Impact of different Tillage Practices on soil Moisture Variation and Physical Properties of Soil in North Bihar

By

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(Soil and Water Engineering)

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Regd. No. MT/ SWE/34/20011-012 of R.A.U.

Dedicated

to

My Parents

"Whose perpetual affection and blessings always inspired me for higher ambition in life"

SWETA

RAJENDRA AGRICULTURAL UNIVERSITY, BIHAR
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Dated ...17-10-... **2013**

Certificate

This is to certify that the thesis entitled **"Impact of different Tillage Practices on soil Moisture Variation and Physical Properties of Soil in North Bihar"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING (SOIL AND WATER ENGINEERING)** in the Faculty of Post-Graduate Studies, Rajendra Agricultural University, Bihar, Pusa (Samastipur) is the faithful record of *bona-fide* research work carried out by **Ms. SWETA KUMARI** under my supervision and guidance. No part of this thesis has been submitted anywhere for any other degree or diploma.

The assistance and help received during the course of this investigation from all the sources have been duly acknowledged.

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We, the undersigned, members of the Advisory Committee of **Ms. SWETA KUMARI,** a candidate for the degree of **MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING (SOIL AND WATER ENGINEERING)** have gone through the manuscript of the thesis and agree that the thesis entitled **"Impact of different Tillage Practices on Soil Moisture Variation and Physical Properties of Soil in North Bihar"** may be submitted by her in the partial fulfilment of the requirements for the award of the degree.

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ABSTRACT

A field experiment entitled **"Impact of different Tillage Practices on soil Moisture Variation and Physical Properties of Soil in North Bihar"** was conducted at the research farm of Rajendra Agricultural University, Bihar, Pusa (Samastipur) during *rabi* season of 2011-12 in randomized block design with eight treatment combinations replicated thrice to evaluate the effect of various conservation tillage treatments on the soil physical properties and yield of wheat crop. The selected treatments were - puddled transplanted rice + conventional tillage wheat, puddled transplanted rice + zero tillage wheat, rice and wheat on permanent beds with crop residue, zero tillage rice + conventional tillage wheat, zero tillage rice + zero tillage wheat without crop residue, zero tillage rice + zero tillage wheat with crop residue, unpuddled transplanted rice + zero tillage wheat and zero tillage rice with brown manuring + zero tillage wheat. The soil of the experimental plot was sandy loam, calcareous with pH value 8.4 and poor in fertility.

The effect of tillage treatments on the productivity of wheat crop and soil properties (soil moisture content, bulk density and infiltration characteristics) during wheat growth in rice – wheat cropping system were investigated. The results indicated that the treatment of rice and wheat on permanent beds with crop residue significantly influenced the soil moisture content throughout the root zone of the crop, bulk density of the soil, infiltration rate and ultimately the yield of the crop. The highest grain yield (60.46 q/ha) was recorded under this treatment.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS

ABBREVIATIONS	DESCRIPTION
I	Infiltration rate
a	Constant parameter
b	Basic infiltration rate
α	Constant parameter
t	Elapsed time
%	Percent
y	Accumulated depth

LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
°C	Degree Celsius
Am.	American
g	Gram
Agril.	Agricultural
CAE	College of Agricultural Engineering
Engg.	Engineering
et al.	Et alli
etc.	Et cetra
Fig.	Figure
B.D.	Bulk density
ha	Hectare
q	Quintal
i.e.	That is
J.	Journal
m	Metre
cm	Centimetre
No.	Number
R.A.U.	Rajendra Agricultural University
S.N.	Serial Number
h	Hour
Min.	Minute
Soc.	Society
M.C.	Moisture content
Sci.	Science
Res.	Research
Int.	International
Biol.	Biology
Appl.	Application
Environ.	Environment
Ecol.	Ecology
Till.	Tillage

CHAPTER – I

INTRODUCTION

INTRODUCTION

Rice and wheat are the two major food crops of India. Therefore, primary food security concerns are focused on improving and sustaining their productivity. With the advent of the “Green Revolution”, these two crops have come to occupy a significant area around 13.5 million ha in the Indo-Gangetic Plain (IGP) of South Asia, which extends from Pakistan in the west to Bangladesh in the east. Rain fed rice predominates in the abundant rainfall zones of the eastern IGP where there is scope for growing rice under ponded water conditions during the rainy season while irrigated rice is grown in the western IGP. Wheat assumes greater prominence in the western IGP, where it is normally grown with irrigation in the winter in rotation with rice. Cultivation of rice and wheat in the IGP of Nepal and adjoining parts of India is prehistoric, although in the north-western IGP of Pakistan and India it is a recent phenomenon.

Rice – Wheat is a predominant cropping system in India, Pakistan, Bangladesh and Nepal. Rice-wheat cropping system (RWCS) is the major cropping system in the Indo-Gangetic Plain (IGP) of India. Major rice-wheat growing states are Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar, and West Bengal. However, majority of the 10.5 million ha rice-wheat cropping system are concentrated in Punjab, Haryana and western Uttar Pradesh (Singh and Kaur, 2012).

Tillage is practiced in soils for controlling weeds, breaking crusts (improving water entry), increasing surface roughness (assisting water storage) and preparing seedbed. The type of tillage method to be practiced, however, depends upon the soil type and the climate of the area. The cost of cultivation is also influenced by used tillage method. For Vertisols and vertic soils, preparation of seedbed, improvement of soil structure and conservation of soil and water are of great concern (Coughlan *et al.*, 1989). It is suggested that to enhance the productivity of these soils best tillage systems need to be practiced. Various techniques viz., use of crop residue mulch, deep tillage, raised bed in the form of ridges or broad beds and furrow systems have been recommended for these soils by various researchers. However, zero tillage (ZT) has been widely acclaimed as highly effective practice for conservation of soil and water in Vertisols as compared with conventional tillage (CT) which enhances water conservation through improved infiltration and reduced evaporation.

There is a need to predict the effect of soil tillage, seedbed preparation, and sowing techniques on crop establishment. These technical changes are costly for growers, but their effects are not easy to predict. They cause changes in physical condition of the seedbed and in seed placement which interact with seed treatment, seed characteristics, and cultivars to determine the features of the crop stand.

The term conservation agriculture has recently been introduced by FAO as which aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water, biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. Many farmers have been adopting conservation tillage practices that reduce tillage requirement and maintain a residual cover on the soil. Conservation tillage is the collective umbrella term commonly given to no tillage, direct drilling, minimum tillage and or ridge tillage, to denote that these practices has a goal of same nature.

In India, efforts to adopt and promote resource conservation technologies have been underway for nearly a decade, but, it is only in the past 4 to 5 years that these technologies are finding rapid acceptance by the farmers. Efforts to develop and spread conservation agriculture have been made through the combined efforts by several State Agricultural Universities, ICAR institutes and CGIAR promoted Rice-Wheat Consortium for the Indo-Gangetic Plains. Unlike, in the rest of the world, spread of technologies is taking place in the irrigated regions in the Indo-Gangetic plains in India where rice-wheat cropping system dominates. Conservation agriculture systems have not been tried or promoted in other major agro–eco-regions like rainfed semi-arid tropics, arid regions or the mountain agro - ecosystems. Conservation agriculture in rainfed semi-arid and arid regions is characterized by variable and unpredictable rainfall, structurally unstable soils and low overall productivity. Results of most research station studies show that zero/ reduced tillage system without crop residues left on the soil surface have no particular advantage because much of the rainfall is lost as runoff due to rapid surface sealing of soils. It would, therefore, appear that no tillage alone in the absence of soil cover is unlikely to become a favoured practice. In rainfed eco-system, rain water availability is the major constraint. It is important to conserve more and more drop of water to sustain soil profile. Utilization of limited rainfall is the challenge for management. Without tillage, it is difficult to harvest more rain water particularly in vertisols which has low infiltration rate.

The primary focus of developing and promoting conservation agriculture practices has been development and adoption of zero- till seed cum fertilizer drill for sowing wheat crop in the rice - wheat system. Other interventions being tested and promoted include raised bed planting system, laser aided land leveling, residue management alternatives, alternative to rice-wheat cropping system in relation to conservation agriculture technologies, etc. The area planted with wheat adopting zero-till drill has been rapidly increasing over the past five to six years. In a sample study amongst farmers adopting zero-tillage, it was observed that the area brought under zero-tillage vis-a-vis total area under wheat crop varied with an overall average of 45 percent under zero tillage system.

Initial plant population has direct bearing on crop yield and seedling emergence. Thus, desirable crop yields are achieved by providing seeds with an environment that encourages early germination and emergence. Several researchers have emphasized the importance of analyzing the sustain establishment process and have shown that the main factors affecting germination, seedling emergence and plant establishment are associated with the mechanical characteristics of the seedbed. Tillage influences bulk density, penetration resistance, aggregate mean weight diameter and surface roughness and also influences the moisture conservation, infiltration characteristic and water requirement.

According to United Nations Organization (UNO), water crisis is the major threat for mankind in 21st century. Among 1400 million cubic km of water in the world, 97% is salty sea water, 2% is frozen in glaciers and only 1% is available as fresh water from the total available water (Kirloskar, 2003). Therefore, food security in Asia is threatened by declining water availability due to competition among agricultural, industrial, environmental, and domestic uses. By the 2025, 30 percent of the human population would be threatened by water scarcity because worldwide 70% water withdrawal is used in irrigated agriculture (Rosegrant, 1998).

Infiltration rate is defined as the volume flux of water flowing into the soil profile per unit of soil surface area. Environmental factors that control infiltration rate are rainfall intensity, soil properties (including texture, pore characteristics, organic content and structure), vegetation, land use, depth of soil, and initial moisture. The use of efficient irrigation methods with reduced water losses is critical in most of South Africa due to water scarcity. This makes studies on determination of infiltration rates of utmost importance. The measurement of infiltration rate of water into the soil is an important indication concerning the efficiency of irrigation and drainage, optimizing the availability of water for plants, improving the yield of crops and minimizing erosion. Irrigation systems should be designed and managed so that the application rate of water does not exceed the infiltrability of the soil. Knowledge of the soil infiltration parameters is of the utmost importance for optimum performance and management of surface irrigation.

The productivity of cropping system is stagnating and behind that puddling is one of the constraints. Puddling is time consuming and capital intensive. In rice – wheat cropping system, wheat yield has been reported to decrease due to the deterioration of soil structure caused by puddling in rice because this affects seedling emergence in wheat. Rice grown with conservation tillage can produce yields similar to that under conventional puddling with minimized expenses on field preparation. These provide the basis for investigating possibilities of avoiding puddling operations by direct seeding in rice, which in turn would ease the sowing of the wheat crop.

The Indo Gangetic plain is one of the world's major food grain producing regions. The states falling under this region viz., Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar and West Bengal are also the major rice - wheat growing states spread over 10.5 million hectare in the country. During the past 30 years, agricultural production growth in this region had been able to keep pace with population demand for food in the country mainly due to adoption of green revolution technologies including yield growth followed by area expansion. But this opportunity is ceasing very fast due to limited scope for increasing the availability of arable land and natural resources. The other issue is the conservation of the basic resources of land and water for sustainability of agriculture in Indo Gangetic plain. It is generally believed that the rice-wheat system has strained the natural resources in this region and more input are required to attain the same yield level.

It is therefore, imperative to promote alternative technologies that would help to conserve the much needed, but gradually depleting natural resources while boosting productivity growth in the long run by maintaining soil health and production environment. In the absence of specific information on impact of different tillage practices on soil moisture and other physical properties of soil in North Bihar conditions the present study was undertaken to determine the effect of different tillage practices on soil moisture, crop yield and soil physical properties under the rice – wheat system of the North Bihar. The wheat crop is selected for the study.

Keeping the above facts in mind the experiment "Impact of Different Tillage Practices on soil Moisture Variation and Physical Properties of Soil in North Bihar" was conducted with following objectives:

1) To study the moisture variation in different tillage practices during the crop period

2) To study the physical properties of soil (bulk density, infiltration rate) in different tillage practices

3) To study the crop yield in different tillage practices

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CHAPTER – II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A comprehensive review of literature is an essential part of any scientific investigation to provide an insight into the theoretical framework as well as methods and procedure for meaningful interpretation of findings. In this section the review of past work done pertaining to the proposed study has been presented below.

2.1. Effect of tillage on soil moisture content

Karlen *et al*. (1994) reported that the mulch helped to promote more stable soil aggregate as a result of increased microbial activity and better protection of the soil surface and with a normal application of mulch and additional residue did not increase this value while Deshpande and Durgude (2012) found that for long term (10 yrs), aggregate stability increased by using more mulch and water filled pore space increased.

Baruah *et al.* (1997) studied the effect of nutrient sources and moisture conservation practices on water use of mustard succeeding rice in acidic sandy loam soils of Jorhat, India, during 1992-93. They revealed a higher profile soil moisture (60 cm depth) both at rice harvest and during cultivation of mustard crop under treatments incorporating organic amendments compared with no organic amendment incorporation. Among the moisture conservation practices, stubble mulching and tillage after rice harvest followed by normal tillage showed better performance over normal tillage practices alone. Consumptive use of water was lower with all the organic source incorporated treatments as compared to no organic source incorporation. The higher water use efficiency was recorded with Eupatorium odoratum (2.00 k/ha-mm) among organic amendments and stubble mulching (1.98 kg/ha-mm) among moisture conservation practices.

Boutahar and Dimanche (1997) studied the three soil tillage practices - summer ploughing, autumn ploughing and chisel were evaluated through their effect on soil physical characteristics and on water content during three months after wheat seeding. A comparison was made with no tillage. Primary field preparation allowed a porous layer up to 20 cm depth which reduced bulk density and penetration resistance. The water content and its distribution in the profile were significantly affected by the tillage implements. No tillage allows the best distribution of water in the profile which is the most suited to seed germination and plant stand. The increasing porosity due to autumn tillage reduced the amount of water stored in the soil in comparison with the no-tillage case.

Acharya *et al.* (1998) conducted experiments for moisture conservation for rainfed wheat production with alternative mulches and conservation tillage in the hills of north-west India where rainfed wheat suffers from lack of optimum moisture at sowing. Field experiments were conducted on a silty clay loam (Typic Hapludalf) to evaluate the effectiveness of mulches and conservation tillage for rainfed wheat. The treatments were ten factorial combinations of five mulch-tillage practices and two nitrogen levels (60 kg/ha and 120 kg/ha). Mulch treatments consisted of application of 10 t/ha (dry weight basis), to previous standing maize, of either wild sage (Lantana camara) or eupatorium (Eupatorium adenophorum [E. trapezoideum]) in combination with either conventional or conservation (minimum) tillage prior to wheat sowing. These alternative practices were compared to the conventional practice of soil tillage after harvest of maize with no mulch. Application of these weed mulches to standing maize maintained friable soil structure owing to a fivefold higher mean population of earthworms. Mulches increased soil water contents in the seed-zone by 0.06-0.10 %v/v compared with the conventional farmer practice of soil tillage after maize harvest. Mulch-conservation tillage treatments favourably moderated the hydro-thermal regime required for growing a wheat crop. The mean root mass density under these treatments at wheat flowering was greater by 1.27-1.40 times over the conventional farmer practice.

Guo *et al.* (1999) reported that tillage-induced changes on soil physical properties. They studied in a silt loam under double crop rotation at Massey University, New Zealand and compared the conventional tillage (CT) (which involved mouldboard ploughing and rolling, then two passes of a power harrow within suitable intervals, followed by seeding with a no-tillage seed drill set at 150 mm row spacing), no-tillage (NT) in which weeds were controlled by herbicide spray with 4 litres Roundup/ha (360 g glyphosate/litre) and with 1 litre Versatill/ha (300 g clopyralid/litre), followed by direct seeding with (as in CT) a seed drill followed by chain harrowing and permanent pasture (PP) (as a control treatment). Soil bulk density, water content, infiltration, penetration resistance, earthworm populations, and pH were measured during 2 cropping seasons after barley and oats crop harvest in March and August 1996, respectively. Most soil properties were significantly ($P < 0.05$) affected by tillage practices after 2 crops. Soil water content, infiltrability, and earthworm populations were similar in the NT and PP treatments, but higher than those found in the CT treatment. Conversely, soil bulk density at 0-50 mm depth was in the order of CT > NT > PP. Soil pH was not different among the 3 treatments. The results indicated that the adoption of no-tillage practices is likely to maintain soil physical characteristics and soil quality at levels similar to those under permanent pasture.

Xu. Di *et al*. (1999) studied effects of tillage practices on the variation of soil moisture and the yield of summer maize. They observed that the conventional tillage, no-tillage and subsoiling on soil water and yields of maize. Compared with conventional tillage, no-tillage practices maintained higher soil water storage in the upper profile during the early part of the growing season. This gain was attributed to decreased evaporation losses caused by stubble cover and the fact that there was no disturbance of the surface soil under no-tillage. Water storage in the subsoiling treatment was less than that of the soil under conventional tillage as soil physical properties in the deep tilled soils were largely altered. Root length and yields were highest under subsoiling and similar in conventional and no-tillage treatments.

Linda *et al*. (2003) studied the soil samples were analysed for particle size distribution, bulk density, water stable aggregates, organic carbon, and soil water retention at different tensions. Values of field capacity and permanent wilting point were found maximum in lowland and minimum in upland soils. Regression analysis of soil moisture parameters with other important soil physical parameters showed a positive and significant contribution of clay, organic matter content, total porosity and geometric mean diameter of aggregates towards field capacity, permanent wilting point and available water capacity. However, an adverse effect of sand and bulk density was found on these moisture retention parameters.

Khan *et al*. (2006) studied the objectives to evaluate the effect of various tillage practices on selected soil parameters including soil moisture content, bulk density and soil strength of sandy loam soil under rainfed condition during the wheat and chickpea growing seasons (2002-05). Five tillage treatments: No Tillage, Chisel Plough once and Tine Type Cultivator twice, Mould board Plough once and Tine type cultivator twice, Disk Harrow once and Tine Type Cultivator twice and Tine Type Cultivator 3 times were used in the study. The experiment was laid out in randomized complete block design with five treatments and four replications. The results showed that tillage treatments had significant effects on soil moisture content, bulk density and soil strength at 0-30 and 31-60 cm depths during the wheat-chickpea rotation growing seasons. On an average, field prepared by chisel plough once and tine type cultivator twice and mould board plough once and tine type cultivator twice were resulted higher soil moisture content, lower bulk density and soil strength as compared to No Till and shallow tillage treatments on sandy loam type of soil during wheat-chickpea rotation under rainfed condition.

Joshi *et al.* (2007) studied the importance of reduced tillage in sustainable agriculture. They found reduced-tillage practices (which may or may not involve retention of crop residues) and their effects differ from those of conventional tillage in several ways: soil physical properties (soil moisture, bulk density etc.) shifts in host-weed competition; soil moisture availability (especially when sowing deeply or under stubble); and the emergence of pathogen populations that survive on crop residues. There may be a need for genotypes suited to special forms of mechanization (e.g. direct seeding into residues) and to agronomic conditions such as allelopathy, as well as specific issues relating to problem soils.

Kumar and Singh (2008) studied the water retention characteristics of soil and to develop models of water retention as a function of matric suction as well as a function of some physical properties for prediction of available water holding capacity of different depths of soil profile. Some physical properties of soil such as particle size distribution and bulk density were determined. The moisture retention characteristics curves of the soil profile revealed that water retained in different soil depths changed very rapidly as the soil water suction increased from 0.33 bar to 5.0 bar which may be due to the loosely bounded water associated with pores whereas beyond 5.0 bar suctions release of water is quite slow that indicate the strongly bounded water by swelling of clay particles. Water retention curves of each soil layer showed best fit to the power function (R_2 values of 0.98, 0.95, 0.99 and 0.91, respectively for 0-30, 30-60, 60-90 and 90-120 cm soil depth) compared to linear and exponential functions. Textural composition and bulk density of the soils were also correlated with water retentions at field capacity and permanent wilting point.

Bertolino *et al.* (2010) studied effects of plough pan development on surface hydrology and on soil physical properties in South-eastern Brazilian plateau. Conventional and minimum tillage practices were implemented in two plots for 3 years and soil matric potential (SMP) was monitored in each plot via nests of tensiometers and Watermark Reg., sensors installed at different depths. They found that soils under the conventional tillage system developed a plough pan layer at about 20 cm depth that had 44 per cent less total porosity as compared to surface conditions. It is shown that soils under the conventional tillage system tended to stay saturated for longer periods of time after each rainfall event. Besides, during intense rainy periods soils under the conventional tillage system may develop hydrologic conditions that favor lateral flows while soils under the minimum tillage system were still draining. They found that conventional tillage in this area generated modifications in soil fabric, especially in pore-size distribution and connectivity, which induced important changes in soil hydrology and soil erosion. The agricultural practices used in this area, associated with the local steep hill slopes and intense rainfall events, are definitely not adequate and require the introduction of soil and water conservation practices in order to become sustainable.

2.2. Effect of tillage on bulk density

Prasad *et al.* (1994) studied the interactive effects of tillage, irrigation and N rates on root growth, water and N use and yield of maize on loamy sand and sandy loam soils. Treatments included combinations of two tillage systems, 10 cm-deep conventional tillage (CT) and 35 to 40cm deep chiseling 35 cm apart with a single tine chisel. Deep tillage decreased bulk density and soil strength in the tilled zone which caused deeper and denser rooting compared with CT.

Bordovsky *et al.* (1999) studied the effect of tillage, cropping, and residue management on soil properties in the Texas rolling plains during 1979-1989 on a fine sandy loam to determine the effects of tillage (reduced vs. conventional), cropping, and residue management (with residue vs. without residue) on soil properties under dry land and irrigated systems. Cropping included a grain sorghum and wheat monoculture and double-cropped, reduced tillage wheat-grain sorghum under irrigation only. Surface soil organic matter in plots with irrigated grain sorghum and wheat increased with time. They observed that reduced-tillage irrigated grain sorghum and wheat, and especially reduced-tillage, double-cropped grain sorghum and wheat plots, had significantly higher organic matter content than conventional-tillage grain sorghum and wheat plots. Bulk density under the reduced tillage system was higher than with the conventional tillage system. However, saturated hydraulic conductivity of the surface soil was increased by reduced tillage practices compared with conventional tillage. This may have been attributable to higher amounts of micro aggregates and larger macro-pores under the reduced tillage system. Residue removal decreased the hydraulic conductivity of surface soil, especially in reduced-tillage grain sorghum and wheat plots. Micro aggregation values were higher with residue retained than with residue removed (27.1 vs. 23.5 g kg^{-1} in dry land and 32.3 vs. 27.1 g kg^{-1} in irrigation). Results indicate that residue removal from these soils should be discouraged. Because of higher bulk density, use of a reduced tillage system may result in the need for occasional deep chiseling to reduce the effects of compaction.

Singh *et al*. (2000) studied the integrated nutrient management in rice-wheat system carried that the application of farmyard manure (FYM) significantly brought down the bulk density of both surface and subsurface soils in comparison with the control. The application of different levels of fertilizer did not affect the bulk density. Neither organic nor inorganic fertilizer could affect the porosity of the surface soil. However, higher porosity of subsurface soil was recorded due to the application of FYM and green manure (GM). Combined application of FYM and recommended level of NPK recorded highest water retention at both field capacity (32.33 %) and wilting point (6.86 %). Root-length density and dry matter added through root was significantly higher in FYM-treated plots than in that of GM and control.

Kumar and Pandey (2002) studied that the effect of tillage operations combined with crop residues applied to paddy in paddy-wheat cropping system on some of the properties (i.e., hydraulic conductivity, mean weight diameter, aggregation per cent, bulk density and soil strength) related to soil aggregation. Hydraulic conductivity, mean weight diameter and aggregation per cent were maximum in that treatment among the main treatments while bulk density and soil strength were maximum in the control. In the subplot treatments, hydraulic conductivity, mean weight diameter and aggregation per cent were maximum in that while bulk density and soil strength were maximum in that treatment. It is concluded that green manuring with S. rostrata as well as the incorporation of rice husks has a positive effect on the improvement of clay soils.

Rahman *et al.* (2003) compared the effects of zero tillage with continuous fodder crop, zero tillage with continuous orchard, conventional tillage with sweet potato and maize (in summer), and wheat, barley, rye and rape (in winter) and puddling with continuous rice on some selected physical and chemical properties of sandy clay pumice *Andisol* in Japan under colder climate. They found that the mean dry bulk density was lower for conventional tillage, compared with zero tillage with continuous fodder crop, zero tillage with continuous orchard and for puddling. Highest content of organic matter was found in NT compared to other practices. On the other hand, soil pH and electrical conductivity were significantly lower under NT than other practices. The tillage had significant effects on soil hardness at different matric suction. Conventional tillage held highest moisture at 0 pF. On the other hand, puddled soil showed highest moisture retention capacities between 1.5 and 7.0 pF than zero tillage and conventional tillage. Gravitational water and gravitational capillary water contents was highest while capillary water, shrinkage water and hygroscopic water contents were lowest under CT. Gravitational drainage and non-easily available water were significantly lowest and easily available water, total available water and non-available water were significantly highest under puddling condition compared to other tillage systems.

Prikner *et al*. (2004) examined a new portable soil core sampler for the purpose to design an efficient sampler, which allows comparison of disturbed and undisturbed soil samples. That is to provide the possibility of applying the results for further experiments in the soil compaction sphere as well. Pressing the core sampler into the soil usually avoids the vibration that causes fracturing, but soil may be displaced in front of the core due to compression if the static loading rate exceeds the rate at which soil can enter into the core sampler hammering, compared with hydraulically pressing, the core sampler into the soil appears to cause more distortion within the soil core, which increases variability.

Khattak *et al*. (2006) conducted field experiments with the objectives to evaluate the impact of various tillage practices on some soil parameters of clay loam soil including soil moisture content, bulk density and soil strength. They found tillage treatments had significant effects on soil moisture content, bulk density and soil strength at 0-30 and 31-60 cm depths during the wheat-chickpea rotation growing seasons. By comparing soil moisture content during three consecutive years (2002-05) of wheat-chickpea rotations, the mean highest soil moisture content was found in tillage treatment Disk Harrow once and Tine Type Cultivator thrice (DHTC3) and the lowest mean soil moisture content of 15.27 per cent in Chisel Plough once and Tine Type Cultivator thrice CPTC3 at 0-30 cm depth respectively, while at 31-60 cm depth, the mean highest soil moisture content of 18.03 per cent was possessed by tillage treatment

DPTC3 and the mean lowest soil moisture content was recorded 16.29 per cent in tillage plot Tine Type Cultivator 4 times TC4. By comparing, mean minimum bulk density of 1.21 g cm^{-3} in tillage treatment Disk Harrow once and Tine Type Cultivator thrice DHTC3 and the mean highest of 1.28 g cm^{-3} was recorded in Tine Type Cultivator 4 times TC4 at 0-30 cm depth respectively. Similarly, the bulk density at 31-60 cm depth, the mean minimum bulk density was possessed 1.26 g cm^{-3} by tillage treatments Disk Plough once and Tine Type Cultivator thrice DPTC3 and Disk Harrow once and Tine Type Cultivator thrice DHTC3, and the highest bulk density was found 1.33 g cm^{-3} by tillage treatment Tine Type Cultivator 4 times TC4. Similarly soil strength at 0-30 cm depth, mean least soil strength of 330 N cm^{-2} was found in Disk Plough once and Tine Type Cultivator thrice DPTC3 and the highest soil strength of 363 N cm^{-2} was observed in the Mould board Plough once and Tine type cultivator thrice MBTC3 in Tine Type Cultivator 4 times TC4 plots. While at 31-60 cm depth, tillage treatment of DPTC3 resulted lowest value of 439 N cm^{-2} soil strength up to their plowing depth respectively, and in the TC4 treatment resulted highest value of 492 N cm^{-2}. On an average, field prepared by disk plow/disk harrow once and tine type cultivator 3 times (DPTC3) (and Disk Harrow once and Tine Type Cultivator 3 times (DHTC3) Chisel Plough once and Tine Type Cultivator 3 times (CPTC3); were resulted higher soil moisture conservation, lower bulk density and least soil strength as compared to mouldboard plow/chisel plough in combination with tine type cultivator or alone tine type cultivator on clay loam type of soil during wheat-chickpea rotation under Rod Kohi command irrigated area.

Peigne *et al.* (2007) suggested to adopt conservation tillage to preserve soil quality and fertility and to prevent soil degradation-mainly erosion and compaction. The potential advantages of conservation tillage in organic farming are reduced erosion, greater macro porosity in the soil surface due to larger number of earthworms, more microbial activity and carbon storage, less run-off and leaching of nutrients, reduced fuel use and faster tillage. The disadvantages of conservation tillage in organic farming are greater pressure from grass weeds, less suitable than ploughing for poorly drained, unstable soils or high rainfall areas, restricted N availability and restricted crop choice. The success of conservation tillage in organic farming hinges on the choice of crop rotation to ensure weed and disease control and nitrogen availability. Rotation of tillage depth according to crop type, in conjunction with compaction control measures is also required. A high standard of management is required, tailored to local soil and site conditions. Innovative approaches for the application of conservation tillage, such as perennial mulches, mechanical control of cover crops, rotational tillage and controlled traffic, require further practical assessment.

Jabro *et al. (*2010) studied the effects of conventional (CT) and strip (ST) tillage practices on bulk density, water content, infiltration rate and hydraulic conductivity in sandy loam soil. Soil cores were collected during growing season from each plot at 0 to 10 and 10 to 30 cm depths under each tillage practice to measure bulk density and water content. In-situ infiltration rate and hydraulic conductivity measurements were determined using a pressure ring infiltrometer (PI) and a constant head well permeameter (CHWP) at the soil surface and 10-30 cm depths, respectively. They found that the CT operations increased soil compaction, which consequently altered bulk density, thereby reducing hydraulic conductivity of the soil.

Avci (2011) reported that the conservation agriculture is a key tool in sustainable production systems throughout the world and is developed around soil management technology that minimizes soil disturbance, maximizes the soil cover and promotes crop diversity to offer benefits to farmers and to the environment. It has been particularly effective at sustaining crop production in semi-arid rain-fed regions such as the Central Anatolian soils, where potential evaporation exceeds precipitation during most months of the year, dry farming is extensively practiced, water and wind erosion is common, and proper application of water and soil conserving tillage technology is critical. The area under plow expanded its limits as the number of tractors in agriculture dramatically increased in the 1960s. This is the starting point for inappropriate use of the agricultural land. The conservation agricultural technologies, therefore, are of utmost importance for the region. Common farmers' practices of a fallow-wheat system in the central plateau of Turkey are incompatible with the conservation agriculture concept. The objective of this study is to re-evaluate the performances of the partial and full conservation tillage practices previously tried in the region. They found (1) agreeing with the conservation principles, fallow tillage as a primary operation in the fallow phase was found to be useless compared with leaving the land without tillage; (2) therefore, much research has focused on spring tillage as a primary operation and employed conventional, semi-conservative and conservative methods. Results showed that the conventional system, in addition to being ecologically unfriendly, is unprofitable as compared with other conservation practices regarding the updated cost analysis; (3) similarly, tillage depth in primary spring tillage was determined to be shallower than the depths currently practiced by farmers, in agreement with the conservation principles; (4) fallow tillage operations in summer to create dust mulch for eliminating soil moisture loss did not increase the crop yields and soil moisture as compared with chemical fallow; (5) no-till fallow was similar to the conventional clean fallow system in terms of moisture and yield levels. However, no-tillage resulted in 50 per cent reduction in the cost of tillage besides its ecologically-friendly effects; (6) the existing dry land agricultural systems in the plateau should be transformed into or changed toward sustainable systems, although further research is required on residue and stubble management, and integrated weed control methods to drill the soil with high amounts of residue on the field.

Jabro *et al.* (2011) studied the bulk density, water content, and hydraulic properties of a sandy loam soil with conventional or strip tillage. Tillage produces a more favorable soil physical environment for seed germination and plant growth. A study was carried out to compare effects of conventional and strip tillage practices on soil bulk density, water content, final infiltration rate and saturated hydraulic conductivity for a sandy loam where sugar beet (Beta vulgaris L.) was grown during the year 2007 and 2008 growing seasons. They found a significant difference (in 2007) in bulk density between conventional tillage and strip tillage plots at 10- to 30-cm depth, soil water content did not differ significantly between conventional tillage and strip tillage plots. In 2008, soil bulk density and water content did not differ significantly between conventional tillage and strip tillage plots at both depths. The log-transformed infiltration rate was affected by tillage practice at Phosphorus level < = 0.1 in 2007 but was not significantly affected in 2008. The effects of tillage on log-transformed Ks were significant at P < = 0.05 in 2007 and P < = 0.1 in 2008. Soil Ks values were 68 and 56 per cent greater for ST than for CT in 2007 and 2008, respectively. They concluded that strip tillage reduced soil compaction in the row, consequently increased total porosity, reduced bulk density, and thereby increased infiltration rate and saturated hydraulic conductivity of the soil.

2.3. Effect of tillage on infiltration characteristics

Olsen and Borresen (1997) compared the soil with conventional tillage practice to soil with reduced tillage using computer tomography (CT) to assess the long-term effects of changes in tillage practices on soil properties. The advantage of CT is that it nondestructively provides a spatial density distribution. The macropores are effectively separated from the soil matrix with micropores. Soil with conventional tillage had a loose structure with a wide range of densities in the ploughing layer. Below the ploughing depth the soil was compact with very little macropores. The soil with reduced tillage had a nearly uniform density profile, but macroporosity in the subsoil was significantly larger than near the surface. Computer tomography is a useful tool for nondestructively measuring bulk density and macroporosity. The effect of an increased number of macropores on solute infiltration was also visualised using CT.

Ray and Gupta (2001) studied the effect of green manuring and tillage practices on physical properties of puddled loam soil under rice-wheat cropping system at the Indian Agricultural Research Institute, New Delhi, India, for two years. As the optimum soil physical environment for the puddled rice and upland wheat differs substantially, cropping sequence that includes both crops requires special management practices to become sustainable. Observations on temporal changes in soil bulk density, saturation percentage, saturated hydraulic conductivity, size distribution of macropores and infiltration rate were monitored regularly during the study period. They found that incorporation of green manure before puddling for rice improved the soil aggregation and thereby decreased the bulk density and increased the saturated hydraulic conductivity, saturation percentage and macropores. It was also found to improve infiltration rate, soil dispersion, and soil strength. Green manuring caused significant reduction in soil strength in the 0-15 cm layer of the puddled soil.

Ghazal (2002) studied the effect of tractor wheel compaction on soil bulk density and infiltration rate of a loamy sand soil at two different sites in the Kingdom of Saudi Arabia. Mean soil bulk density ranged between 1.55-1.7 g/cm^3 at the first site and 1.44-1.75 g/cm^3 at the second site under different tractor wheel compactions. Soil bulk density increased proportionally with repeated compaction and was related to soil moisture contents at the time of application of compaction force. However, mean cumulative water infiltration ranged between 1.53-5.79 cm/h and the mean infiltration rate of soil between 1.32-5.70 cm/h in different compaction treatments. Among the various compaction treatments, the "4-passes" treatment caused 69 per cent reduction in infiltration rate of soil. The highest compaction treatment (8-passes of tractor wheel) caused up to 77 per cent reduction in infiltration rate of soil. Soil bulk density and infiltration rate of soil were highly correlated. They found difference in soil bulk density and infiltration rate of soil was significant among all the compaction treatments when compared to the control treatment (zero-pass). The research findings showed an excellent potential for improving the physical properties of light textured soils to achieve higher irrigation efficiency if simply tractor (highly used conventional agricultural implement) coupled with other commonly adopted tillage practices are used for soil compaction.

Gregory *et al*. (2005) reported that the double infiltrometer test is a well recognized and documented technique for directly measuring infiltration rate as reported as Bouwer (1986) and ASTM (2003).

Bhattacharyya *et al.* (2008) reported that the conventional tillage system generally improve the soil organic content (SOC), plant available water capacity (PAWC), aggregation and soil water transmission. They studied the difference between the conventional tillage and zero tillage system with all irrigation treatment on rice and wheat crop, in this PAWC was significantly higher with zero tillage than conventional tillage. Zero tilled and frequently irrigated plots showed enhanced infiltration characteristics and saturated hydraulic conductivity.

Lili *et al*. (2008) that double ring infiltrometer method be more conveniently be applied to the field conditions than methods like single ring infiltrometer, disc permeameter, rainfall simulator, runoff-no-ponding, runoff- on- out and linear source method to measure soil infiltration rate.

Ndaeyo and Aiyelari (2010) studied the water infiltration characteristics into soil profile as influenced by different tillage practices with conventional (CT), minimum (MT) traditional (TT) and zero (ZT) on soil infiltration rate, sorptivity and transmissivity. The adjoining natural forest (NF) was also incorporated as the fifth treatment (control). All the treatments were triplicated and within each plot, a series of six infiltration runs (tests) were carried out. They obtained that infiltration rate, sorptivity and transmissivity were generally higher in NF and ZT plots than the tilled plots. This implies that zero tilled treatment had improved infiltration characteristics with time than the tillage treatments. Moreover, surface runoff and nutrient loss would be higher in tilled soil than the zero tillage and this has implication for water management.

Celik and Ersahin (2011) reported the tillage influence on infiltration characteristic. Tillage practices can pronouncely affect the soil hydraulic and physical properties even shortly after tillage applications. They compared short-term effect of conventional, reduced and no-till on some soil physical properties and infiltration rate. Both reduced tillage and no tillage decreased infiltration rate, significantly, and this was attributed to decreased total and macroporosity. Furthermore, residue burning decreased infiltration rate significantly compared to residue incorporated soils in conventionally tilled soils, and this was attributed to decreased total porosity and macroporosity in the former. The results suggest that reduced and no-tillage should be applied cautiously in soils to avoid problems such as water loss by runoff in sloping areas and water logging in level areas.

2.4. Effect of tillage on crop yield

Aslam *et al.* (1993) studied the improving wheat yield in the rice-wheat cropping system of the Punjab through zero tillage in 1985-88 at 34 locations in the Punjab, Pakistan, wheat was direct drilled into rice stubble or sown using conventional methods (an average of 4-6 cultivations). They found the effect of no-tillage vs. conventional tillage was significant in the 2nd and 3rd years, and overall no-tillage increased wheat yield by 10%. In trials when no-tillage plots were sown as soon as possible after harvesting rice (10-44 d earlier than with cultivation) rather than on the same date as in the conventional system, the yield increase was 41%. Increased yield in no-tillage crops was associated with higher tiller numbers, better seedling establishment and fewer weeds. The cost of cultivation and sowing was Rs 825/ha in the conventional system and Rs 125/ha with no-tillage.

Islam *et al.* (2005) studied the tillage and mulch effects on some soil physical properties and yield of wheat in shallow red brown terrace soils of Bangladesh during two consecutive *rabi* (winter) seasons of 2000/2001 and 2001/2002 to determine the tillage and mulch effects on physical properties of shallow red brown terrace soils, using wheat as the test crop. Laboratory investigations were also carried out to analyze these properties. The physical properties of the soil were markedly influenced by tillage and mulch. Bulk density was significantly altered by different tillage practices wherein the lowest bulk density was observed in disc ploughing at 0-10 cm soil depth. The lowest value of soil strength was recorded in the ploughed zone of disc and chisel ploughing and the highest values in minimum tillage. Mulch had less effect on bulk density and soil strength. Polyethylene mulch showed the highest temperature and the lowest was observed under straw mulch. Minimum tilled plots showed the maximum level of soil temperature at 10 cm depth all through the day. Similar trend in results was also observed for weekly mean soil temperature. Cumulative infiltration and infiltration rates were higher in disc and chisel ploughing and lower in minimum and conventional tillage methods. Disc ploughing and rice straw mulch significantly increased grain and straw yield of wheat. Average grain yield increases over minimum tillage were 13 per cent with conventional tillage, 23 and 20 per cent with disc ploughing and chisel ploughing, respectively. Similarly grain yield increases over no mulch were 23, 18 and 11 per cent with rice straw mulch, water hyacinth and polyethylene mulch, respectively.

Khattak *et al.* (2005) studied to enhance wheat yield and yield components by controlling weeds with deep tillage treatments under clay loam soil conditions. They found in the deep tillage treatments wheat yield was increased by 7 per cent compared to the shallow tillage treatment. Mould board plough and rotavator appeared to have effectively controlled weeds hence, more soil moisture and nutrients were available for crop growth, which ultimately led to higher wheat yield.

Vadi *et al.* (2005) studied the effect of different tillage practices and mulches on growth and yield of crop as well as on moisture conservation. Four tillage methods conventional tillage; deep ploughing in row by bullock plough; deep ploughing in row by tractor plough and deep ploughing by tractor plough and five mulches -no mulch, soil mulch,5 tonnes wheat straw mulch/ha, 10 tonnes groundnut shell mulch/ha; and 10 tonnes castor shell mulch/ha were used. Among the different tillage practices, deep ploughing by tractor plough recorded significantly higher plant height, spread as well as grain and straw yield of pigeon pea. Deep ploughing by tractor plough also recorded higher soil moisture content at flowering and pod formation stage, indicating more conservation of rain water under deep tillage. In case of mulch treatment, deep ploughing in row by bullock plough; deep ploughing in row by tractor plough were found equally effective and resulted to higher plant height, spread as well as grain and straw yield as compared to other treatments. Numerically higher soil moisture content at different growth stages was found under wheat mulch treatment. Interaction effect between tillage and mulches was found insignificant.

Gangwar *et al. (*2006) studied the alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo-Gangetic plains was conducted to evaluate the effect of three tillage practices (conventional, zero and reduced/strip) with two nitrogen levels (120 and 150 kg N ha^{-1}) applied in primary strips and three crop residue management practices (removal, burning and incorporation) in secondary strips in wheat after rice. Reduced tillage resulted in significantly higher overall mean wheat yield compared to conventional and zero tillage. Residue incorporation resulted in highest mean yield during third year. Maximum mean yield was obtained in reduced tillage followed by conventional tillage under residue incorporation in third year. The weed dry weight recorded at 30 days after sowing was highest under zero tillage and lowest under conventional tillage. Among crop residue management practices, the highest dry weight of weeds was recorded under residue incorporation. The highest infiltration rate was recorded in residue incorporation followed by residue burning whereas; the lowest in zero tillage. Soil bulk density was the highest under zero tillage and the lowest in residue incorporation. There were no changes in soil available P and K after each crop sequence in relation to tillage practices during first 2 years. Higher organic carbon was measured under zero tillage compared to other treatments. Residue incorporation increased soil organic carbon and available P while higher available K was monitored in burning treatment during the third year. These results suggested that reduced tillage and in situ incorporation of crop residues at 5 Mg ha^{-1} along with 150 kg N ha^{-1} were optimum to achieve higher yield of wheat after rice in sandy loam soils of Indo-Gangetic plains of India.

Gupta and Sayre (2007), Gupta and Seth (2007) and Saharawat *et al.* (2010) studied the zero till wheat in rice-wheat cropping system has been addressing the several issues of sustainability and its success has encouraged the farmers to adopt the double no – till practice for long term sustainability of the system. They reported that major benefits of zero till technology including- reduced costs due to savings in fuel & labor, timely planting of kharif & rabi crops, resulting in higher yields, reduce weed density, saving of irrigation water (up to 15-20%), improved input use efficiency because of better crop stands due to good seed and fertilizer nutrients placement & buildup in SOC due to reduced burning of crop residues (Phillips *et al*., 1980) and reduce oxidation of soil carbon.

Wang *et al.* (2007) studied the rapidly increasing population and associated quest for food and feed in China has led to increased soil cultivation and nitrogen (N) fertilizer use, and as a consequence to increased wind erosion and unbalanced crop nutrition. In this the long-term effects of various combinations of maize stover, cattle manure and nitrogen (N) and phosphorus (P) fertilizer applications on maize yield and nutrient and water use efficiencies under reduced tillage practices. Grain yields and NP K uptakes and use efficiencies were greatly influenced by the amount of rain during the growing season (GSR) and by soil water at sowing (SWS). There were highly significant interactions between GSR and added stover and manure, expressed in complex annual variations in grain yield and N, P and K use efficiencies. In conclusion, balanced combinations of stover, manure and NP fertilizer gave the highest yield and NRE. Reduced tillage with adding stover and manure in autumn prior to ploughing is effective in minimizing labour requirement and wind erosion. The potentials of split applications of N fertilizer, targeted to the need of the growing crop (response farming), should be explored to further increase the N use efficiency.

Adeyemo and Agele (2010) studied the effects of tillage and manure application on soil physical and chemical properties, growth and yield of maize grown on an intensively mechanized. The tillage constituted the main plot while farm yard manure and NPK fertilizer were the subplots. There was an unmanured control. Ploughing was carried out using mould board plough mounted on a tractor and harrowing was carried out after ploughing. There were no significant differences ($P<0.05$) in soil moisture contents and bulk densities (0 to 60 cm depth) between tillage alone and tillage systems combined with manure application at 4 and 10 weeks after planting. The tillage-manure combination produced higher values of soil organic matter (1.3, 1.6 %), total N (0.08, 0.11 %) and available P (14.5, 18.9 mg/g) over tillage alone. Compared with tillage systems alone, application of manure significantly increased ($P=0.05$) root and shoot dry weights, leaf area (0.11 and 0.25 m^2), cob and seed yield of maize. The increases in grain yield due to manure and NPK fertilizers were 10, 13 and 12 per cent, respectively.

Odofin *et al.* (2011) carried out agronomic and economic evaluation of different conservation and conventional farming practices on a sandy clay. The zero tillage treatments recorded significantly higher penetration resistance than manual ridging in both years. In terms of soil moisture content, seedling emergence, plant height, grain yield and stover + grain yield, however, the control and the test treatments were not significantly different. The insignificantly different pooled grain yield ranged from 2,043 kg ha^{-1} for slash-and-clear reduced tillage to 2,387 kg ha^{-1} for manual ridging. There was a wide variation in treatment costs from Naira 9,000 ha^{-1} for slash-and-mulch zero tillage to Naira 55,100 ha^{-1} for ploughing, harrowing and ridging. This resulted into slash-and-mulch, herbicide-based and slash-and-clear zero tillage treatment having significantly higher yield-cost ratio than the control. Slash-and-mulch and herbicide-based zero tillage practices are therefore recommended for promotion among Nigerian peasant farmers. The two other conservation farming practices, namely slash-and-mulch and herbicide-based reduced tillage, which recorded insignificantly higher yield-cost ratio than the control are also recommended.

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CHAPTER – III

MATERIALS & METHODS

MATERIALS AND METHODS

This chapter deals with the materials used and methods adopted during the course of the present investigation. The details of the experimental site, soil, climatic conditions and the experimental details are presented in this chapter.

3.1 Experimental site

The experiment was conducted at the experimental farm of Rajendra Agricultural University, Pusa in Samastipur district of Bihar in India. The site is located at $85^0$40'60 E longitude and $25^0$58'60 N latitude and is situated at 54.4 m above mean sea level (MSL). The present investigation was carried out during *rabi* season of 2011-12 with the objectives to study the physical properties of soil and effect of conservation tillage on growth and yield of wheat (*Triticum aestivum*). The topography of the experimental plot was uniform and flat.

3.2 Soil of the experimental plot

Soil at the experimental site was sandy loam, calcarious, coarse in texture, granular in structure, moderate in fertility, poor in organic matter and nitrogen. The other physical and chemical properties of the soil are presented in Table 3.1

Table 3.1 Physical and chemical properties of soil

Particular	Characteristics
Texture class	Sandy loam
Particles distribution	Sand – 53.02% Silt – 36.91% Clay – 10.07%
pH	8.4
EC	0.73 mmhos/cm
Organic carbon	0.42%
Available nitrogen	0.040%
Olsen phosphorus	4.10 ppm
Available potash	49.02 ppm
Free $CaCO_3$	25.50%

3.3 Climatic and weather conditions

The climate of the experimental site comes under humid subtropical climate which is influenced greatly by the monsoon. The average annual rainfall is 1270 mm out of which nearly 1026 mm is received during the monsoon extending from the middle of June to middle of October. The period between 3rd week of December to first half of January enjoys occasional winter showers. The average maximum temperature during the hottest month of May-June goes up to 40^0C and the average minimum temperature is about 20^0C, whereas during monsoon the average maximum temperature is about 33^0C and average minimum temperature about 23^0C. In winter, the average maximum temperature is about 25^0C and minimum temperature goes down to about 6^0C. The maximum temperature rises to 34^0C during the harvest time in the month of April. The humidity is about 80 per cent apart from the monsoon season. Frequent droughts and floods are common in the region.

3.4 Experimental layout

Treatment details

Eight treatments in the form of combinations of tillage and crop establishment methods for a rice-wheat cropping systems were used in this experiment. The different combinations of treatments used in the experimental plot are mentioned in Table 3.2

Number of Treatments - Eight

Table 3.2 Treatment details

Treatment Number	Treatment combinations
T_1	Puddled transplanted rice + Conventional tillage wheat (PTR + CTW)
T_2	Puddled transplanted rice + Zero tillage wheat (PTR + ZTW)
T_3	Rice & Wheat on permanent beds with crop residue (+R)
T_4	Zero tillage rice + Conventional tillage wheat (ZTR + CTW)
T_5	Zero tillage rice + Zero tillage wheat without crop residue (ZTR + ZTW - R)
T_6	Zero tillage rice + Zero tillage wheat with crop residue (ZTR + ZTW + R)
T_7	Unpuddled transplanted rice + Zero tillage wheat (UPTR + ZTW) (only rice residue)
T_8	Zero tillage rice with brown manuring + Zero tillage wheat (ZTR with BM + ZTW)

Experimental design – Randomized block design (RBD)

Crop - Wheat

Variety- HD2733

Replication: 3

Plot area: $467m^2$

3.5 Fertilizer Dose

All plots received same amount of fertilizer nutrients @ N - 150 kg/ha, P_2O_5 - 60 kg/ha and K_2O - 60 kg/ha both for rice and wheat.

3.6 Weedicide

All plots received same amount of weedicide Bispyriback sodium 25g / ha.

3.7 Schedule of operation practices

Various important field operations performed in experimental plots throughout the experiment are detailed in table 3.3.

Table 3.3 Schedule of operation practices

S. No.	Particulars of operations	Date of operation
1.	1st moisture sampling	22.11.2011
2.	Sowing of wheat	24.11.2011
3.	2nd moisture sampling	26.12.2011
4.	1st irrigation	27.12.2011 - 28.12.2011
5.	3rd moisture sampling	03.01.2012
6.	4th moisture sampling	07.02.2012
7.	2nd irrigation	08.02.2012 - 09.02.2012
8.	5th moisture sampling	15.02.2012
9.	Harvesting	15.04.2012 & 18.04.2012
10.	6th moisture sampling	16.04.2012 & 19.04.2012
11.	Infiltration measurement	31.05.2012 - 04.06.2012
12.	Core sampling of soil for determination of bulk density	11.06.2012

3.8 Observation to be recorded during experiment

Measurement of soil moisture content at different depths (0-15 cm, 15-30 cm, 30-45 cm, 45- 60 cm & 60-75 cm) before sowing, before and after each irrigation and after harvesting of wheat crop.

Bulk density after harvesting of wheat crop.

Infiltration measurement after harvesting of wheat crop.

Grain yield of wheat crop.

3.9 Methodology adopted

Methodologies of various observations recorded during growth period of crop are described below**:**

3.9.1 Soil moisture content

The soil moisture content of soil is usually defined as the amount of water lost when dried at 105^{o}C for about 24 hrs. The soil moisture content was determined by using Gravimetric method. The sampling was done for the soil moisture content before sowing, before and after each irrigation and after harvesting in different plots. Soil samples were taken with the help of screw auger at all desired depths. The soils was thoroughly mixed and then filled into air tight aluminum boxes. The soil samples were weighted and then were dried in an oven at 105^{o}C for about 24 hrs, until all moisture was driven off. After removing from oven they were cooled slowly to room temperature and weight again. Soil moisture content was determined on weight basis by using the following relationship:

$$\text{Soil moisture content} = \frac{W_1 - W_2}{W_2} \times 100 \qquad \text{--(i)}$$

Where,

W_1 – weight of moist soil (g)

W_2 – weight of oven dry soil sample (g)

3.9.2 Sampling procedure for determination of bulk density of the soil

Bulk density of the soil is defined as the weight of the dried soil per unit volume of the undisturbed soil sample. Bulk density of the soil of different treatments was

Plate-1. Collection of soil samples for moisture content measurement

Plate-2. Collection of soil samples for bulk density measurement determined by the method suggested by Blake (1965). Core samples of one each from 0 to 15 cm and 15 to 30 cm soil depths were taken from three locations of each plot. The mean value of the two depths was considered the bulk density of the particular location. The sampling was done with the help of core soil sampler. The cylinder of the core soil sampler, which has its cutting edge, was driven into the soil and an undisturbed soil sample was collected from all the plots. The samples were carefully trimmed at both ends of the core sampler. The soil was removed from the sampler, kept in an aluminum box and then dried in hot air oven at 105^0 C for about 24 hours. The oven dried soil was then weighed. The volume of the soil samples was taken as the inner volume of core cylinder. The inner diameter of the core cylinder was 5.187 cm and height of the core cylinder was 6.5 cm.

Bulk density of samples

$$D_b = M/V \qquad \text{--(ii)}$$

Where,

D_b = Bulk density of soil (g cm^{-3})

M = Mass of the oven dry soil sample (g)

V = Volume of the soil sample (cm^3)

3.9.3 Measurement of infiltration rate

The downward movement of the water from the soil surface in to the soil is called infiltration. Infiltration rate is the soil characteristic determining the rate at which water enters the soil under specific conditions including the presence of excess water. Infiltration rate of soil under different treatment was determined by using Double Ring Infiltrometer method (Bouwer, 1986 & Brouwer *et al*. 1988). In double ring infiltrometer method, two cylinders are used. The inner cylinder was used for infiltration measurement having 30 cm diameter. The outer cylinder of diameter 60 cm was used to form the buffer pond. Both cylinders were marked at the 10 cm level from the lower edge and were driven into the soil up to the mark with the help of falling weight type hammer striking on an iron plate, placed on the top of the cylinders. Both cylinders were also marked at the 5 cm level from the upper edge in the inner side. A piece of polythene sheet was placed inside the inner cylinder and then water was filled in both the cylinders up to the marked level. The polythene sheet was removed with the care so that the soil does not get disturbed. The level of water in the inner cylinder was noted down at different time intervals. After each reading, water level in both the cylinders was brought to the marked level by adding water quickly. The observations were recorded until the rate of infiltration reached almost constant.

3.9.4 Infiltration equation

Based on the observations recorded, infiltration equations were derived for all the eight treatments, to study the infiltration behavior of the soil as influenced by different tillage practices. For the design purposes, the relationship between accumulated infiltration and elapsed time was usually expressed by the following empirical equation, known as modified Kostiakov's equation.

$$y = at^{\alpha} + bt \qquad \text{-- (iii)}$$

Where,

y = accumulated infiltration in time t, cm.

t = elapsed time or infiltration opportunity time, min and

a, α and b = characteristic constants.

3.12 Statistical analysis

The data observed in respect of soil moisture content and bulk density from the field experiment were analyzed statistical. The values of standard error mean (S.Em.(±)) and critical difference (C.D.) at 5% level of significance were determined.

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CHAPTER – IV

RESULTS & DISCUSSION

RESULTS AND DISCUSSION

The present investigation was undertaken to study the Impact of different Tillage Practices on Soil Moisture Variation and Physical Properties of soil in North Bihar.

The results of experiment as influenced by different treatments have been summarized and presented in this chapter with the help of appropriate tables and suitable diagrams. The results are presented in respect of variation of soil moisture content, bulk density of the soil and infiltration rate due to various tillage operations. The infiltration equations as a result of different treatments of tillage have been derived.

4.1 Effect of tillage practices on soil moisture content

As a result of various tillage operations the physical properties of the soil get affected. To study the impact of these tillage operations on the soil moisture content, soil samples at different depths of 0 to 15, 15 to 30, 30 to 45, 45 to 60 and 60 to 75 cm were taken before sowing, before and after each irrigation and after harvesting of wheat crop from all the plots. The observations recorded during the course of investigation are presented in Appendix-B.

4.1.1 Soil moisture content before sowing of wheat crop

The data were statistically analyzed and have been presented in Table 4.1 and graphically represented in Fig.1

The mean values of soil moisture content before sowing at 0 to 15, 15 to 30, 30 to 45, 45 to 60 and 60 to 75 cm depths vertically down ward varied from 20.11 per cent to 24.29 per cent, 18.86 to 22.22 per cent, 20.12 to 25.53 per cent, 22.23 to 27.81 per cent and 25.15 to 28.66 per cent, respectively. Among all the treatments the highest values of soil moisture content at different depths were observed in treatment T_3 (rice and wheat on permanent beds with crop residue). At 0 to 15 cm soil depth, treatment T_3 (rice and wheat on permanent beds with crop residue) was found significantly superior to treatments T_1 (PTR + CTW), T_2 (PTR + ZTW), T_4 (ZTR + CTW), T_5 (ZTR + CTW – R), T_7 (UPTR + ZTW only rice residue) and T_8 (ZTR with BM + ZTW). However, T_3 was found statistically at par with T_6 (ZTR + ZTW + R). At 15 to 30 cm depth, treatment T_3 (rice and wheat on permanent beds with crop residue) was significantly superior to treatments T_1, T_2 and T_4 but was at par with treatments T_5, T_6, T_7 and T_8.

Table 4.1. Mean soil moisture content at different depth before sowing as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15cm	15-30cm	30-45cm	45-60cm	60-75cm
T_1	20.11	18.86	20.12	22.23	25.15
T_2	21.47	20.25	23.89	24.97	26.25
T_3	24.29	22.22	25.53	27.81	28.66
T_4	20.97	19.67	20.59	23.01	26.13
T_5	22.42	20.62	24.01	25.52	26.29
T_6	23.93	22.11	25.21	27.50	28.18
T_7	22.47	21.31	24.96	25.63	26.68
T_8	22.96	21.53	25.16	26.13	26.98
SEm (±)	0.43	0.55	0.49	0.51	0.58
C.D. at 5%	1.31	1.69	1.50	1.54	1.76

At 30 to 45 cm treatment T_3 was significantly superior to treatments T_1, T_2, T_4 and T_5 and was statistically at par with treatments T_6, T_7 and T_8. At 45 to 60 cm soil depths, treatment T_3 was significantly superior to tillage treatments T_1, T_2, T_4, T_5, T_7 and T_8 but was statistically at par with T_6 (ZTR + ZTW + R) and at 60 to 75 cm soil depth treatment T_3 was significantly superior to tillage treatments T_1, T_2, T_4, T_5 and T_7 but was statistically at par with T_6 (ZTR + ZTW + R) and T_8 (ZTR with BM + ZTW). The lowest values of soil moisture content were observed in T_1 (PTR + CTW) at all the depths. This signifies the ill effects of intensive tillage and puddling because puddling breaks the soil aggregates and reduces the water transmission through pores. Similar results were also observed by Bodman and Rubin (1948), Sharma and De Datta (1986) and Acharya and Sood (1992). They also reported that puddling breaks the soil aggregates and peds into fine plastic mud thereby, practically eliminating the water transmission (macro) pores.

In general the soil moisture content at 0 to 15 cm soil depth in different treatments followed the sequence: T_1 (20.11 %) < T_4 (20.97 %) < T_2 (21.47 %) < T_5 (22.42 %) < T_7 (22.47%) < T_8 (22.96%) < T_6 (23.93%) < T_3 (24.29%). Similar trend of soil moisture content at all depths in all treatments was recorded. Soil moisture content in 15 to 30 cm depth was found minimum in comparison to other depths in all treatments. This may be due to more compaction of the soil of this layer due to tillage operations.

4.1.2 Soil moisture content before first irrigation of wheat crop

The data pertaining to soil moisture content at different depths before first irrigation have been presented in Table 4.2 and graphically represented in Fig. 2.

Table 4.2. Mean Soil moisture content at different depths before first irrigation as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15	15-30	30-45	45-60	60-75
T_1	20.08	18.56	20.04	22.01	25.07
T_2	21.36	20.24	23.82	24.91	26.01
T_3	23.87	22.01	25.32	27.62	28.12
T_4	20.86	19.43	20.39	23.00	25.96
T_5	22.38	20.42	23.98	25.48	26.13
T_6	23.67	21.48	25.20	27.49	27.88
T_7	22.41	21.11	25.02	25.61	26.19
T_8	22.76	21.18	25.12	25.87	26.76
SEm (±)	0.61	0.57	0.59	0.50	0.55
C.D. at 5%	1.84	1.72	1.82	1.52	1.68

Perusal of data in Table 4.2 indicates that tillage treatments influenced the soil moisture content significantly at all the depths. The mean values of soil moisture content before first irrigation at the depth of 0 to 15 cm, 15 to 30 cm, 30 to 45 cm, 45 to 60 cm and 60 to 75 cm were in the range obtained of 20.08 to 23.87 per cent, 18.56 to 22.01 per cent, 20.04 to 25.32 per cent, 22.01 to 27.62 per cent and 25.07 to 28.12 per cent, respectively. In all the treatments, the highest value of soil moisture content of 23.87 per cent, 22.01 per cent, 25.32 per cent, 27.62 and 28.12 per cent were observed at different soil depths, vertically down ward in treatment T_3. At 0 to 15 cm and 15 to 30 cm soil depth T_3 was significantly superior to treatments T_1, T_2 and T_4 but statistically at par with treatments T_5, T_6, T_7 and T_8. At 30 to 45 cm soil depth, treatment T_3 was significantly superior to treatments T_1 and T_4 and statistically at par with treatments T_2, T_5, T_6, T_7 and T_8; at 45 to 60 cm soil depth treatment T_3 was significantly superior to all treatments except treatment T_6 (ZTR + ZTW + R) and at 60

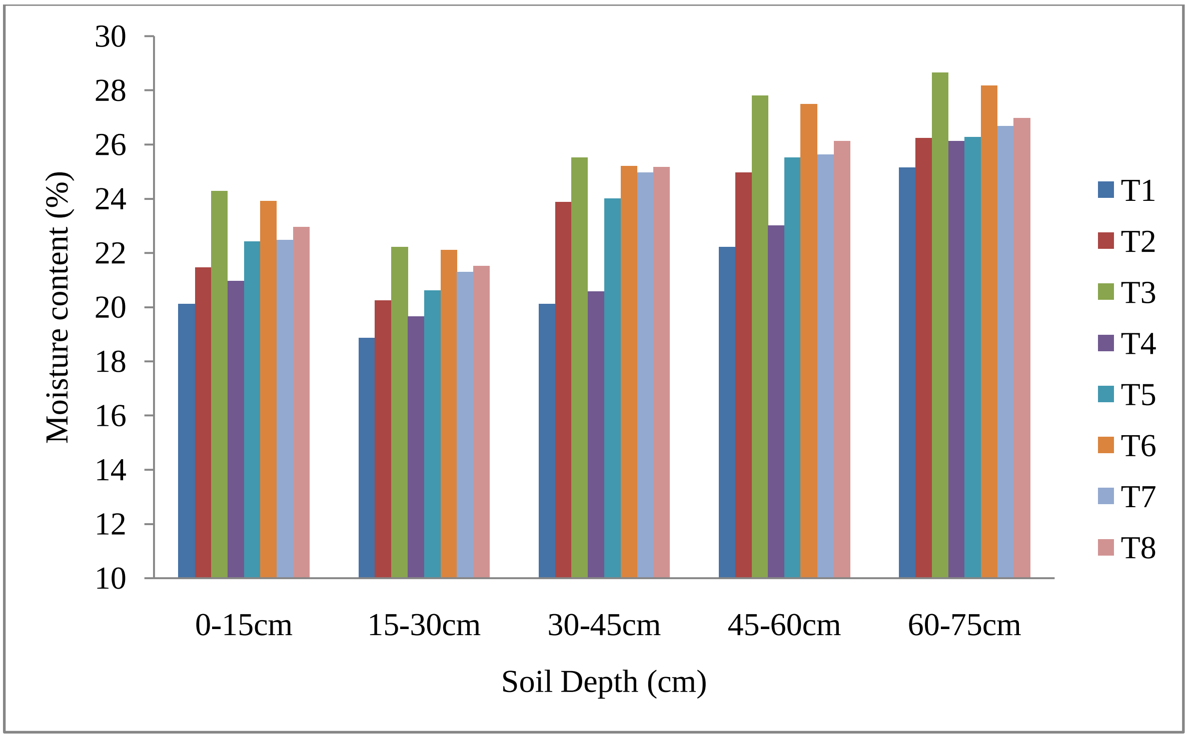

Fig. 1. Soil moisture content at different depth before sowing as affected by different treatments

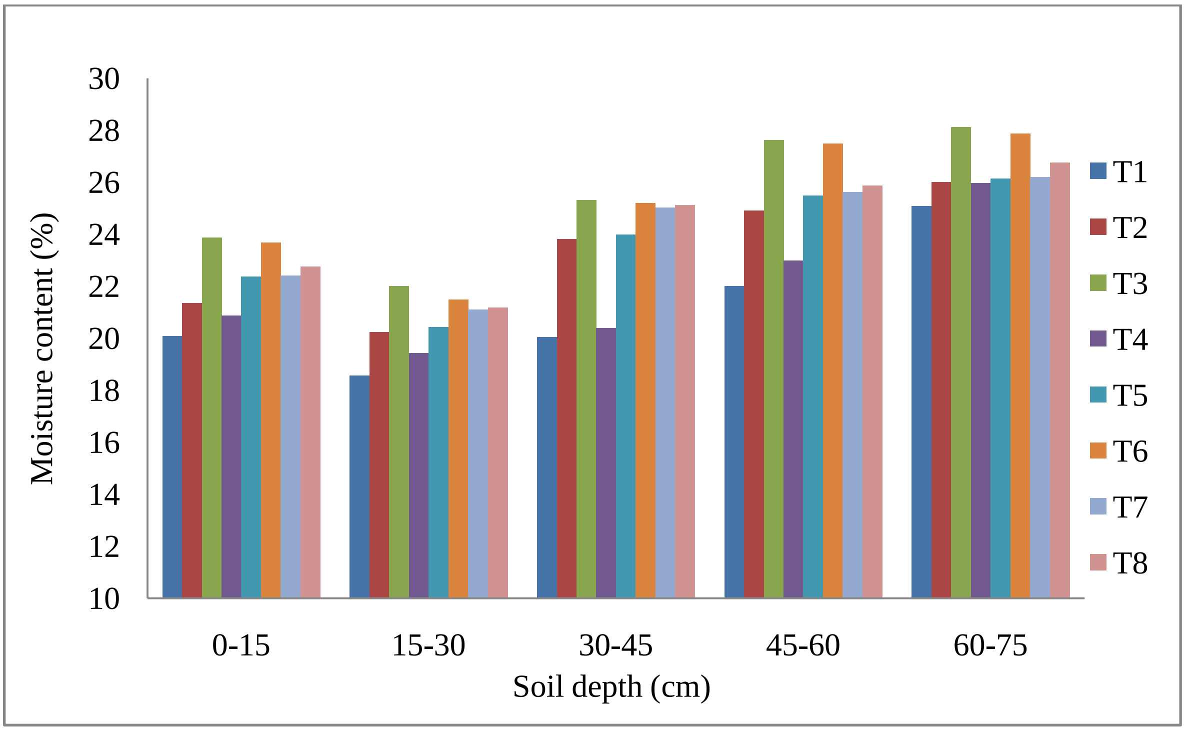

Fig. 2. Soil moisture content at different depths before first irrigation as affected by different treatments

to 75 cm soil depth treatment T_3 was also significantly superior to all treatments except treatment T_6 and T_8. This signifies the importance of permanent beds and crop residue incorporation. Similar results were also observed by Anikwe *et al.* (2007) who reported that mulching the soil surface favorably improves soil moisture content. The lowest values of soil moisture content of 20.08, 18.56, 20.04, 22.01 and 25.07 percent were recorded in the treatment T_1 (PTR + CTW) at all different depths, vertically downward.

In general the soil moisture content at soil depth 0 to 15 cm in different treatments followed sequence: T_1 (20.08 %) < T_4 (20.86 %) < T_2 (21.36 %) < T_5 (22.38%) < T_7 (22.41 %) < T_8 (22.76 %) < T_6 (23.67 %) < T_3 (23.87 %). Similar trend of soil moisture content among treatments were recorded at all depths. Soil moisture content in 15-30 cm soil depth was minimum in comparison to other depths in all treatments. This may be due to more compaction of soil at this depth.

4.1.3 Soil moisture content after first irrigation of wheat crop

Data on soil moisture content at different depths from all the plots, recorded after first irrigation have been presented in Table 4.3 and graphically depicted in Fig.3

Table 4.3. Mean soil moisture content at different depths after first irrigation as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15	15-30	30-45	45-60	60-75
T_1	26.12	25.07	27.46	27.79	27.96
T_2	26.23	25.11	27.66	27.96	28.13
T_3	28.26	26.29	28.28	28.78	29.23
T_4	26.21	25.09	27.53	27.82	28.02
T_5	26.82	25.14	27.83	28.01	28.23
T_6	28.18	26.17	28.21	28.75	29.09
T_7	26.87	25.96	28.02	28.43	28.75
T_8	26.98	25.99	28.19	28.54	28.98
SEm (±)	0.52	0.56	0.52	0.46	0.58
C.D. at 5%	NS	NS	NS	NS	NS

The effects of different tillage practices were non-significant on all soil depths on soil moisture content after first irrigation in all treatments. The mean values of soil moisture content after first irrigation at different depths vertically downward were found in the range of 26.12 to 28.26, 25.07 to 26.29, 27.46 to 28.28, 27.79 to 28.78 and 27.96 to 29.23 percent, respectively. Among all the treatments the highest values of soil moisture content of 28.26, 26.29, 28.28, 28.78 and 29.23 percent at all depths were found in treatment T_3 (rice and wheat on permanent beds with crop residue). The statistical analysis of the data showed no significant difference in soil moisture content due to different treatments because the soil was nearly at saturation level at this time. The lowest values of moisture content of 26.12, 25.07, 27.46, 27.79 and 27.96 percent were recorded at different depths in treatment T_1 (PTR + CTW).

In general the soil moisture content at 0 to 15 cm soil depth in different treatments followed the sequence: T_1 (26.12 %) < T_4 (26.21 %) < T_2 (26.23 %) < T_5 (26.82 %) < T_7 (26.87%) < T_8 (26.98%) < T_6 (28.18%) < T_3 (28.26%). Similar trend of soil moisture content among treatments was recorded at depths 15 to 30, 30 to 45, 45 to 60 and 60 to75 cm. The soil moisture content increased with depth except to 15 to 30 cm soil depth in all treatments.

4.1.4 Soil moisture content before second irrigation of wheat crop

The data related to soil moisture content before second irrigation as influenced by various treatments have been presented in Table 4.4 and graphically represented in Fig.4.

Table 4.4. Mean soil moisture content at different depths before second irrigation as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15	15-30	30-45	45-60	60-75
T_1	20.97	18.76	20.23	22.28	25.58
T_2	21.53	20.98	24.21	25.55	26.43
T_3	24.32	22.21	25.84	27.92	28.81
T_4	21.01	19.81	20.62	23.31	26.41
T_5	22.91	20.99	24.90	25.96	26.56
T_6	23.96	22.20	25.64	27.31	28.22
T_7	22.97	21.11	25.47	25.97	26.58
T_8	23.01	21.61	25.53	26.21	26.99
SEm (±)	0.52	0.59	0.55	0.56	0.61
C.D. at 5%	1.57	1.78	1.65	1.69	1.85

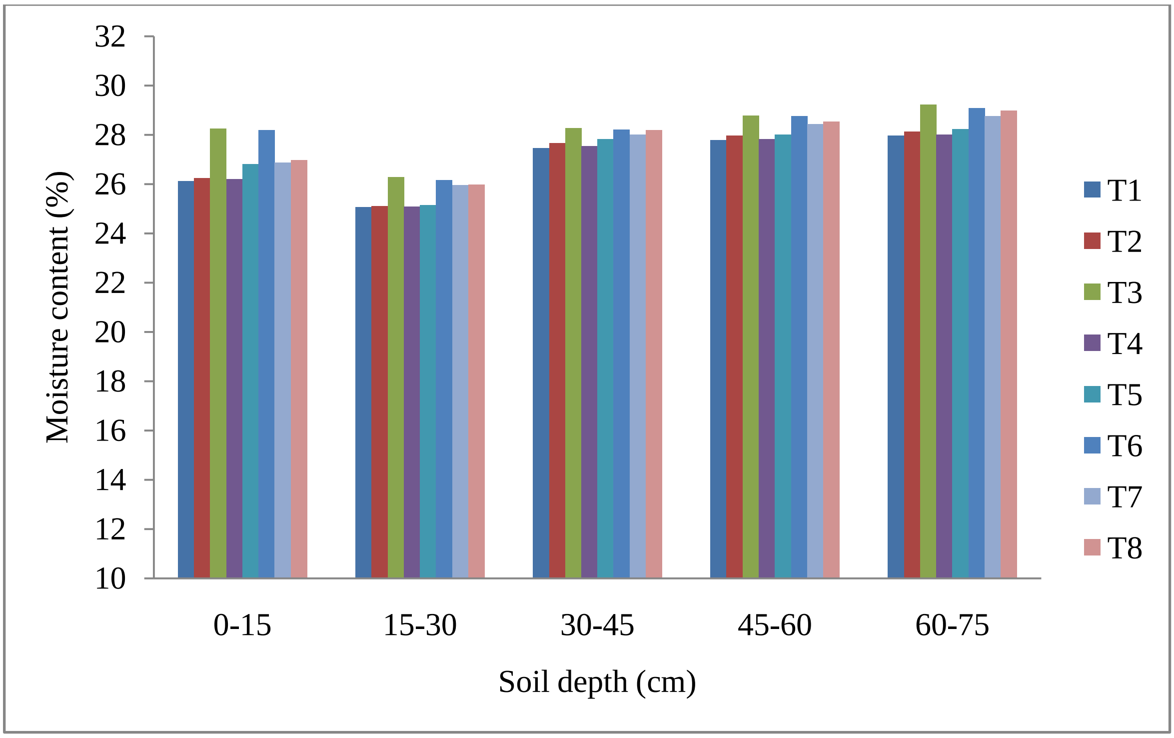

Fig. 3. Soil moisture content at different depths after first irrigation as affected by different treatments

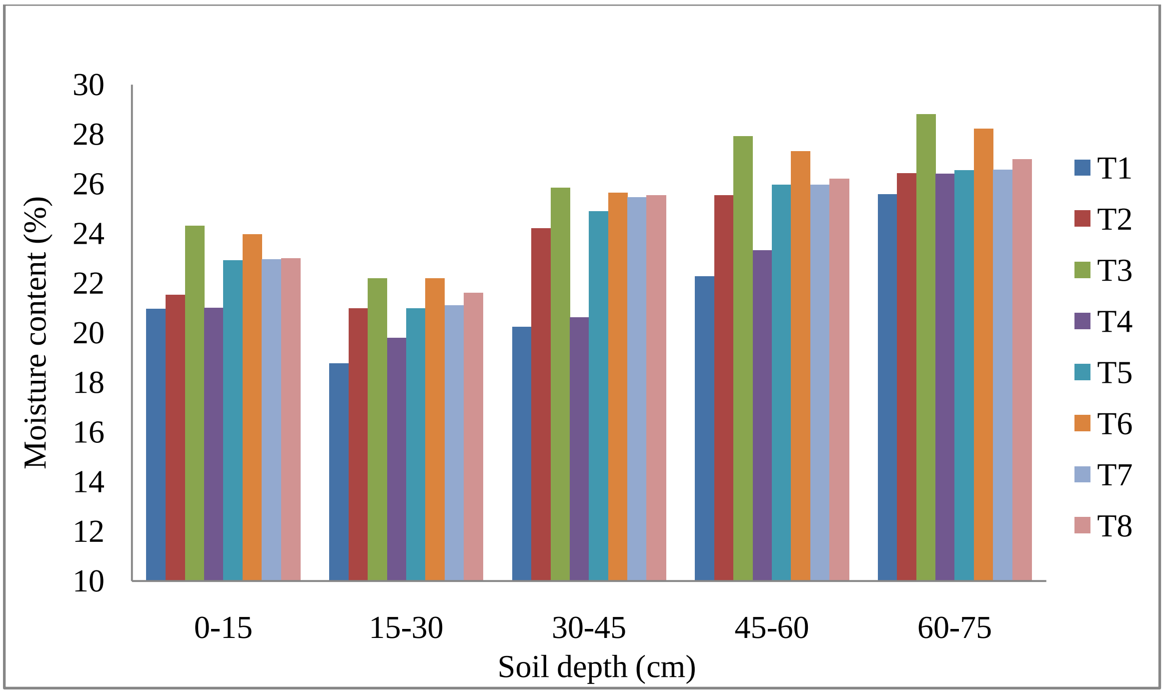

Fig. 4. Soil moisture content at different depths before second irrigation as affected by different treatments

The soil moisture content before second irrigation was significantly influenced by different tillage practices at all different soil. The mean values of soil moisture content before second irrigation at the depths of 0 to 15, 15 to 30, 30 to 45, 45 to 60 and 60 to 75 cm were found in the range of 20.97 to 24.32 per cent, 18.76 to 22.21 per cent, 20.23 to 25.84 per cent, 22.28 to 27.92 per cent and 25.58 to 28.81 per cent, respectively. In all treatments the highest value of soil moisture content of 24.32 per cent, 22.21 per cent, 25.84 per cent, 27.92 per cent and 28.81 per cent were found at different depths vertically downward in treatment T_3 (rice and wheat on permanent beds with crop residue). At 0 to 15 cm depth treatment T_3 was significantly superior to treatments T_1 (PTR + CTW), T_2 (PTR + ZTW) and T_4 (ZTR + CTW) and statistically at par with T_5 (ZTR + ZTW - R), T_6 (ZTR + ZTW with crop residue), T_7 (UPTR + ZTR only rice) and T_8 (ZTR with BM + ZTW); At 15 to 30 cm and 30 to 45 cm soil depth, treatment T_3 was significantly superior to T_1 and T_4 and statistically at par with T_2, T_5, T_6, T_7 and T_8. At 45 to 60 cm soil depth, treatment T_3 was significantly superior to all treatments except T_6 (ZTR + ZTW + R) and at 60 to 75 cm soil depth, treatment T_3 was significantly superior to all treatments but statistically at par with treatment T_6 and T_8. This signifies the importance of permanent beds and incorporation of crop residue. Similar results were observed by Kumar and Goh (2000) who reported that the efficient crop residue management strives for improved crop yield by increasing soil moisture availability, decreasing erosion, improving soil structure and increasing soil water holding capacity. The lowest value of soil moisture content of 20.97 per cent, 18.76 per cent, 20.23 per cent, 22.28 and 25.58 per cent were found in treatment T_1 (PTR + CTW) at all soil depths vertically downward, respectively.

In general the soil moisture content at 0 to 15 cm soil depth in different treatments followed the order: T_1 (20.97 %) < T_4 (21.01 %) < T_2 (21.53 %) < T_5 (22.91%) < T_7 (22.97%) < T_8 (23.01%) < T_6 (23.96%) < T_3 (24.32%). Similar trend was of soil moisture content among treatments was recorded at all other soil depths. The soil moisture content at depth 15 to 30 cm was minimum in comparison to other depths in all the treatments. This may be due to more compaction of 15-30 cm soil depth.

4.1.5 Soil moisture content after second irrigation of wheat crop

The data generated in respect of different tillage treatments at different soil depths of 0 to 15, 15 to 30, 30 to 45, 45 to 60 and 60 to 75 cm have been presented in Table 4.5 and graphically illustrated in Fig.5.

Table 4.5. Mean soil moisture content at different depths after second irrigation as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15	15-30	30-45	45-60	60-75
T_1	26.22	25.12	27.55	27.86	28.19
T_2	26.53	25.29	27.61	28.02	28.57
T_3	28.31	26.37	28.29	28.89	29.53
T_4	26.23	25.21	27.59	27.88	28.32
T_5	26.83	25.32	27.67	28.05	28.97
T_6	28.21	26.28	28.26	28.82	29.24
T_7	26.89	25.98	28.22	28.47	28.99
T_8	26.99	26.01	28.23	28.57	29.19
SEm (±)	0.52	0.59	0.55	0.59	0.59
C.D. at 5%	NS	NS	NS	NS	NS

The mean values of soil moisture content after second irrigation at the soil depths 0 to 15, 15 to 30, 30 to 45, 45 to 60 and 60 to 75 cm varied in the range of 26.22 to 28.31 per cent, 25.12 to 26.37 per cent, 27.55 to 28.29 per cent, 27.86 to 28.89 per cent and 28.19 to 29.53 per cent, respectively. The statistical analysis of the data showed non - significant difference in soil moisture content due to different treatments. The highest value of soil moisture content of 28.31 per cent, 26.37 per cent, 28.29 per cent, 28.89 per cent and 29.53 per cent were found in treatment T_3 (rice and wheat on permanent beds with crop residue) and the lowest value of soil moisture content of 26.22 per cent, 25.12 per cent, 27.55 per cent, 27.86 and 28.18 per cent were recorded in T_1 (PTR + CTW) at all depth of soil.

In general, the soil moisture contents at 0 to 15 cm in all treatments followed the order: T_1 (26.22 %) < T_4 (26.23 %) < T_2 (26.53 %) < T_5 (26.83 %) < T_7 (26.89%) < T_8 (26.99%) < T_6 (28.21%) < T_3 (28.31%). Similar trends were observed on soil moisture content at all soil depths. Soil moisture content increased with depth except at 15 to 30cm soil depth in all treatments. This may be due to more compaction of 15 to 30 cm soil depth.

4.1.6 Soil moisture content after harvesting of wheat crop

The observations recorded in respect of different soil depth from all treatments after harvesting of wheat crop have been presented in Table 4.6 and graphically represented in Fig.6.

Table 4.6. Mean soil moisture content at different depths after harvesting as affected by different treatments

Treatment	Mean moisture content (%)				
	0-15	15-30	30-45	45-60	60-75
T_1	20.01	18.57	20.10	22.12	25.04
T_2	21.33	20.13	23.68	24.85	26.18
T_3	24.13	22.03	25.23	27.23	28.56
T_4	20.57	19.52	20.43	22.76	25.99
T_5	22.32	20.56	24.00	25.17	26.23
T_6	23.89	22.01	25.01	26.99	28.01
T_7	22.39	21.11	24.13	25.47	26.72
T_8	22.66	21.33	24.98	26.11	26.78
SEm (±)	0.51	0.55	0.48	0.51	0.46
C.D. at 5%	1.54	1.67	1.44	1.53	1.41

The perusal of data (Table 4.6) reveals that the soil moisture content at different depths varied significantly in all the treatments after harvesting of crop. The mean values of soil moisture content varied significantly from 20.01 to 24.13 per cent, 18.57 to 22.03 per cent, 20.10 to 25.23 per cent, 22.12 to 27.23 per cent and 25.04 to 28.56 per cent, respectively with soil depth vertically downward after harvesting of the crop. In all the treatments, T_3 (rice and wheat on permanent beds with crop residue) was significantly superior to all treatments except T_6 (ZTR + ZTW + R) and T_8 (ZTR with BM + ZTW) at 0 to 15 cm and 45 to 60 cm soil depth; at 15 to 30 cm and 30 to 45 cm soil depth T_3 (rice and wheat on permanent beds with crop residue) was significantly superior to T_1 (PTR + CTW), T_2 (PTR + ZTW) and T_4 (ZTR + CTW) while statistically at par with T_5 (ZTR + ZTW - R), T_6 (ZTR + ZTW + R), T_7 (UPTR + ZTW, only rice residue) and T_8 (ZTR with BM + ZTW) and at 60 to 75 cm soil depth, T_3 was significantly superior to all treatments except T_6.

In general soil moisture content at 0 to 15 cm soil depth in different treatments followed sequence: T_1 (20.01 %) < T_4 (20.57 %) < T_2 (21.33 %) < T_5 (22.32 %) < T_7 (22.39%) < T_8 (22.66%) < T_6 (23.89%) < T_3 (24.13%). Similar trend of soil moisture content among treatments was recorded at all other soil depths. Soil moisture content at 15 to 30 cm soil depth was found minimum as compared to other soil depths in all treatments. This may be due to more compaction of 15 to 30 cm soil depth.

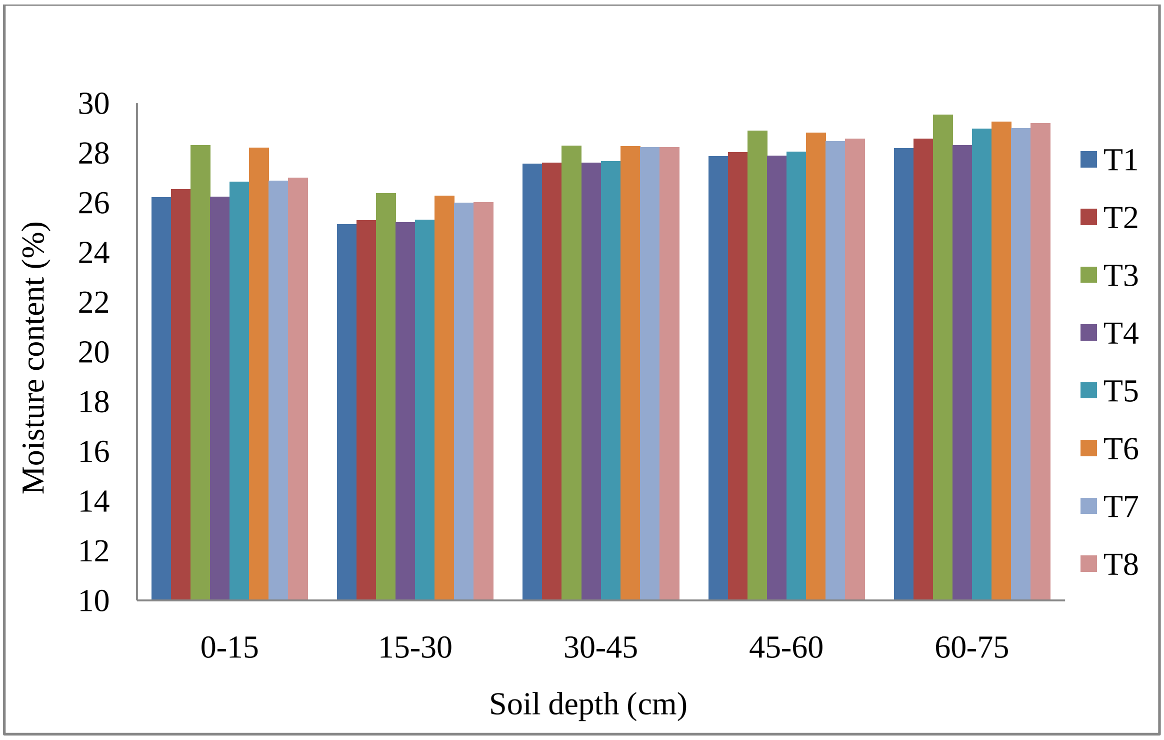

Fig. 5. Soil moisture content at different depths after second irrigation as affected by different treatments

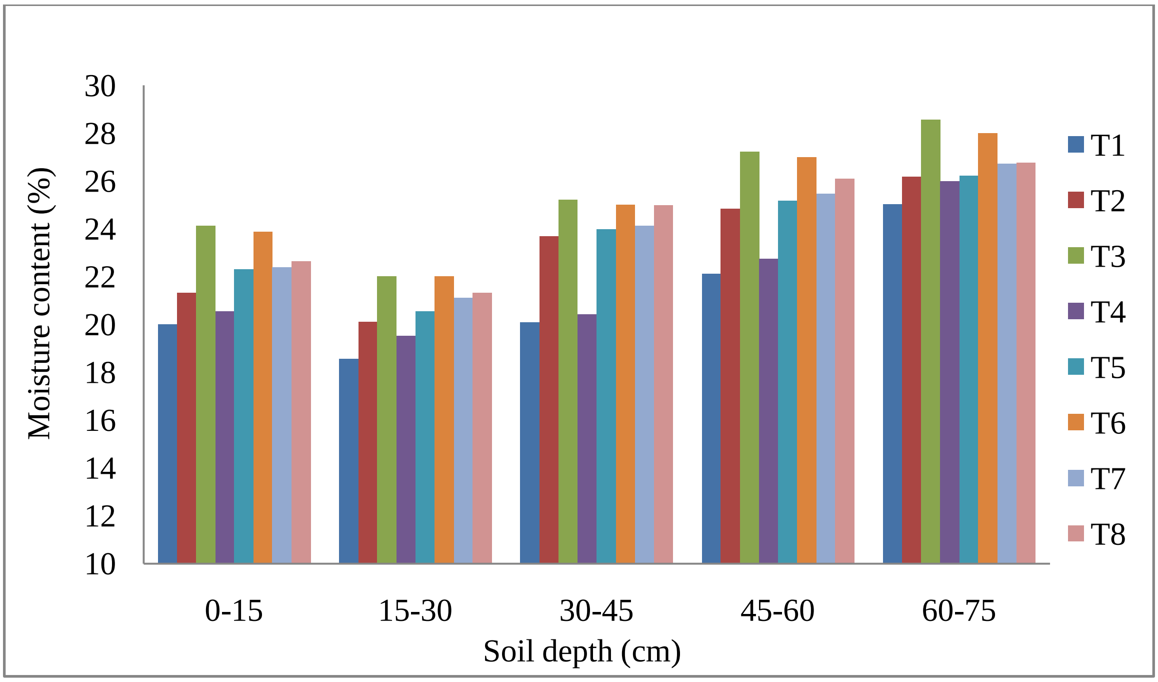

Fig. 6. Soil moisture content at different depths after harvesting as affected by different treatments

At all depths T_3 (rice and wheat on permanent beds with crop residue) had highest soil moisture content. This signifies the good effect of permanent bed and crop residue. Similar results were observed by Karlen *et al.* (1994) who reported that the mulch helped to promote more stable soil aggregate as a result of increased microbial activity and better protection of soil surface. Similar results were also observed by Deshpande and Durgude (2012) who showed that for long term (10 yrs.) aggregate stability increased by using more mulch, water filled pore spaces increased.

4.2 Effect of tillage practices on bulk density of the soil

Undisturbed core samples from three locations in each plot were taken after harvesting of wheat crop, for estimation of the effect of tillage operations on bulk density of the soil. The data pertaining to bulk density have been presented in Table 4.7 and graphically represented in Fig.7.

Table 4.7. Mean bulk density of soil as affected by different treatments

Treatment	Bulk density (g cm^{-3})
T_1	1.55
T_2	1.53
T_3	1.47
T_4	1.51
T_5	1.52
T_6	1.44
T_7	1.49
T_8	1.51
SEm (±)	0.02
C.D. at 5%	0.05

The perusal of data reveals that tillage has significant effect on bulk density of the soil. The mean values of bulk density varied from 1.44 g cm^{-3} to 1.55 g cm^{-3}. The highest value of bulk density of 1.55 g cm^{-3} was recorded under T_1 (PTR + CTW) which was significantly higher to treatment T_3 (rice and wheat on permanent beds with crop residue), T_6 (ZTR + ZTW + R) and T_7 (UPTR + ZTR only rice) and was statistically at par with T_2 (PTR + ZTW), T_4 (ZTR + CTW), T_5 (ZTR + ZTW - R) and T_8 (ZTR with BM + ZTW). This may be due to puddling and ill effect of intensive tillage. Similar results were also observed by Bolton and Datta (1979); Bhagat and Acharya (1987) and Prihar *et al.* (1990), who reported that puddle soil shrink on

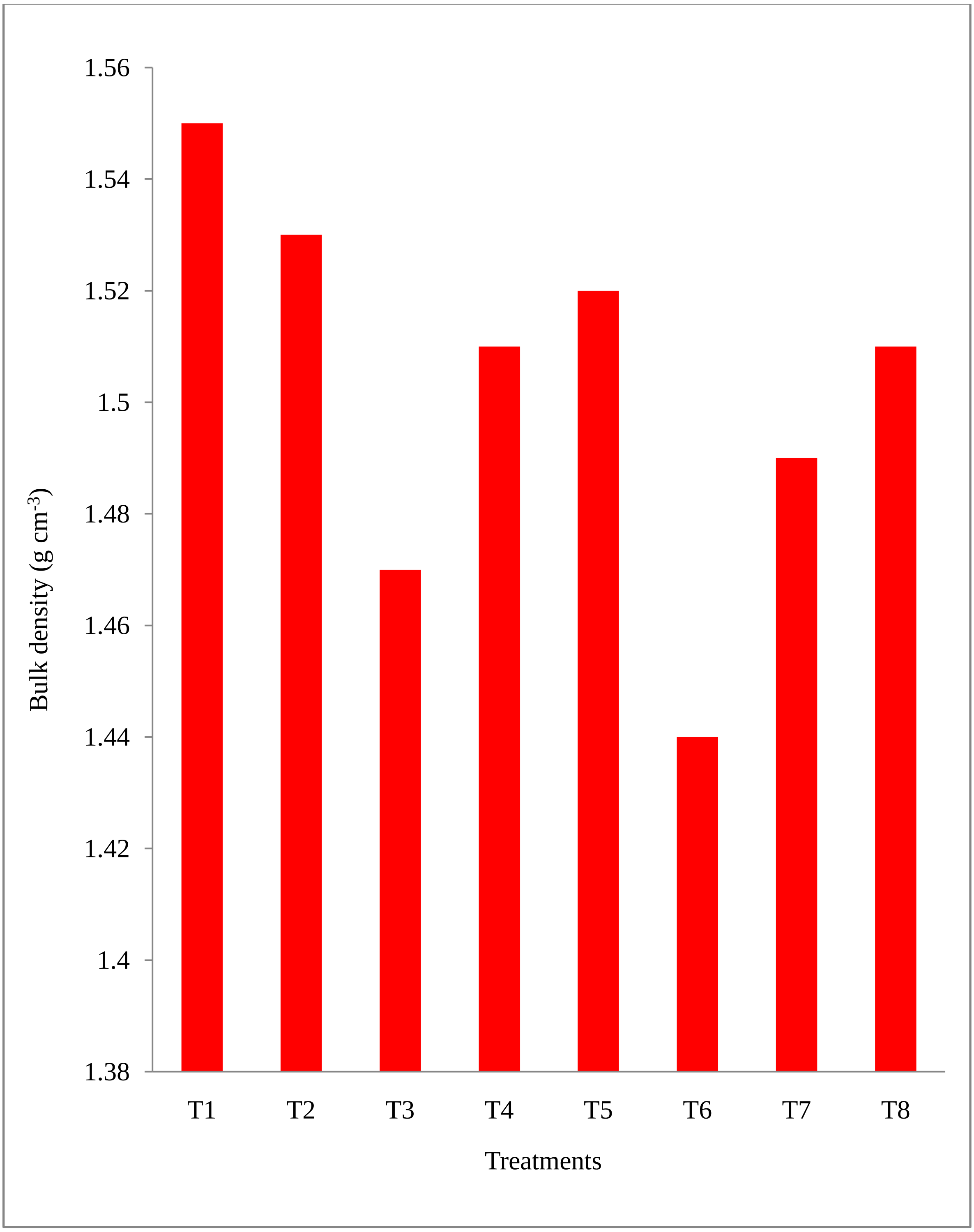

Fig. 7. Bulk density of soil as affected by different treatments

drying, become compact, hard and produce surface fissures in size, depth and pattern. The lowest value of bulk density of 1.44g cm^{-3} was observed in treatment T_6 (ZTR + ZTW with crop residue) which was significantly lower over all other tillage treatments reflecting the importance of zero tillage and crop residue incorporation. Similar results were also observed by Carman (1997). Kumar (2000) also reported that increasing the number of tillage operation, decreases dry bulk density of the soil.

4.3 Effect of tillage practices on infiltration characteristics of the soil

To study the effect of different conservation tillage practices on the infiltration characteristics of the soil, infiltration measurement was done using double cylinder infiltrometer in each plot after harvesting of the wheat crop. The data recorded during course of infiltration study has been presented in Table 4.8. The observations were taken from eight different treatments and the values of infiltration rate and accumulated or cumulative infiltration computed from the observed data as affected by different tillage practices for wheat crop are presented in Table 4.8.

Table 4.8(a). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_1

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	1.10	13.20	1.10
10	5	o.80	9.60	1.90
15	5	0.60	7.20	2.50
20	5	0.30	3.60	2.80
25	5	0.20	2.40	3.00
30	5	0.16	1.92	3.16
45	15	0.25	1.00	3.41
60	15	0.22	0.88	3.63
75	15	0.20	0.80	3.83
105	30	0.34	0.68	4.17
135	30	0.32	0.64	4.49
165	30	0.30	0.60	4.79
225	60	0.28	0.28	5.07
285	60	0.28	0.28	5.35
345	60	0.28	0.28	5.63

Table 4.8(b). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_2

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.92	11.04	0.92
10	5	0.69	8.28	1.61
15	5	0.56	6.72	2.17
20	5	0.47	5.64	2.64
25	5	0.40	4.80	3.04
30	5	0.34	4.08	3.38
45	15	0.39	5.00	3.77
60	15	0.35	1.40	4.12
75	15	0.32	1.28	4.44
105	30	0.37	0.74	4.81
135	30	0.33	0.66	5.14
165	30	0.28	0.56	5.42
225	60	0.32	0.32	5.74
285	60	0.32	0.32	6.06
345	60	0.32	0.32	6.38

Table 4.8(c). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_3

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.90	10.80	0.9
10	5	0.70	8.40	1.60
15	5	0.62	7.44	2.22
20	5	0.58	6.96	2.80
25	5	0.46	5.52	3.26
30	5	0.42	5.04	3.68
45	15	0.60	2.40	4.28
60	15	0.50	2.00	4.78
75	15	0.42	1.68	5.2
105	30	0.52	1.04	5.72
135	30	0.47	0.94	6.19
165	30	0.40	0.80	6.59
225	60	0.55	0.55	7.14
285	60	0.55	0.55	7.69
345	60	0.55	0.55	8.24

Table 4.8 (d). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_4

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.89	10.68	0.89
10	5	0.68	8.16	1.57
15	5	0.54	6.48	2.11
20	5	0.44	5.28	2.55
25	5	0.38	4.56	2.93
30	5	0.34	4.08	3.27
45	15	0.46	1.84	3.73
60	15	0.36	1.44	4.09
75	15	0.30	1.20	4.39
105	30	0.38	0.76	4.77
135	30	0.35	0.70	5.12
165	30	0.32	0.64	5.44
225	60	0.30	0.30	5.74
285	60	0.30	0.30	6.04
345	60	0.30	0.30	6.34

Table 4.8(e). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_5

Elapsed time (minute)	Time interval (minute)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.11	13.20	1.10
10	5	0.70	8.40	1.80
15	5	0.50	6.00	2.30
20	5	0.33	3.96	2.63
25	5	0.22	2.64	2.85
30	5	0.16	1.92	3.01
45	15	0.48	1.92	3.49
60	15	0.39	1.56	3.88
75	15	0.33	1.32	4.21
105	30	0.48	0.96	4.69
135	30	0.34	0.68	5.03
165	30	0.31	0.62	5.34
225	60	0.35	0.35	5.69
285	60	0.35	0.35	6.04
345	60	0.35	0.35	6.39

Table 4.8(f). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_6

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.90	10.8	0.90
10	5	0.76	9.12	1.66
15	5	0.59	7.08	2.25
20	5	0.48	5.76	2.73
25	5	0.37	4.44	3.10
30	5	0.29	3.48	3.39
45	15	0.42	1.68	3.81
60	15	0.37	1.48	4.18
75	15	0.34	1.36	4.52
105	30	0.45	0.90	4.97
135	30	0.45	0.90	5.42
165	30	0.45	0.90	5.87
225	60	0.48	0.48	6.35
285	60	0.48	0.48	6.83
345	60	0.48	0.48	7.31

Table 4.8(g). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_7

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	0.80	9.60	0.80
10	5	0.53	6.36	1.33
15	5	0.42	5.04	1.75
20	5	0.37	4.44	2.12
25	5	0.33	3.96	2.45
30	5	0.28	3.36	2.73
45	15	0.42	1.68	3.15
60	15	0.35	1.40	3.50
75	15	0.30	1.20	3.80
105	30	0.46	0.92	4.26
135	30	0.43	0.86	4.69
165	30	0.41	0.82	5.10
225	60	0.45	0.45	5.55
285	60	0.45	0.45	6.00
345	60	0.45	0.45	6.45

Table 4.8(h). Infiltration rate and accumulated infiltration at different time interval after harvesting of wheat crop in treatment T_8

Elapsed time (min.)	Time interval (min.)	Infiltrated depth (cm)	Infiltration rate (cm hr^{-1})	Accumulated depth (cm)
0	0	0	—	—
5	5	1.10	13.20	1.10
10	5	0.72	8.64	1.82
15	5	0.50	6.00	2.32
20	5	0.40	4.80	2.72
25	5	0.23	2.76	2.95
30	5	0.15	1.80	3.10
45	15	0.47	1.88	3.57
60	15	0.40	1.60	3.97
75	15	0.27	1.08	4.24
105	30	0.48	0.96	4.72
135	30	0.34	0.68	5.06
165	30	0.32	0.64	5.38
225	60	0.36	0.36	5.74
285	60	0.36	0.36	6.10
345	60	0.36	0.36	6.46

On the basis of end time infiltration rate different treatments may be arranged in order: T_1 (0.28 cm h^{-1}) < T_4 (0.30 cm h^{-1}) < T_2 (0.32 cm h^{-1}) < T_5 (0.35 cm h^{-1}) < T_8 (0.36 cm h^{-1}) < T_7 (0.45 cm h^{-1}) < T_6 (0.48 cm h^{-1}) < T_3 (0.55 cm h^{-1}) while on the basis of accumulated infiltration the treatments may be arranged in the order: T_1 (5.63 cm) < T_4 (6.34 cm) < T_2 (6.38 cm) < T_5 (6.39 cm) < T_7 (6.45 cm) < T_8 (6.46 cm h^{-1}) < T_6 (7.31 cm) < T_3 (8.24 cm).

Highest value of end time (345 minutes) infiltration rate of 0.55 cm h^{-1} and accumulated infiltration of 8.24 cm were observed in treatment T_3 (rice and wheat on permanent beds with crop residue) followed by T_6 (ZTR + ZTW + R), T_7 (UPTR + ZTW + only rice residue) and T_8 (ZTR + BM + ZTW) which signifies the importance of permanent bed and crop residue incorporation. Infiltration characteristics of the soil depend on the size distribution, geometry, continuity and stability of the soil pores. Water transmission through the soil profile also depends on the soil moisture content, bulk density i.e. aggregation and the presence of macro pore channels (Shaver *et al*., 2002). Similar results were also observed by Walia *et al.* (1995) and Singh *et al*. (1996) who reported that in long term experiment in the rice – wheat cropping system in sandy loam soil, the incorporation of both rice and wheat straw compared with their removal increased both infiltration rate and accumulated infiltration by modifying mainly soil structure, proportion of macro pores and aggregate stability. These increases have been observed in treatments where crop residues were retained on the soil surface or incorporated by conventional tillage. Jones and Singh (2000) also reported that mulching the soil surface favorably improved infiltration, Jat *et al.* (2009) also reported that the steady state infiltration rate and soil aggregation (30.25 mm) were higher under permanent beds and double zero tillage and lower in conventional tillage system. The higher steady infiltration rate also observed in T_6 (ZTR + ZTW + R) may be due to higher soil organic carbon (SOC) and lower bulk density (Table 4.7) and also due to minimum distribution that maintained the continuity of water conducting pores.

On the basis of data recorded during infiltration test (Table 4.8) infiltration equations were derived for different treatments. It is evident from Fig.8. That equation, representing the modified Kostiakov's equation is in conformity of the observations recorded during the experimentation. These equations derived for different treatments have been presented with Fig.-8. and values of a, b, alpha and R^2 are shown in Table 4.9.

Table 4.9 Value of parameters of modified Kostiakov's equation

Treatment	a	b	α	R^2
T1	0.9044	-0.00615	0.36498	0.986213
T2	0.633755	-0.0185	0.510958	0.98896
T3	0.579708	-0.02567	0.576471	0.995813
T4	0.589491	-0.02041	0.531779	0.990997
T5	0.686147	-0.01139	0.46184	0.996933
T6	0.647528	-0.01314	0.49479	0.991784
T7	0.470853	-0.01275	0.534858	0.99606
T8	0.717256	-0.01094	0.452569	0.995685

The values of the parameter b are negative and very close to zero, hence may be neglected. This derived equation takes the form of Kostiakov's equation. The coefficient of determination (R^2) values shows a close agreement with the observed data in all the cases.

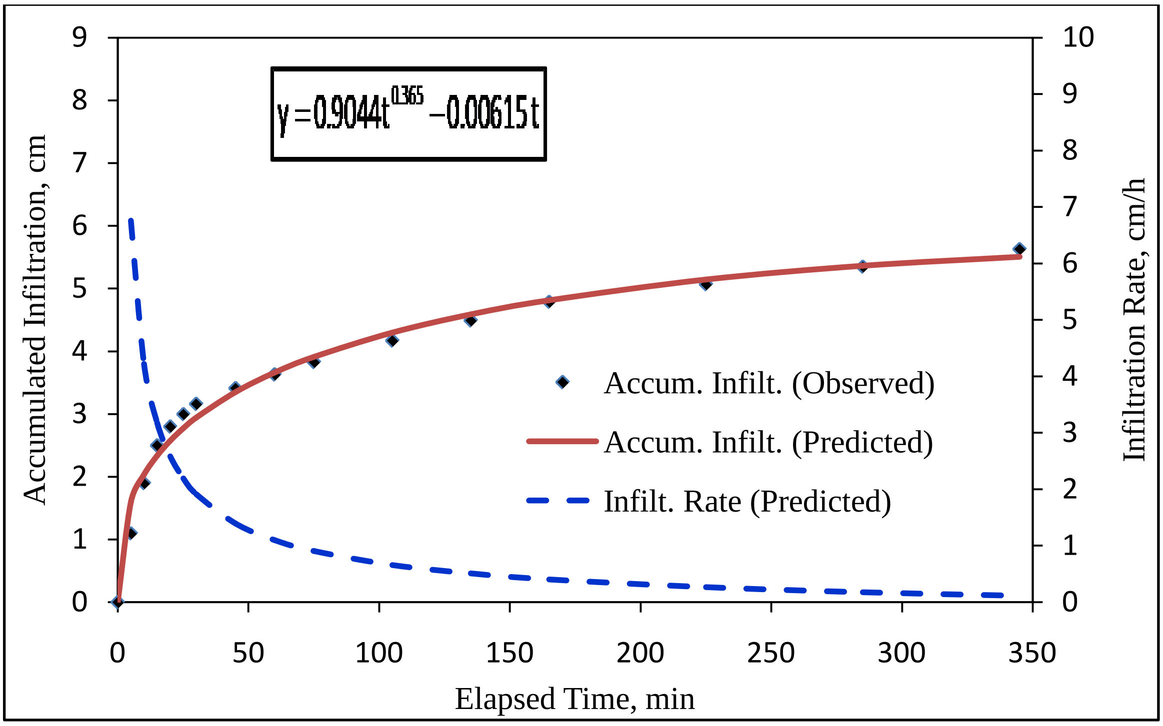

Fig. 8(a). Effect of tillage practices on infiltration behavior in treatment T_1

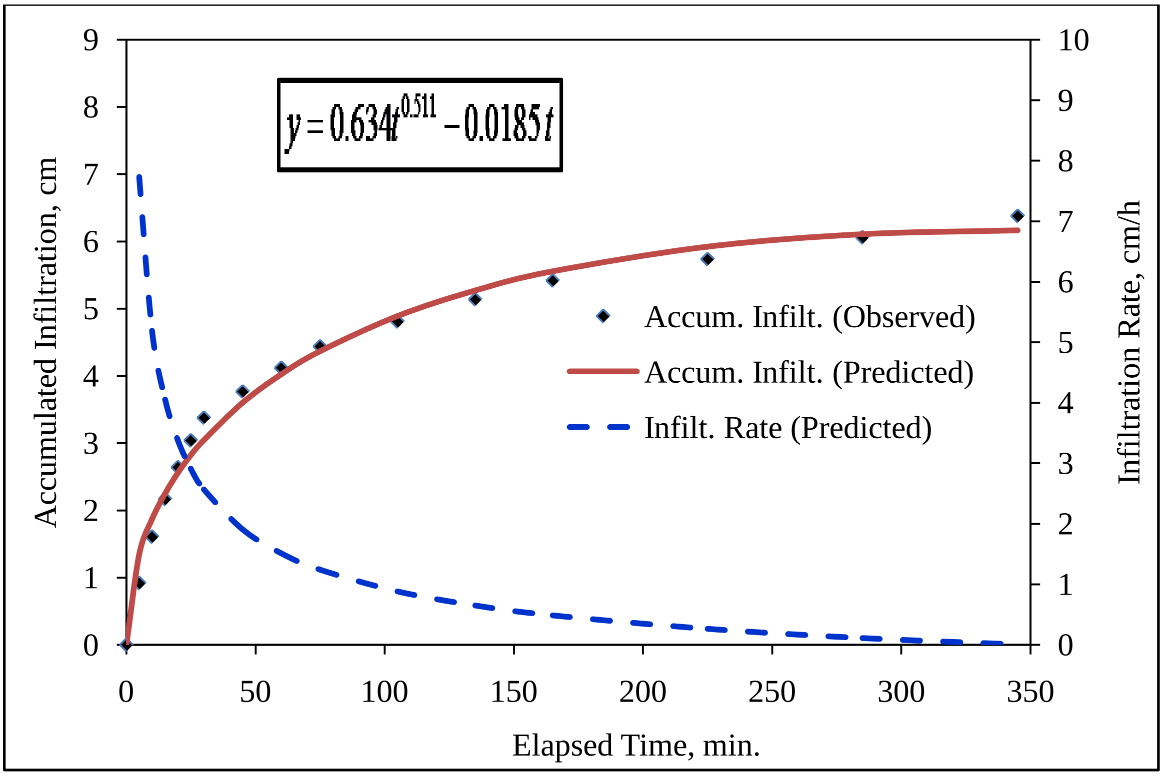

Fig. 8(b). Effect of tillage practices on infiltration behavior in treatment T_2

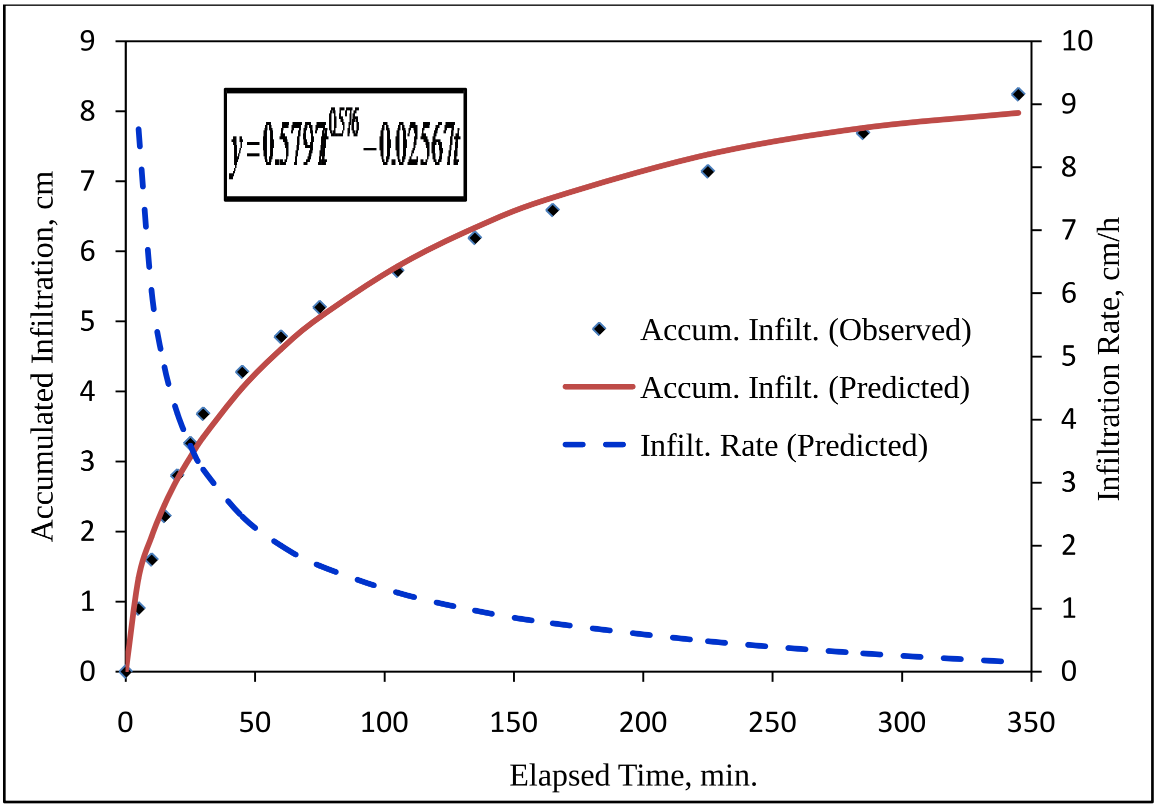

Fig. 8(c). Effect of tillage practices on infiltration behavior in treatment T_3

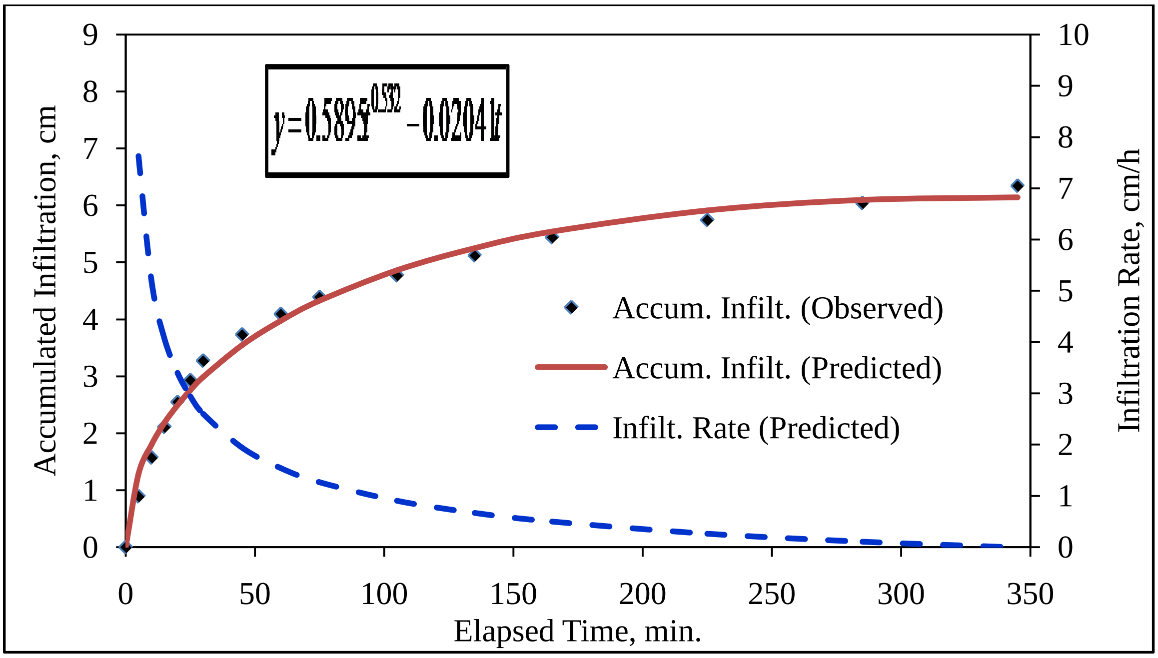

Fig. 8(d). Effect of tillage practices on infiltration behavior in treatment T_4

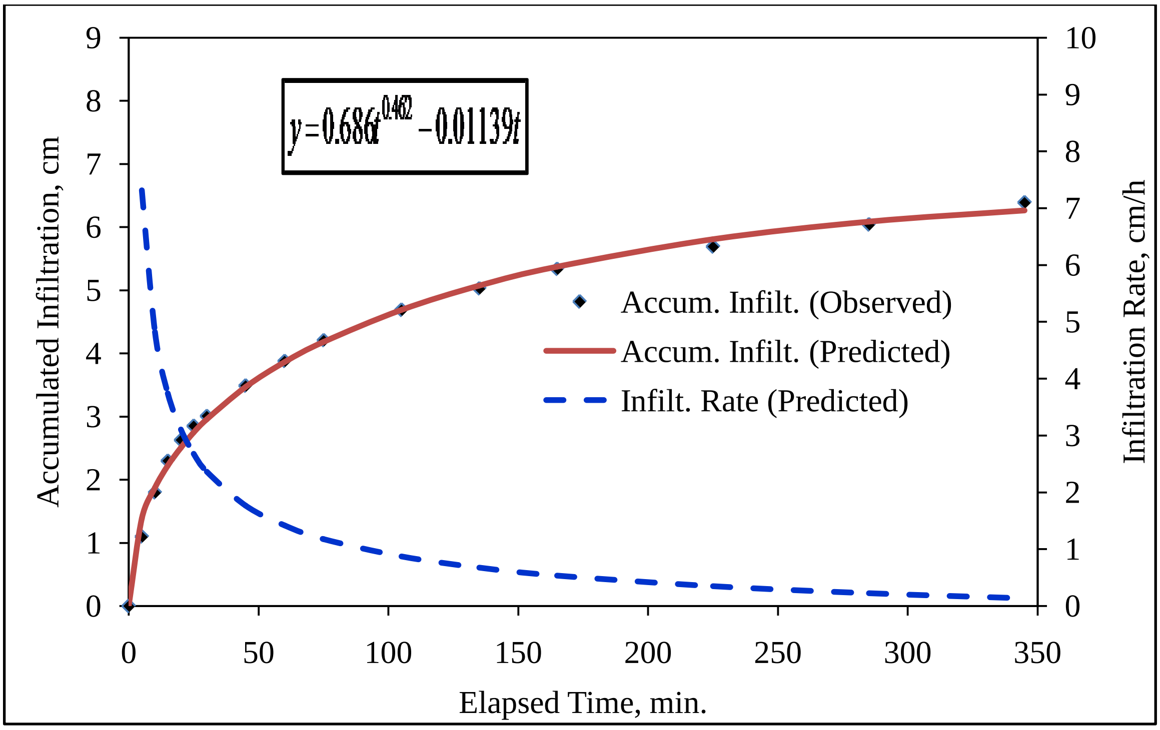

Fig. 8(e). Effect of tillage practices on infiltration behavior in treatment T_5

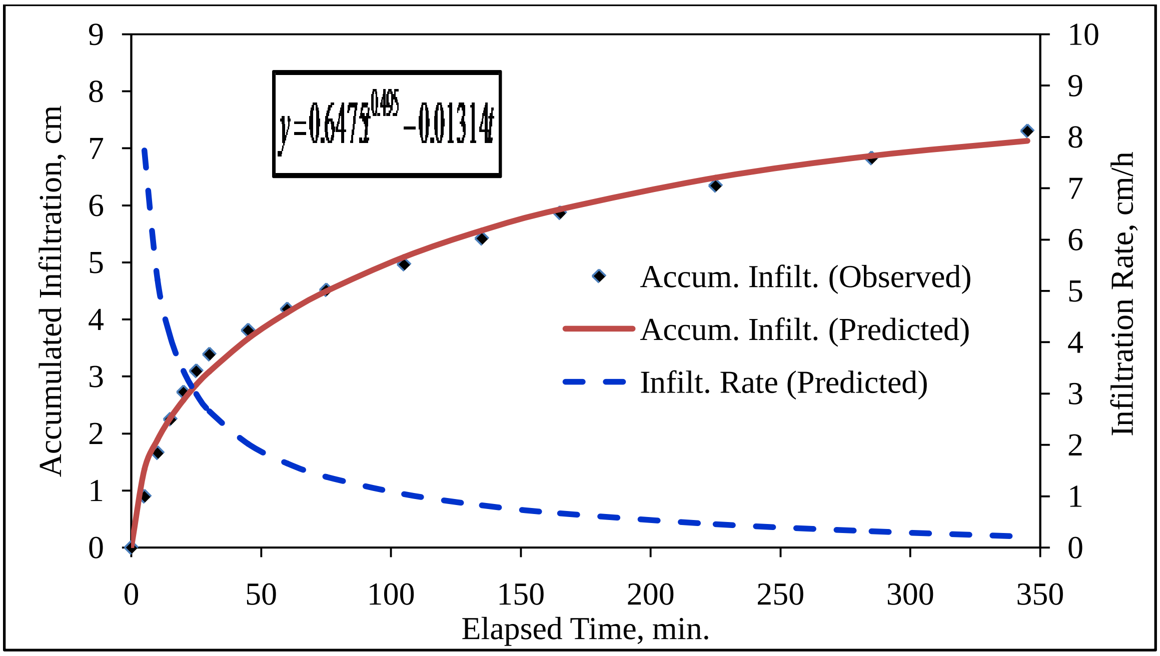

Fig. 8(f). Effect of tillage practices on infiltration behavior in treatment T_6

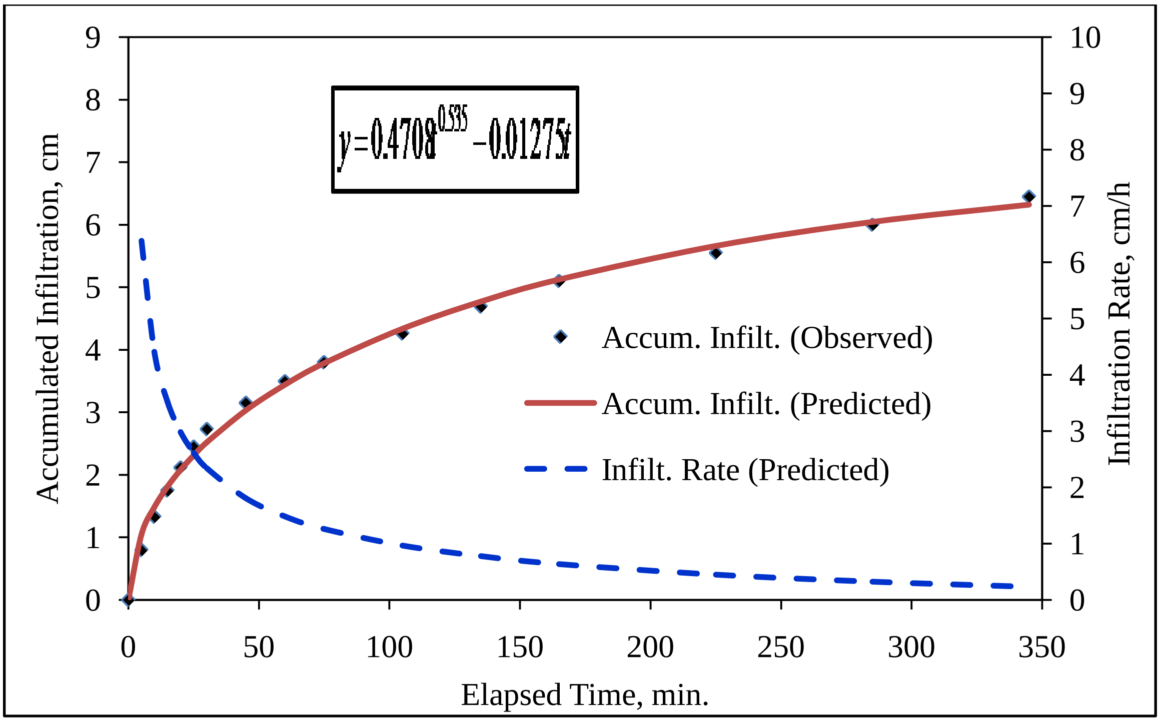

Fig. 8(g). Effect of tillage practices on infiltration behavior in treatment T_7

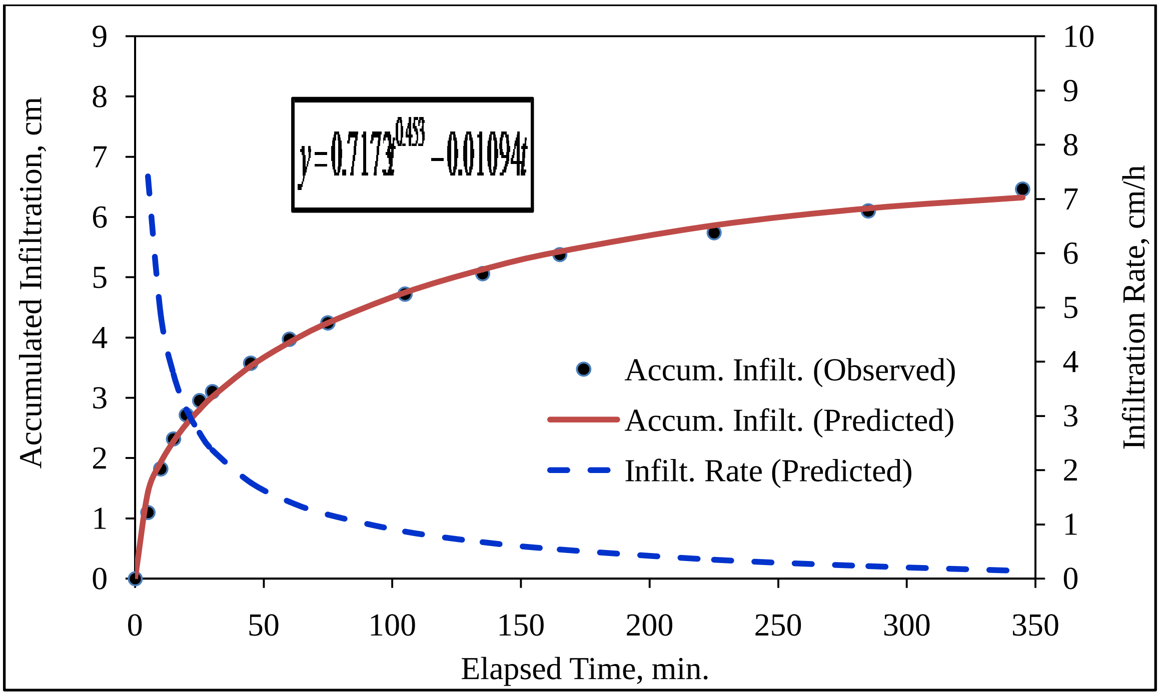

Fig. 8(h). Effect of tillage practices on infiltration behavior in treatment T_8

GRAIN YIELD:

The proportion of ultimate economic yield out of the total product is the kingpin in evaluating the success of any scientific investigation. Yield of grain is a complex character resulting from the interaction effect of many physical characters of the soil with each other and with the tillage practices. Among the physical properties of soil - soil moisture content, bulk density and infiltration rate of the soil plays vital roles in crop production. Yield of the crop has been found to differ much with change in tillage practices. As known, with date of sowing, there is a natural change in the atmospheric parameters viz., temperature of soil and environment, light intensity, sun-shine hours, relative humidity, rainfall and other allied effects. In the present experiment engineering components such as conventional tillage, zero tillage, puddling, brown manuring and mulching were taken as variables while the other parameters remained same. Therefore, change in the yield parameters observed are the ultimate reflection of the treatments applied. The data gathered in respect of grain yield of wheat as influenced by different treatments are presented in Table 4.10 and also graphically illustrated in Fig. 9.

Table 4.10. Grain Yield of wheat crop as affected by different treatments

Treatment	Grain Yield (q ha^{-1})
T_1	43.66
T_2	43.98
T_3	60.46
T_4	50.88
T_5	51.03
T_6	59.71
T_7	52.84
T_8	45.50
SEm (±)	1.64
C.D. at 5 %	4.97

Perusal of the data clearly demonstrates the influence of tillage practices on yield of wheat crop. The grain yield varied from 43.66 q ha^{-1} to 60.46 q ha^{-1}. The highest value of the grain yield of 60.46 q ha^{-1} was observed in treatment T_3 (rice and wheat on permanent beds with crop residue). T_3 was found significantly superior to treatments T_1 (PTR + CTW), T_2 (PTR + ZTW), T_4 (ZTR + CTW), T_5 (ZTR + ZTW-R),

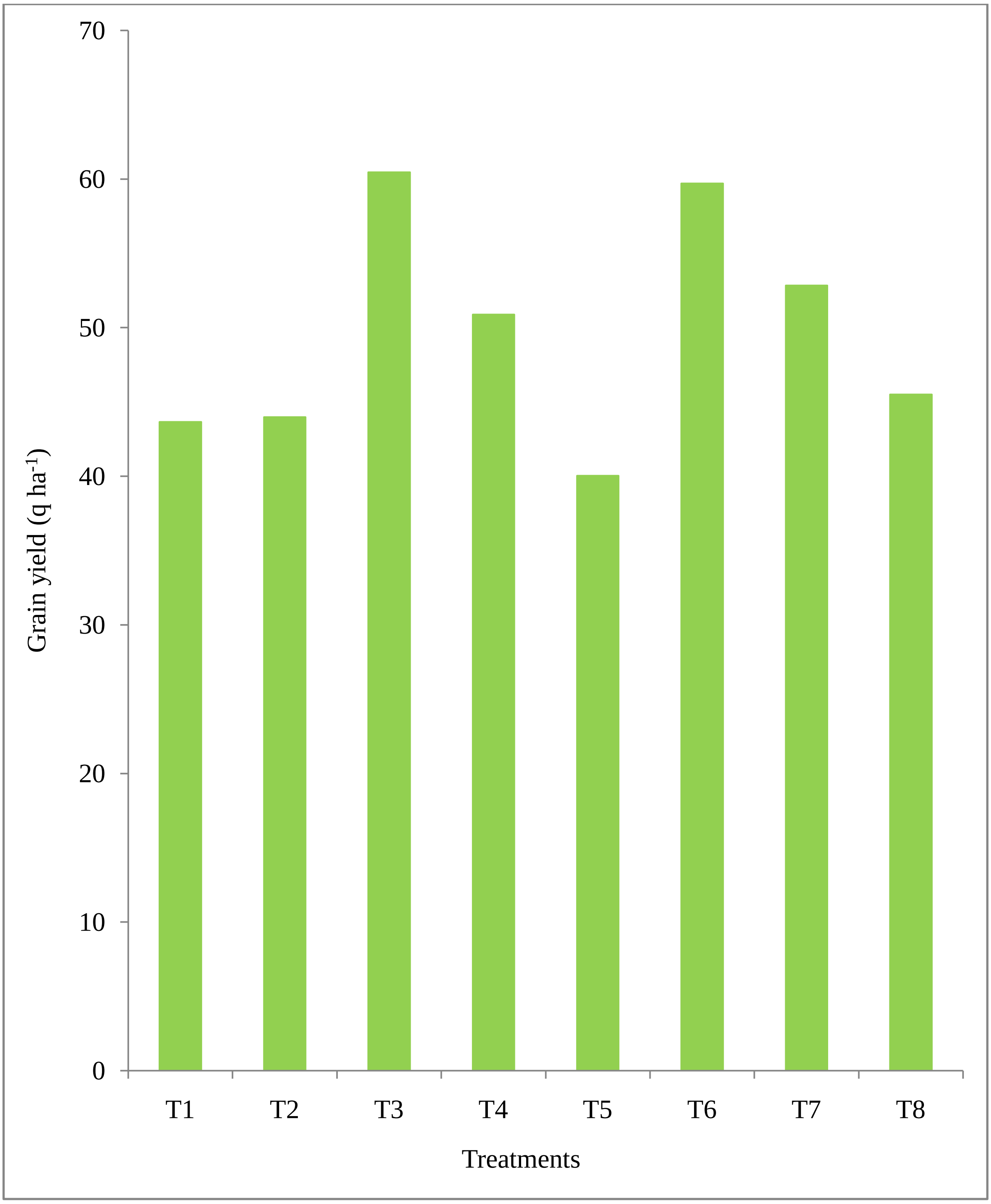

Fig. 9. Grain Yield of wheat crop as affected by different treatments

T_7 (UPTR + ZTW + only rice residue) and T_8 (ZTR with BM + ZTW) and statistically at par with T_6 (ZTR + ZTW + R) which signifies the good effect of permanent beds and crop residue incorporation because this treatment have low bulk density, higher moisture content, so root growth of crop is good and crop wealth better than other treatments therefore production of wheat more obtained in this plot. The high yields recorded might be due to good amount of rainfall (41 mm) received at critical stages during the month of January. Similar results were observed by Khan, (2010) who reported that grain yield of wheat was increased by 66.67 percent with raised bed in comparison to flat planting. Similar results were also observed by Tomar *et al.* (2006) who reported that grain yield of rice and wheat was significantly affected by tillage system as well as moisture regimes. Grain yield of wheat was significantly lowered in puddle rice plots (43.66 to 43.98 q ha^{-1}) than non- puddle rice plots (45.50 to 60.46 q ha-1). Grain yield of the wheat was also higher when rice straw and green manure were incorporated in treatments T_3, (60.46 q ha^{-1}), T_6 (59.71 q ha^{-1}) and T_7 (52.84 q ha^{-1}) in comparison to other treatments. Similarly Sarkar (1997) also reported that one half of the crop residues along with recommended fertilizers consistently produce high yields of both the crops (rice and wheat). Similar result was also obtained by Verma and Sharma (2000) who reported that productivity of wheat was always higher because of mulching with rice straw. On the basis of data recorded on grain yield (Table 4.10), different treatments may be arranged in the order: T_1 (43.66 q ha^{-1}) < T_2 (43.98 q ha^{-1}) < T_8 (45.50 q ha^{-1}) < T_4 (50.88 q ha^{-1}) < T_5 (51.03 q ha^{-1}) < T_7 (52.84 q ha^{-1}) < T_6 (59.71q ha^{-1}) < T_3 (60.46 q ha^{-1}).

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CHAPTER – V

SUMMARY & CONCLUSIONS

SUMMARY AND CONCLUSIONS

The rice-wheat cropping system occupies 24 million hectare of land in South Asia and China and is important for food security of the region. This system provides a staple food grain supply for more than 400 million people of the world population, and is critical for the food security of Asia. The rice-wheat cropping system is practiced over a variety of soil and climatic conditions with a wide range of agronomic practices. To insure food security for the increasing population, the challenge is to increase production while maintaining and enhancing the quality of the land resource. During the green revolution, production increased in both the area under production and system productivity. However, little additional land is now available and traditional farmlands are increasingly lost to urbanization. Since most of the land is already double – and even triple – cropped, further intensification is not a viable option with current resources and management. Therefore future demands will have to be met primarily through increase in yields per unit land area. Therefore, it is essential that the performance of the system be continuously monitored for productivity of the land.

Life of both the natural and human system is critically dependent on water. It is the primary requirement for not only survival of human being but also for their socio-economic development and a healthy ecosystem. In addition, access to water plays a critical role in poverty alleviation and food security. The prevailing trends towards rising population, increasing urbanization, spreading of more water intensive life styles as well as agricultural technology sweeping around the world are going to make water resources even scarcer unless timely action is taken.

Considering the importance of water management, the present investigation entitled “Impact of different tillage practices on soil moisture variation and physical properties of soil in North Bihar” was carried out at Rajendra Agricultural University Farm, Pusa (Samastipur) during *rabi* season of 2011-12 with the following specific objectives:

1. To study the moisture variation in different tillage practices during the crop period

2. To study the physical properties of soil (bulk density infiltration rate) in different tillage practices
3. To study the crop yield in different tillage practices

The experiment consisted of eight treatments of conservation tillage practices and was conducted in a randomized block design (RBD) with three replications. The plots of 467 m^2 were used for the experimentation. The soil of the experimental plot was sandy loam, calcareous and alkaline in nature having pH 8.4.

EC	0.73 mmhos/cm
Organic carbon	0.42 %
Available nitrogen	0.040 %
Olsen phosphorus	4.10 ppm
Available potash	49.02 ppm
Free $CaCO_3$	25.50 %

It was low in fertility status in terms of organic carbon (0.42 %), available nitrogen (0.040 %), phosphorous (4.10 ppm), available potash (49.02 ppm) free $CaCo_3$ (25.50 %). The treatments consisted of puddled transplanted rice + conventional tillage wheat (PTR + CTW), puddled transplanted rice + zero tillage wheat (PTR + ZTW), rice and wheat on permanent beds with crop residue (+R), zero tillage rice + conventional tillage wheat (ZTR + CTW), zero tillage rice + zero tillage wheat without crop residue (ZTR + ZTW - R), zero tillage rice + zero tillage wheat with crop residue (ZTR + ZTW + R), unpuddled transplanted rice + zero tillage wheat (UPTR + ZTW) (only rice residue) and zero tillage rice with brown manuring + zero tillage wheat (ZTR with BM + ZTW).

The effect of various treatments on the soil moisture regimes, bulk density, infiltration characteristics of the soil and yield of wheat crop was studied. The results obtained, which have been presented and discussed in the preceding chapter, are summarised below:

1. Treatment T_3 (rice and wheat on permanent beds with crop residue) resulted in the highest soil moisture content at all the depths all around the crop growth period which was found significantly superior to T_1 (PTR + CTW), T_2 (PTR + ZTW) and T_4 (ZTR + CTW) in general. This may be the good effect of permanent beds and crop residue both.

2. The soil moisture content at 15 to 30 cm soil depth was found minimum as compared to other soil depths in all the treatments all the time. This may be due to more compaction of this layer as a result of various tillage operations.

3. The values of bulk density of soil recorded in treatments T_3 (rice and wheat on permanent beds with crop residue), T_6 (ZTR + ZTW + R) and T_7 (UPTR + ZTR only rice) were significantly lowered as compare to T_1 (PTR + CTW). This signifies the ill effects of puddling in rice crop and intensive tillage in wheat crop.

4. The highest value of end time (345 minutes) infiltration rate of 0.55 cm h^{-1} and accumulated infiltration of 8.24 cm were observed in treatment T_3 (rice and wheat on permanent beds with crop residue) followed by T_6 (ZTR + ZTW + R), T_7 (UPTR + ZTW + only rice residue) and T_8 (ZTR + BM + ZTW). This signifies the effect of residue incorporation which modifies the soil structure, increases the proportion of macro pores and contributes to aggregate stability.

5. The highest value of the grain yield (60.46 q ha^{-1}) was observed in treatment T_3 (rice and wheat on permanent beds with crop residue) which signifies the good effect of permanent beds and crop residue incorporation because this treatment has resulted in low bulk density and higher moisture content which might have provided good soil environment for the growth of roots and ultimately better crop health and yield compared to other treatments.

Finally it can be concluded that the treatment rice and wheat on permanent beds with crop residue has outperformed the other treatments by retaining more soil moisture, keeping the bulk density of the soil low, increasing the infiltration rate and producing more grain yield of wheat crop.

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APPENDIX

APPENDIX – A

Daily rainfall data recorded at meteorological observatory of Pusa Farm
(November, 2011 to March, 2012)

Nov., 2011	**RF (mm)**	**Dec., 2011**	**RF (mm)**	**Jan., 2012**	**RF (mm)**	**Feb., 2012**	**RF (mm)**	**Mar., 2012**	**RF (mm)**
1	0.0	**1**	0.0	**1**	0.0	**1**	0.0	**1**	0.0
2	0.0	**2**	0.0	**2**	17.8	**2**	0.0	**2**	0.0
3	0.0	**3**	0.0	**3**	0.0	**3**	0.0	**3**	0.0
4	0.0	**4**	0.0	**4**	0.0	**4**	0.0	**4**	0.0
5	0.0	**5**	0.0	**5**	0.0	**5**	0.0	**5**	0.0
6	0.0	**6**	0.0	**6**	0.0	**6**	0.0	**6**	0.0
7	0.0	**7**	0.0	**7**	0.0	**7**	0.0	**7**	0.0
8	0.0	**8**	0.0	**8**	0.0	**8**	0.0	**8**	0.0
9	0.0	**9**	0.0	**9**	14.0	**9**	0.0	**9**	0.0
10	0.0	**10**	0.0	**10**	9.2	**10**	0.0	**10**	0.0
11	0.0	**11**	0.0	**11**	0.0	**11**	0.0	**11**	0.0
12	0.0	**12**	0.0	**12**	0.0	**12**	0.0	**12**	0.0
13	0.0	**13**	0.0	**13**	0.0	**13**	0.0	**13**	5.5
14	0.0	**14**	0.0	**14**	0.0	**14**	0.0	**14**	1.0
15	0.0	**15**	0.0	**15**	0.0	**15**	0.0	**15**	0.0
16	0.0	**16**	0.0	**16**	0.0	**16**	0.0	**16**	0.0
17	0.0	**17**	0.0	**17**	0.0	**17**	0.0	**17**	0.0
18	0.0	**18**	0.0	**18**	0.0	**18**	0.0	**18**	0.0
19	0.0	**19**	0.0	**19**	0.0	**19**	0.0	**19**	0.0
20	0.0	**20**	0.0	**20**	0.0	**20**	0.0	**20**	0.0
21	0.0	**21**	0.0	**21**	0.0	**21**	0.0	**21**	0.0
22	0.0	**22**	0.0	**22**	0.0	**22**	0.0	**22**	0.0
23	0.0	**23**	0.0	**23**	0.0	**23**	0.0	**23**	0.0
24	0.0	**24**	0.0	**24**	0.0	**24**	0.0	**24**	0.0
25	0.0	**25**	0.0	**25**	0.0	**25**	0.0	**25**	0.0
26	0.0	**26**	0.0	**26**	0.0	**26**	0.0	**26**	0.0
27	0.0	**27**	0.0	**27**	0.0	**27**	0.0	**27**	0.0
28	0.0	**28**	0.0	**28**	0.0	**28**	0.0	**28**	0.0
29	0.0	**29**	0.0	**29**	0.0	**29**	0.0	**29**	0.0
30	0.0	**30**	0.0	**30**	0.0	**-**	-	**30**	0.0
		31	0.0	**31**	0.0	**-**	-	**31**	0.0
Total	**0.0**		**0.0**		**41.0**		**0.0**		**6.5**

APPENDIX – B

B1: Soil moisture content before sowing of wheat crop

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	20.07	20.62	19.64
T_2	21.43	20.98	22
T_3	24.23	25.01	23.63
T_4	20.02	21.9	20.99
T_5	23.21	22.85	21.2
T_6	23.96	23.62	24.21
T_7	22.96	21.45	23
T_8	23	22.64	23.24

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	18.3	18.44	19.84
T_2	20.17	21.46	19.12
T_3	21.09	22.93	22.64
T_4	21.12	18.54	19.35
T_5	20.72	21.13	20.01
T_6	21.56	22.36	22.41
T_7	21.25	20.67	22.01
T_8	22.52	21.13	20.94

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	21.14	18.7	20.52
T_2	24.62	24.11	22.94
T_3	24.87	25.6	26.12

T_4	21.01	20.77	19.99
T_5	24.8	24.04	23.19
T_6	24.41	25.33	25.89
T_7	24.42	25.62	24.84
T_8	24.34	25.86	25.28

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	21.43	22.24	23.02
T_2	25.11	23.84	25.96
T_3	27.55	28.81	27.07
T_4	22.03	23	24
T_5	26.22	25.53	24.81
T_6	27.62	28	26.88
T_7	26.43	24.82	25.64
T_8	26.01	26.81	25.57

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	25.02	25.61	24.82
T_2	25.38	26.25	27.12
T_3	28.86	29.2	27.92
T_4	26.15	25.23	27.01
T_5	26.59	26.4	25.88
T_6	28.28	28.88	27.38
T_7	26.74	24.82	28.48
T_8	26.98	27.92	26.04

B2: Soil moisture content before first irrigation

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	21.12	20.08	19.04
T_2	21.36	22.63	20.09
T_3	23.18	24.56	23.87
T_4	20.86	21.58	20.14
T_5	21.03	22.38	23.73
T_6	23.18	24.56	23.27
T_7	22.41	23.24	21.58
T_8	21.85	22.76	23.67

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	17.47	19.65	18.56
T_2	20.24	21.46	19.02
T_3	20.91	23.11	22.01
T_4	20.34	19.43	18.52
T_5	19.50	20.42	21.34
T_6	22.38	21.48	20.58
T_7	21.11	22.24	19.98
T_8	20.13	21.18	22.23

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	18.95	21.13	20.04
T_2	23.82	24.48	23.16
T_3	24.41	26.23	25.32
T_4	21.91	20.39	18.87
T_5	24.89	23.98	23.07
T_6	24.06	25.20	26.34
T_7	25.02	26.12	23.92
T_8	24.23	25.12	26.01

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	20.78	23.24	22.01
T_2	24.91	25.24	24.58
T_3	26.43	28.81	27.62
T_4	24.11	23	21.89
T_5	25.48	26.28	24.68
T_6	28.38	27.49	26.6
T_7	25.06	25.61	26.16
T_8	26.78	25.87	24.96

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	24	26.14	25.07
T_2	26.01	27.32	24.7
T_3	27.03	29.21	28.12
T_4	26.69	25.96	25.23
T_5	26.13	27.32	24.94
T_6	27.2	27.88	28.56
T_7	25.10	26.19	27.28
T_8	27.67	26.76	25.85

B3: Soil moisture content after first irrigation

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	27.21	26.12	25.03
T_2	26.23	27.53	24.93
T_3	29.13	27.39	28.26
T_4	25.30	26.21	27.12
T_5	26.29	26.82	27.35
T_6	28.84	27.52	28.18
T_7	26.87	27.20	26.54
T_8	26.98	27.89	26.07

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	23.42	26.72	25.07
T_2	25.11	26.00	24.22
T_3	25.57	27.01	26.29
T_4	26.11	25.09	24.07
T_5	24.17	25.14	26.11
T_6	25.23	26.17	27.11
T_7	25.96	26.69	25.23
T_8	26.78	25.99	25.20

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	26.28	28.64	27.46
T_2	28.72	27.68	26.00
T_3	27.38	29.18	28.28
T_4	27.53	28.35	26.71
T_5	27.28	27.83	28.38
T_6	29.00	28.21	27.42
T_7	28.02	28.99	27.05
T_8	29.58	28.19	26.80

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	26.62	28.96	27.79
T_2	27.24	27.96	28.68
T_3	28.04	29.52	28.78
T_4	27.82	28.14	27.50
T_5	29.14	28.01	26.88
T_6	29.25	28.75	28.25
T_7	28.43	29.32	27.54
T_8	29.45	28.54	27.63

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	27.96	28.69	27.23
T_2	27.10	29.16	28.13
T_3	28.12	30.34	29.23
T_4	26.70	28.02	29.34
T_5	29.34	28.23	27.12
T_6	30.19	29.09	27.99
T_7	27.94	28.75	29.56
T_8	28.98	29.89	28.07

B4: Soil moisture content before second irrigation

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	20.16	21.78	20.97
T_2	22.34	21.53	20.72
T_3	23.40	25.24	24.32
T_4	21.01	22.23	19.79
T_5	22.91	23.74	22.08
T_6	23.24	23.96	24.68
T_7	23.79	22.97	22.15
T_8	21.81	23.01	24.21

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	17.84	19.68	18.76
T_2	20.98	21.86	20.10
T_3	21.08	23.34	22.21
T_4	20.79	19.81	18.83
T_5	20.12	20.99	21.86
T_6	2020.93	22.20	23.47
T_7	21.11	22.31	19.91
T_8	22.72	21.61	20.50

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	19.09	21.37	20.23
T_2	24.21	25.34	23.08
T_3	24.76	26.92	25.84
T_4	21.58	20.62	19.66
T_5	25.86	24.90	23.94
T_6	24.80	25.64	26.48
T_7	25.47	26.58	24.36
T_8	24.74	25.53	26.32

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	21.22	23.34	22.28
T_2	25.55	26.62	24.48
T_3	27.00	28.84	27.92
T_4	21.77	23.31	24.85
T_5	25.96	26.68	25.24
T_6	26.36	27.31	28.26
T_7	25.20	25.97	26.74
T_8	27.24	26.21	25.18

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	24.67	26.49	25.58
T_2	25.50	26.43	27.36
T_3	27.88	29.74	28.81
T_4	27.86	26.41	24.96
T_5	26.56	27.48	25.64
T_6	27.02	28.22	29.42
T_7	26.58	27.84	25.32
T_8	27.89	26.99	26.09

B5: Soil moisture content after second irrigation

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	26.22	27.42	25.02
T_2	27.34	26.53	25.72
T_3	27.38	29.24	28.31
T_4	25.12	27.34	26.23
T_5	25.98	26.83	27.68
T_6	27.30	28.21	29.12
T_7	26.89	27.78	26.00
T_8	27.87	26.99	26.11

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	24.01	26.23	25.12
T_2	26.72	25.29	23.86
T_3	25.51	26.37	27.23
T_4	25.21	26.13	24.29
T_5	26.24	25.32	24.40
T_6	24.80	27.76	26.28
T_7	25.98	26.86	25.10
T_8	27.15	26.01	24.89

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	27.55	28.46	26.64
T_2	28.52	27.61	26.70
T_3	27.36	29.22	28.29
T_4	26.24	28.94	27.59
T_5	26.81	27.67	28.53
T_6	29.34	28.27	27.18
T_7	28.22	29.14	27.30
T_8	27.33	28.23	29.13

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	27.86	28.68	27.04
T_2	26.81	29.23	28.02
T_3	27.84	29.94	28.89
T_4	26.84	27.88	28.92
T_5	29.12	28.05	26.98
T_6	27.92	28.82	29.72
T_7	28.47	29.65	27.29
T_8	29.74	28.57	27.40

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	28.19	29.35	27.03
T_2	27.66	29.48	28.57
T_3	28.60	30.46	29.53
T_4	27.21	28.32	29.43
T_5	30.13	28.97	27.81
T_6	28.36	29.24	30.12
T_7	28.99	29.87	28.11
T_8	30.49	29.19	27.89

B6: Soil moisture content after harvesting of wheat crop

At 0 to 15 cm soil depth

Treatment	R I	R II	R III
T_1	19.71	21	19.32
T_2	21.13	20.63	22.23
T_3	23.3	23.98	25.11
T_4	20.48	21.26	19.97
T_5	22.58	23.02	21.36
T_6	24.68	23.18	23.81
T_7	22.29	23	21.88
T_8	22.46	21.7	23.82

At 15 to 30 cm soil depth

Treatment	R I	R II	R III
T_1	19.68	18.48	17.55
T_2	19.11	21.01	20.27
T_3	22.13	22.84	21.12
T_4	18.84	19.2	20.52
T_5	20.76	21.26	19.66
T_6	21.41	21.51	23.11
T_7	21.04	20.27	22.02
T_8	22.12	20.82	21.05

At 30 to 45 cm soil depth

Treatment	R I	R II	R III
T_1	21	19.32	19.98
T_2	22.62	24.42	24
T_3	25.13	26.03	24.53
T_4	19.84	20.12	21.33
T_5	24.54	24.22	23.24
T_6	24.9	25.51	24.62
T_7	24	23.16	25.23
T_8	25.48	24.68	24.78

At 45 to 60 cm soil depth

Treatment	R I	R II	R III
T_1	23.22	22.01	21.13
T_2	24.11	25.45	24.99
T_3	26.47	27.22	28
T_4	23.62	22.06	22.6
T_5	24.31	25.13	26.07
T_6	27.86	26.87	26.24
T_7	24.82	25.21	26.38
T_8	26.44	26.57	25.32

At 60 to 75 cm soil depth

Treatment	R I	R II	R III
T_1	24.36	25.78	24.98
T_2	26.01	25.51	27.02
T_3	28.46	27.98	29.24
T_4	25.88	26.72	25.37
T_5	26.12	25.54	27.03
T_6	28.78	27.99	27.26
T_7	26.12	27.33	26.71
T_8	27.93	26.46	25.95

APPENDIX – C

Bulk density of soil after harvest of wheat crop

Treatment	R I	R II	R III
T_1	1.57	1.56	1.53
T_2	1.51	1.52	1.56
T_3	1.49	1.44	1.48
T_4	1.49	1.50	1.54
T_5	1.51	1.55	1.50
T_6	1.47	1.43	1.42
T_7	1.47	1.52	1.48
T_8	1.50	1.54	1.49

APPENDIX – D

Yield of wheat

Treatment	R I	R II	R III
T_1	44.56	41.06	45.36
T_2	44.5	46.97	40.47
T_3	63.46	58.66	59.26
T_4	48.58	50.08	53.98
T_5	48	53.78	51.31
T_6	62.3	59.21	57.62
T_7	50.14	53.34	55.04
T_8	45.83	42.86	47.81