a Mallic Ochraqualf in northwest Ohio. *J. Sustainable Agri.* 14, 53-65.
- Lalitha Kumari, A., K. Veeraiah and S. Ratna 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.
- Lampurlanes J., Cantero-Martinez C. 2003. Bulk density and penetration resistamnce under different tillage system and crop management system and their relationship with Barley root system. *Agro. J.* 2003: 95(3): 526-536.
- LI Ling-Ling, Gao-bao huang, Ren-zhi Zhang, Yin chan Knowg. 2011. *Agricultural Sciences in China* 10(6): 850-859.
- Mahavishnan, K., Bhanu Rekha, K and Mangal Prasad. 2006. Productivity of Cotton (*Gossypium hirsutum* L.) and sunflower(*Helianthus annuus* L.) as influenced by integrated nutrient management option in cotton-sunflower cropping system. *International Journal of Tropical Agriculture.* 24(1-2): 229-237.
- Mali D.V., V.K. Kharche, S.D. Jadhao, R.N. Katkar, N.M. Konde, S.M. Jadhao and B.A. Sonune, 2015. Effect of long-term fertilization and manuring on soil quality and productivity under sorghum (*Sorghumbicolor*)-wheat (*Triticumaestivum*) sequence in Inceptisol. *Indian J. Agri. Sci.* 85(5): 695-700.
- Mandal, A., Ashok, K., Dhyan Sing., Swarup, A and Ebine Masto, R. 2010. Effect of long term application on biological and biochemical activities in soil during cropdevelopment stages. *Bioresource Technology.* Vol 99: 3585-3592.
- Martinez, E., J. P., Fuentes, P Silva, S. Valle, & E. Acevedo,. 2008. Soil physical properties and wheat root growth as affected by no tillage and conventional tillage systems in a Mediterranean environment of Chile. *Soil & Tillage Research*, 99, 232–244.
- 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*

- 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 (*Gossypiumhirsutam*). *J. Cotton Res. Dev.*, 23(2): 255-257.
- MolinaLucila 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.
- 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.
- Murillo J. M, F. Moreno¹, I. F. Girón and M. I. Oblitas. 2004Conservation tillage: long term effect on soil and crops underrainfed conditions in south-west Spain (Western Andalusia). *Spanish Journal of Agricultural Research* (2004) 2 (1), 35-43.
- Muruganandam, S.; Israel., D.W. and Robarge, W.P. 2009 Activities of nitrogen minerlization enzymes associated with soil aggregate size fraction of three tillage systems. *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 underpigeonpea based intercropping system. *International journal of farm sciences* 6(1): 101-113, 2016.
- Narayana E., D. Aaparna and Mridula George, 2011. Response of *Bt* cotton (*Gossypium hirsutum*L.) for integrated rain water and nutrient management. *J. Cotton Res. Dev.*, 25(1): 68-70.
- Naveen Kumar B.T and H.B. Babalad to Different Conservation Agricultural Practices under Rainfed Situations. *Int.J.Curr.Microbiol.App.Sci* (2017) 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.
- Nawlakhe, S.M. and D.D. Mankar, 2009. Effect of Integrated nutrient management on soil moisture content and soil physio-chemical properties under long-term experiment site in cotton+greengram intercropping. *J. Soils and Crops*, 19(2): 287-294.
- 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. and Kumawat, P.D. (2003). Response of hirsutum cotton varieties to spacing and nitrogen levels. *J. Cotton Res. Dev.*, 17(1): 41-42.
- 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 Duboisaa,, 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.
- Odyuo Ekonhung, Y.K. Sharma and S.K. Sharma, 2015. Potassium Fractions of Soils of SASRD Research Farm of Nagaland University and Response of Soybean to Potassium. *J. Indian Soc. Soil Sci.*, 63(2): 181-185.
- 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.
- Panse V. G. and P. V. Sukhatme, 1985. Statistical methods for agricultural workers. ICAR, New Delhi.
- 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-Wheat cropping system. *Indian J. Agronomy*. 50(4): 269-273.
- Patil D.S. and R.S. Raut. 2002. Effect of phosphorus solubilizing bacteria isolates on fertility status of soils and its subsequent effect on Sunflower crop. Abstr. State level seminar on “Land Resources Management for Food Security and Permanency”, January 5-6, Dr. B.S.K.K.V., Dapoli : 112.
- 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.
- 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

- Praharaj, C.S., K. Sankaranarayanan and T.P. Rajendran, 2004. Studies on fibre yield and quality as influenced by cropping systems and integrated nutrient scheduling to cotton. In International symposium on "Strategies for sustainable cotton production – A global vision" 2. Crop Production, 23-25, Nov. 2004, UAS, Dharwad : 69-74.
- Praharaj, C.S., K. Sankaranarayanan, N. Gopalakrishnan and T.P. Rajendran, 2010. Agronomic options for higher crop growth, yield and soil fertility in upland cotton (*Gossypium hirsutum*) through *insitu* management of plant wastes in south zone. *Indian J. Agri. Sci.*, 80 (4): 298–305.
- Prakash, Y.S., P.B.S. Bhadoria and Amitava 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, 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.
- 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 Setty, R. A. (2007). Integrated nutrient management practices in cotton-based cropping system in Tungabhadra project area of Karnataka. *J. Cotton Res. Dev.*, 21(2):174-177.
- Rashidi, M. and F, Keshavarzpour. 2007. Effect of different tillage methods on soil physical properties and crop yield of watermelon (*Citrullus Vulgaris*) *ARPJ Journal of Agricultural and Biological Science* 2 (6): 2007.
- Rathod, V. E., Sagare, B. N., Ravankar, H. N., Sarap, P. A. and Hadole, S. S. (2003) Efficacy of amendments for improvement in soil properties and yield of cotton grown in sodic Vertisols of Vidarbha using alkali water. *Journal of Soils and Crops*, 13(1): 176-178.
- Rattan, R.K., S. Neelan and S.P. Datta, 1999. Micronutrient depletion in Indian soils: extent, causes and remedies. *Fertil. News*. 44(2): 35-50.
- Rautaray, S.K. 2005. Nutrient dynamics, dehydrogenase activity and response of the riceplant to fertilization sources in an acidic lateritic soil. *Acta Agric. Scand. B. Soilplant Science*. 55: 162 – 169.
- 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.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.
- Rhoton, F. E. (2000). Influence of time on soil response to no-till practices. *Soil Science Society of America Journal*, 64, 700–709.
- Rita, S. Thakre and V.R. Gupta, 2003. Effect of cropping system and Nutrient Management on Microbial population in Vertisols. *PKV Res. J.*, 27(2) : 145-149.
- Rudrappa, L., T.J. Purkhasthya, S. Dhyam 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.
- 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.
- Sakarvadia, H.L., K.B. Polara, K.B. Parmar, N.B. Babariya and B.B. Kunjadia, 2009. Effect of potassium and zinc on growth, yield, quality parameter and nutrient uptake by cotton. *Asian J. Soil Sci.* 4 (1):118-120.
- Sankar Maruthi, G.R., K.L. Sharma, V.V. Gabhane, M.B. Nagdeve, M. Osman, Pushpanjali, K.A. Gopinath, Reshma Shinde, M.M. Ganvir, A.P. Karunakar, B. Anitha Chorey, P.K. Mishra, B. Venkateswarlu, A.K. Singh, M. Suma Chandrika and K. Sammi Reddy, (2014). Effects of long-term fertilizer application and rainfall distribution on cotton productivity, profitability, and soil fertility in a semi-arid Vertisol, *Communications in Soil Sci. and Plant Analysis*, 45(3): 362-380.
- 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
- Santhy, P., S. Jayasree Sankar, P. Muthuvel and D. Selvi, 1998. Long term fertilizer experiment - status of N, P and K fractions in soil. *J. Indian Soc. Soil Sci.*, 46(3): 395-398.
- Schwab E. B., D. W. Reeves,* C. H. Burmester, and R. L. Raper. Conservation Tillage Systems for Cotton in the Tennessee Valley. *SOIL SCI. SOC. AM. J.*, VOL. 66, MARCH–APRIL 2002.
- Sekhon K.S., G.S. Battar, B.S. Sidhu and Sudeep 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.Santhy and M.Dhakshinamoorthy. 2004. Microbial population and biomass in rhizosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol J. Indian Soc. Soil Sci., 52 (3): 254-257.
- 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
- Shaaban, M.M., M.M. El-Fouly and A.A. Abdel-Maguid, 2004. Zinc-Boron relationship in wheat plants grown under low or high levels of calcium carbonate in the soil. Pakistan J. Biol. Sci. 7:633-639.
- Shah M. S. and N. Verma 2012. Integrated nutrient management in *hirsutum cotton* plant. Archives 12 (2): 983-984.
- Sharma MP, Bali SV and Gupta DK 2000. Crop yield and properties of inceptisol as influenced by residue management under rice-wheat cropping sequence. *Journal of the Indian Society of Soil Science* 48(3): 506-509.
- Sharma, K.L., J. Kusuma Grace, P.K. Mishra, B. Venkateswarlu, M.B. Nagdeve, V.V. Gabhane, G. Maruthi Sankar, G.R. Korwar, G. Ravindra Chary, C. Srinivasa Rao, Pravin N. Gajbhiye, M. Madhavi, U.K. Mandal, K. Srinivas and Kausalya Ramachandran, 2011. Effect of soil and nutrient management treatments on soil quality indices under cotton-based production system in rainfed semi-arid tropical Vertisol, *Communications in Soil Sci. and Plant Analysis*, 42(11): 1298-1315.
- Sharma, R.P. and T.S. Verma, 2000. Effect of long-term Lantana addition on soil potassium fractions yield and potassium uptake in rice-wheat cropping in an acid Alfisols. *J. Pot. Res.*, 16(1-4): 41-47.
- Shokati B and A. G. Ahangar, 2014. Effect of conservation tillage on soil fertility factors: review. *International Journal of Biosciences*. Vol. 4, No. 11, p. 144-156.
- Singh Muneshwar, Shri Ram, R.H. Wanjari and Pankaj Sharma, 2014. Balance and forms of potassium under rice-wheat system in a 40-year-old long-term experiment on Mollisols of Pantnagar. *J. Indian Soc. Soil Sci.*, 62(1): 38-44.
- 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. Agron. Congress*, Nov. 26-30, 2002, New Delhi : 360-361.
- Singh, M.V., 2003 Organic pools and dynamic in relation to land use, tillage and organic practices on the maintenance of soil fertility. ISSS Bhopal.pp-1-92.

- Singh, R. K., S. K. Singh and J. C. Tarafdar (2008). Influence of cropping sequence and nutrient management on soil organic carbon and nutrient status of Typic Rhodustalfs. *J. Indian Soc.* 56(2): 174-181.
- Singh, R.P., P.N. Dubey, T.K. Sen and A.K. Maji, 2006. Distribution of potassium in soils of Manipur encompassing physiographic and hydrothermal variation. *J. Indian Soc. Soil Sci.*, 54(2): 197-202.
- Six, J., Elliott, E.T. & Paustian, K. 2000. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biology & Biochemistry*, 32, 2099–2103.
- soil health and productivity of wheat in rice-wheat cropping
- 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.
- Soniya Thakare, K., Ravankar, H.N. and Patil, M.N. (2005). Soil properties and nutrient availability as influenced by long term fertilization to sorghum-wheat sequence in Vertisols., *PKV Res. Journal.* 29(2):215-217
- 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., 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.
- Sornpoon W, H. and P. W. Jayasuriya. (2013). Effect of different tillage and residue management practices on growth and yield of corn cultivation in Thailand. *Agric Eng Int: CIGR Journal.* Vol. 15, No.3.
- Subbiah, B.V. and G.V. Asija, 1956. A rapid procedure for determination of available nitrogen in soils. *Current Sci.*, 25: 256-260.
- 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.

- 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 residual effects of organic sources on rice productivity and soil quality of Vertisol. *J. Indian Soc. Soil. Sci.*, 57(1): 53-57.
- Surekha K and K.V. Rao, 2009. Direct and residual effects of organic sources on rice productivity and soil quality of Vertisol. *J. Indian Soc. Soil. Sci.*, 57(1): 53-57.
- Surekha, K., M. Narayana Reddy, K.V. Rao and P.C. Sta 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.
- 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.
- Talashikar, S.C., V.B. Mehta, A.A.K. Dosani, R.V. Dhopavkar and J.S. Dhekale, 2006. Influence of soil reaction on acidity parameters, and fractions of organic matter, nitrogen, phosphorous and potassium in lateritic soils of Kokan. *J. Indian Soc. Soil Sci.*, 54(2): 174-178.
- 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.
- system. *Journal of Applied and Natural Science* 7 (1) : 58 – 66.
- Tadesse Tilahun, Nigussie Dechassa, Wondimu Bayu, Setegn Gebeyehu. Effects of Farmyard Manure and Inorganic Fertilizer Application on Soil Physico-Chemical Properties and Nutrient Balance in Rain-Fed Lowland Rice Ecosystem. *American Journal of Plant Sciences*, 2013, 4, 309-316.
- Tamboli, B.D., I.R. Bagwan, A.B. Pawar, B.D. Bhakare, S.R. Shelke, J.R. Kadam and A.N. Deshpande, 2013. Integrated nutrient management for sustaining *rabi* sorghum yield, economics and soil fertility on Inceptisol under dryland condition. *Indian J. Dryland Agric. Res. & Dev.*, 28(1): 70-73.
- Thakur, R.C. and C.M. Sharma, 2004. Status of use of organic in crop production in Himachal Pradesh- North Western hill state of India. 6th IFOAM Asia scientific Conference. 142-160.
- Thierfelder, Christian and C. Wall. (2009). Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil and Tillage Research*. 105. 217-227.

- Thimmareddy, K., Desai, B. K. and Vinoda Kumar, S. N. 2013. Uptake of NPK, availability of NPK and quality parameters of *Bt* Cotton (*Gossypium hirsutum* L.) as influenced by different bio-fertilizers and *in situ* green manuring under Irrigation. *Intern. J. Agril. Environ. Biotech.* 6: 623-28.
- Tisdall, J.M. & Oades, J.M. 1982. Organic matter and water-stable aggregates in soils. *European Journal of Soil Science*, 33, 141–163.
- 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, V.N., I.K. Benri, K.N. Tiwari and R.M. Upadhyay, 2001. Integrated nitrogen Management throughout natural green manuring under wheat-Mungbean cropping sequence. *J. Indian Soc. Soil Sci.* 49:271-275.
- Tolanur, S. I and V. P. Badanur (2003). Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of rabi sorghum-chickpea system and fertility of Vertisol. vol. (51): 41-44
- Tomar R.K., D. Singh¹, K.S. Gangwar¹, R.N. Garg, V.K. Gupta, R.N. Sahoo, D. Chakraborty and Naveen Kalra. 2006. Influence of tillage systems and moisture regimes on soil physical environment, growth and productivity of rice-wheat system in upper gangetic plains of Western Uttar Pradesh. *Indian J. Crop Science*, 1(1-2): 146-150.
- 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
- Varalakshmi, L.R., C.A. Srinivasamurthy and S. Bhaskar, 2005. Effect of integrated use of organic manures and inorganic fertilizers on organic carbon, available N, P and K in sustaining productivity of groundnut-finger millet cropping system. *J. Indian Soc. Soil Sci.*, 53(3): 315-318.
- Veenstra Jessica J., William R. Horwath, Jeffrey P. Mitchell and Daniel S. Munk. 2006. Conservation tillage and cover cropping influence soil properties in San Joaquin Valley cotton-tomato crop. <http://CaliforniaAgriculture.ucop.edu> • july–september 2006.
- Venkateswarlu, B., and Srinivasarao, Ch., 2004. Soil microbial diversity and the impact of agricultural practices. *Indian J. Dry land Agric. Res. & amp; Dev.* 19(2), 97–105.

- Venugopalan MV, Rajendran TP, Chandran P, Goswami SN, Challa O, (2010) Comparative evaluation of organic and non-organic cotton (*Gossypium hirsutum*) production systems. *Indian Journal of Agricultural Sciences* 80: 287–292.
- Verma Arvind; 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. and A.K. Mathur, 2009. Effect of integrated nutrient management on active pools of soil organic matter under maize-wheat system of Typic Haplustept. *J. Indian Soc. Soil Sci.*, 57(3): 317-322.
- Vineela C., S.P. Wani, Ch.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. *Appli. Soil Eco* 40(1): 165-179.
- Vora V. D., K.D. Rakholiya, K. V. Rupapara, G. S. Sutaria and K. N. Akbari. 2015. Integrated nutrient management on Bt cotton and post harvest soil fertility under dry farming. *Asian J. of Agri. Res.* Vol.9(6): 350-356.
- Wagh N.S., R.N. Katkar and V.K. Kharche. 2016. Effect of tillage and nutrient management on soil properties, growth and seed cotton yield. *IJTA*. Vol. 34, No. 6, 2016.
- Wankhade, S.T., A.B. Turkhede, R.N. Katkar, V.M. Solanke and B.A. Sakhare, 2001. Effect of bio-mulching and fertilizers on growth and yield of cotton. *J. Crop Res.*, 21 (1): 34-37.
- Watnabe and Olsen (1965). Test of an ascorbic acid method for determining phosphorus in water and NaHCO_3 extract from soil. *Soil. Sci. Soc. Am. J.* 29 (6): jan1965.
- 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. 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.
- Yeboah S., R. Zhang, L. Cai¹, L. Li¹, J. Xie, Z. Luo, J. Liu¹, J. Wu. 2017. Tillage effect on soil organic carbon, microbial biomass carbon and crop yield in spring wheat-field pea rotation. *Plant Soil Environ.* Vol. 62, 2016, No. 6: 279–285.

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