IMPACTS OF MAIZE BASED CONSERVATION AGRICULTURE PRODUCTION SYSTEM ON SOIL PROPERTIES IN NORTH CENTRAL PLATEAU ZONE OF ODISHA

A

THESIS SUBMITTED TO

THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,
BHUBANESWAR

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

BY

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2012

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CERTIFICATE

This is to certify that the thesis entitled **"Impacts of maize based conservation agriculture production system on soil properties in North central plateau zone of Odisha"** submitted in partial fulfilment of the requirements for the award of the Degree of **MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)** of the Orissa University of Agriculture and Technology, Bhubaneswar is an authentic record of *bona fid*e research work carried out by **BHAGINI NABANITA** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that the help and information availed during the investigation have been duly acknowledged by her.

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Chairman
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Place: Bhubaneswar
Date:

CERTIFICATE OF APPROVAL

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ABSTRACT

Natural resources and environmental quality in agriculture are subjected to degradation, warrant for immediate and long term solutions. Conservation agriculture systems with suitable crop and soil management packages have been identified as one of the solution. The North central plateau zone of Odisha has an undulating topography and the soils of these areas are facing various types of losses. Maize is a major crop in this agroclimatic zone. To study the impact of maize based cropping system under conventional and minimum tillage practice a field experiment was conducted at Regional Research and Technology Transfer Station (RRTTS), O.U.A.T, Kendujhar during Kharif and subsequent Rabi season (2011-2012).

Conventional and minimum tillage with maize and maize+cowpea intercrop were taken during kharif and each treatment plot was divided into 3 subplot treatments like horsegram, mustard and fallow during Rabi. Soil sample were collected before Kharif and after Kharif and Rabi season to study the impact of treatments on soil bulk density, texture, pH, organic carbon, available N, P, K, Ca, Mg following the standard procedure. Nutrient dynamics was studied by resin bag technique. Yield and nutrient uptake by crop were also recorded.

From the above study it was revealed that minimum tillage improved the bulk density of soil by reducing its value 0.007 Mgm^{-3} than conventional tillage

during Kharif. Decrease in sand with increase in silt and clay content was observed in minimum tillage than conventional tillage. The pH and organic carbon of the soil had increased to a tune of 0.2 unit and 0.29g/Kg in minimum tillage than conventional tillage. The available nutrient content of soil were found increased by 4.5Kg/ha N, 0.06Kg/ha P, 4.8Kg/ha K, 0.46 cmol(p^+)/Kg Ca and 0.32 cmol(p^+)/Kg Mg after harvest of Kharif crops in minimum tillage than conventional tillage. Nutrient dynamics studied by resin bag technique revealed 17.93 ppm N/5g resin, 22.6 ppm P/5g resin, 56.92 ppm K/5g resin, 30.69 ppm Ca/5g resin, 12.04 ppm Mg/5g resin were estimated in conventional tillage over a value of 15.35 ppm N/5g resin, 20.56 ppm P/5g resin, 54.01 ppm K/5g resin, 29.14 ppm Ca/5g resin,11.59 ppm Mg/5g resin in minimum tillage treatments. From the analysis of nutrient uptake by different crops it was found that the maximum uptake of nutrients to a tune of 158.0 Kg/ha N, 17.17 Kg/ha P in conventional tillage maize+cowpea intercrop in Kharif followed by horse gram in Rabi and minimum in MT-M-F. But the potassium uptake was maximum 122.8 Kg/ha in CT-M+C-M and minimum in MT-M-F. Maize equivalent yield was found to be maximum 85.83 qha^{-1} in conventional tillage maize+cowpea intercropping treatment followed by minimum tillage maize+cowpea, conventional tillage maize and minimum tillage maize in decreasing order. The more yield was observed in case of conventional tillage than minimum tillage due to better root proliferation at initial period of conservation practice.

During Rabi season the bulk density, fine earth fraction, pH, organic carbon, available N,P, K, Ca, Mg of soil followed the similar trend as Kharif season in different tillage treatments. Among different crops horse gram reduce the bulk density by 0.001Mgm^{-3} ,increase the pH 0.01 unit, organic carbon content 0.03g/Kg , available N 0.5Kg/ha, available P 0.02 Kg/ha, available K 0.2 Kg/ha, available Ca 0.02 cmol(p^+)/Kg, available Mg 0.03 cmol(p^+)/Kg than mustard crop. So horse gram was found to superior than mustard. Minimum tillage although gave less yield than conventional tillage in the first year but improve the soil physical properties and chemical properties slowly.

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INTRODUCTION

Persistent use of conventional farming practices based on extensive tillage combined with in situ burning of crop residues have magnified soil erosion losses and degradation of soil resource base steadily. Dust bowl of 1930s in the U.S Great Plains due to exposure of soil to wind erosion causing loss of about 91 million hectares of land is one of the famous results of poor tillage practice (Utz *et al.* 1938). Many soils have been worn down to their nadir for most of the soil physical, chemical and biological parameters which are essential for effective, stable and sustainable crop production. Therefore in spite of the availability of improved varieties with high yield potential, the potential increase in production is not attained due to poor soil and crop management (Reynolds and Tuberosa, 2008). But there is a demand of rising food production by 70% until the year 2050 to meet the food security of growing world population of more than 9 million people.

In India, growing population of the country may stabilize around 1.4 billion by 2025 and 1.6 billion in the year 2050 calling for 380 and 480 metric tonne food grain production per annum respectively. Rising population per capita income are pushing up demand which needs to be met through enhancing productivity per unit area input and time. Although green revolution was highly successful and resulted in dramatic yield increase, conservation efforts to protect soil resources were not always given appropriate attention.

As soil is the most vital resource for providing food to the ever increasing population, it is mandatory that wide spread soil degradation is brought to a halt. Soil should be used rationally and conserved properly for realizing agricultural productivity on a sustainable basis. So to achieve this sustainable production without any degradation of natural resource base and environment a set of crop-nutrient-water-landscape system management practice popularly known as conservation agriculture production system has been identified as one of the immediate and long term solutions.

Conservation agriculture is nothing but a concept of resource saving agriculture crop production that strives to achieve acceptable profits together with high and sustained production levels simultaneously conserving the environment (FAO). It is not based on maximizing yields by exploiting soil and agro ecosystem. Instead of that it is based on optimizing yields and profits, to stabilize agricultural, economic and environmental benefits. It advocates that the combined social and economic benefits gained from combined production and protecting the environment, including reduced input and labour costs are greater than those from production alone. Conservation agriculture is the integration of ecological management with modern, scientific, agricultural production. It employs all modern technologies combined with traditional knowledge of soil husbandry that enhance the soil quality and ecological integrity of the soil.

Conservation agriculture emphasizes that the soil is a living body, having a great importance for sustenance of life on the planet. It promotes minimum disturbance of soil through minimum tillage or conservation tillage, maintain permanent organic soil cover and a healthy and living soil through crop rotation. Conservation tillage includes no tillage, direct tillage, minimum tillage or ridge tillage. Conservation tillage is a set of practice that promotes retention of at least 30% surface cover by residues, conserve soil water, soil structure, nutrients, soil biota and save time (Baker *et al.*2002). Permanent organic cover can be a growing crop or dead mulch. Conservation tillage with surface mulch or residues provide protection to soil from wind erosion, reduces surface soil crusting, increases water infiltration, reduces water loss by runoff and evaporation, promotes biological activity which enhances nitrogen mineralization and accumulate organic matter (Cassel *et al.* 1995). Crop rotation increases diversity in plant production, reduce risk of pest and weed infestation and enhances efficient use of water and available nutrients.

So conservation agriculture including minimum tillage, cover crops and crop rotation enhances soil and water conservation, control soil erosion, improves soil physical characteristics, chemical parameters and biological activities, ultimately improves the soil fertility and productivity. It represents a practical concept to achieve improved soil health and better soil-crop-nutrient-water management leading to ecologically and environmentally sustainable agriculture.

So far no proper systematized research work relating to the aspects of conservation agriculture production system has been carried out in the state Odisha. Kendujhar district coming under North central plateau zone has an undulating topography and soils of these area are subjected to various types of losses and degradation process which needs conservation. Maize is a major crop of the area and detail study of its impacts on soil properties has not been taken up. Hence the present investigation was ventured to study the impacts of maize based conservation agriculture production system on soil properties of North central plateau zone of Odisha conducted at Regional Research and Technology Transfer Station (RRTTS), Kendujhar with the following objectives.

1) To study the effect of conventional and minimum tillage on soil properties.
2) Effect of maize +cowpea intercropping and sole maize on soil properties.
3) Change in soil properties by different tillage practices and crop
4) Nutrient dynamics through resin bag
5) Uptake of nutrients by the crops.
6) Yield of crops influenced by different tillage practices.
7) Economics of production.

REVIEW OF LITERATURE

The research work on conservation agriculture at different places of the world has been carried out by different workers. Although the work in Odisha is meagre keeping the objectives of present investigation "Impacts of maize based conservation agriculture production system on soil properties in North Central Plateau Zone of Odisha" in view attempt has been made to present a brief account of previous research findings in the form of review on the following heads.

2.1 Definition of conservation agriculture

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2.1 DEFINITION OF CONSERVATION AGRICULTURE:

"Conservation Agriculture" refers to a general set of practices that are focused an three main concepts:- minimum tillage to reduce soil disturbance; continuous soil cover to reduce rainfall impact, suppers weeds and conserve organic mattes and optimal crop rotation to maintain soil fertility and provide nutritional self-efficiency (FAO, 2000).

Conservation agriculture [CA] can be defined by a statement given by the (Food and Agricultural Organization of the United Nations) as

"**a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment" (FAO 2007).**

Conservation agriculture (CA) aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture" (FAO)

"Conservation Agriculture maintains a permanent or semi-permanent organic soil cover. This can be a growing crop or dead mulch. Its function is to protect the soil physically from sun, rain and wind and to feed soil biota. The soil micro-organisms and soil fauna take over the tillage function and soil nutrient balancing. Mechanical tillage disturbs this process. Therefore, zero or minimum tillage and direct seeding are important elements of CA. A varied crop rotation is also important to avoid disease and pest problems" (FAO website)

2.2 PRINCIPLES OF CONSERVATION AGRICULTURE:

Conservation agriculture is characterized by three principles which are linked to each other (FAO, 2010), namely:

1. Continuous minimum mechanical soil disturbance = No-tillage

2. Permanent organic soil cover = mulching and Cover cropping

3. Diversification of crop species grown in sequence or associations = Rotation

2.3 IMPORTANCE OF CONSERVATION AGRICULTURE:

Conservation Agriculture can support intensification of agricultural production in the face of a shrinking land base without compromising soil quality reducing production per until of available water (FAO, 2008).

Conservation agriculture production system are recommended as a general solution to the problems of rural communities facing poor agricultural productivity and declining natural resource quality (Fowler and Rockstrom; 2001; Derpsch 2003, Hubbs 2007, Hubbs *et al.*, 2008, Kienzele 2009).

Hubber 2007 noted that conservation agriculture advocates the combined social and economic benefits gained from combining production and protecting the environment, hence it becomes in integration of ecology management with modern scientific agricultural production. This is compounded by the fact that yield improvement under farming takes a few years to be manifested.

Compared to conventional tillage there are several benefits from conservation tillage such as economic benefits by labour, cost and time saved, erosion protection, soil water conservation and increases of soil organic matter (Uri *et al*.1998, wang and Gao 2004)

2.4 CONSERVATION TILLAGE:

"Conservation tillage is the collective umbrella term commonly given to no-tillage, direct-drilling, minimum-tillage and/or ridge-tillage, to denote that the specific practice has a conservation goal of some nature. Usually, the retention of 30% surface cover by residues characterizes the lower limit of classification for conservation-tillage, but other conservation objectives for the practice include conservation of time, fuel, earthworms, soil water, soil structure and nutrients. Thus residue levels alone do not adequately describe all conservation tillage practices." (Baker *et al*. 2002)

Conservation tillage is a widely-used terminology to denote soil management systems that result in at least 30% of the soil surface being covered with crop residues after seeding of the subsequent crop (Jarecki and Lal 2003).

2.5 IMPACTS OF CONSERVATION PRACTICES ON SOIL PROPERTIES:

Reducing tillage affects several aspects of the soil. With time, conservation tillage improves soil quality indices (Dick, 1983; Lal *et al*., 1998), including soil organic C storage (Dick, 1983; Lamb *et al*., 1985; Dao, 1991; Unger, 1991; Edwards *et al*., 1992; Eghball *et al*., 1994; Bruce *et al*., 1995; Potter *et al*., 1998).

Conservation tillage is an effective practice to control soil degradation on intensively farmed cropland (Larney and Kladivko, 1989; Grant and Lafond, 1993) and to increase soil water storage (Gantzer and Blake, 1978; Dao, 1993).

Unger (1991) and Bruce *et al.* (1995) reported that soil nutrients become stratified when no-till management is employed.

Karlen *et al*. (1994) showed that normal rates of residue combined with zero-tillage resulted in better soil surface aggregation, and that this could be increased by adding more residues.

Conservation tillage can usually lead to greater accumulation of surface nutrients, compared to traditional tillage, with soil ploughing (Franzluebbers and Hons, 1996; Holanda *et al*., 1998).

surface (0–30 cm) soil in a no-till system was shown to contain more moisture and to be cooler than a comparable plough tillage soil (Doran *et al.*, 1998).

Residue retention and direct seeding have a major influence on improving water infiltration, organic matter content and fertility of a soil (Wall, 1999).

No-Tillage (NT) plus mulch reduces surface soil crusting, increases water infiltration, reduces run-off and gives higher yield than tilled soils (Cassel *et al*. 1995; Thierfelder *et al*. 2005).

Bissett & O'Leary (1996) showed that infiltration of water under long term (8–10 years) conservation tillage (zero and subsurface tillage with residue retention) was higher compared to conventional tillage (frequent ploughing plus no residue retention) on a grey cracking clay and a sandy loam soil in south-eastern Australia.

Kumar & Goh (2000) reviewed that crop residues of cultivated crops are a significant factor for crop production through their effects on soil physical, chemical and biological functions as well as water and soil quality.

No-tillage practices featuring residue cover and less soil disturbance have been shown to reduce runoff by 52.5% and reduce erosion by 80.2% compared to traditional tillage (Wang, 2000). Landers (2001) concluded an improvement of the infiltration capacity under NT farming.

Hatfield *et al*. (2001) reported a 34-50% reduction in soil water evaporation as a result of crop residue mulching.

Trials conducted in the higher potential areas of Zimbabwe between 1988 and 1995 indicated that mulching significantly reduced surface runoff and hence soil loss (Erenstein, 2002).

Roldan *et al*. (2003) showed that after 5 years of NT maize in Mexico, soil wet aggregate stability had increased over conventional tillage (TT) as had soil enzymes, soil organic carban (SOC) and microbial biomass (MBM). They conclude that NT is a sustainable technology.

Experiments conducted by *Liu (2004)* showed that conservation tillage systems can increase organic matter, nitrogen, phosphorus, and potassium in the topsoil layer.

Luo *et al.*(2005) reported that conservation tillage can improve soil physical properties and soil fertility in northern China.

Madari *et al*. (2005) showed that NT with residue cover had higher aggregate stability, higher aggregate size values and total organic carbon in soil aggregates than TT in Brazil.

Bescanca *et al*. (2006) reported that Conservation tillage leads to positive changes in the physical, chemical properties of a soil.

Bolliger *et al*. (2006) observed that positive changes on soil physical and chemical properties occur only after several years of practicing conservation agriculture. NT has positive effects on soil properties, yields and prevents erosion (Derpsch, 2006).

Conservation agriculture improve soil quality such as improved sequestration of organic carbon(Coprbeels *et al*,2006) and improved soil fertility reported by Hobbs and Gupta (2004).

2.5.a soil physical property like bulk density:

Bautista *et al.*(1996) found that minimum tillage plus mulch reduces soil bulk density.

Ekeberge and Riley (1997) found that bulk density was lower with minimum tillage than with conventional tillage at a depth of 3-7cm in a loam soil in Southeast Norway.

Hussein *et al.*(1998) reported that bulk density was lower with minimum tillage than with conventional tillage in the top 8cm of an eroded silt loam in Southern Illinois.

Yang and Wander (1999) lower bulk density values with minimum tillage than mouldboard plough in the 0-5cm and 20-30cm soil layer.

Hernanz *et al.*(2002) found significantly lower bulk density under minimum tillage than conventional tillage from 0-10cm with cereal monoculture and from 0-15cm in a wheat-vetch(*vicia sativa l.*) rotation. But the more compacted top soil with minimum tillage had no adverse effect on crop yield with either rotation.

Kay and Vanden Bygaart (2002) observed that bulk density was lower under minimum tillage than mouldboard plough in the top 20cm of the soil profile with the greatest difference at 5-10cm. This was probably due to organic matter content at 0-5cm was greater under minimum tillage than mouldboard plough. Similar results were obtained by Deen and Kataki in 2003.

Soil physical properties like bulk density influenced by conservation tillage (Osunbitan *et al*., 2004).

Blanco-Canqui *et al.*(2006) reported that maize residue retention at 5 and 10Mg/ha for a period of one year reduced bulk density in 0-5cm layer from

1.42 Mg/m^3 control) to 1.26 Mg/m^3 and 1.22 Mg/m^3 respectively in minimum tillage system in a silt loam soil.

Dolan *et al* (2006) conducted an experiment taking conventional tillage, chisel tillage and minimum tillage treatments on a silt loam soil with a maize-soyabean rotation in Minnesota. They found that the treatments where residues were harvested had 6% higher bulk density in 0-5cm and 5-10cm soil depth than the treatments with residues returned.

Blanco-Canqui and Lal (2007) measured bulk density in minimum tillage plots that had been uncropped and receiving 3 levels of wheat straw mulch (0,8, 16 Mg ha^{-1} yr^{-1}). The bulk density under higher mulch treatment was 58% lower and that under the low mulch treatment was 19% lower than the bulk density under the unmulched treatment for 0-3cm depth. In the 3-10cm depth bulk density under higher mulch treatment was 36% lower and that under the low mulch treatment was 9% lower than under the control.

Gal *et al*. (2007) observed lower bulk density in 0-30cm layer under minimum tillage than conventional.

Thomas *et al.* (2007) reported that bulk density was lower with minimum tillage than with conventional tillage in the top 10cm of a Luvisol in Southern Queensland.

D'Haene *et al.*(2008) reported that bulk density was lower in 5-10cm soil layer under minimum tillage than conventional tillage on silt loam soils with crop rotations in Belgium.

2.5.b Soil chemical properties

i)Soil reaction (pH):

Compared to conventional tillage under minimum tillage higher value of pH was measured (Crovetto,1996).

ii) Organic carbon:

There is a marked stratification of soil organic matter with soil depth under no-tillage system (Blevins *et al*.1984)

Schultz (1988) showed that soil organic carbon content increased by 1% with stubble retention.

Havlin *et al.* (1990) determined that reducing tillage and maintaining surface residues in a long-term study increased soil organic carbon content. He conducted an experiment having three crop rotation-continuous soybean, continuous sorghum, sorghum –soybean. These were managed for 12 years under conventional and no tillage systems (o and 100%surface residue cover respectively). Under no tillage soil organic matter increased up to 45% as the level of residue increased from 1 to 3 t/ha/yr.

No-till promotes conservation of mineralizable C from crop residues (Franzluebbers *et al*., 1994a).

Karlen *et al.*(1994) revealed that the low bulk density in minimum tillage with straw cover attributed to the increased soil organic carbon after long term minimum tillage practice.

Bruce *et al.*(1995) and Potter *et al.*(1998) reported that conservation tillage improves soil quality indices including soil organic carbon storage with time.

Campbell *et al.*(1996a.) and Lal (2005) reported that minimum tillage combined with permanent soil cover increased organic carbon in the surface layer.

Studdert *et al.* (1997) showed that Soil organic C loss with tillage and continuous cropping may be minimized by proper residue management and crop selection.

A study in eastern Paraguay about ‘changes in soil organic matter after land use change’ showed that no tillage practices had a significant higher organic matter content compared with conventional tillage practices (Riezebos and Loerts, 1998).

Freitas *et al.*(1999) reported an increase in organic matter of soil after 4 years of minimum tillage in clayey cerrado oxisol.

Wall (1999) reported that residue retention and direct seeding have a major influence on organic carbon content of a soil.

Bayer *et al.* (2000) stated that minimum tillage is a promising strategy to maintain or even increase soil organic carbon by minimizing loss of organic matter.

Clapp *et al*. (2000) reported that when corn Stover was returned to soil organic carbon increase 14% in the top 15cm layer.

Motta *et al*. (2002) showed that conservation tillage increase soil organic carbon. In Texas Zibilske *et al*.(2002) recorded that no tillage resulted in soil organic matter increase up to 58% in the top 4cm of soil for no till treatment.

Six *et al*. (2002) concluded that there is an increase in soil organic matter after doing a literature review about soil organic matter dynamics in tropical and temperate countries under the NT system. He concluded that in the upper 40 cm the soil organic matter increases after 6-8 years.

Roldan *et al.* (2003) showed that after 5 years of minimum tillage maize in Mexico, soil organic carbon had increased over conventional tillage.

Cover crops contribute to the accumulation of organic matter in the surface soil horizon (Roldan *et al*. 2003; Alvear *et al*. 2005; Diekow *et al*. 2005; Madari *et al*. 2005; Riley *et al*. 2005), and this effect is increased when combined with no tillage.

Balota *et al.* (2004) showed that in Brazil in a 20-year experiment residue retention and minimum tillage increased organic carbon by 45% at 0-50cm depth compared with traditional tillage.

Heenan *et al.*(2004) in Australia showed that soil organic carbon increased 3.8 t/ha where stubble was retained and soil no tilled and if a legume included in the rotation then soil organic carbon accumulation was the highest.

Alvear *et al.*(2005) and Diekow *et al.*(2005) revealed that conservation agriculture produces more soil organic carbon than when soils are tilled.

Madari *et al.* (2005) and Riley *et al*. (2005) showed that conservation tillage with residue cover had higher total organic carbon in soil aggregates than traditional tillage in Brazil.

Roldan *et al*. (2005) recorded that no-tillage resulted in soil organic matter increase of up to 33% in the 0–5 cm layer in Mexico.

Vagen *et al.* (2005) reported that addition of crop residues in combination with minimum tillage can yield attainable carbon accumulation rates up to 0.36Mg C ha^{-1} $yr^{-1.}$

Koch and Stockfisch (2006) reported that conservation tillage concentrated soil organic matter and carbon in the top soil layer (0-10cm) in Germany.

Li *et al*. (2006) conducted a 4 years no-tillage experiment and showed that active C and total organic C down to 10 cm depth were up to 5% higher in no-tillage than traditional tillage systems.

Liang *et al*. (2007) demonstrated that no tillage significantly increased the concentration of soil organic C in 5–20 cm soil layer by 5.6–5.9% on the clay loam soils after 3 years in the humid north eastern China.

iii) Available nitrogen:

Schultz (1988) showed that N content increased by 1% with stubble retention.

Havlin *et al.* (1990) determined that reducing tillage and maintaining surface residues in a long-term study increased soil N content in the surface 2.5cm layer.

Dao (1993) stated that surface mulch reduce water losses from the soil by evaporation and also helps moderate soil temperature. This enhances available N especially in the surface layers.

Campbell *et al.* (1995,1996a) reported more nitrogen content under no tillage and conservation tillage compared with traditional tillage.

Crovetto (1996) reported higher value of nitrogen under minimum tillage compared to conventional tillage.

Larney *et al.* (1997) reported that minimum tillage had a greater effect on mineralizable nitrogen than total nitrogen.

Wienhold and Halvorson (1999) found that nitrogen mineralization generally increased in the 0-5cm soil layer as the intensity of tillage decreased.

Bayer *et al.* (2000) stated that minimum tillage is a promising strategy to maintain or even increase soil nitrogen content.

Graham *et al.* (2002) measured significant increase in nitrogen content with increasing additions of crop residues. Similar result was obtained by Govaerts *et al*. (2007c).

Astier *et al.*(2006) and Govaerts *et al.* (2007c) observed a significantly higher total nitrogen under minimum tillage than conventional tillage in the highlands of Mexico. Similar results were obtained by Borie *et al.* (2005) and Atreya *et al.* (2006) in other agro-ecological regions.

Thomas *et al*. (2007) recorded that the total nitrogen to 10 cm depth under no-tillage was 21% higher than for traditional tillage.

iv) Available Phosphorus:

Sidiras and Pavan (1985) observed higher values of phosphorus under minimum tillage compared to conventional tillage.

Unger (1991) and Matowo *et al.* (1999) found higher extractable phosphorus levels in minimum tillage compared to tilled soil in the top soil.

Ismail *et al.* (1994) observed after 20 years of minimum tillage extractable phosphorus was 42% greater at 0-5 cm depth compared to conventional tillage in a silt loam.

Franzluebbers and Hons (1996) revealed that accumulation of phosphorus at the surface layer of minimum tillage.

Franzluebbers and Hons (1996), Du Preez *et al*. (2001) reported higher extractable phosphorus levels in minimum tillage than in tilled soil largely due to reduced mixing of the phosphorus fertilizer with the soil leading to lower P-fixation.

Ohno and erich (1997) reported that where crop residues are returned to the soil phosphorus availability increase may be due to the adsorption of phosphorus to mineral surface.

Duiker and Beegle (2006) suggested there may be less need for phosphorus stater fertilizer in long term minimum tillage due to high available P levels in the top soil where the seed is placed.

v) Available potassium:

Follett and Peterson (1988) observed either higher or similar extractable potassium levels in minimum tillage compared to mouldboard tillage.

Standley *et al.* (1990) also observed higher extractable potassium levels in top soil when sorghum stubble was retained than when the stubble was removed.

Lal (1990),Unger (1991) and Ismail *et al.*(1994) found that higher extractable potassium levels at the soil surface as tillage intensity decreases.

Franzluebbers and Hons (1996) reported that minimum tillage conserves and increases availability of nutrients like potassium near the soil surface where crop roots proliferate.

Du preeze *et al.*(2001)observed increased levels of potassium in minimum tillage compared to conventional tillage.

vi) Available Calcium, Magnesium:

Sidiras and Pavan (1985) found increased available Calcium, Magnesium concentrations to 60cm depth in both oxisol and Alfisol in Brazil under minimum tillage.

Edwards *et al.* (1992) observed higher extractable Calcium concentration with zero tillage than with conventional tillage.

Motta *et al.* (2002) showed that conservation tillage had higher value of surface Calcium contents compared to traditional tillage.

2.6 NUTRIENT DYNAMICS THROUGH RESIN BAG:

Ion exchange resin (IER) bags technique pioneered by Binkley and Matson (1983).

Weil *et al* (1988) found increased resin phosphorus in the upper 5cm of no tilled soil. Surface area is also known to play an important role in ion capture by IER devices (Skogley and Dobermann, 1996)

IER bags in many ways work similarly to plant roots: they are exposed to ambient conditions, are in intimate contact with the rhizosphere, and cause minimal disturbance to the soil (Arnone, 1997). There are, however, some important differences: unlike soil organisms, resin bags have no active uptake mechanisms, so nutrient transport processes are relatively more important to resin bags than to plants or microbes (Stark, 2000). It is not known how effectively IER bags compete with plants and microbes for nutrients (Stark, 2000).

Ion flux could not be calculated per weight (or volume) of soil, because the ions that were transported into the resin bag originated from an unknown volume of soil (Stark, 2000).

The validity of data from resin bags may partly depend on their depth in the soil. Resin bags at the same depth as the majority of root biomass are likely to experience a nutrient environment similar to that of the plants, while resin bags located below most root biomass may only receive nutrients that have been lost by leaching (Niklaus *et al*., 2001)**.**

2.7 INTERCROPPING:

Intercropping can be defined as the growing of two or more crops simultaneously in alternate rows or otherwise in the same area (Willey, 1979).It is an insurance against failure of crops in aberrant weather conditions and a means for utilization of natural resources in time and space.

2.7.a Crop Compatibility:

Choice of compatible crops plays a vital role in the success of any intercropping system. Crop combinations differ with geographical location, these may be intercropping of tree crops, intercropping of tree and field crops or intercropping of field crops. Intercropping is a potentially beneficial system. It shows substantial yield advantages over sole cropping and reduces risk of drought. This advantage can be achieved not only by means of costly inputs but by simple expedient of growing crops together (Willey, 1979). To find out the best crop combination for higher monetary return benefiting to production technology for intercropping system is required.

On the basis of morphology and growth duration, a variety of crop combinations: consisting of cereals and legumes such as maize and cowpea were identified. Combination of early maturing and drought tolerant crops such as millet and sorghum dominate the areas with annual rainfall of less than 600 mm in Nigeria, in areas with annual rainfall greater than 600 mm, cereals and legumes of varying maturity are used to ensure efficient utilization of above and underground resources (Ofori & Stern, 1987). Maize seems to dominate as the cereal component and it is combined with many different legumes like cowpea (Ruthenberg, 1980),

In high rainfall areas of West Africa, a common crop combination is maize and cowpea (Okigbo and Greenland, 1976) whereas in South and Central America, maize and different types of beans dominate the system (Francis, 1986).

Crop compatibility is an essential ingredient of sound intercropping system. The crop not competing with each other by pattern of differences in growth rhythm, duration, nutrient and water requirements have better temporal use of resources. The combined crop canopy may utilize solar radiation better and the combined root system may explore nutrients and moisture from more soil volume resulting in spatial complementarily (Ruthenberg, 1980).

2.7.b Benefits of intercropping:

Pandey and Singh (1985) obtained maximum dry matter (27.3 q/ha) from cowpea when it was sown with maize in 1:1 row ratio.

Das and Chaterjee, (1977) reported that maize and cowpea produced 75q of dry matter per hectare when grown together.

Several benefits are derived from intercropping. These include stability of production, insurance against crop failure, better resource use and income, meet the needs of small farmers and employment generation (Rao and Willey, 1980, Roy Sharma *et a.*, 1981; Chatterjee and Maiti, 1984; Tomar., 1984; Koshta and Karanjkar, 1986).

Improvement in nitrogen nutrition of maize by intercropping with cowpea was reported by Eaglesham *et al* (1981).

Cowpea not only maintains the soil fertility but also utilizes more phosphorus from the applied source (Reddy and Saxena, 1983).

According to Pandey *el al*.(1999) paired planting of maize at 30 cm and using the inter space for growing soybean with paired row at 30 cm significantly increased the maize-equivalent yield.

Gill and Tripathy (1986) reported that mixed cropping of maize and cowpea had higher dry matter yield (67.4 q/ha) than any of the sole crops indicating its superiority over pure crops.

Rout *et al* (1989) from their intercropping trial involving maize, sorghum, cowpea and rice bean in different row proportions concluded that highest dry fodder yield (48.7 q/ha) was obtained from maize + cowpea (2:1) as compared to other combinations as well as their pure stands.

Raja and Reddy (1990) concluded that cowpea could increase the maize productivity by 52% compared to sole maize under moderate dose of fertilizer application. Adiku *et al.* (1998) reported similar findings from Ghana (Africa).

Cowpea being a legume, fixes the atmospheric nitrogen and improves the soil fertility. Phosphorus fertilization in legumes is of great importance as it affects nodulation, growth and yield (Thakuria, 1991).

Gangwar *et al.* (1994) reported that maize+cowpea in the proportion of 50:50 gave higher yield than their counterparts in monoculture system.

Alim (1996) reported that among the different intercropping systems, maize +cowpea (1:1) had more number of active leaves than the others. Maize + cowpea (2:2) produced the highest dry matter yield of 92.88 q/ha. Where as sole cowpea gave an yield of 61.43 q/ha .

Tripathy *et al,* (1997) indicated that maize + cowpea intercropping system (2:2) recorded higher dry fodder yield than that grown in 1:1 ratio.

Jena and Saren (1998) observed that the yield and its attributes of intercrop maize was not so much different from sole maize. Cobs/plant ranged from 0.72 to 0.77 and remained unaffected.

Krishna *et al.* (1998) obtained linear response to nitrogen by maize + cowpea intercropping. The dry matter yield was 5.13 t/ha at higher level of nitrogen application (180 kg N/ha). Sharma (1993) reported similar results.

2.8 CONSERVATION AGRICULTURE PRODUCTION SYSTEM-YIELD:

Lal (1991) reported from two studies of 8 yr or more that larger maize grain yields were maintained with a mulch based no tillage system than with a plough based system.

Yields in the rice-wheat (RW) systems of the Indo-Gangetic Plains in South Asia are higher with no-till because of timelier planting and better stands. Yields of 200-500 kg/ha are found with no-till wheat in this system (Hobbs and Gupta 2004). Yield gains are also reported in other systems.

In recent year, there has been demonstrations evidence of the merit of practicing conservation agricultural production system (CAPS) in enhancing food and livelihood securities (Timsina *et al.*, 2006).

2.9 CONSERVATION AGRICULTURE PRODUCTION SYSTEM BENIFIT: COST RATIO:

One of the major benefits of Conservation agriculture, which makes it popular with farmers. is it costs less in terms of money but also time. Once again in the rice wheat (RW) systems of South Asia (Hobbs and Gupta 2004), no-till wheat significantly reduced the costs of production; farmers estimate this at about 1500 rupees/ha (US$ 60/ha), mostly due to using less diesel fuel, less labour, and less pumping of water. Since planting can be accomplished in one pass of the seed drill, time for planting was also reduced, thus, freeing farmers to do other productive work.

No-till uses less diesel fuel and thus results in lower carbon dioxide emissions, one of the gases responsible for global warming. In RW systems, 40-60 litters of diesel fuel are saved because farmers can forego the practice of ploughing many times to get a good seedbed after harvesting rice planted after puddle rice in degraded soils (Hobbs and Gupta 2004).

Weeds have been shown to germinate less in conservation agriculture in RW systems (50-60%less) because the soil is less disturbed and less grassy weeds (*Phalaris minor*) germinate than in tilled soils. There is also evidence of allelopathic properties of cereal residues in respect to inhibiting surface weed seed germination (Lodhi and Malik 1987; Steinsiek *et al.* 1982: Jung *et al*. 2004). Weeds will also be controlled when the cover crop is cut, rolled flat, or killed by herbicides.

The review of literature presented in this section shows that studies in respect to conservation agriculture influencing soil properties are very scanty and suggest for more soil specific study in order to evolve a suitable management strategy.

MATERIALS AND METHODS

In order to fulfil the objectives of the present study" Impacts of Maize based conservation agriculture production system on soil properties in North Central Plateau Zone of Odisha" an experiment was conducted under SMARTS (Sustainable Management of Agricultural Resources For Tribal Societies) project at Regional Research and Technology Transfer Station (RRTTS), O.U.A.T, Kendujhar. The materials used and methods followed in this study are discussed under the following heads.

3.1 Materials

3.1.1 Experimental Site:

The regional Research and Technology transfer Station, O.U.A.T, Kendujhar is situated at 21° 55'N latitude and 85° 37'E longitude in the district of Kendujhar at an altitude of 615m above the MSL. It comes under North Central Plateau zone of odisha.

3.1.2 Climate and Weather condition:

The experimental site experiences a hot and sub humid climate. Metrological data (mean of 10 years) from the period 2001-2010 presented in Table 3.1 revealed that the mean annual rainfall at the centre is 1527.26mm. The rainfall is monsoonic and unimodal. August is the rainiest month and January the driest month with the mean rainfall of 286.96 and 4.36mm, respectively. April is the hottest (37.50^0C) and January is the coolest (11.73^0C) month. The relative humidity varies from the minimum of 34.72% in March to 87.53% in September.

Table 3.1 Mean monthly meteorological data (2001-2010) at Kendujhar

Month	Mean monthly rain fall (mm)	Mean monthly temperature (^{0}C)		Mean monthly relative humidity (%)	
		Max.	Min.	Morning	Afternoon
January	4.36	27.23	11.73	65.91	48.38
February	28.22	29.56	14.87	65.47	39.93
March	27.68	34.33	18.91	59.43	34.72
April	38.02	37.50	22.58	53.38	35.86
May	115.44	36.63	23.91	63.27	48.21
June	276.52	33.57	24.11	75.13	71.06
July	280.42	30.20	23.46	83.98	81.04
August	286.96	30.09	23.25	68.4	84.61
September	275.5	30.00	22.59	87.53	85.23
October	65.14	30.45	19.53	75.83	70.52
November	38.54	28.78	16.41	72.99	64.98
December	5.90	26.70	12.25	70.72	58.83

Table 3.2(a) Mean monthly meteorological data during the cropping season (June 2011- February 2012)

Month	Rain fall (mm)	No. of rainy days	Temperature(^{0}C)		Relative Humidity (%)	
			Max.	Min.	Morning	Afternoon
June	359.9	16	32.5	22.8	78.73	77.56
July	157.5	22	30.8	22.5	82	80.12
August	315.5	27	29.03	21.5	89.16	88.22
September	684.5	24	28.96	21.56	88.73	87.06
October	55.1	5	31.03	19.19	73.61	71
November	0	0	31.2	17.8	67.2	59.03
December	0	0	28.19	13.77	68.03	58.83
January	94.7	11	24.77	12.16	65.25	78.03
February	7.8	01	29.93	13.75	43.96	61.68

Table 3.2(b) Mean weekly meteorological data during the cropping season (June 2011- February 2012)

Month	Met. Week	Rain fall (mm)	Rainy days	Temp (^{0}C)		Relative Humidity (%)	
				Mean Max.	Mean Min.	(Morning)	(Afternoon)
June	23	34.50	2	35.00	23.12	73.71	69.28
	24	219.10	6	31.45	22.15	81.71	89.85
	25	29.80	3	31.10	23.48	78.85	76.14
	26	35.10	6	30.41	22.85	84.28	79.57
July	27	45.00	5	30.75	22.31	81.14	76.71
	28	31.90	5	31.95	23.11	81.85	83.42
	29	48.30	7	29.04	22.81	84.85	85.71
	30	20.90	4	27.59	21.67	81.14	76.00
August	31	26.30	3	32.01	22.98	83.00	85.14
	32	34.50	6	28.44	22.45	90.71	88.71
	33	105.80	7	28.81	21.77	89.14	87.28
	34	73.90	6	30.97	21.95	88.42	85.57
	35	127.49	7	28.33	21.88	93.42	92.85
September	36	125.70	7	27.52	21.67	92.00	91.42
	37	146.00	5	30.07	21.98	91.71	86.28
	38	345.90	7	28.17	21.54	91.57	89.28
	39	5.20	3	30.70	21.08	77.85	79.00
October	40	0.00	0	32.24	20.42	69.85	68.14
	41	9.20	2	31.75	21.70	85.71	81.28
	42	0.20	1	31.07	19.72	71.40	72.42
	43	36.20	1	28.52	17.42	72.85	66.28
November	44	0.00	0	29.3	14.64	63.42	60.42
	45	0.00	0	29.82	14.77	60.57	57.00
	46	0.00	0	29.25	15.42	73.00	59.14
	47	0.00	0	27.81	13.95	68.28	60.57
December	48	0.00	0	27.57	13.45	70.28	60.57
	49	0.00	0	28.38	13.12	70.00	62.00
	50	0.00	0	26.77	12.07	79.28	61.85
	51	0.00	0	25.64	7.70	61.14	46.57
	52	0.00	0	25.4	12.87	69.71	71.71
January	01	4.20	2	26.85	16.28	86.00	71.28
	02	77.30	4	21.14	10.57	73.42	65.42
	03	0	0	26.57	10.85	71.85	53.42
	04	1.6	1	25.57	12.16	80.14	69.57
February	05	116	2	24.14	10.57	68.28	57.14
	06	0.00	1	29.28	13.42	58.85	46.85
	07	7.80	0	28.71	15.14	82.00	58.42
	08	0.00	0	32.00	13.57	53.57	32.14
	30	24.00	4	33.00	23.81	84.90	82.70

The prevailing weather during the crop growing season has been presented in monthly mean wise in Table 3.2(a) and meteorological week wise in Table 3.2(b) and depicted in Fig 3.1 and 3.2. The highest rainfall was in September (684.5mm) and the lowest in February (7.8mm).There was no rain in the month of November and December. The mean monthly maximum temperature was the highest in June (32.50^{0}C) and lowest on January (12.16^{0}C). The morning relative humidity was observed to be in the range of 43.96% in February to 89.6% in August; whereas the afternoon relative humidity could range between 59.03% in November to 88.22% in August.

3.1.3 Cropping history

The crops grown at the experimental site during different growing season for the preceding three years are represented in Table 3.3

Table 3.3 Cropping history of the experimental plot

Year	Kharif	Rabi	Summer
2008-09	Maize	Onion	Fallow
2009-10	Maize	Tomato	Fallow
2010-11	Black gram	Mustard	Fallow
2011-12	Maize + cowpea (Experimental)	Mustard & horse gram(Experimental)	

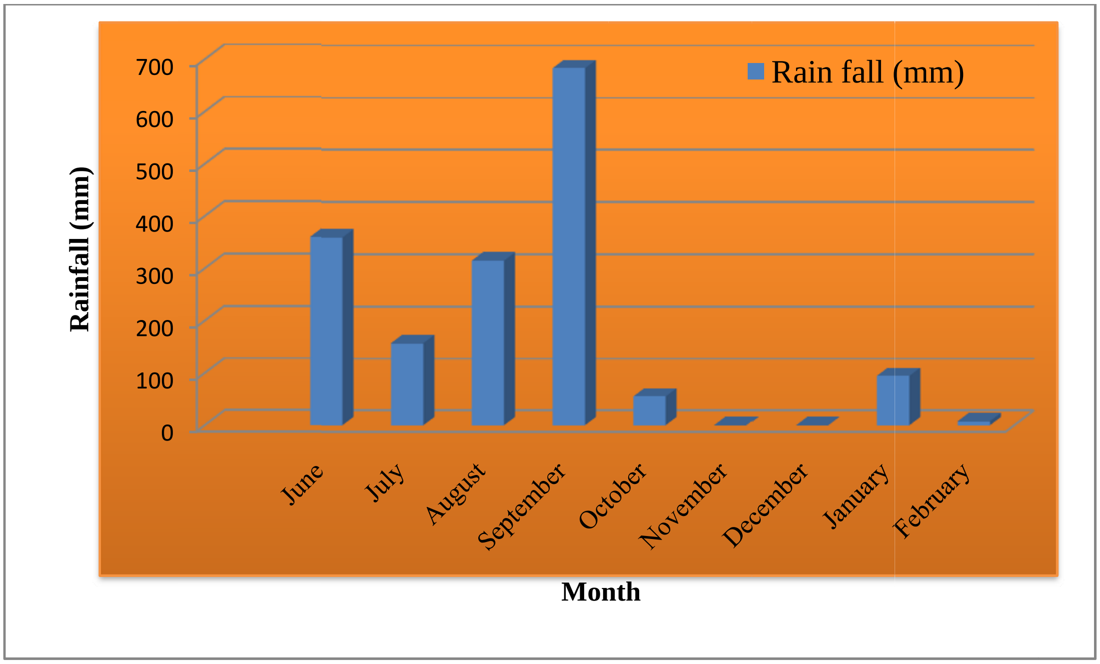


Fig.3.1: Mean monthly rainfall data during the cropping season (June 2011-February 2012)

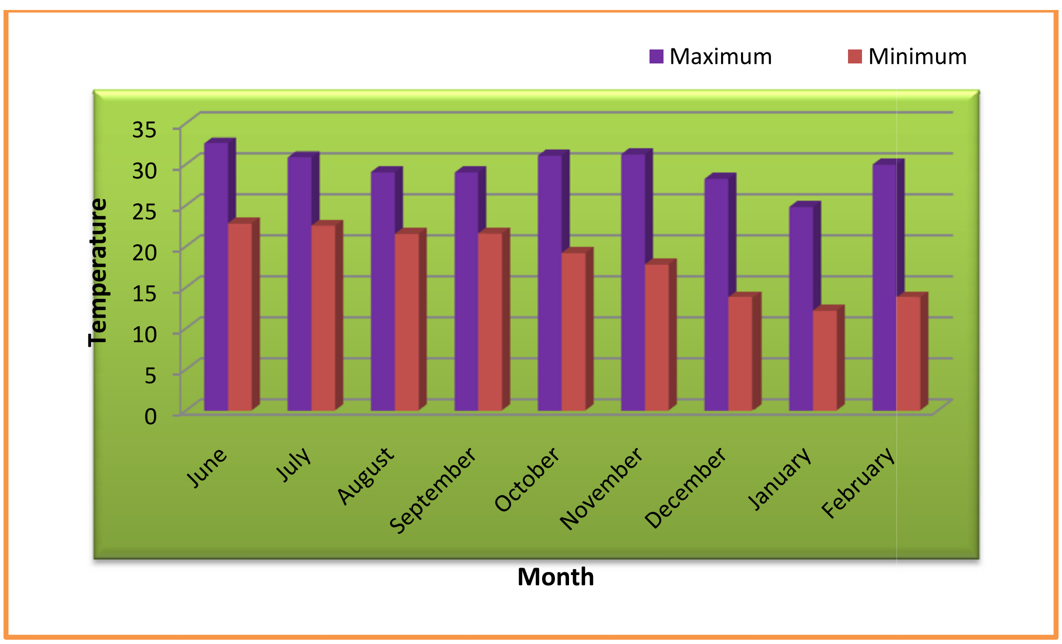


Fig.3.2: Mean monthly temperature data during the cropping season (June 2011-February 2012).

3.1.4 Experimental details:

In order to achieve the principle of crop rotation the experiment was conducted in 2 seasons (Kharif and Rabi season). In Kharif season, the experiment was laid out in randomized block design with 4 treatments replicated 3 times with sole maize and maize + cowpea intercropping system. The treatments are given in table-3.4 and depicted in fig.3.3(a).

Table-3.4 Description of treatments of Kharif season

Treatment	Descriptions
CT-M	Conventional tillage with sole maize
CT-M+C	Conventional tillage with maize+cowpea
MT-M	Minimum tillage with sole maize
MT-M+C	Minimum tillage with maize+cowpea

In Rabi season, each plot of Kharif was divided into 3 subplots cultivated with horse gram, mustard and fallow under split plot design. The treatments are given below in table 3.5 and depicted in fig.3.3(b).

Table -3.5 Description of treatments of Rabi season

Treatment	Description
CT-M-F	Conventional tillage with sole maize -fallow
CT-M-M	Conventional tillage with sole maize - mustard
CT-M-H	Conventional tillage with sole maize -horsegram
CT-M+C-F	Conventional tillage with maize+cowpea- fallow
CT-M+C-M	Conventional tillage with maize+cowpea - mustard
CT-M+C-H	Conventional tillage with maize+cowpea - horse gram
MT-M-F	Minimum tillage with sole maize -fallow
MT-M-M	Minimum tillage with sole maize - mustard
MT-M-H	Minimum tillage with sole maize - horse gram
MT-M+C-F	Minimum tillage with maize+cowpea - fallow
MT-M+C-M	Minimum tillage with maize+cowpea - mustard
MT-M+C-H	Minimum tillage with maize+cowpea - horse gram

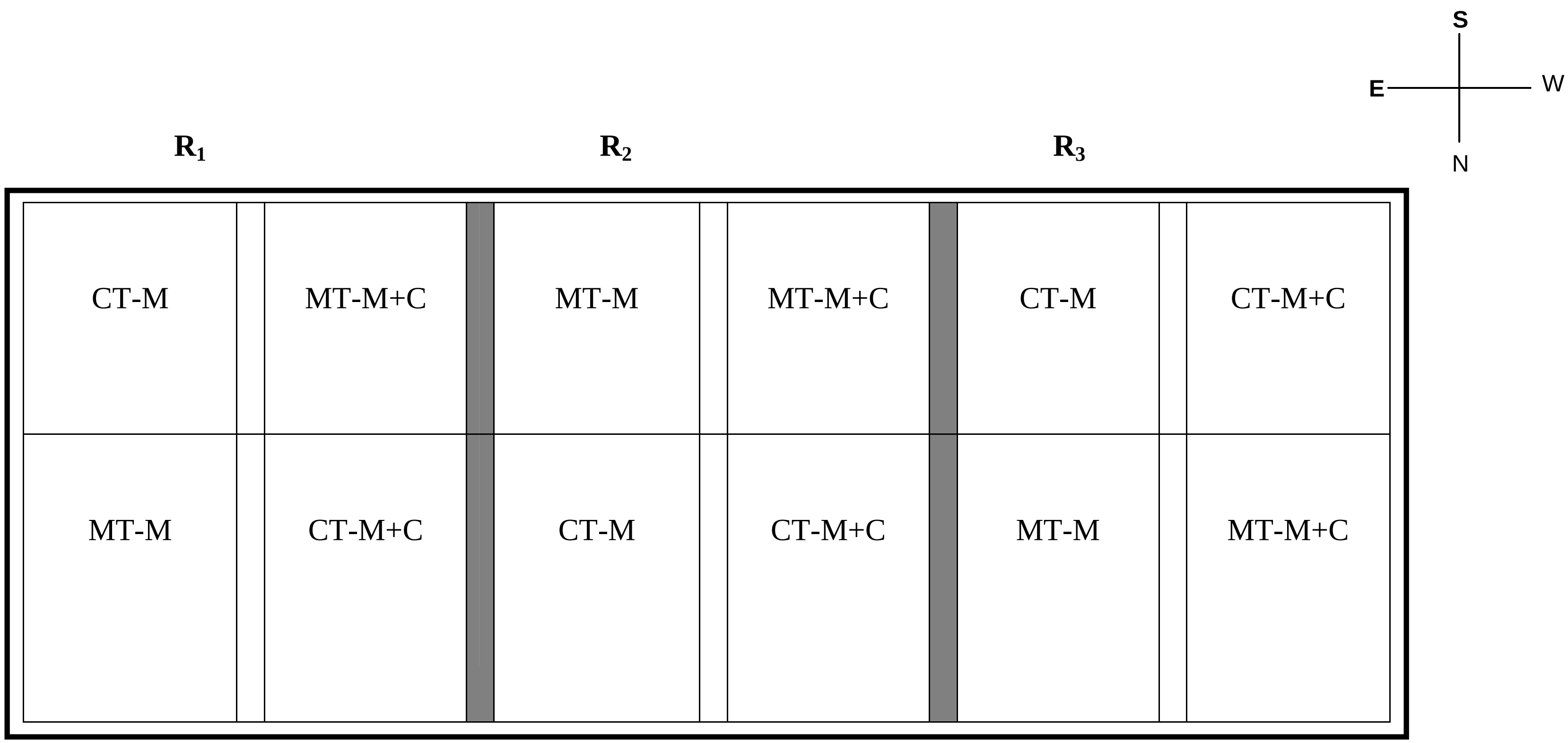
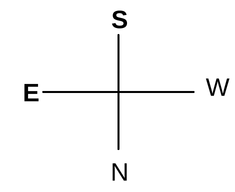


Fig. 3.3(a) Layout plan of the experiment during Kharif season

Experimental design: RBD
Number of treatments: 04
Number of replication: 03
Individual plot size: 10.2m×7.2m

CT-M - Conventional tillage with sole maize
CT-M+C - Conventional tillage with maize +cowpea
MT-M - Minimum tillage with sole maize
MT-M+C - Minimum tillage with maize+cowpea



R_1		R_2		R_3	
CT-M-F	MT-M+C-M	MT-M-H	MT-M+C-H	CT-M-M	CT-M+C-F
CT-M-H	MT-M+C-F	MT-M-F	MT-M+C-M	CT-M-H	CT-M+C-M
CT-M-M	MT-M+C-H	MT-M-M	MT-M+C-F	CT-M-F	CT-M+C-H
MT-M-F	CT-M+C-H	CT-M-M	CT-M+C-F	MT-M-M	MT-M+C-H
MT-M-H	CT-M+C-F	CT-M-H	CT-M+C-M	MT-M-H	MT-M+C-F
MT-M-M	CT-M+C-M	CT-M-F	CT-M+C-H	MT-M-F	MT-M+C-M

Fig. 3.3(b) Layout plan of the experiment during Rabi season

Experimental design: Split plot
Number of treatments: 12
Number of replication: 03
Individual plot size: 7.2m×3.2m

Main plot

CT-M - Conventional tillage with sole maize
CT-M+C - Conventional tillage with maize +cowpea
MT-M - Minimum tillage with sole maize
MT-M+C - Minimum tillage with maize+cowpea

Sub plot

F-Fallow
M-Mustard
H-Horse gram

3.1.5 Soil characteristics:

The soil of the experimental field belongs to moderately well drained mixed red and black soil (*Vertic Haplaquepts*). The initial soil properties are listed in and table-3.6

Table-3.6 Initial physical and chemical properties of the soil

Particulars	**Values**
Bulk density	1.34
Texture	Clay loam Sand 54.6% Silt 15.2% Clay 30.2%
pH	7.33
Organic carbon (g/kg)	6.60
Available N(Kg/ha)	259.3
Available Phosphorous (Kg/ha)	15.45
Available Potassium (kg/ha)	328.6
Ca[cmol (p^{+})/kg]	17.00
Mg [cmol (p^{+})/kg]	6.00

3.1.6 Description of crop varieties

3.1.6.1 Maize (CV.Nilesh) :- It is a maize hybrid developed by Nirmala hybrids, Hyderabad having a duration of 100-110 days suitable for Kharif, Rabi and Summer season. The hybrid is well acclimatised to agro-climatic situation of North central plateau zone of Odisha by virtue of its genetic make up.

3.1.6.2 Cowpea (CV.Hariyally Bush) :- Hariyally Bush is a cowpea variety developed from screening of elite cowpea germ plasm of west Bengal. The variety has shown promising performance in the kendujhar through front line demonstration and on farm testing conducted by KVK, kendujhar.

3.1.6.3 Mustard (CV.Parvati) :- The Variety was released from AICRP on Rapeseed and Mustard, OUAT, Bhubaneswar, Odisha. It matures within 75 days and is suitable for both rained and irrigated condition throughout Odisha. The plant height is 97-110cm. The oil content is 41-50%. The seeds are semi bold, round, light brown in colour and test weight is 5-25g. The siliqua is medium, long, flat, slightly flat and brawn red colour. The variety yields 15qha^{-1}. It tolerates soil moisture stress.

3.1.6.4 Horse gram (CV.Athagada local) :- Athagada local was the test variety for horse gram. It is a farmer's variety of 100 days duration. It suits well to rainfed situations of Odisha and tolerates winter too.

3.1.7 Field operations:

The field operations carried out during the growing season is presented in table 3.7 indicating calendar of operation.

Table 3.7 Calendar of operations :

Kharif Season:

Sl. No.	Field operations	Date
1.	First Ploughing & trimming of bunds	30/05/2011.
2.	Layout & soil sample collection	31/05/2011
3.	Second & third ploughing for conventional tillage	03/06/2011
4.	Levelling	04/06/2011
5.	FYM and Fertilizer application	05/06/2011
6.	sowing	06/06/2011
7.	Gap filling and thinning	12/06/2011
8.	Thinning	16/06/2011
9.	Hoeing and first top dressing of fertilizer and earthing up	27-28/06/2011
10.	Plant Protection (Spray of Malathion)	07/07/2011
11.	Harvesting of cowpea	06/08/2011 11/08/2011 16/08/2011 21/08/2011
12.	Harvesting of Maize	21-22/09/2011

Rabi Season :

Sl. No.	Field operations	Date
1.	Land preparation by ploughing once	10/10/2011
2.	Layout	12/10/2011
3.	FYM and Fertilizer application	13/10/2011
4.	Sowing of Mustard and Horse gram	13/10/2011
5.	Gap filling	18/10/2011
6.	Thinning	23/10/2011
7.	Hoeing and Weeding	04/11/2011
8.	Harvesting of Mustard	04/01/2012
9.	Harvesting of Horse gram	20/01/2012

3.1.7.1 Field Preparation

In Kharif season, primary tillage was done and field was laid out initially .Then the portion of the field having conventional tillage was given secondary and tertiary tillage and final layout was prepared. In Rabi season, each of the treatment plot was further divided into three sub plots to accommodate the rest of the treatments and the sub-plots were ploughed once, levelled and kept ready for sowing.

3.1.7.2 Manure & Fertilizer

The rainy season crops were applied with FYM at an uniform rate of 5t/ha. The chemical fertilizer applied for Maize, Cowpea, Mustard and Horse gram was applied as per the details indicated in the Table 3.8. The fertilizer applied for Maize + Cowpea was based on additive series, taking into consideration 100 per cent plant population of maize and 50 percent plant population cowpea. The fertilizers were applied in line basally for the crop except maize where nitrogen was applied in three split viz. 25% basal 50% at first earthing up and rest 25% at second earthing up stage. \

Table 3.8 Fertilizer dose for different experimental crops grown

Crops	Fertilizer Dose (kg/ha)		
	N	P_2O_5	K_2O
Maize	80	40	40
Cowpea	20	40	20
Mustard	40	20	20
Horse gram	20	40	20

3.1.7.3 Sowing, Seed rate and Spacing:-

During Kharif season, for sole maize, spacing of 60 x 30cm was adopted for which a seed rate of 15kg/ha was required. But maize + cowpea as intercrops were sown in 1:1 ratio at a uniform spacing of 30cm. The spacing adopted for cowpea was 15cm from plant to plant within the row. A seed rate of 10kg/ha was required taking into consideration that the cowpea plant population is 50 percent of normal sole cowpea. Sowing was done by opening lines using trench hoe and the seeds were covered with soil after sowing. During Rabi season, mustard and horse gram were sown as sole crops. Both the crops were line sown at row spacing of 30cm and subsequent thinning of plants was made to maintain plant to plant spacing of about 10cm within the row. A seed rate of 7.5kg and 25.0kg/ha was required for mustard and horse gram, respectively. Sowing was done by opening lines using trench hoe and the seeds were covered with soil after sowing.

3.1.7.4 Harvesting :

The crops were harvested at the time of their respective maturity. In Rabi crops from each plot were harvested separately from each treatment and brought to the threshing floor after bundling and proper levelling. The bundles were dried in sun for 5-6 days. After drying threshing and winnowing was done and yield according to treatments were found out.

3.1.8 Installing resin bags in the field:

Five resin bags were placed in inter row space of each treatment plot at the RRTTS, Kendujhar at a depth of 15cm below the soil surface. They were incubated for a period of four weeks.

Procedure:

A hole of 15cm depth was created and the soil was removed by khurpi. The resin bag was placed in the hole and a bamboo stick tied with ribbon flag (30cm long) was inserted to mark the placement of resin bags. The soil was filled and was tapped down to ensure good contact with the resin bags.

3.2 Methods

3.2.1 Collection and processing of soil samples:

The initial soil samples were collected before imposing any treatments by following the method of composite random sampling. The samples were dried under shade and crushed and sieved through 2mm sieve. Then the samples were preserved in polythene with proper label for analysis. The soil sample after harvest of maize and cowpea (in Kharif season) and mustard, horse gram (in Rabi season) were also collected in the same way and kept in polythene with proper labelling.

3.2.2 Plant samples:

The plant samples of maize, cowpea, horse gram and mustard were collected treatment wise, dried and grinded. Then the samples were kept in polythene with proper label for analysis.

3.2.3 Record of field:

After harvest of Kharif crops, yield were recorded in terms of seed and pod Kg/plot for maize and cowpea respectively. For horse gram and mustard yields were in terms of Kg seeds per plot. Then the data were converted to qha^{-1}.

3.2.4 Method of analysis:

3.2.4.1 Soil analysis: The soil samples were analysed for different physicochemical properties following the standard methods given.

3.2.4.1.1 Bulk density:

The bulk density of soil samples was determined by core method as described by Black(1965).

3.2.4.1.2 Soil texture:

The percentage of sand, silt, clay were determined with the help of Bouyoucos hydrometer following the standard procedure (Piper, 1950) after Kharif and Rabi. After Rabi equal quantity (50g) of soil sample from each sub plots were taken, mixed thoroughly and the composite soil sample was taken for analysis.

50g of soil sample was taken in a beaker and 15ml of 10% sodium hexametaphosphate was added followed by 200ml of distilled water and was stirred for 15 minutes with a mechanical stirrer. The content were transferred to a 1000ml measuring cylinder and the volume was made up to 1 litre. At 5 minutes and 5 hours the temperature and hydrometer reading were taken. Percentage sand, silt, clay were calculated and the textural class was determined using international triangular diagram.

3.2.4.1.3 Soil pH:

As suggested by Jackson (1973) the pH of soil samples was determined in 1:2 soil:water suspension after equilibration for half an hour with intermittent stirring using the glass electrode pH meter.

3.2.4.1.4 Organic carbon:

Organic carbon of the soils were determined by wet oxidation method of Walkley and Black as outlined in soil chemical analysis (Page *et al*.,1982).

3.2.4.1.5 Available nitrogen:

Available nitrogen was determined by using alkaline potassium permanganate ($KMnO_4$) method (subbiah and Asija, 1956).

5g of soil sample was taken in a 800ml kjeldahl flask and then 25ml of 0.32% KMnO4 and 25ml of 2.5% NaOH solution was added with some distilled water. Distillation was done by Kelplus Nitrogen Auto Analyzer and the distillate was collected at receiver tube in the 250ml conical flask containing 20ml boric acid (2%) with mixed indicator. The distillate was titrated against 0.02N H_2SO_4 to a pink colour end point. From the amount of H_2SO_4 consumed the amount of available nitrogen was calculated.

3.2.4.1.6 Available phosphorus:

Available phosphorus in the soil samples was determined spectrophotometrically by Olsen's method (Olsen *et al*.,1954).

2.5g of soil was added with 50ml of Olsen's extractant (0.5N $NaHCO_3$) and was shaken for 30 minutes and filtered through Whatman No.1 filter paper. 5ml of aliquot was transferred to 25ml volumetric flask and was acidified to pH 5.0 with 5N H_2SO_4 followed by addition of 4ml of ascorbic acid solution. Then the volume was made up to 25ml with distilled water and was shaken. Phosphorus concentration was determined by the help of spectrophotometer at 882nm. Phosphorus concentration was calculated from standard graph prepared by taking known phosphorus concentration.

3.2.4.1.7 Available potassium:

Available potassium of soil was determined by extracting the soil with neutral normal ammonium acetate solution and estimated by flame photometer.

5g of soil sample was equilibrated with 25ml of neutral normal ammonium acetate by shaking for 5minutes. Then it was filtered by the help of

Whatman No.1 filter paper and the potassium concentration in the filtrate was measured in a flame photometer after necessary dilution as described by Page *et al.*(1982).

3.2.4.1.8 Available calcium and magnesium:

Available calcium and magnesium of soil sample were determined by method described by Page *et al*.1982.

2.5g of soil along with 20ml of neutral normal ammonium acetate solution was shaken for 30 minutes in a horizontal shaker. Then the sample was filtered and volume was made up to 50ml.

5ml of extract was taken and 3ml of 10% NaOH, 10 drops of each of Hydroxyl amine hydrochloride, TEA (Triethanol amine) and Calcon indicator was added. Then the content was titrated against standard 0.01N EDTA(Ethylene Diamine Tetra Acetic Acid) as described by Jackson(1973). Then % Ca was determined from the quantities of EDTA consumed during titration.

First (Ca+Mg)% was determined by taking 5ml of aliquot. Then little distilled water, 15ml of NH_4Cl-NH_4OH buffer and 10 drops of each of the Hydroxyl amine hydrochloride, TEA, Potassium ferrocyanide were added. The content was gently heated and was made cool. Then 10 drops of EBT (Eriochrome Black-T) was added and titrated against standard 0.01N EDTA to turquoise blue end point as described by Jackson(1973). % Mg was calculated by deducting Ca% from (Ca+Mg)%.

3.2.4.2 Determination of captured nutrient in resin bag:

After four weeks of incubation period the resin bags were removed carefully not to damage and were kept in plastic bags for each plot. The resin bags were washed in deionised water to remove the soil particles. Then the cleaned resin bags were placed in 500ml conical flask and 50ml of 0.5 molar HCl was added to each resin bag in the flask. In this way the resin bags were kept for two hours for complete conversion of bicarbonate to carbon dioxide. Then the resin bags in the flask were shaken for one hour on a shaker. After that the solution was filtered and was stored in storage bottle for nutrient (N, P, K, Ca, Mg) analysis. The nutrients were analysed following the standard analytical procedure.

3.2.4.3 plant analysis:

3.2.4.3.1 Analysis of nitrogen: Nitrogen in the plant sample(leaves) was estimated by Micro kjeldahl method (Jackson,1973).

3.2.4.3.2 Analysis of Phosphorus:

The plant samples were digested following prescribed method. 0.5g of leaves sample was taken in a 100ml conical flask and was pre-digested with 10ml concentrated HNO_3. Then 5ml of diacid (HNO_3:$HClO_4$=3:2) was added and the digestion was continued in a hot plate until dense white fumes evolved. Then the flask was allowed to slightly cool and filtered through Whatman No-1 filter paper by washing the content 5 times each with little distilled water. The content was transferred to 50ml volumetric flask and the volume was made up to 50ml by adding distilled water. The content was mixed thoroughly.

Phosphorus was analysed by Vanado-Molybdo-Phosphoric acid yellow colour method as described by Jackson (1973) at 470nm by the help of spectrophotometer.

3.2.4.3.3 Analysis of Potassium:

The plant samples were digested following the method same as phosphorus. 5ml of aliquot was diluted with distilled water to 25ml and potassium concentration was estimated as described by Jackson (1973) by the help of Flame photometer.

3.2.5 Maize-equivalent yield

Maize-equivalent yield (MEY) was calculated by the formula as follows:

$$\text{MEY } (\text{qha}^{-1}) = \frac{\text{Yield of other crop produce}(\text{q ha}^{-1}) \times \text{price of that produce}(\text{Rs q}^{-1})}{\text{Price of maize grain}(\text{Rs q}^{-1})}$$

The maize equivalent yield of the cropping system was found out by addition of yield of maize component and the maize equivalent yield of other component crop taken in intercropping and the Rabi crop if any (mustard and horse gram).

3.2.6 Economics of production

Studies on economics of production was made by keeping a record on operations carried out, labour engaged power, input utilized for production and the return from the output. The cost of cultivation for each treatment was worked out for component crops in the system. The gross were calculated taking to account the prevailing price of outputs. Net return per hectare and return per rupee invested were also worked out as per the following formula.

$$\text{Net return} = \text{Gross return} - \text{Cost of cultivation}$$

$$\text{Return per rupee invested} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

3.2.7 Statistical Analysis:

Data in respect of soil physical and chemical properties for various treatments were subjected to analysis of variance following standard statistical procedure (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

In order to investigate the effect of conservation agricultural production system on soil physical characteristics, chemical properties, nutrient uptake and yield of crops in a maize based cropping system an experiment was conducted at Regional Research and Technology Transfer Station (RRTTS), Kendujhar on an alkaline soil. The experimental results of the field experiment and laboratory analyses carried out during the period of investigation are reported and discussed in this chapter under the following heads.

4.1 Effect of different tillage and crops on some physical properties of soil

- 4.1.1 Bulk density
- 4.1.2 Texture

4.2 Effect of different tillage and crops on some chemical properties of soil

- 4.2.1 Soil reaction (pH)
- 4.2.2 Soil organic carbon
- 4.2.3 Available nitrogen
- 4.2.4 Available phosphorus
- 4.2.5 Available potassium
- 4.2.6 Available calcium
- 4.2.7 Available magnesium

4.3 Nutrient dynamics through resin bag

4.4 Effect of different treatments on nutrient uptake by crops

- 4.4.1 Nutrient uptake by maize
- 4.4.2 Nutrient uptake by cowpea
- 4.4.3 Nutrient uptake by horse gram
- 4.4.4 Nutrient uptake by mustard

4.5 Effect of different treatments on crop yield

- 4.5.1 Yields of maize and cowpea
- 4.5.2 Yields of horse gram and mustard

4.6 Economics of production

4.1 EFFECT OF DIFFERENT TILLAGE AND CROPS ON SOME PHYSICAL PROPERTIES Of SOIL

4.1.1 Bulk density:

Soil physical properties are relatively permanent and changes very slowly with time as compared to chemical and biological properties. Bulk density is a basic physical property of soil which regulates soil water holding capacity, pore space, nutrient and water movement etc. in soil. It is influenced by minimum tillage (Osunbitan *et al*.,2004) The impact of different tillage and crop on bulk density of soil after harvest of Kharif and Rabi crops was found out by prescribed procedure.

Table- 4.1 Effect of tillage and crop on bulk density (Mgm^{-3}) of soil (0-20cm) after harvest of Kharif and Rabi crops.

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	1.347	1.350	1.347	1.348	1.348
CT-M+C	1.346	1.348	1.345	1.347	1.347
MT-M	1.341	1.341	1.338	1.340	1.340
MT-M+C	1.340	1.339	1.337	1.338	1.338
MEAN	1.345*	1.345	1.342	1.343	
CD(0.05)	NS	Tillage –NS Crop- NS T×C –NS			

*initial

Data pertaining to bulk density was recorded in Table- 4.1. The results revealed that after Kharif crops the value of bulk density varied from 1.340 to1.347 Mgm^{-3}. The value of bulk density decreased in minimum tillage as compared to conventional tillage. The maximum bulk density was recorded in conventional tillage with sole maize and minimum in minimum tillage with maize +cowpea intercrop. The bulk density of soil increased by 0.002 and 0.001Mgm^{-3}

in case of CT-M and CT-M+C respectively over initial bulk density of 1.345 Mgm^{-3} whereas reduced by 0.004 and 0.005 Mgm^{-3} in case of MT-M and MT-M+C respectively. Minimum tillage reduced the bulk density of soil though non significant than the conventional tillage. After harvest of Rabi crops the bulk density varied from 1.348 Mgm^{-3} in CT-M to 1.338 Mgm^{-3} in MT-M+C. Among different crops grown in Rabi season the bulk density varied from 1.342 to 1.345 Mgm^{-3}. The minimum value was recorded in case of horse gram plot and maximum in fallow.

The minimum tillage helped in increasing the organic matter content and porosity of the soil which reduced the bulk density of soil than initial. Similar result was found by Kay and Vanden Bygaart (2002) and Deen and Kataki in 2003.

This conditions favour plant growth and maintenance of soil health. In comparison to sole maize with maize+cowpea intercropping showed better performance than the former. The latter one had showed a reduction in bulk density than the former one. In case of sole maize crop the bulk density remained almost same as initial but in maize +cowpea intercropping bulk density reduced. This showed maize +cowpea not only conserve the soil but also improves the porosity and adds more organic matter to the soil resulting in reduction of bulk density.

After harvest of Rabi crops the bulk density of soil was decreased in horse gram .This was due to the effect of horse gram which is a leguminous crop as well as its phyllotaxy acts as an umbrella to protect the soil. It not only adds nitrogen but also improves the porosity. These effects were not found from mustard crop which is a non leguminous crop and tall in morphology.

4.1.2 Texture:

Texture is another important physical property of soil. It directly influences the plant growth by regulating many physical and chemical characteristics. Surface area, ion exchange, porosity, nutrient holding capacity, water air movement are directly or indirectly influenced by texture. It is relatively sTable because change is very slow by different weathering and pedogenic process. Clay is finer than silt and sand which influences more in regulating nutrient and water holding capacity of soil. The proportion of clay opt to be maintain or increase to some extent for better growth of crop. In the other hand drastic reduction in clay and increase in the sand content in the soil is an indication of soil degradation.

Table 4.2 Effect of tillage and crop on fine earth fraction of soil (0-20cm) Kharif crops.

Treatment	Sand (%)	Silt (%)	Clay(%)
CT-M	54.6	15.0	30.4
CT-M+C	53.6	15.6	30.8
MT-M	53.8	14.8	31.4
MT-M+C	52.6	15.8	31.6
INITIAL	54.6	15.2	30.2

The effect of tillage and crop on sand, silt and clay content of the soil were determined and presented in Table 4.2. After Kharif season the sand content of soil varied from 52.6 to 54.2%. Maximum sand content was found in treatment CT-M whereas minimum in MT-M+C. In comparison to initial sand content of soil (54.6%) in all the treatments sand content was decreased. The maximum decrease of 2.0% in MT-M+C. The silt content varied from 14.8 to 15.8% in comparison to initial value 15.2%. The clay content varied from 30.4 to 31.6% in comparison to initial of 30.2%the minimum value was observed in CT-m followed by CT-M+C, MT-M and MT-M+C in an increasing order. The value of silt and clay increased from conventional tillage to minimum tillage. Maize +cowpea intercrop helped in increasing the silt and clay content than sole maize crop.

Table 4.3 Effect of tillage and crop on fine earth fraction of soil (0-20cm) after Rabi crops.

Treatment	Sand (%)	Silt (%)	Clay(%)
CT-M	53.8	15.4	30.8
CT-M+C	52.6	16.2	31.2
MT-M	52.8	15.4	31.8
MT-M+C	52.2	15.6	32.2

After Rabi crops taking composite soil sample sand, silt and clay % were determined and recorded in Table 4.3. The sand content varied from 52.2 to 53.8%, silt content varied from 14.6 to 15.6 %and clay content varied from 30.8 to32.2 %. The sand content slightly increased in conventional tillage than its initial value whereas a decreasing value was observed in case of minimum tillage. But a reverse trend was observed in case of silt and clay content in their respective treatments. Maize + cowpea intercropping showed greater decreasing effect on content of sand over sole maize crop and a reverse trend in case of silt and clay.

In case of conventional tillage the reduction in sand content after Kharif is less than minimum tillage which was due to increase in clay and silt content. This showed silt and clay fraction of soil was conserved by minimum tillage as compared to conventional tillage. In maize +cowpea intercrop, cowpea being a cover crop had influenced physically and biologically in protecting the losses of clay and silt more than sole maize crop.

4.2 EFFECT OF DIFFERENT TILLAGE AND CROPS ON SOME CHEMICAL PROPERTIES Of SOIL

4.2.1 Soil reaction (pH) :

Soil reaction is one of the most important fundamental physicochemical characteristics of soil. It influences most of the soil properties. The availability of most of the nutrients, microbial growth and soil health basically depends on it.

Table 4.4 Effect of tillage and crop on pH (1:2) of soil (0-20cm) after harvest of Kharif and Rabi crops.

Treatments	Kharif	Rabi			
		Fallow	**Horsegram**	**Mustard**	**Mean**
CT-M	7.32	7.31	7.32	7.31	7.31
CT-M+C	7.33	7.32	7.33	7.33	7.32
MT-M	7.34	7.35	7.36	7.35	7.35
MT-M+C	7.36	7.36	7.38	7.37	7.37
MEAN	7.33*	7.34	7.35	7.34	
CD(0.05)	NS	Tillage -NS Crop -NS T×C - NS			

*initial

Results pertaining to soil pH measured after Kharif and Rabi crops recorded in Table 4.4. The data showed that the pH of soils varied from 7.32 to 7.36 unit after Kharif. Maximum pH was found in treatment MT-M+C where as minimum in CT-M. In comparison to initial pH of soil the pH of minimum tillage was increased (Sidiras and Pavan, 1985) and that of in conventional tillage remained same. The increase in pH of soil in MT-M+C was by 0.03 unit than the initial.

After harvest of Rabi crops the pH of soil varied from 7.31 in CT-M to 7.37 in MT-M+C. A similar trend as Kharif, in change of pH in different tillage practice was observed after Rabi. Among different crops horse gram was found to influenced most and increased the soil pH by 0.01 unit over mustard and fallow.

The increase in pH in minimum tillage than conventional tillage was due to accumulation of more basic cations like Ca^{2+} and Mg^{2+} in former tillage practice. Maize +cowpea intercropping helps in conserving cations than sole maize crop which had manifested in raised soil reaction. Further increase in pH after Rabi was due to additional effect of accumulation of basic cations with time.

4.2.2 Organic Carbon (g/Kg):

Soil organic matter improve the availability of N, P and other nutrients, increases the cation exchange capacity which reduces potential leaching losses of elements like K^{+}, Ca^{2+}, Mg^{2+} etc., greater water holding capacity and maintain better soil structure.

Table 4.5 Effect of tillage and crop on Organic carbon (g/Kg) of soil (0-20cm) after harvest of Kharif and Rabi crops

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	6.45	6.41	6.47	6.43	6.44
CT-M+C	6.51	6.48	6.54	6.50	6.51
MT-M	6.73	6.72	6.77	6.74	6.74
MT-M+C	6.81	6.84	6.86	6.83	6.84
MEAN	6.60*	6.61	6.66	6.63	
CD(0.05)	0.08	Tillage -0.05	Crop -0.02	T×C –NS	

*initial

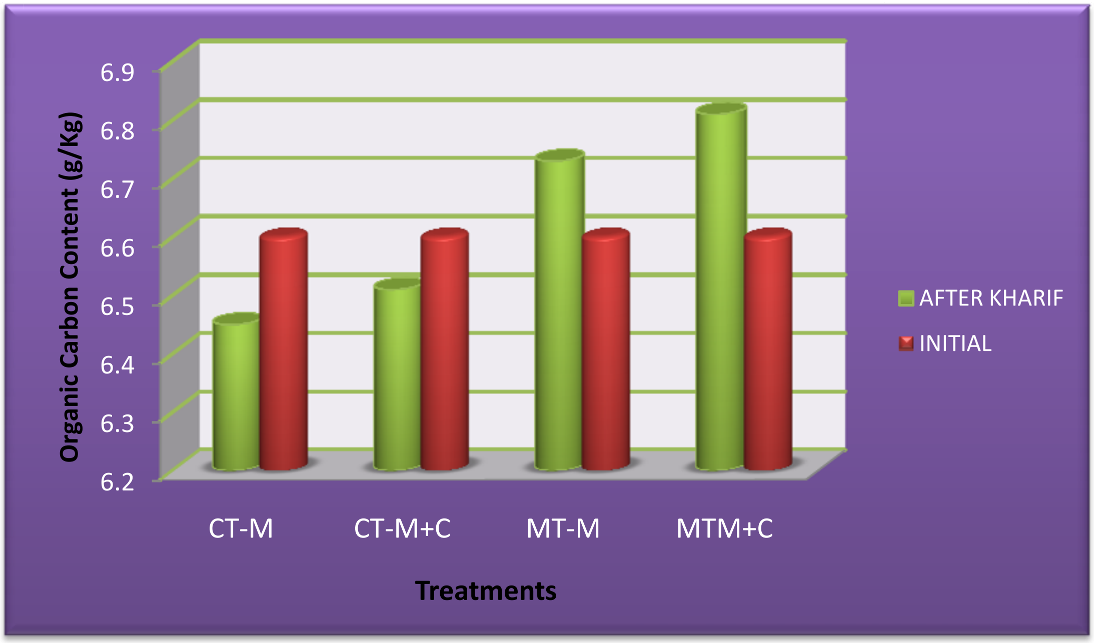


Fig 4.1(a): Effect of tillage and crop on organic carbon content (g/Kg) of soil after harvest of Kharif crops.

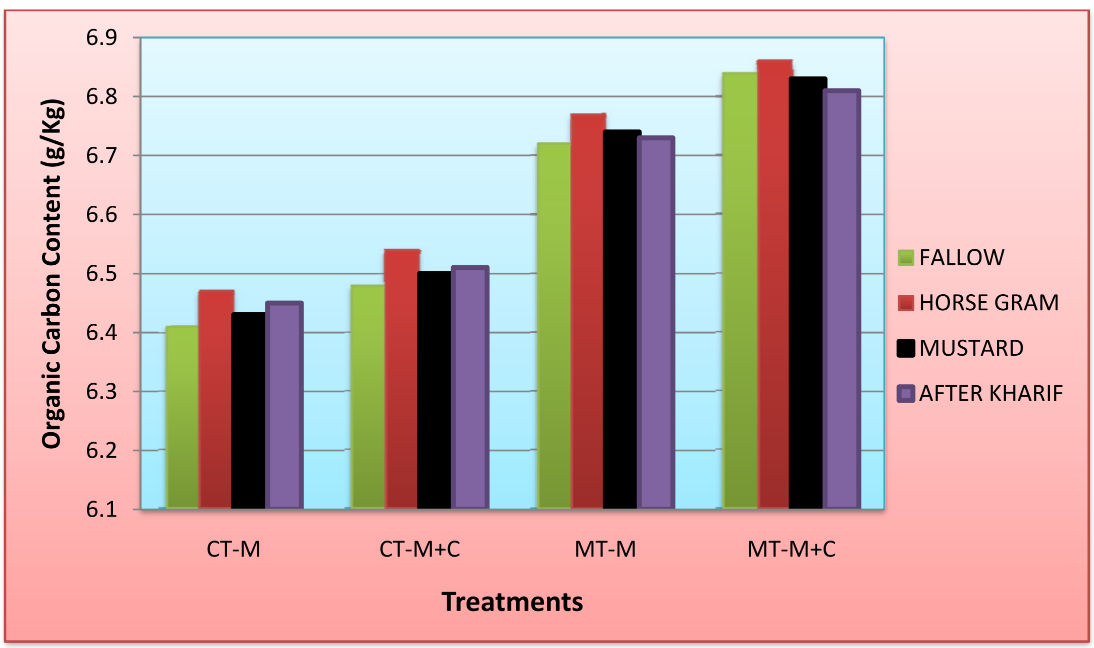


Fig 4.1(b): Effect of tillage and crop on organic carbon content (g/Kg) of soil after harvest of Rabi crops.

Organic carbon content (g/Kg) of soil after harvest of Kharif and Rabi crops influenced by tillage and crops was determined using standard procedure. The results were presented in Table 4.5 and depicted in Fig 4.1(a) and Fig 4.1(b). The data revealed that the soil organic carbon content varied from 6.45 g/Kg in treatment CT-M to 6.81g/Kg in MT-M+C. The organic carbon content of the soil increased significantly in case of minimum tillage than conventional tillage and maize +cowpea intercropping had accumulated more organic carbon in comparison to sole maize crop in both the tillage practices (Table 9). After harvest of Rabi crops, the data showed that due to different tillage practice the organic carbon content varied from 6.44g/Kg in CT-M to 6.84 g/Kg in MT-M+C. There was significant variation in organic carbon content between conventional and minimum tillage practice. Within the same tillage condition the organic carbon content was also showed significantly higher value in maize +cowpea than sole maize. Among different crops taken in Rabi season, the organic carbon content varied from 6.61 to 6.66g/Kg. The maximum value was observed in horse gram and minimum in fallow. The organic carbon content showed a significant variation among different crops.

The content of organic carbon in MT-M+C intercrop was significantly more than CT-M due to incorporation of more organic matter through cowpea in the soil. Similar result was observed by Havlin *et al.* (1990). Minimum tillage prevented the loss of organic carbon by atmospheric oxidation as exposed surface area was minimum in case of minimum tillage over conventional tillage. During Rabi season horse gram plot had higher quantity of organic carbon over mustard and fallow because of its dwarf nature which cover the soil. Mustard was less protective in nature than horse gram. In fallow there was no addition of organic matter by the crop rather the loss was more as the soil was exposed. After Rabi the quantum of organic carbon in the soil were more in respective tillage practices of Kharif due to additional quantity of organic matter occurred during the season.

4.2.3 Available Nitrogen:

Nitrogen is an integral component of many essential plant compounds. Plant absorb nitrogen in both NO_3^- (nitrate) and NH_4^+ (ammonium) form. It is a major part of amino acids which are the building blocks of all proteins, enzymes. In addition to that nitrogen is an integral part of chlorophyll and also essential for carbohydrate use within plants. A good supply of nitrogen stimulates root growth and development as well as uptake of other nutrients. Plants respond quickly to increased availability of nitrogen. Considering the importance of nitrogen, in the present investigation available nitrogen content of soil were analysed to know how it is being influenced by different treatments.

Table 4.6 Effect of tillage and crop on available N (Kg/ha) of soil (0-20cm) after harvest of Kharif and Rabi crops

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	256.7	256.2	257.0	256.4	256.5
CT-M+C	258.1	257.5	258.7	257.9	258.0
MT-M	261.2	261.1	261.8	261.5	261.5
MT-M+C	262.6	263	263.4	262.8	263.1
MEAN	259.3*	259.5	260.2	259.7	
CD(0.05)	1.51	Tillage -0.84 crop – 0.18 T×C –NS			

*initial

Data pertaining to available nitrogen (Kg/ha) content influenced by tillage and crop was determined after Kharif and Rabi crops recorded in Table 4.6 and depicted in Fig 4.2(a) and Fig 4.2(b). The data showed that the available nitrogen content of soil varied from 256.7 Kg N/ha to 262.6 Kg N/ha after Kharif. The maximum value was observed in treatment MT-M+C and minimum in CT-M. The available nitrogen content was increased in minimum tillage and decreased in conventional tillage the initial value of 259.3 Kg N/ha. Maximum increase to a tune of 3.3 Kg N/ha was found in MT-M+C treatment. The data showed that there was significant variation in available nitrogen content between conventional tillage and minimum tillage. Maize+ cowpea intercrop had accumulated more available nitrogen (260.4KgN/ha) than sole maize crop (259.0KgN/ha).

After Rabi crops the available nitrogen content varied from 256.5Kg N/ha in CT-M to 263.1 Kg N/ha in MT-M+C. The available nitrogen content in MT-M+C, MT-M, CT-M+C and CT-M were found to be in a decreasing order. The value of available nitrogen in MT-M+C was significantly higher than CT-M and CT-M+C and statistically at par with MT-M. Among different crops available nitrogen content varied between 259.5 Kg N/ha to 260.2 Kg N/ha. The maximum value was shown in horse gram plot which was statistically significant than mustard and fallow.

The higher value of available nitrogen in MT-M+C over other treatments was due to incorporation of cowpea biomass and by preventing the volatilization loss of nitrogen in an alkaline soil due to less exposure of soil with the help of minimum tillage. Similar result was observed by Graham *et al.* (2002). Secondly minimum tillage produced less yield. Hence less uptake than conventional tillage.

Maize +cowpea intercropping though consume more nitrogen than sole maize crop but saved more nitrogen due to nitrogen fixation by cowpea. Similar result was found by Thakuria in 1991. Secondly cowpea being a leguminous crop, by incorporation of its biomass enriched the soil by nitrogen, resulting in a net positive balance after Kharif. During Rabi season more quantity of nitrogen was found in horse gram plot than mustard and fallow because extra gain of nitrogen through biological nitrogen fixation and its soil covering nature.

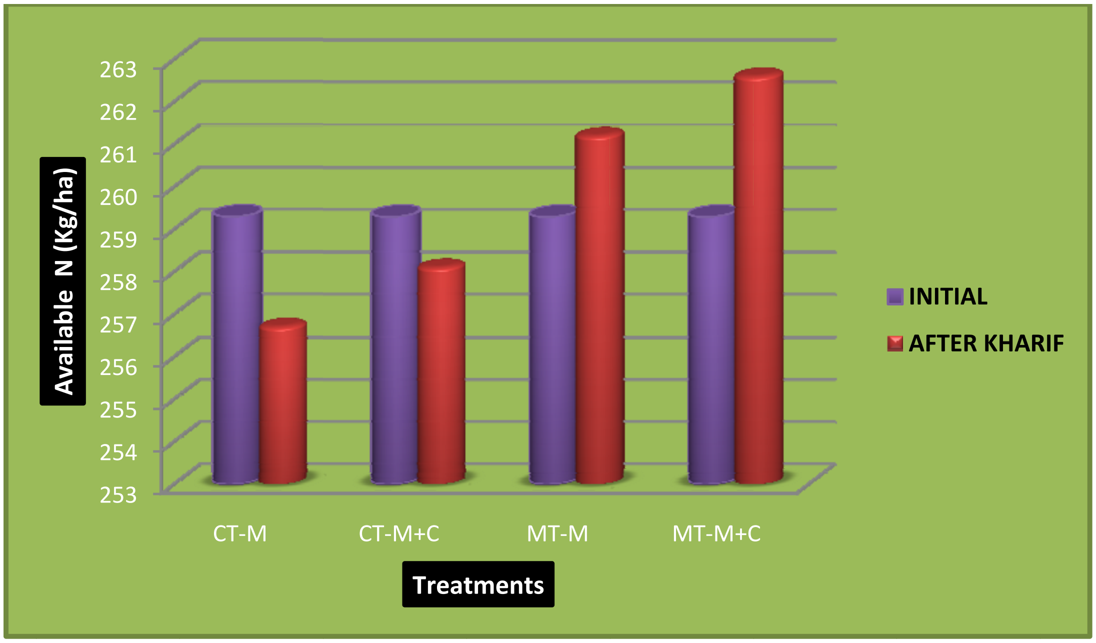


Fig 4.2(a): Effect of tillage and crop on available N (Kg/ha) of soil after harvest of Kharif crops.

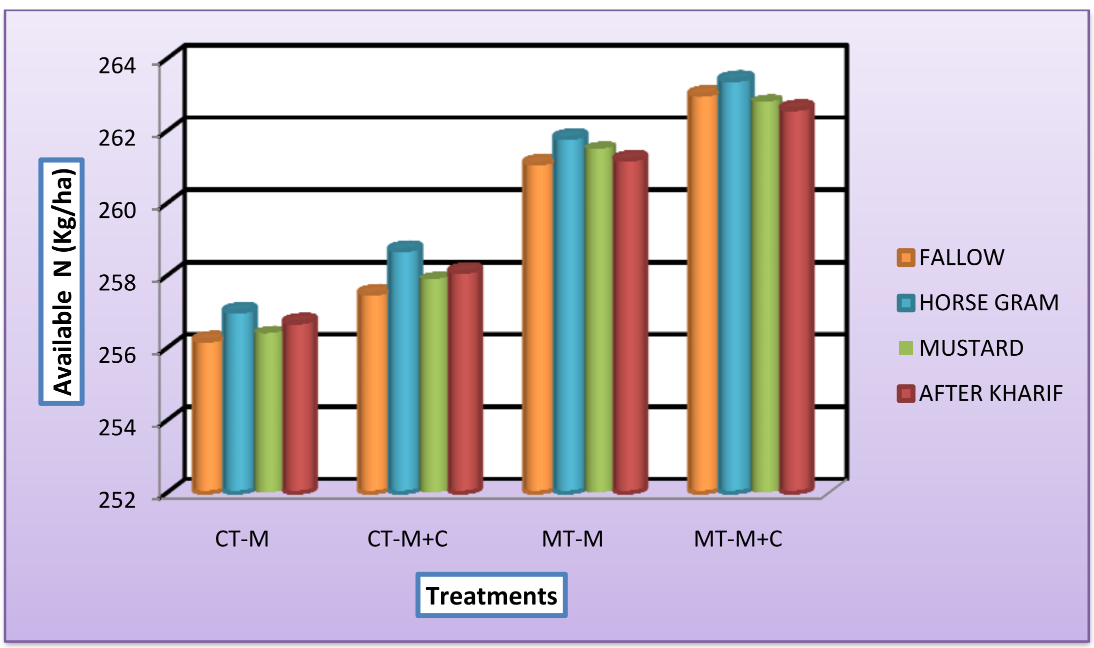


Fig 4.2(b): Effect of tillage and crop on available N (Kg/ha) of soil after harvest of Rabi crops.

4.2.4 Available phosphorus:

Phosphorus is an essential nutrient for plant, next to nitrogen. Plant absorbs phosphorus dissolved in the soil solution as phosphate ions (HPO_4^{2-}, $H_2PO_4^-$). Adequate phosphorus nutrition enhances many aspects of plant physiology, including photosynthesis, nitrogen fixation, root growth, flowering, fruiting and maturation.

Table 4.7 Effect of tillage and crop on available P (Kg/ha) of soil (0-20cm) after harvest of Kharif and Rabi crops

Treatments	Kharif	Rabi			
		Fallow	Horse gram	Mustard	Mean
CT-M	15.41	15.36	15.38	15.37	15.37
CT-M+C	15.43	15.37	15.40	15.39	15.39
MT-M	15.47	15.45	15.50	15.48	15.48
MT-M+C	15.49	15.51	15.54	15.53	15.53
MEAN	15.45*	15.42	15.46	15.44	
CD(0.05)	0.03	Tillage -0.09 crop – 0.02 T×C -NS			

*initial

Available phosphorus content of soil after harvest of Kharif crops influenced by maize and maize +cowpea taken in conventional and minimum tillage practice after Kharif crops was analysed and presented in Table 4.7 and depicted in Fig 4.3(a). The data showed that the available phosphorus content of soil varied between 15.41 Kg P/ha to 15.49 Kg P/ha . The maximum value was observed in MT-M+C and minimum in treatment CT-M. The available phosphorus content increased in minimum tillage than conventional tillage (Table 9). Significant variation was observed between the treatments.

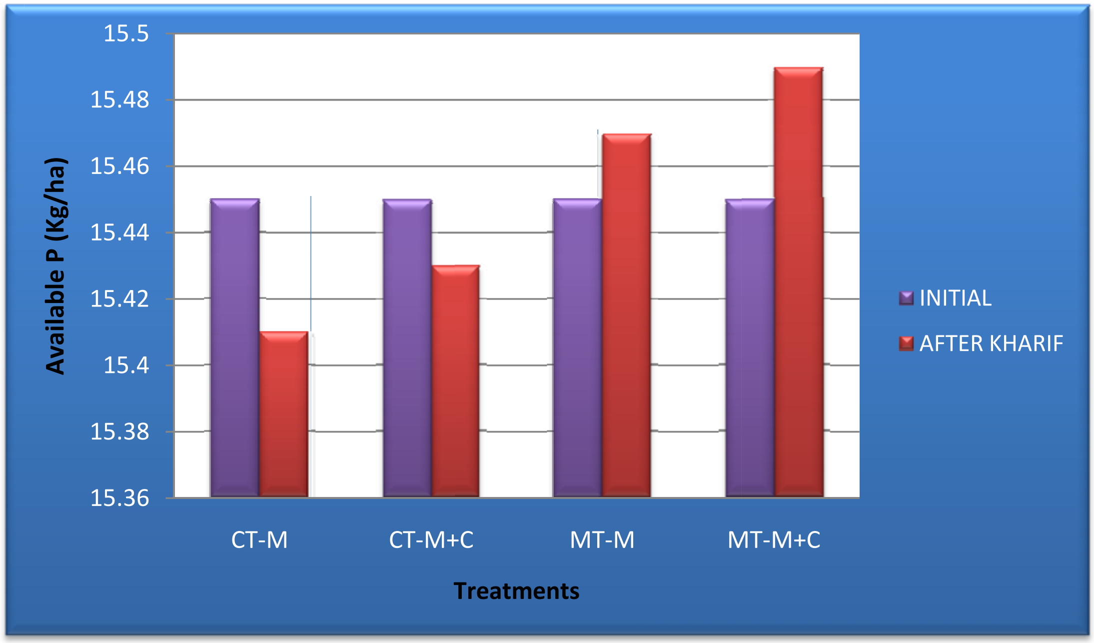


Fig 4.3(a): Effect of tillage and crop on available P (Kg/ha) of soil after harvest of Kharif crops.

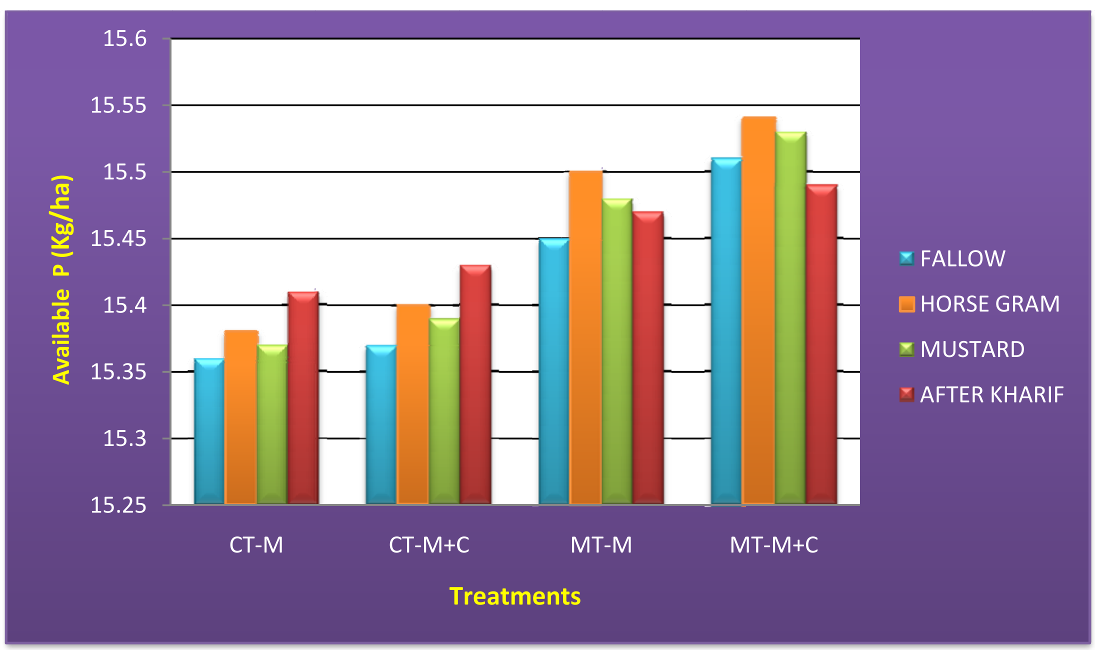


Fig 4.3(b): Effect of tillage and crop on available P (Kg/ha) of soil after harvest of Rabi crops.

Results pertaining to the available phosphorus content influenced by different treatments after Rabi crops were recorded in Table 4.7 and shown in Fig 4.3(b). The value of available phosphorus varied from 15.37 Kg P/ha in CT-M to 15.53 Kg P/ha in treatment MT-M+C. Among different crops the value varied from 15.42 Kg P/ha to 15.46 Kg P/ha. The available phosphorus content of soil was increased in horse gram than mustard and fallow but they were statistically at par. In case of minimum tillage available phosphorus although increased than conventional tillage they were statistically at par.

The phosphorus content in MT-M+C intercropping was found more over other treatments because phosphorus was added through incorporation of cowpea biomass and loss was minimum. The uptake of phosphorus was less in minimum tillage than conventional tillage. Hence more phosphorus was found in minimum tillage than conventional tillage. This type of result was obtained by Ohno and erich (1997). In case of maize + cowpea intercrop phosphorus accumulation is more than sole maize crop because more quantity of soil bound phosphorus were released to available form by root activity of crops particularly a legume cover crop as cowpea. In Rabi season horse gram being a legume crop secreted more organic acids which dissolved more Ca bound phosphorus than mustard crop in an alkaline soil like Kendujhar. As the fallow has no root activity much phosphorus was not released.

4.2.5 Available potassium:

Potassium present in the soil solution only as a positively charged cation - k^+. Its behaviour in the soil influences primarily by soil cation exchange properties and mineral weathering. Potassium plays numerous roles in plant and remains in the ionic form (K^+) in the cell or acts as an activator for cellular enzymes.

Data pertaining to available potassium content (Kg/ha) influenced by tillage determined after Kharif and Rabi was recorded in Table 4.8 and depicted in Fig 4.4(a) and Fig 4.4(b). The result showed that the value of available potassium content varied from 325.7 Kg K/ha in treatment CT-M to 331.6 Kg K/ha in MT-M+C after Kharif crops. The available potassium content was increased in minimum tillage by 4.8 Kg K/ha than conventional tillage and they were statistically significant.

Table 4.8 Effect of tillage and crop on available K (Kg/ha) of soil (0-20cm) after harvest of Kharif and Rabi crops.

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	325.7	325.0	325.3	325.1	325.1
CT-M+C	326.8	326.2	326.5	326.3	326.3
MT-M	330.5	330.3	330.9	330.7	330.6
MT-M+C	331.6	332.0	332.3	332.1	332.1
MEAN	328.6*	328.4	328.8	328.6	
CD(0.05)	1.21	Tillage -0.74 crop – 0.13 T×C -NS			

*initial

After harvest of Rabi crops, due to tillage practice the available potassium content varied from 325.1 Kg K/ha to 332.1 Kg K/ha. The maximum was recorded in MT-M+C and minimum was in CT-M. The increased value of available potassium in MT-M+C was statistically significant with other treatments. Among different crops the available potassium content varied from 328.4 to 328.8 Kg K/ha. The maximum value was observed in horse gram followed by mustard and fallow in a decreasing order. The difference in available potassium content among crops were statistically significant.

Higher potassium content in MT-M+C than other treatments was due to more conservation of potassium by the former practice. Minimum tillage might have minimized the loss of potassium than conventional tillage. Similar result was found by Franzluebbers and Hons (1996). In other hand incorporation of plant tissues of maize root as well as cowpea legume added potassium to the soil. So maize +cowpea intercropping proved to save more potassium than sole maize crop.

The residual potassium of horse gram plot was more than mustard and fallow because it is a cover crop. Uptake of potassium was more by mustard than horse gram. The potassium status in different tillage practices in Rabi showed the same trend as Kharif confirming the beneficial effect of minimum tillage in saving nutrients than conventional tillage.

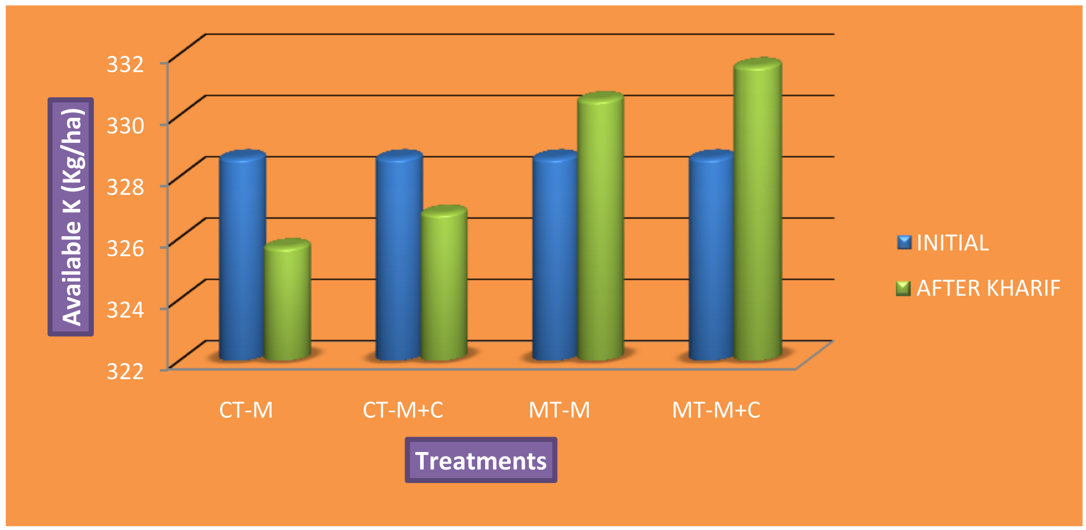


Fig 4.4(a): Effect of tillage and crop on available K (Kg/ha) of soil after harvest of Kharif crops.

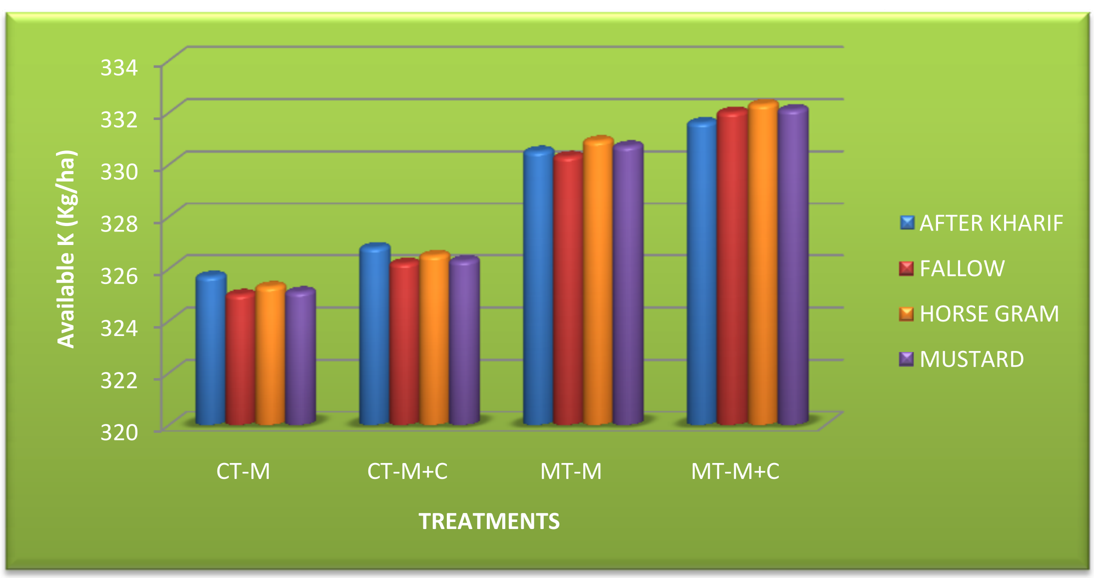


Fig 4.4(b): Effect of tillage and crop on available K (Kg/ha) of soil after harvest of Rabi crops..

Table 4.9 Mean value of soil properties influenced by different tillage and crops in Kharif and Rabi season

	Kharif				Rabi				
Particulars	**CT**	**MT**	**M**	**M+C**	**CT**	**MT**	**Fallow**	**Horse gram**	**mustard**
BD(Mgm^{-3})	1.347	1.341	1.344	1.343	1.348	1.339	1.345	1.342	1.343
pH(1:2)	7.33	7.35	7.33	7.35	7.32	7.36	7.34	7.35	7.34
Organic carbon(g/Kg)	6.48	6.77	6.59	6.66	6.48	6.79	6.61	6.66	6.63
Available N (Kg/ha)	257.54	261.9	259.0	260.4	257.3	262.3	259.5	260.2	259.7
Available P (Kg/ha)	15.42	15.48	15.44	15.46	15.38	15.51	15.42	15.46	15.44
Available K (Kg/ha)	326.3	331.1	328.1	329.2	325.7	331.4	328.4	328.8	328.6
Available Ca [cmol(p^+)/Kg]	16.82	17.28	17.01	17.09	16.77	17.31	17.02	17.06	17.04
Available Mg [cmol(p^+)/Kg]	5.84	6.16	5.97	6.03	5.81	6.19	5.97	6.02	5.99

4.2.6 Available Calcium:

In neutral and calcareous soils Ca^{2+} occupies the majority of exchange sites. Exchangeable and solution Ca^{2+} are in dynamic equilibrium and provide the majority of plant available calcium. Calcium is essential for cell elongation and division cell membrane structure and permeability. It is important to nitrogen metabolism, protein formation by enhancing NO_3^- uptake and provides some regulation of cation uptake.

Table 4.10 Effect of tillage and crop on available Ca [cmol (p^+)/Kg] of soil (0- 20cm) after harvest of Kharif and Rabi crops

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	16.78	16.72	16.76	16.74	16.74
CT-M+C	16.86	16.78	16.82	16.80	16.80
MT-M	17.24	17.22	17.26	17.24	17.24
MT-M+C	17.32	17.34	17.38	17.36	17.38
MEAN	17*	17.02	17.06	17.04	
CD(0.05)	0.05	Tillage -0.06 crop – 0.013 T×C -NS			

*initial

The available calcium [cmol(p^+)/Kg] content of soil after Kharif and Rabi crops was determined and presented in Table 4.10 and shown in Fig 4.5(a) and Fig 4.5(b). The data revealed that available calcium content varied from 16.78 to 17.32 [cmol (p^+) Ca/Kg] after Kharif crops. The maximum value was observed in MT-M+C and minimum in CT-M. Maize +cowpea intercrop was accumulated more available calcium than sole maize crop (Table 9). There was significant variation shown between the treatments.

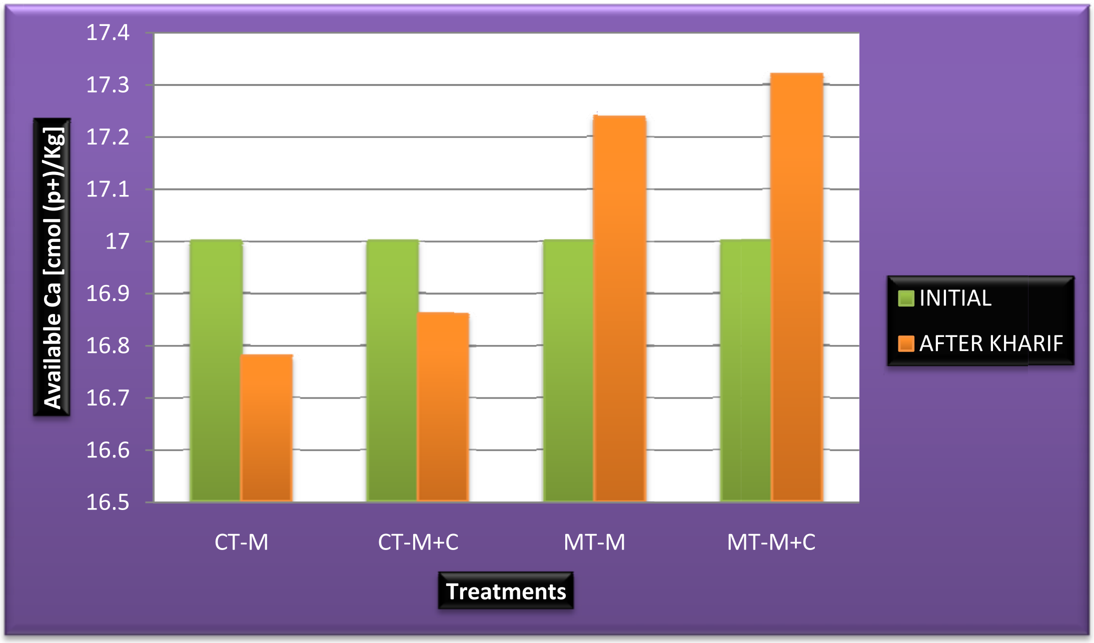


Fig 4.5(a): Effect of tillage and crop on available Ca [cmol (p^+)/Kg] of soil after harvest of Kharif crops.

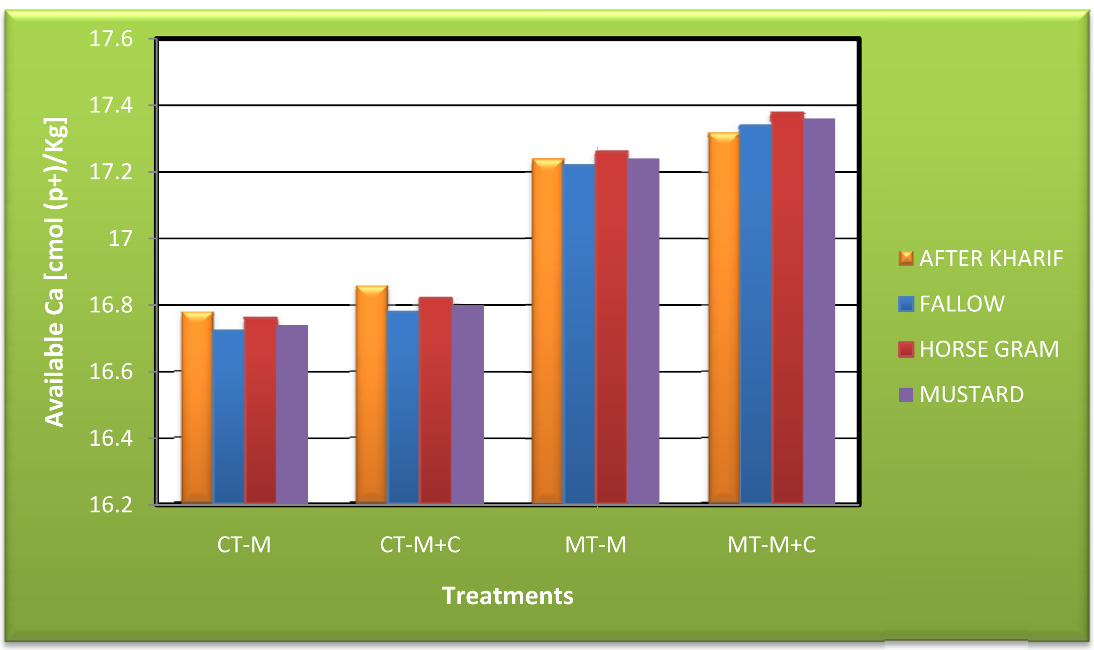


Fig 4.5(b): Effect of tillage and crop on available Ca [cmol (p^+)/Kg] of soil after harvest of Rabi crops.

After Rabi crops the available calcium varied from 16.74 [cmol(p^+) Ca/Kg] in CT-M to 17.38 [cmol(p^+) Ca/Kg] in MT-M+C. The available Calcium increased significantly in minimum tillage than conventional tillage. Among the crops taken in Rabi, available calcium varied from 17.02 to 17.06 [cmol(p^+) Ca/Kg]. Although the available calcium was maximum in horse gram the value was statistically at par with mustard and fallow.

4.2.7 Available magnesium:

Soil magnesium originates from weathering of several magnesium bearing minerals. Mg^{2+} ion content of soil is less than Ca^{2+} because they are not adsorbed as strongly by clay and organic matter as Ca^{2+} ion and further Mg^{2+} ions are more susceptible to leaching than Ca^{2+}. Plant absorb magnesium as Mg^{2+} ion. It is a constituent in chlorophyll, activates many enzymes, promotes uptake and translocation of phosphorus and movement of sugar in the plants.

Table 4.11 Effect of tillage and crop on available Mg [cmol (p^+)/Kg] of soil (0-20cm) after harvest of Kharif and Rabi crops

Treatments	Kharif	Rabi			
		Fallow	Horsegram	Mustard	Mean
CT-M	5.80	5.74	5.78	5.76	5.76
CT-M+C	5.88	5.82	5.86	5.84	5.85
MT-M	6.14	6.12	6.18	6.16	6.15
MT-M+C	6.18	6.20	6.24	6.22	6.22
MEAN	6.0*	5.97	6.02	5.99	
CD(0.05)	0.04	Tillage -0.83 crop – NS T×C -NS			

*initial

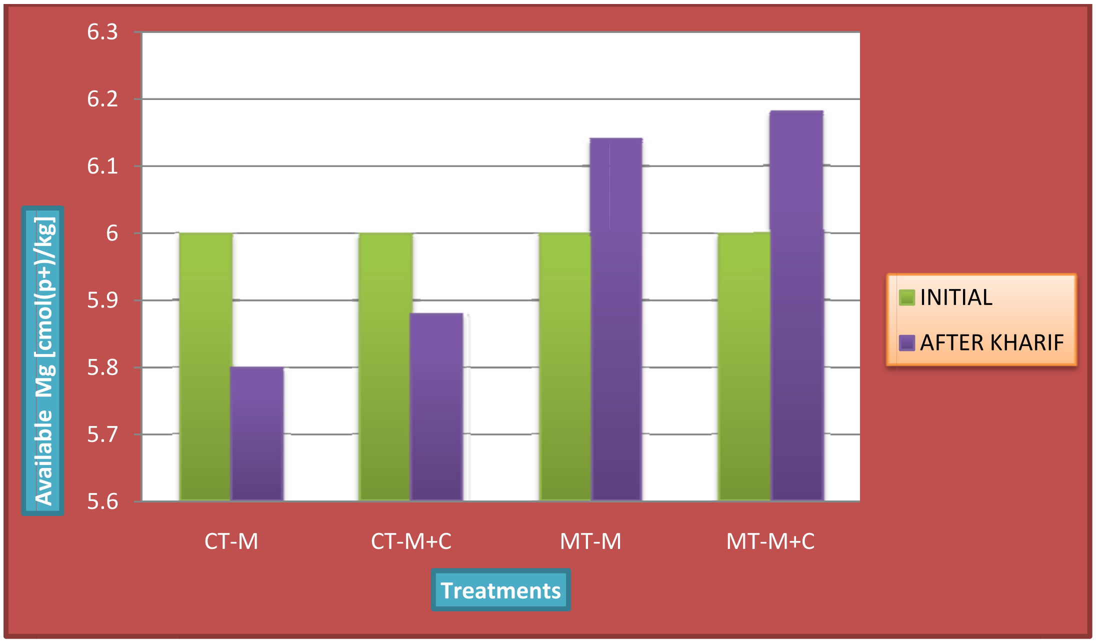


Fig 4.6(a): Effect of tillage and crop on available Mg [cmol (p^+)/Kg] of soil after harvest of Kharif crops.

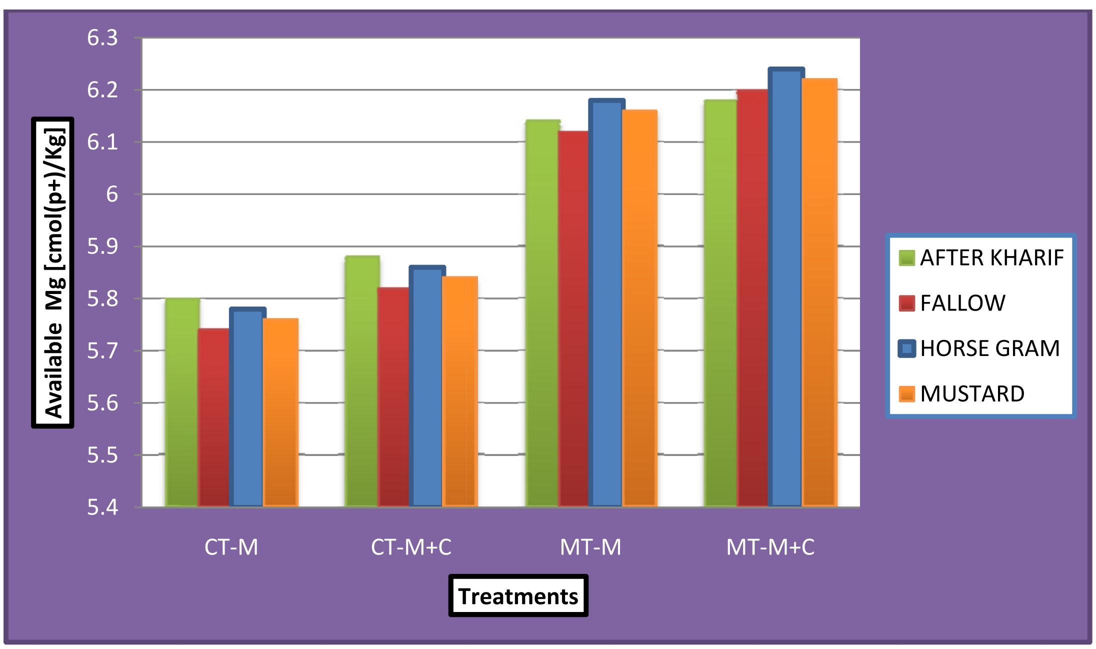


Fig 4.6(b): Effect of tillage and crop on available Mg [cmol (p^+)/Kg] of soil after harvest of Rabi crops.

Results pertaining to available Magnesium [cmol(p^+) /Kg] content of soil after Kharif and Rabi crops were recorded in Table 4.11 and depicted in Fig 4.6(a) and Fig 4.6(b). After Kharif crops the available magnesium varied from 5.80 to 6.18 [cmol(p^+)Mg /Kg] . The maximum value was observed in MT-M+C and minimum in CT-M. There was significant variation observed between the treatments. Maize+ cowpea intercrop was accumulated more available magnesium than sole maize crop (Table 9).

The data showed that after harvest of Rabi crops available magnesium varied from 5.76 [cmol(p^+)Mg /Kg] in CT-M to 6.22[cmol(p^+)Mg /Kg] in MT-M+C. The available magnesium content though increased in minimum tillage it was statistically at par with conventional tillage. The value of available magnesium varied from 5.97 to 6.02 [cmol(p^+)Mg /Kg] among different crops taken during Rabi crops.

Increased quantity of Ca^{2+} and Mg^{2+} in MT-M+C was found over other treatments during Kharif season because more Ca^{2+} might have been solubilised by acidic root exudates in an alkaline soil. The released Ca^{2+} and Mg^{2+} were conserved more by minimum tillage than conventional tillage because of less disturbance in the former tillage practice. Similar result was obtained by Sidiras and Pavan (1985) in both *Oxisols* and *Alfisols* in Brazil under minimum tillage.

Secondly, less uptake of nutrient in minimum tillage. Maize +cowpea intercropping saved more Ca^{2+} and Mg^{2+} over sole maize not only because of more solubilisation but also addition of these nutrients through incorporation of cowpea biomass. After Rabi season, horse gram plot contained more Ca^{2+} and Mg^{2+} than mustard and fallow indicated that legume crop is more potential in increasing the availability of these nutrients than the mustard crop.

4.3 NUTRIENT DYNAMICS THROUGH RESIN BAG:

Ion exchange resins are polymers with weak electrical charge either positive or negative. They act similarly to soil colloids, exchanging ions on the resin surface with ions in the surrounding medium. Ion exchange resin bags integrate the supply of nutrients over a period of time and even stimulates the effect of plant roots on removal and replacement of nutrients in solution.

Table 4.12 Nutrient dynamics (ppm/5g resin) through resin bag in different tillage treatments.

Treatments	N	P	K	Ca	Mg
CT-M	15.85	21.89	56.57	30.39	11.96
CT-M+C	20.00	23.31	57.27	30.98	12.12
MT-M	15.07	20.00	53.09	29.09	11.71
MT-M+C	15.64	21.12	54.93	29.19	11.46

Nutrient dynamics through resin bag was determined by prescribed procedure and recorded in Table 4.12. The data revealed that the value of nitrogen varied from a minimum of 15.07 ppm N/5g resin in MT-M to 20.00 ppm N/5g resin in CT-M+C. The phosphorus content varied from 20.00 ppm to 23.31 ppm P/5g of resin, potassium varied from 53.09 ppm to 57.27 ppm K/ 5g of resin and calcium, magnesium value varied from 29.09 ppm to 30.98 ppm Ca/5g of resin and 11.71 ppm to 12.12 ppm Mg respectively. The maximum value was observed in CT-M+C and minimum in MT-M.

4.4 EFFECT OF DIFFERENT TREATMENT ON NUTRIENT UPTAKE BY CROPS

4.4.1 Nutrient uptake by maize crop:

Nutrient uptake of maize influenced by different tillage practices was determined and recorded in Table 4.13. The value of nitrogen uptake was varied from 52.3 Kg N/ha to 63.5 Kg N/ha, Phosphorus uptake was varied from 7.3 to 9.2 Kg P/ha and potassium uptake varied from 49.4 to 59.8 Kg K/ha. The maximum uptake was found in CT-M and minimum was in MT-M. In comparison to minimum tillage nutrient uptake was more in conventional tillage.

Table 4.13 Nutrient uptake (Kg/ha) of maize crop influenced by different treatments.

Treatments	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
CT-M	63.5	9.2	59.8
CT-M+C	54.7	7.9	51.2
MT-M	52.3	7.3	49.4
MT-M+C	61.8	8.8	57.6

4.4.2 Nutrient uptake by cowpea crop:

Table 4.14 Nutrient uptake (Kg/ha) of cowpea crop influenced by different treatments.

Treatments	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
CT-M	-	-	-
CT-M+C	60.7	6.64	48.35
MT-M	-	-	-
MT-M+C	45.8	5.10	36.58

The nutrient uptake by cowpea crop influenced by tillage practices was presented in Table 4.14. The nitrogen uptake was maximum 60.7 Kg N/ha in CT-M+C and minimum 45.8 Kg N/ha in MT-M+C. The phosphorus uptake was more in CT-M+C i.e 6.64 Kg P/ha and less in MT-M+C i.e 5.1 Kg P/ha. The potassium uptake was 48.35 Kg K/ha in CT-M+C and 36.58 Kg K/ha in MT-M+C.

4.4.3 Nutrient uptake by horse gram:

Table 4.15 Nutrient uptake (Kg/ha) of horse gram crop influenced by different treatments.

Treatments	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
CT-M	26.5	1.58	8.36
CT-M+C	42.6	2.63	13.92
MT-M	25.8	1.52	8.10
MT-M+C	29.2	1.88	10.53

Nutrient uptake of horse gram influenced by different tillage practices was determined and recorded in Table 4.15. The value of nitrogen uptake was varied from 25.8 Kg N/ha to 42.6 Kg N/ha, Phosphorus uptake was varied from 1.52 to 2.63 Kg P/ha and potassium uptake varied from 8.10 to 13.92 Kg K/ha. The maximum uptake was found in CT-M+C and minimum was in MT-M. In comparison to minimum tillage nutrient uptake was more in conventional tillage.

4.4.4 Nutrient uptake by mustard:

Table 4.16 Nutrient uptake (Kg/ha) of mustard crop influenced by different treatments.

Treatments	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
CT-M	10.82	1.35	19.43
CT-M+C	13.45	1.66	23.25
MT-M	9.32	1.15	16.56
MT-M+C	12.95	1.58	22.84

Nutrient uptake of mustard influenced by different tillage practices was determined and recorded in Table 4.16. The value of nitrogen uptake was varied from 9.32 Kg N/ha to 13.45 Kg N/ha, Phosphorus uptake was varied from 1.15 to 1.66 Kg P/ha and potassium uptake varied from 16.56 to 23.25 Kg K/ha. The maximum uptake was found in CT-M+C and minimum was in MT-M. In comparison to minimum tillage nutrient uptake was more in conventional tillage.

Table 4.17 Total nutrient uptake (Kg/ha) by crops in the system

Treatment	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
CT-M-F	63.50	9.20	59.8
CT-M-H	90.00	10.78	68.16
CT-M-M	74.32	10.55	79.23
CT-M+C-F	115.40	14.54	99.55
CT-M+C-H	158.00	17.17	113.47
CT-M+C-M	128.85	16.20	122.8
MT-M-F	52.30	7.30	49.4
MT-M-H	78.10	8.82	57.5
MT-M-M	61.62	8.45	65.96
MT-M+C-F	197.60	13.90	94.18
MT-M+C-H	136.80	15.78	104.71
MT-M+C-M	120.55	15.48	117.02

4.5 EFFECT OF DIFFERENT TREATMENTS ON CROP YIELD

4.5.1 Yield of maize and cowpea:

Table 4.18 Yield (qha^{-1}) of maize and cowpea influenced by different tillage.

Treatments	Maize yield (qha^{-1})	Cowpea pod yield (qha^{-1})
CT-M	52.1	-
CT-M+C	44.4	16.4
MT-M	43.0	-
MT-M+C	50.2	12.4

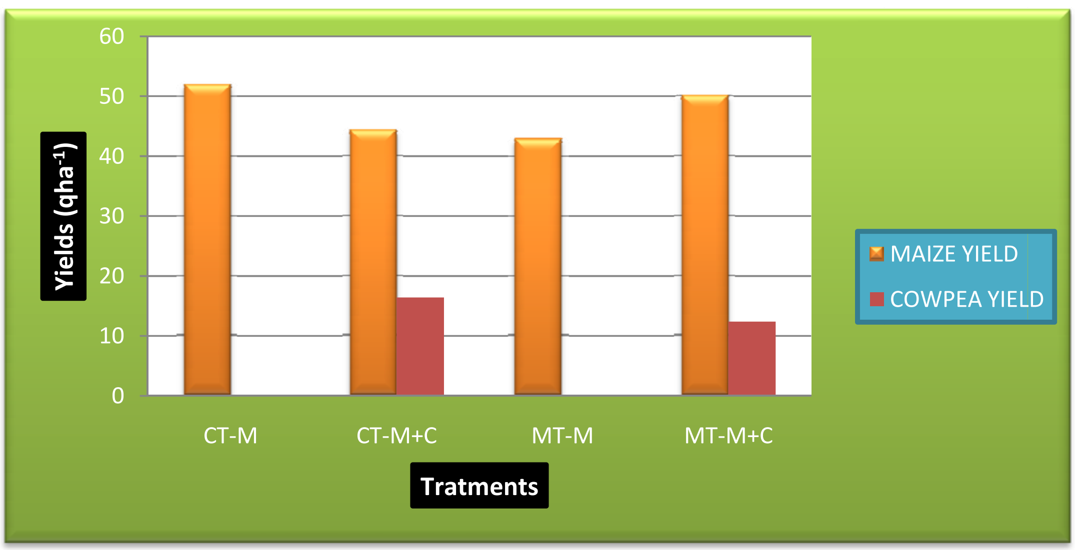


Fig 4.7(a): Yield (qha^{-1}) of maize and cowpea influenced by different tillage.

Yield of maize and cowpea influenced by different tillage practices were recorded in Table 4.18 and depicted in Fig 4.7(a). The yield of maize was maximum 52.1 qha^{-1} in CT-M followed by MT-M+C, CT-M+C and MT-M in a decreasing order. The yield of cowpea was maximum 16.4 qha^{-1} in CT-M+C and minimum 12.4 qha^{-1} in MT-M+C.

The maize yield was maximum in CT-M because at the initial stage of conservation tillage conventional tillage was provided a better edaphic condition with more root proliferation. In maize +cowpea intercrop there was a competition for nutrient, water, aerial space, root growth etc. between the crops which resulted in the reduction of maize yield in intercropping than that of sole maize in conventional tillage. But in case of minimum tillage cowpea increased the porosity of soil which cause better proliferation of roots of maize in maize+cowpea intercropping than sole maize. So the yield of maize in intercropping was more than sole crop.

4.5.2 Yield of horse gram and mustard:

Table 4.19 Yield (qha^{-1}) of horse gram and mustard influenced by different tillage.

Treatments	Horse gram (qha^{-1})	Mustard (qha^{-1})
CT-M	**6.86**	**8.25**
CT-M+C	**11.45**	**10.20**
MT-M	**6.62**	**7.10**
MT-M+C	**8.65**	**9.80**

The yields of horse gram and mustard recorded in Table 4.19 and shown in Fig4.7(b) and Fig 4.7 (c). The yield of horse gram was measured maximum 11.45qha^{-1} in CT-M+C-H and minimum 6.62 qha^{-1} in MT-M-H. The yield of mustard was varied from 7.1qha^{-1} to 10.2qha^{-1}. The maximum value was observed in CT-M+C-M and minimum was in MT-M-M.

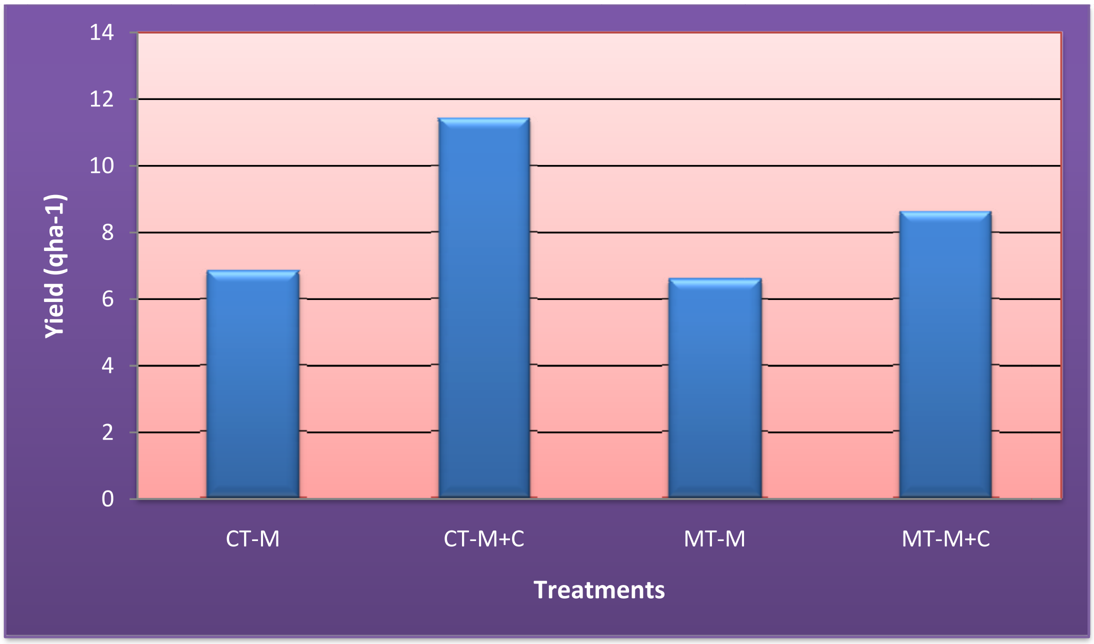


Fig 4.7(b): Yield (qha^{-1}) of horse gram influenced by different tillage.

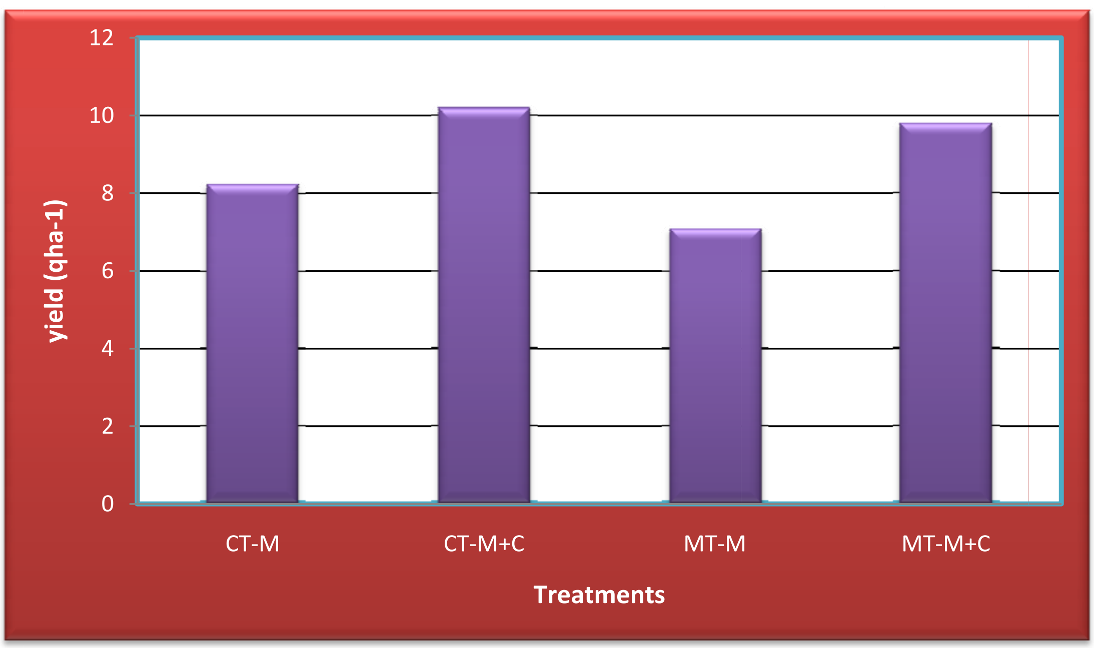


Fig 4.7(c): Yield (qha^{-1}) of mustard influenced by different tillage.

The yield of mustard was found more in comparison to horse gram due to its genetic character although horse gram resulted in better soil condition in their respective main plot treatments. In conventional tillage yield of both crops were found more than minimum tillage and intercrop plots in Kharif followed by mustard and horse gram yields more than sole crop plots. It was due to the effect of cowpea during Kharif.

4.6 SYSTEM PRODUCTIVITY:

Table 4.20 System productivity in terms of maize equivalent yield (MEY) as influenced by different treatments

Treatment		System productivity (MEY, qha^{-1})
Main plots	CT-M	63.03
	CT-M+C	85.83
	MT-M	52.73
	MT-M+C	84.40
	CD(0.05)	3.59
Sub plots	Fallow	59.73
	Horse gram	70.08
	Mustard	84.78
	CD(0.05)	1.08

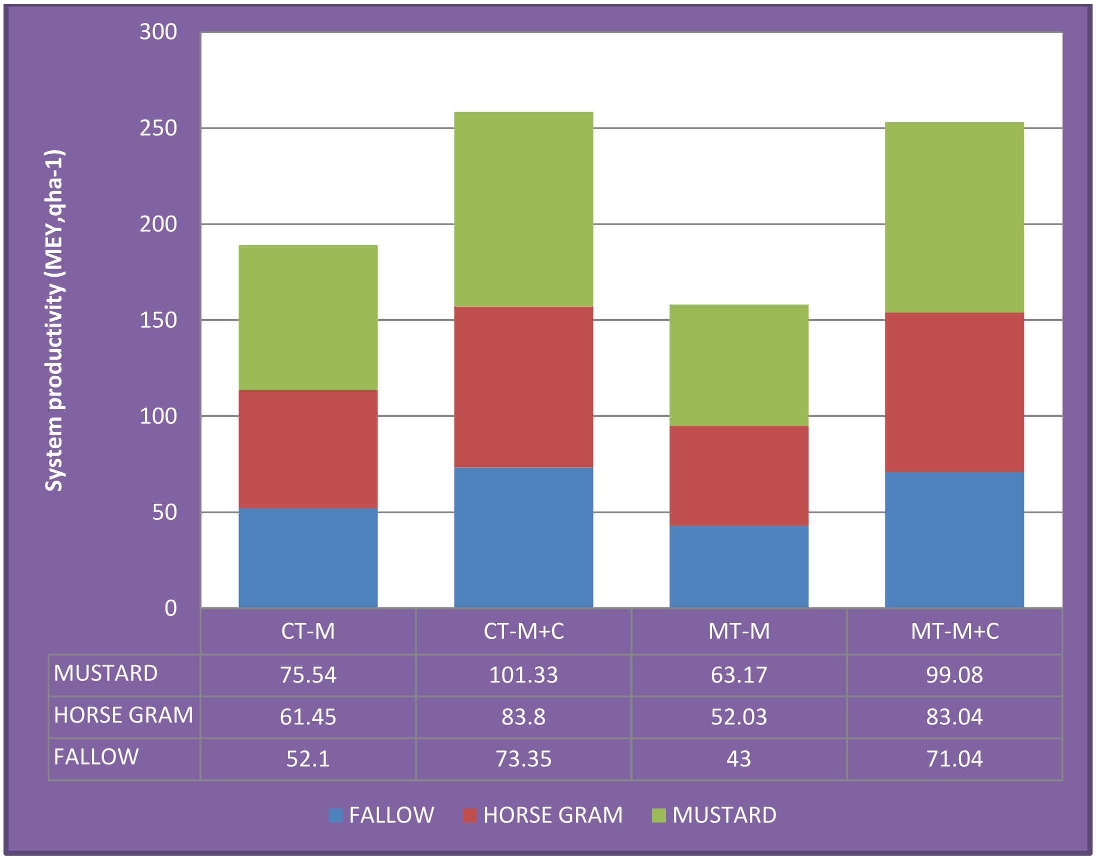
N.B: Price of maize seed Rs 880 q^{-1}, cowpea green pod Rs1500q^{-1}, mustard seed Rs 2500q^{-1} and horse gram seed Rs 1500 q^{-1} were taken in to consideration for calculation of maize equivalent yield(MEY).

The system productivity influenced by different tillage and crop expressed in terms of maize equivalent yield (qha^{-1}) was recorded in Table 4.20. The system productivity differed significantly with respect to the main plot treatments. The data showed that the maize equivalent yield varied from 52.73 qha^{-1} to 85.83 qha^{-1} MEY between the tillage treatments. The maximum value was observed in CT-M+C and minimum in MT-M. The system productivity of growing maize+cowpea under conventional tillage closely followed by growing maize+cowpea under minimum tillage (84.40 qha^{-1} MEY) and they remain at par with each other. But these two treatments were significantly superior than growing sole maize under conventional tillage (63.03 qha^{-1} MEY) and minimum tillage (52.73 qha^{-1} MEY).

Table 4.21 Interaction effect of Kharif season treatments (main plot) and Rabi treatments (sub plot) on system productivity (MEY) as Influenced by different tillage and crops

Main plot (Kharif season treatments)	Sub plot (Rabi season treatments)		
	Fallow	Mustard	Horse gram
CT-M	52.10	75.54	61.45
CT-M+C	73.35	101.33	83.80
MT-M	43.00	63.17	52.03
MT-M+C	71.04	99.08	83.04
CD(0.05)	T×C 2.16		

The interaction effect of main plot and sub plot treatments were found significant and presented in Table 4.21 and depicted in Fig 4.8. The Kharif season treatment CT-M+C followed by growing of mustard during the Rabi recorded the highest system productivity of 101.33qha^{-1} MEY. This was significantly superior to all other treatments except the Kharif season treatment MT-M+C followed by the Rabi season treatment growing of mustard (99.08 qha^{-1} MEY), which was comparable to the former treatment. However, minimum tillage-maize followed by fallow recorded the least system productivity (43.00 qha^{-1} MEY).



	CT-M	CT-M+C	MT-M	MT-M+C
MUSTARD	75.54	101.33	63.17	99.08
HORSE GRAM	61.45	83.8	52.03	83.04
FALLOW	52.1	73.35	43	71.04

Fig 4.8: System productivity influenced by different tillage and crops

The system productivity (MEY,qha^{-1}) was more in CT-M+C followed by mustard and horse gram because not only due to higher yield but also higher price of the above crops. Due higher price the system productivity were found to be more in mustard plots than horse gram and fallow.

4.7 ECONOMICS OF PRODUCTION

The economics of crop production, judged through various parameters like cost of cultivation, gross return, net return and return per rupee invested have been presented in Table 4.21.

Table 4.21 Economics of production as influenced by Conservation agriculture production system.

Main plot (Kharif season treatments)	Cost of Cultivation (Rs ha^{-1})	Goss Return (Rs ha^{-1})	Net Return (Rs ha^{-1})	Return Per rupee invested
CT-M	33661	55466	21805	1.64
CT-M+C	41479	75430	33951	1.82
MT-M	35757	55724	19967	1.56
MT-M+C	38191	74260	36069	1.94
Sub plot (Rabi treatments)				
Fallow	37272	65220	27948	1.75
Mustard	43015	87320	44305	2.03
Horse gram	40527	77812	37285	1.92

In Kharif season, conventional tillage with maize+cowpea intercrop incurred the highest cost of cultivation of Rs 41,479 ha^{-1}. However, the least cost was involved in growing maize under minimum tillage (Rs 33,661 ha^{-1}). In the Rabi season, growing horse gram was the costliest proposition (Rs 47,811 ha^{-1}) followed by mustard (Rs 35,882 ha^{-1}).Fallow obviously had the least cost of cultivation.

As regards to the gross return, among the Kharif season treatments, CT-M+C registered the highest value of Rs 75,430 ha^{-1} and lowest was CT-M (Rs 55466 ha^{-1}). Whereas, in respect of Rabi season treatments, kept under sub plot, growing of mustard could fetch more gross return (Rs74,606 ha^{-1}) than horse gram (Rs 61,670 ha^{-1}) and fallow (Rs 52,394 ha^{-1}). The highest net return of Rs 36,069 ha^{-1} was recorded from MT-M+C followed by CT-M+C (Rs 33,951 ha^{-1}). The CT-M and MT-M could fetch the net return of Rs 21,805 ha^{-1} and Rs 19,967 ha^{-1}, respectively. Among the Rabi season crops, mustard could bring in a net return of Rs 44,305 ha^{-1} as compared to Rs 37, 285 ha^{-1} under horse gram and Rs 27,948 ha^{-1} under fallow.

The return per rupee invested was the highest (1.94) for MT-M+C imposed during Kharif season, closely followed by CT-M+C (1.82). The other two treatments following these two were CT-M (1.64) and MT-M (1.56). In Rabi season sub plot treatments it was highest (2.03) when mustard was grown, followed by horse gram (1.92) and fallow (1.75).

SUMMARY AND CONCLUSION

Conventional agriculture production practices based on excessive soil tillage causes degradation of soil physical make up, soil fertility status and increase soil erosion. To counter these challenges the concept of resource saving agricultural production system popularly known as conservation agriculture arises.

In order to investigate the effect of conservation agricultural production system on soil physical, chemical properties, nutrient uptake and yield of crops in a maize based cropping system an experiment was conducted at Regional Research And Technology Transfer Station (RRTTS),Kendujhar on an alkaline soil. The experiment was conducted during Kharif and subsequent Rabi 2011-12. The experiment was laid out in randomized block design in Kharif having 4 treatments namely CT-M, CT-M+C, MT-M, MT-M+C and during Rabi season each plot was divided into 3 subplots cultivated with horse gram, mustard and fallow under split plot design.

The soil samples from the treatment plot after harvest of Kharif and Rabi crops were collected and used for this study. Soil were analysed for physical and chemical properties like bulk density, texture, pH, soil organic carbon , available nitrogen, available phosphorus, available potassium, available calcium and available magnesium. Nutrient dynamics was measured through resin bag technique. The plant samples were analysed for nutrient uptake. Yield was recorded for both Kharif 2011 and Rabi 2011-12. The data were statistically analysed following the procedure as prescribed by Gomez and Gomez (1984).

The salient findings of the study are summarized below:

Effect of tillage practices and different crops on various soil physical and chemical properties showed that conventional and minimum tillage practices adopted in this experiment did not have any significant influence on bulk density of soil, fine earth fraction and pH. But organic carbon, available nitrogen, available phosphorus, available potassium, available calcium and available magnesium were significantly influenced.

Tillage practice with different crops did not have any significant influence on soil bulk density which varied from 1.347 Mgm^{-3} in CT-M to 1.340 Mgm^{-3} in MT-M+C after Kharif season. After Rabi crops bulk density varied between 1.348 Mgm^{-3} to 1.338 $Mgm^{-3.}$ After both Kharif and Rabi minimum tillage reduced the bulk density due to addition of organic matter. Bulk density was decreased in horse gram and no change was found in mustard and fallow. This was due to horse gram being a leguminous crop it covers the soil and not only adds nitrogen but also improves porosity.

Soil pH changed by different treatments varied from 7.32 to 7.36 unit after Kharif. The maximum was in MT-M+C and minimum in CT-M. After Rabi, soil pH varied from 7.31 in CT-M to 7.37 in MT-M+C treatment. The increase in pH in minimum tillage than conventional tillage was due to accumulation of more basic cations Ca^{2+}, Mg^{2+} in former tillage practice. Among different crops taken in Rabi season horse gram was found to increase the soil pH by 0.01 unit over mustard and fallow.

Tillage and crops influencing soil organic carbon content was varied from a minimum value of 6.45 g/Kg in CT-M to a maximum value of 6.81 g/Kg in MT-M+C after Kharif crops. After Rabi the value varied from 6.44 g/Kg in CT-M to 6.84 g/Kg in MT-M+C. The content of organic carbon in MT-M+C was significantly higher than other because of incorporation of more organic matter through cowpea. Minimum tillage also prevented the loss of organic carbon as exposed surface area was less than conventional tillage. After Rabi, horse gram plot had higher organic carbon than mustard and cowpea because of its dwarf nature which covers the soil better.

Results on available nitrogen (Kg/ha) content in conventional and minimum tillage showed a significant variation. The value varied from 256.7 Kg N/ha to 262.6 Kg N /ha in CT-M and MT-M+C respectively after Kharif. Maize

+cowpea intercrop had accumulated more available nitrogen than sole maize crop. After Rabi the available nitrogen content varied from a minimum value of 256.5 Kg N/ha in CT-M to a maximum value of 263.1 Kg N/ha in MT-M+C. Among crops horse gram showed a higher value of available nitrogen 260.2 Kg N/ha than mustard and fallow. The increase of available nitrogen in MT-M+C due to incorporation of cowpea biomass and preventing volatilization loss of nitrogen by less exposure of soil in minimum tillage. In M+C intercropping cowpea fixed nitrogen and its incorporation enriched the soil by more nitrogen. After Rabi horse gram cause extra gain of nitrogen by biological nitrogen fixation showed a higher value of available nitrogen content.

Available phosphorus influenced by tillage and crop showed a significant variation between conventional and minimum tillage. The value of available phosphorus varied from 15.41 Kg P/ha to 15.49 Kg P/ha after Kharif. The maximum value was observed in MT-M+C and minimum in CT-M. Maize +cowpea intercrop had more available phosphorus than sole maize crop. After Rabi the value varied from a minimum of 15.37 Kg P/ha in CT-M to a maximum of 15.53 Kg P/ha in MT-M+C. Among different crops in Rabi horse gram showed a higher value of available phosphorus than mustard and fallow. The available phosphorus was more in MT-M+C because of incorporation of cowpea biomass and uptake was less. In maize +cowpea intercrop and horse gram plot more soil bound phosphorus released to available form by acid secreted from root activity of cowpea and horse gram being legume crop.

The available potassium content of soil influenced significantly by tillage and crop. After Kharif the value of available potassium varied from 325.7 Kg K/ha to 331.6 Kg K/ha in CT-M and MT-M+C respectively. The available potassium content varied from a minimum of 325.1 Kg K/ha in CT-M to 332.1 Kg K/ha in MT-M+C after Rabi. Among crops horse gram plot showed a significantly higher value of available potassium than mustard and fallow. Minimum tillage increased the available potassium content than conventional tillage might be because of minimization of loss and more conservation due to incorporation of crop residues.

Available Ca^{2+} and Mg^{2+} significantly influenced by different treatments. The values were varied from 16.74 to 17.38 cmol(p^+) Ca/Kg and 5.80 to 6.18 cmol(p^+) Mg/Kg in CT-M and MT-M+C respectively. Increased Ca^{2+} and Mg^{2+} in MT-M+C might have been due to solubilisation of these elements by acidic root exudates in an alkaline soil. Minimum tillage may conserve more Ca^{2+} and Mg^{2+} than conventional tillage. Among different crops taken in Rabi crops horse gram showed a higher value of Ca^{2+} and Mg^{2+} than mustard and fallow.

Results on nutrient dynamics through resin bag showed that maximum nutrient captured by resin bag in treatment CT-M+C i.e 20.00 ppm N, 23.31 ppm P, 57.27 ppm K, 30.98 ppm Ca, 12.12 ppm Mg and minimum in MT-M i.e 15.07 ppm N, 20.00 ppm P, 53.09 ppm K, 29.09 ppm Ca, 11.71 ppm Mg.

Nutrient uptake by maize crop showed that nitrogen uptake varied from 52.3 to 63.5 Kg/ha, phosphorus varied from 7.3 to 9.2 Kg/ha, potassium varied from 49.4 to 59.8 Kg/ha in MT-M and CT-M respectively. The nutrient uptake by cowpea was more in CT-M+C than MT-M+C.

In mustard the nitrogen uptake was varied from 9.32 to 13.45 Kg/ha, phosphorus varied from 1.15 to 1.66 Kg/ha, potassium varied from 16.56 to 23.25 Kg/ha in MT-M-M and CT-M-M respectively. In horse gram the maximum nutrient uptake of 42.6 Kg N/ha, 2.63 Kg P/ha, 13.92 Kg K/ha were observed in CT-M+C-H and minimum of 25.8 Kg N/ha, 1.52 Kg P/ha, 8.10 Kg K/ha, were seen in MT-M-H.

The yield of maize was varied from a maximum 52.1 qha^{-1} in CT-M to a minimum 43.0 qha^{-1} in MT-M. The yield of cowpea was more in CT-M+C i.e 16.4 qha^{-1} and less in MT-M+C i.e 12.4 qha^{-1} . The maximum yield of horse gram was in CT-M+C-H and minimum in MT-M-H. The yield of mustard was varied from 7.1qha^{-1} to 10.2qha^{-1}. The maximum was observed in CT-M+C-M and minimum in MT-M-M. The yields were more in conventional tillage than minimum tillage because of more root proliferation in case of former than latter.

The system productivity was varied from 52.73 qha^{-1} to 85.83 qha^{-1} between the main plot treatments. The maximum value was observed in CT-M+C and minimum was in MT-M. In Rabi season CT-M+C-M was maximum system productivity than others because of higher yield and price. The benefit over the cost incurred for different treatments after Kharif was found to be 1.94, 1.82, 1.64, 1.56 in MT-M+C, CT-M+C, CT-M, MT-M respectively. The benefit cost ratio (B:C) of the system at the end was found to be 2.03, 1.92 and 1.75 in case of mustard, horsegram and fallow respectively. Minimum tillage maize + cowpea and mustard in Rabi season were found to be most beneficial from economic point of view.

CONCLUSION

From the study “Impacts of Maize based conservation agriculture production system on soil properties in North Central Plateau Zone of Odisha” conducted at RRTTS, Kendujhar salient findings in the form of conclusion can be made as follows.

1. Although different tillage practice and crops had not shown any significant changes in soil BD, fine earth fraction and pH but the BD was reduce by minimum tillage than conventional tillage which was ascribed due to less compaction and less exposure of soil, addition of more organic matter and better conservation of soil.
2. The above factors also helped in increasing the relative clay fraction and pH of the soil.
3. The availability of nitrogen, phosphorus, potassium ,calcium, magnesium significantly increased by MT-M+C intercropping in Kharif followed by horse gram in Rabi due to better conservation by minimum tillage, more

nitrogen fixation and recycling by legume and cover crops taken in sequence.

4. pH of soil increased by 0.03 unit in MT-M+C which was reduced by 0.01 unit in CT-M than initial pH after one season. The range was further wider after Rabi season. Similar trend was observed for organic carbon of the soil.
5. The increase in pH and organic carbon was due to more conservation of basic cations like Ca^{2+}, Mg^{2+} and organic matter in minimum tillage than conventional tillage. Also maize +cowpea intercrop followed by horse gram solubilises more basic cations present in soil.
6. Conservation effect by minimum tillage on nutrient solubilisation and recycling maize +cowpea intercropping followed by horse gram crops helped in enhancing the availability of N, P, K, Ca, Mg.
7. The nutrient dynamics by resin bag study showed that CT-M+C captured maximum nutrient like N, P, K, Ca, Mg than MT-M.
8. Maximum nutrient uptake was observed in CT-M+C in Kharif followed by mustard in Rabi than the others because more yield in former treatment.
9. The system productivity at the end of the sequence was highest in CT-M+C-M than the other sequence.
10. During Rabi season farmers are advised to cultivate mustard and horse gram in a sloping terrain of North central plateau zone of Odisha.
11. Minimum tillage is better over conventional tillage from soil health point of view which improved the soil characteristics.
12. Maize +cowpea intercropping is better than sole maize because of better residual effect on subsequent season.

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