EFFECTS OF TILLAGE ON
SOIL HYDRAULIC PROPERTIES
IN SANDY LOAM SOIL

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PROJECT REPORT

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DECLARATION

We here by declare that this project entitled "**EFFECTS OF TILLAGE ON SOIL HYDRAULIC PROPERTIES IN SANDY LOAM SOIL**" is a bonafide record of project work done by us during the course of project and the report has not previously formed the basis for the award to us for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur
Date: 12/12/2011

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CERTIFICATE

Certified that this project report entitled "**EFFECTS OF TILLAGE ON SOIL HYDRAULIC PROPERTIES IN SANDY LOAM SOIL**" is a record of project work done independently by Lakshmi, K.G., Prasanth, V. and Shakira, T. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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Lakshmi, K.G.

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Dedicated to

The Almighty,

Loving parents

and Teachers

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SYMBOLS AND ABBREVIATIONS

^{o}C	degree celcius
/	per
%	percentage
Φ	porosity
*	significant
µm	micrometer
Acc.I	accumulated infiltration
BD	bulk density
cc	cubic centimetre
CD	critical difference
cm	centimeter
D	particle size
Dept.	department
df	degree of freedom
et al.	and other people
etc	etcetera
F-cal	F-value calculated
F-tab	F-value from ANOVA table
h	hour
I_{avg}	average infiltration
J.	journal
K	hydraulic conductivity
k	intrinsic permeability
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	kilogram
Km	kilometer
ln	natural logarithm
log	logarithm
LWRCE	Land and Water Resources and Conservation Engineering

MB	mould board
mg	milligram
min	minutes
mm	millimeter
MS	mean sum of square
N	cumulative percentage finer
No.	number
NS	non significant
s	second
SS	sum of square
V	volume
W	water content

Introduction

CHAPTER II

INTRODUCTION

Soil management practices influence soil-structure through changes in size, stability of aggregates and pore-size distribution, as well as its geometry. The two components of soil management practice that play a vital role in maintaining soil-plant physical conditions in the root zone are (a) tillage and (b) additions of organic matter.

Tillage has been an important aspect of technological development in the field of agriculture. Tillage operation is the mechanical manipulation of soil to develop a desirable soil structure for a seed bed and to establish specific surface configuration for planting, irrigation, drainage, harvesting operations etc. Cumulative effect of tillage operation on soil leads to soil loosening.

Tillage technology begun via human labour with the use of stick or metal jab for seeding. Human tilling methods include the usage of shoveling, picking, hoeing, raking etc. The wooden plow pulled by mule, ox, elephant, water buffalo, or similar sturdy animal was then invented. Draft-animal-powered or mechanized work includes ploughing, rototilling, rolling with rollers, harrowing, and cultivating with cultivator shanks. A major constraint on the use of animals was the availability of adequate fodder, less efficiency, time consuming etc. Subsequently this leads to agricultural mechanization through tractor-drawn implements and other more powerful machinery. Mechanization not only reduces labour requirement but also the time consumed by different farm operations. The applications of machines for agricultural production not only reduce burden and drudgery of farm work, but also increase the efficiency of work.

Various forms of tillage are practiced throughout the world, ranging from the use of simple stick or jab to the sophisticated para-plough. Many tillage operations are designed to loosen and homogenize soil within the zone of tillage, but some tillage operations are intended to shape or firm soil. The practices developed, with whatever equipment used, can be broadly classified into no tillage, primary tillage, secondary tillage, minimum tillage, conservation tillage, conventional tillage and mulch tillage.

But tillage are mainly classified as primary and secondary tillage. There is no strict boundary between them as much as a loose distinction between tillage that is deeper and thorough (primary) tillage that is shallower and sometimes more selective of location (secondary). Primary tillage such as ploughing tends to produce a rough surface finish, whereas secondary tillage tends to produce a smoother surface finish, such as that required to make a good seedbed for many crops. Mouldboard plough, Disc plough are examples of primary tillage implement and disc harrow, cultivator, rotovator etc are examples for secondary tillage implement. Harrowing and rototilling often combine primary and secondary tillage into one operation.

` The main functions of soil tillage are:

- Soil conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation, water infiltration, soil warming, etc.)
- To increase water infiltration and aeration
- To eliminate the competition with weeds
- Residue management (movement, orientation or sizing of residues to minimize negative effects of crop/cover crop residues and promote beneficial effects)
- Land Forming (changing the shape of the soil surface is probably leveling; ridging, roughening and furrowing)

Every method have some negative effects after its usage, the negative effects of tillage includes

- Compaction of soil below the depth of tillage (i.e., formation of a tillage pan)
- Increased susceptibility to water and wind erosion
- Accelerated decomposition of soil organic matter (negative from a long term perspective)

Tillage has various physical, chemical and biological effects on the soil. The modification of surface soil structure affects soil-water processes important in crop production and soil conservation. The physical effects such as aggregate-stability, in-filtration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability.

Tillage Effects on Soil and Crop Production

The soil environment greatly influences crop response and can be altered by crop rotation, tillage and other crop soil management practices. The two practices with major impact on soil conservation are crop residue management and tillage. The traditional ploughing-in of crop residues is now giving way to surface soil residue management, which is more related to soil and water conservation, particularly in the semi-arid tropics. Tillage effects on soils are closely related to the management of crop residues in and on the surface of the soil.

Tillage Effect on Crop Yield

A large volume of experimental data has been published on tillage effects on crop yields under various climates, agro-ecological conditions, soils, crops and residue management systems. Under some of these conditions, the tillage effect is either closely linked to soil aggregation, hence water infiltration rate and water storage capacity, or indirectly related to soil and water conservation.

It is evident from the extensive published data on tillage that the effect of tillage on crop yield differs with different soil and its conditions. The choice of tillage methods depends on several factors but soil properties play an important role in determining intensity, frequency and type of tillage required. In addition to the soil factors, climatic factors such as soil temperature regimes, rainfall characteristics and length of growing season should be taken into account. The relationship between tillage and climate underscores the importance of soil and crop specificity in determining the exact nature of tillage operations.

Tillage modifies the soil structure, decreases soil penetration resistance and soil bulk density. This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by the tillage operation, which increases the tortuous of soil. This all leads to a favorable environment for crop growth and nutrient use.

Tillage Effect on Soil Properties

Effect on chemical properties

Changes in chemical properties are dependent mainly on the organic matter content of the soils. Tillage affects aeration and thus the rate of organic matter decomposition. An uncultivated soil has a relatively stable soil microbial population, a relatively constant amount plant residue returned to the soil and usually a low rate of Nitrogen mineralization. If the soil is disturbed with tillage, there is an immediate and rapid increase in Nitrogen mineralization

Effect on biological properties

Biological activities in the soil are vital to soil tilth and productivity through the activities of earthworms, termites and the many other living creatures in the soil (fungi, algae, protozoa, mites, nematodes, worms, ants, maggots and other insects and insect larvae (grubs)). These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation. The burrowing activities of earthworms increase soil aeration, water infiltration, nitrogen availability to plants, and the microbial activity in the soil and those burrows can be stable for years, acting to increase the extent and density of plant roots as well as stabilizing soil aggregates to improve soil structure and limit erosion. The microbial activity is responsible for organic matter decomposition and the release of soil nutrients essential for plant growth. Soil organic matter, nutrients, and biological activity contribute to ecosystem-level processes and are important for productivity, community structure, and fertility. Agricultural practices such as crop rotations and tillage affect the numbers, diversity, and functioning of the micro- and larger- organisms in the soil community, which in turn affects the establishment, growth, and nutrient content of the crops.

Effect on Physical properties

Tillage affects soil physical, chemical and biological properties. The physical soil characteristics are those that can be seen and/or felt. The soil physical characters are of utmost importance for crop production. The physical properties are of permanent nature and usually difficult to change, compared to soil chemical properties.

Research results have been widely reported the effects of tillage on the physical parameters like soil aggregation, temperature, water infiltration and retention. The magnitude of these changes depends on soil types as well as soil composition. Tillage practices have great influence on soil physical conditions. This is due to the fact that after tillage, settling and trafficking of soil particles takes place resulting in rapid changes in the physical conditions of the soil until a new equilibrium is reached. The physical conditions of a soil can be measured to a greater extent by monitoring its bulk density, infiltration rate and hydraulic conductivity. Those in turn are related to pore size distribution and continuity.

The cumulative effect of tillage operations on soils leads to soil loosening. The degree of loosening may depend upon the soil type, soil moisture content, and the type of tillage operation. The difference in operation results in a change of number, shape, continuity and size distribution of pores network, which control the ability of soil to store and transmit air, water and agricultural chemicals.

The physical behavior of the soil and how it reacts to tillage and planting operations is also determined by the number, size, arrangement and stability of the aggregates. Soils containing a large portion of stable aggregates resist breakdown from tillage operations and allow for rapid infiltration and movement of water into the soil profile. The porosity or aeration of the soil also increases with aggregation, which provides a more favorable environment for plant root growth and microbial activity.

Tillage effects on soils are closely related to the management of crop residues in and on the surface of the soil the crop and land management practices affect soil cover, organic matter, soil structure, and/or porosity. Placement of residues affects the soil surface temperature, rate of evaporation and water content, and nutrient loading and rate of decay. Plant and residue cover protects soil from the harmful effects of raindrops and soil erosion. When eroded soil particles fill pore space, porosity is reduced and bulk density increases.

Soil parameters that are adversely affected by compaction or loosening of soil particles are those which control the content and transmission of water, air and heat. An understanding of how different tillage methods affect these soil physical parameters will be of importance for their proper management.

The objective of this study is;

- To evaluate the tillage effects on bulk density, porosity, saturated hydraulic conductivity, infiltration and moisture content of sandy loam soil.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Tillage operation is the mechanical manipulation of soil to develop a desirable soil structure for a seed bed and to establish specific surface configuration for planting, irrigation, drainage, harvesting operations etc. Cumulative effect of tillage operation on soil leads to soil loosening. Some physical properties of soil that may be affected by the loosening include bulk density, soil strength, infiltration capacity, water redistribution within the soil and the moisture retention. Soil parameters that are adversely affected by compaction or loosening of soil particles are those which control the content and transmission of water, air and heat.

Klute (1982) says that tillage loosen the soil surface, decreasing the soil bulk density, increasing porosity and hence, increases the amount of water held at high water potentials and decreases the amount of water held at lower potentials. This often increases the hydraulic conductivity. These effects decline with time as the soil matrix reconsolidate. Thus techniques to measure soil physical characteristics should be fast and simple in order to monitor rapid changes in surface macroporosity.

Baldev Singh *et al*. (1995) indicate the importance of the return of crop residue to the soil. Incorporation of straw through tillage, or lack thereof, seems not to affect soil hydraulic properties of at least the near surface.

Ferreras et al. (2000) revealed that no tillage and conventional tillage shows high bulk density and low aggregate stability, therefore, they are susceptible to increased structural damage in continuous cropping. The low soil porosity and greater percentage of small pores (<20 mm) in no tillage affected soil saturated hydraulic conductivity.

Green *et al*. (2003) study with regard to the effects of tillage on the soil hydraulic properties under well-structured soil conditions, results for the different tillage treatments are not always consistent across locations, soils and experiment designs. Tillage operations, however, have a transitory effect on soil physical characteristics because of the impact of rain on the freshly tilled soil, which promotes a steady breakdown of soil structure

Rashidi *et al*. (2007) reported that conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact. This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance.

Karina *et al*. (2009) in their study on long-term effects of no-tillage on dynamic soil physical properties reported that soil physical properties, responsible for dynamic processes maintain the soil functionality for crop development in spite of signs of soil compaction under no tillage. The properties that control dynamic processes, Ka and Ksat, still maintained the functionality of the soil management effects on soil hydraulic properties

Jabro *et al*. (2010) evaluated the effects of conventional (CT) and strip (ST) tillage practices on bulk density, water content, infiltration rate and hydraulic conductivity of a Lihen sandy loam soil. Soil bulk density and water content did not differ significantly between conventional and strip tillage in both years with the exception of bulk density. The log-transformed infiltration rate was significantly affected by tillage did not differ significantly between conventional and strip tillage practices in corresponding year. The effects of tillage on soil hydraulic conductivity were significant in both the years. The variation in Ks values in soil was likely due to differences in soil compaction and vehicular traffic passes peculiar to the CT and ST systems. The ST plots likely had better volume of macropores than CT plots, producing greater water flow through the ST soil profile plots in both years.

WATER CONTENT

Shaykewich (1970) in his study on Hydraulic properties of disturbed and Undisturbed soils indicated that disturbed soils, as in sieved and repacked samples have higher water retention capacities at a given water potentials than Undisturbed soils.

Blevins *et al*. (1971) indicated no till treatments had higher volumetric moisture content to a depth of 60 cm during most of the growing season

Voorhees *et al*. (1984) found that the greater soil water stored is with the no tillage systems, compared to the conventional tillage system has generally has not resulted in proportional increase in crop yield. Apparently greater yield potential represented by additional water stored with no tillage is offset by other conditions in the soil environment that limit yield.

Johnson *et al*. (1984) compared three conservation tillage systems, chisel plowing, till plant and no till, to conventional moldboard plowing. Soil moisture advantages with conservation tillage varied because of profile water content, delayed plant growth and soil characteristics.

Tessier *et al*. (1990) indicated changes in soil moisture content due to tillage are not of the magnitude to influence crop production.

Romaneckas *et al*. (2009) studied the influence of reduced soil tillage intensity on some soil physical properties, on sugar beet yield and quality, and weed infestation. Reduction of primary soil tillage intensity increased the amount of moisture and level of soil bulk density in the soil upper layer (0-10 cm) the highest amounts of moisture and soil bulk density were observed in no tilled soil (ZT). Soil tillage intensity had no significant influence on soil moisture content and bulk density in a deeper (10-20 cm) layer.

BULK DENSITY

The soil acts as a support for the plant and is the medium in which plant roots grow. Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Bulk density is dependent on soil texture and the densities of soil mineral (sand, silt, and clay) and organic matter particles, as well as their packing arrangement. High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil.

Kimpe *et al*. (1982) found that when soil is tilled and no traffic is applied, irrigation causes an increase in bulk density; the degree of increase will depend on the degree of water saturation achieved during irrigation and the amount of water applied. He measured a decrease in dry bulk density when loose soil was settled, with increasing soil water contents followed by an increase in bulk density as the water content approached field capacity.

Blevins *et al*. (1983) reported that tillage had no effect on bulk density after a 10-year period of tillage treatments on a medium textured soil. However, other studies have reported a drastic increase in bulk density with no-till compared to moldboard plowing of a clay loam soil. He also found similar bulk density values with conventional and no-till systems and smaller bulk density with chisel tillage on a poorly drained soil.

Gupta *et al*. (1985) tested 87 soils and found that the Wasco sandy loam soil (coarse-loamy, mixed, nonacid, thermic Typic Torriorthent), used also in this experiment, had the highest bulk density of any soil studied when compacted under standard conditions.

Meek *et al*. (1988) found that in a sandy loam soil with poor soil structure and low organic matter, bulk density can be reduced by tillage to a range of 1.4 to 1.5 Mg m- 3, but when wheel traffic is applied, bulk density will increase to values that will depend on factors such as tire pressure, soil moisture, and wheel load.

Pelgrin *et al*. (1990) reported that bulk densities, measured three weeks after tillage application, were similar in the upper 20 cm of a sandy clay loam where tillage was done with disk plow, moldboard plow, cultivator, disk harrow, and no-till. He indicated that bulk density values increased with time and were significantly higher in no-till, dise plow, and cultivator than moldboard plow and disc harrow. He also, reported that soil penetration resistance, measured immediately after tillage application, was identical among tillage treatments in the upper 15 cm , and significantly different between 15 and 40 cm depth.

Erbach *et al*. (1992) evaluated the effect of four tillage treatments - no till, chisel plow, moldboard plow, and para plow systems - on three soils (poorly drained, medium, and fine textured) in Iowa. Results showed that all tillage tools reduced bulk density and penetration resistance to the depth of tillage. However, after planting, only the soil tilled with the para plow remained less dense than before tillage. The effect of changes in bulk density due to compaction on water retention and hydraulic conductivity of soils has been studied by certain researchers.

Osunbitan *et al*. (2005) in their study on Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil showed that soil bulk density increased with increase in length of time after tillage. Soil saturated hydraulic conductivity decreased with the degree of soil manipulation during tillage possibly as a result of the disturbance of the continuity of macropores.

Lionel *et al*. (2009) in their study on Temporal and spatial variability of soil bulk density and near-saturated hydraulic conductivity under two contrasted tillage management systems characterized the main sources of bulk density and hydraulic conductivity variability within an agricultural field cultivated under conventional and conservation tillage practices. The tillage system, physical and hydraulic properties were greatly influenced by the position relative to crop rows. Rows had lower infiltration capacities than inter-rows. Temporal effects appeared to be one of the main sources of variability of bulk density and saturated and near-saturated hydraulic conductivity both at the soil surface and in subsurface (15-cm depth). The timing of tillage events relative to the measurements has a strong influence on these soil properties. Tillage effects on soil physical properties were transient and could lead to worse physical conditions than without tillage. This was particularly clear at the 15-cm depth where, in one month, bulk densities increased by a factor 1.4 and hydraulic conductivity at saturation was divided by a factor 10 under conventional tillage system.

POROSITY

Porosity proves very important for plant growers. The open pore space in a soil contains water or air. The open, available pores control how effectively the soil moves water and air through the layers. Porosity relates directly to bulk density in that the denser the soil, the lower the soil porosity levels. Soils with high porosity allow air to reach plant roots and retain water. Water retention is important for plant roots drawing water and nutrients from soil. Though soils with high porosity levels benefit plants, soils with too high porosity levels may drown plants by retaining too much water.

Logsdon *et al*. (1999) from studies on Macroporosity and its relation to saturated hydraulic conductivity under different tillage practice have shown that the loosening of surface soil by tillage operations increases the total soil porosity.

Borresen (1999) found that the effects of tillage and straw treatments on the total porosity and porosity size distribution were not significant.

Kribaa *et al*. (2001) studied the Effect of various cultivation methods on the structure and hydraulic properties of a soil in a semi-arid climate. He found that the soil capillary porosity of harrowing was higher than at conventional tillage and zero tillage, mainly because harrowing increased the permeability and mostly maintained the original porosities in deeper soil layer only by mixing the soil with straw in 0–10 cm. But conventional tillage overturns the soil layer, which breaks the structure of soil and as a result, decreases the permeability of soil.

Glab and Kulig (2008) showed that minimal and no tillage would decrease the soil porosity for aeration, but increase the capillary porosity; as a result, it enhances the water capacity of soil along with bad aeration of soil.

HYDRAULIC CONDUCTIVITY

Saturated hydraulic conductivity is considered one of the most important parameters for water flow and chemical transport phenomena in soils .It depends on the permeability of the material (pores, compaction) and on the degree of saturation Saturated hydraulic conductivity (K_{sat}) provides the simplest and most consistent means of measuring the rate of water movement through soils Saturated hydraulic conductivity, K_{sat}, describes water movement through saturated media.

Permeability refers to the movement of air and water through the soil, which is important because it affects the supply of root-zone air, moisture, and nutrients available for plant uptake. Permeability is influenced by the size, shape, and continuity of the pore spaces, which in turn are dependent on the soil bulk density, structure and texture Water and air rapidly permeate coarse soils with granular subsoils, which tend to be loose when moist and don't restrict water or air movement. Slow permeability is characteristic of moderately fine subsoil with angular to sub angular blocky structure. It is firm when moist and hard when dry.

Logsdon *et al*. (1993) in their study compared reduced tillage with mouldboard ploughing, minimum tillage provided the highest values of K (due to a different pore size distribution in the surface layer rather than to changes in total porosity).

Shafiq (1994) shows that the soil parameters that are adversely affected by compaction or loosening of soil particles are those that control the content and transmission of water, air, heat and nutrients.

Ranjan *et al*. (2006) in their study on Effect of tillage and crop rotations on pore size distribution and soil hydraulic conductivity in sandy clay loam soil of the Indian Himalayas indicate that conservation tillage may be more desirable than conventional tillage in terms of water flow, both saturated and unsaturated. This sub-temperate climate of the Indian Himalayas, a sandy clay loam soil can effectively be managed with conservation tillage to increase water storage and transmission properties.

Lampurlane *et al*. (2006) on his study on Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions, found that with the adoption of no tillage there can be a decrease in hydraulic conductivity due to reduction in soil porosity. This negative effect no tillage of on infiltration can be counteracted by the presence of residues on the soil surface, resulting in greater water storage. The amount of surface residues plays an important role in soil water conservation, especially in no tillage fallows.

Moret *et al* (2007) studied the Dynamics of soil hydraulic properties during fallow as affected by tillage. No tillage plots presented the most compacted topsoil layer when compared with conventional tillage and reduced tillage. Soil hydraulic conductivity under no tillage for the entire range of pressure head applied, significantly lower than that measured for conventional tillage and reduced tillage. However, no tillage showed the largest mean macropore size but the significantly lowest number of water-conducting pores per unit area follows the order conventional tillage reduced tillage and no tillage, respectively.

INFILTRATION

Water infiltration is the movement of water from the soil surface into the soil profile. Soil texture, soil structure, and slope have the largest impact on infiltration rate. It dependents on the permeability of the surface soil, moisture content of the soil and surface conditions such as roughness (tillage and plant residue), slope, and plant cover. Water moves by gravity into the open pore spaces in the soil, and the size of the soil particles and their spacing determines how much water can flow in. Wide pore spacing at the soil surface increases the rate of water infiltration. The rate of infiltration can be relatively fast, especially as water enters into pores and cracks of dry soil. As the soil wets up and becomes saturated, the infiltration rate slows to the point where water ponding and runoff may occur.

Kooistra *et al*. (1984) reported that when a sandy loam soil is tilled, the infiltration rate will be increased because of the lower bulk density but decreased because large-pore continuity will be disrupted, and the importance of these two factors will depend on the level of compaction of the soil. Infiltration rate of a sandy loam soil that has been compacted will usually be correlated with bulk density. Infiltration rate of a tilled soil may improve with time when cropped if tillage is eliminated. The proper use of tillage, control and timing of traffic, and selection of crops will allow a grower to maintain adequate infiltration levels so that adequate irrigation water can be applied.

Carpenter *et al*. (1985) in discussing the effect of wheel loads on subsoil stresses say, “although soil compaction affects many important soil physical properties, perhaps the most detrimental effect is the drastic reduction in hydraulic conductivity, which ultimately results in soil erosion and reduced crop yields due to reduced infiltration, increased run-off and poor drainage”.

Burch *et al*. (1986) measured enhanced infiltration of simulated rain when the level of tillage disturbance was reduced and suggested that the increase may have been caused by changes in the surface seal. They found that surface residues prevented surface seal in the no-till treatments. The manner in which recently tilled soil is settled may affect infiltration rate.

Baumhardt *et al*. (1990) reported that with interception of raindrops by residues, structural soil crust formation is reduced and consequently infiltration is increased.

Benjamin (1993) studied that porosity characteristics differ among tillage systems and nowadays, study on the soil porosity of different tillage treatment is one of the hotspots in tillage research.

Faizan-ul-haq khan (2001) in his study on tillage effects on soil hydraulic characteristics says that the soil infiltration rate was greater under conventional tillage than under conservation tillage. Infiltration rate was much higher in plots where mouldboard plough was used as primary tillage implement. The soil infiltration rate was greater in the beginning, because of initial soil surface conditions and total porosity affected by different tillage treatments.

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

A field study was conducted to study the effect of different tillage on soil hydraulic properties. Various methods and techniques used in the data generation and validation are described in this chapter.

3.1 Description of study area

3.1.1 Location of the study

Field experiments were conducted in the farm of KCAET campus, Tavanur, at 10 ˚52' 09.97” North Latitude and 75˚ 58' 34.20" East Longitude. It comes under Malappuram District of Kerala State in India. The soil type of study area is sandy loam. The area is under cultivation for more than 25 years.

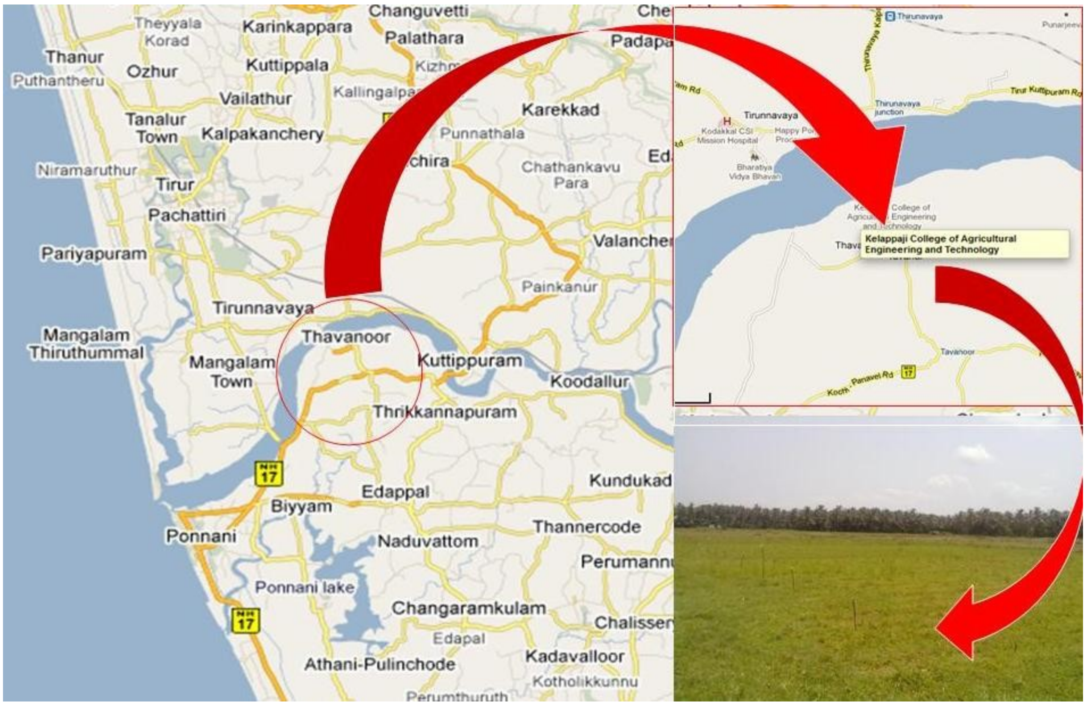

Plate 1 Experimental plot

3.1.2 Climate

Agro-climatically the area falls within the border line of northern zone, central zone and kole lands of Kerala. The average annual rainfall received in the area is about 2900 mm and has a humid climate. Medium to high rainfall zones are available within 10-15 km of the area. The area receives the rainfall mainly from south-west monsoon and north-east monsoon. The average maximum temperature of the study area was 31 ºC and the average minimum temperature was 26 ºC.

3.2 Experimental details

3.2.1Tillage treatments

The experiment was conducted during February – June 2011. An experimental plot consisting of four treatments and five replicates was laid out in randomized complete block design. Each replicates of the treatment is of 20 x 3m size. The layout of the experiment plot is given in fig. 1. The treatments consisted of 4 tillage methods:

T1 - No-tillage (NT)

T2 - Primary tillage (PT)

T3 - Secondary tillage (ST)

T4 - Mulch after tillage (MT).

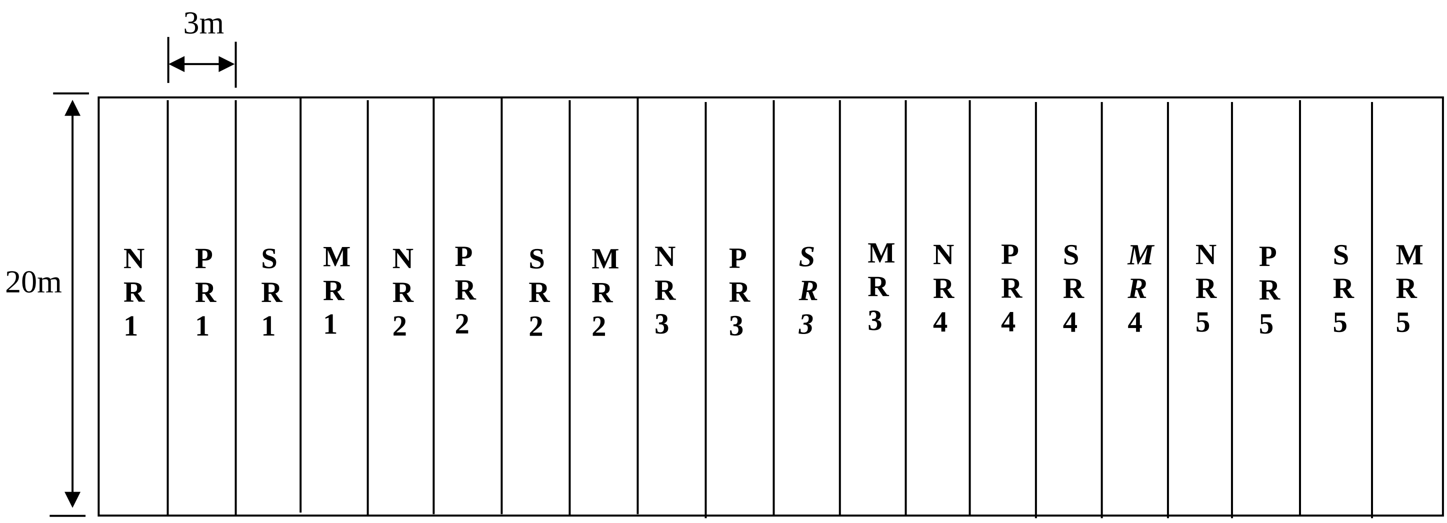

Fig.1 Layout of field

NR1 = Replica 1of No tillage

PR1 = Replica 1of Primary tillage

SR1 = Replica 1of Secondary tillage

MR1 = Replica 1of Mulch after tillage

R2, R3, R4, R5 represents corresponding replicates of treatments NT, PT, ST and MT.

Plate 2 Land before treatments

3.2.1.1 No-tillage (NT)

In NT, vegetation on the plots were manually cleared with cutlasses

3.2.1.2 Primary tillage (PT)

In primary tillage treatment, the mould board plough mounted on a tractor is used to plough the soil. Mouldboard ploughs are used where soil inversion is necessary. The maximum depth of tillage was maintained at 15cm. The parts of mouldboard plough are frog or body, mouldboard or wing, share, landside, connecting rod, bracket and handle. This type of plough leaves no unploughed land as the furrow slices are cut clean and inverted to one side resulting in better pulverization. The two bottom MB Plough is used for the primary tillage.

Plate 3 Soil after primary tillage

3.2.1.3 Secondary tillage (ST)

Secondary tillage involved in the use of cultivator mounted on a tractor to plough the soil. The first ploughing was done by MB plough followed two days after, by another round of ploughing using rotavator and cultivator mounted on the tractor. For both ploughing operations the maximum depth of tillage was maintained at 15 -20cm. The rotavator used was having 18 tynes, 1.25m width and10-20 cm depth of cut. The cultivator used was having 9 tynes , 2m width and 10 – 20 cm depth of depth of cut.

Plate 4 Secondary tillage with cultivator

Plate 5 Secondary tillage with rotavator

3.2.1.4 Mulch after tillage (MT)

Mulch after tillage (MT) treatment involve ploughing operation in a similar way as ST, ie, first set of ploughing using mould board plough is followed by an another round of rotavator. Then the area is uniformly covered with threshed straw at 2 cm thickness. In all the tillage treatments, the maximum depth of tillage was maintained at 15 cm. The readings on this plot are taken one week after mulching.

Plate 6 Mulch after secondary tillage

3.2.2 Data generation

3.2.2.1 Particle size distribution

The percentage of various sizes of particles in the dry soil sample was found by particle size analysis or mechanical analysis. Mechanical analysis was meant for the separation of soil into its different size fractions

3.2.2.2 Sieve analysis

In the BS and ASTM standards, the sieve sizes are given in terms of the number of openings per inch. The number of openings per square inch is equal to the square of the number of sieve. The sieves used for fine sieve analysis are: 2.0 mm, 1.0 mm, 600 µm, 425 µm 300 µm, 212 µm, 150 µm, & 75 µm IS sieves. For this purpose about 1kg of soil was collected from each site after removing a top layer of 5 cm depth. The oven dried soil of about 500 g soil was taken for analysis each time.

Sieving was performed by arranging the various sieves one over the other in the order of their mesh openings-the largest aperture sieve being kept at the top and the smallest aperture sieve being kept at the bottom. A receiver was kept at the bottom and a cover was kept at the top of the whole assembly. The weighed oven dried soil sample was put on the top sieve, and whole assembly was fitted on a sieve shaking machine. The amount of shaking depends upon the shape and the number of particles. At least ten minutes of shaking was done for soils with small particles. The portion of the soil sample retained on each sieve was weighed. The percentage of soil retained on each sieve was calculated on the basis of the total mass of the soil sample taken and from these results percentage passing through each sieve was calculated.

Plate 7 Sieve analysis set up

3.2.2.3 Fine analysis

Calibration of the hydrometer:

1. For determining the volume of the hydrometer bulb (v_h) 800 ml of water was poured into 1000 ml measuring cylinder and the water level is noted. Then immerse the hydrometer in water and note the water level reading. The difference between the two readings was recorded as the volume of the hydrometer bulb plus the volume of the part of the stem which is submerged.

2. To find the area of cross section (A) of the measuring cylinder in which the hydrometer is to be used, the distance between two graduations of the cylinder was measured. The cross sectional area is then equal to the volume included between them.

3 The distance (h) from the neck to the bottom of the bulb is measured, and is recorded as the height of the bulb.

4. With the help of the an accurate scale, the height H between the neck of the hydrometer to each of the other major calibration marks (R_h) is measured.

5. The effective depth corresponding to each major calibration marks (or hydrometer reading) is calculated as:

$$H_e = H + 0.5\,[h - (v_h/A)]$$

6. The calibration curve between the H_e and R_h which was used for finding the effective depth H_e corresponding to hydrometer reading obtained during the test is drawn.

Dispersion of soil:

1. To the oven dried sample in the evaporating dish 100 ml of the sodium hexametaphoshate solution was added and the mixture was then warmed gently for about 10 minutes. Then the mixture transferred to the cup of the mechanical mixer using a jet of distilled water, and stirred it well for about 15 minutes. The sodium hexametaphosphate solution was prepared by dissolving 33g of sodium metahexaphosphate and seven gram of sodium carbonate in distilled water to make one liter of solution.

2. The soil suspension was transferred to 75 micron IS sieve placed on a receiver and using jet of distilled water from a wash bottle, soil on the sieve was washed. The amount of distilled water used during this operation may be about 500ml.

3. The soil suspension passing the 75 micron IS sieve was transferred to 1000 ml measuring cylinder, and more distilled water was added to make the volume to exactly 1000 ml in the cylinder.

4. The material retained on 75 micron IS sieve was collected and kept in the oven for oven drying. Then the dry mass of soil retained on the 75 micron IS sieve was determined.

Sedimentation test with hydrometer:

5 A rubber bung or any other suitable cover was inserted on the top of the 1000 ml measuring cylinder containing the soil suspension and shakes vigorously end over end. Then allow it to stand. Immediately started the stopwatch.

6. Then hydrometer gently immersed to a depth slightly below its floating position and is allowed to float freely. The hydrometer reading after periods of ½, 1, 2 and 4minutes noted. Take out the hydrometer, rinse it with distilled water and allow it to stand in jar containing distilled water at the same temperature as that of the test cylinder.

7. The hydrometer was re inserted in the suspension and readings were taken after periods of 8, 15 and 30 minutes, 1, 2 and 4 hours after shaking. The hydrometer was removed, rinsed and placed in the distilled water after each reading. After end of 4 hour reading, are taken twice within 24 hours.

3.2.2.3 Particle size distribution curve

The results of the mechanical analysis are plotted to get a particle size distribution curve with the percentage finer (N) as the ordinate and the particle diameter as the abscissa, the diameter being plotted on a logarithmic scale.

3.2.2.4 Moisture content

The moist sample was kept in clean container. The mass of the soil and container with lid was determined. With the lid removed, the container was then placed in the oven and maintains the temperature of the oven between 105°c-110°c for about 16-24 hours. After drying the container was removed from the oven and allowed to cool. The lid was then replaced, and the mass of the container and the dry soil was found. The water content was calculated by the following equation:

$$W = \frac{M_2 - M_3}{M_3 - M_1}$$

Where,

M_1= mass of container with lid

M_2= mass of container with lid and wet soil

M_3= mass of container with lid and dry soil

3.2.2.4 Soil bulk density

A core cutter consisting of a steel cutter, 10 cm in diameter and 12.5 cm high, and a 2.5 cm high dolly was driven in the cleaned surface with the help of a rammer, till about 1 cm of the dolly protruded above the surface. The cutter, containing the soil, was dug out of the ground. The dolly was then removed and the excess soil was trimmed off. Soil bulk density was determined from these undisturbed cores as mass per volume of dried soil. The samples were collected a day after the treatments were applied.

Plate 8 Sampling by core cutter

3.2.2.5 Porosity

A value for porosity was calculated from the bulk density ρ_{bulk} and particle density $\rho_{particle}$ as:

$$\Phi = 1 - \left(\frac{\rho_{bulk}}{\rho_{particle}} \right)$$

Particle density was calculated as mass of soil to the volume of soil solid for that the an amount of soil was kept for oven drying and the oven dried sample was added to a known volume of water and the increase in elevation of water level was noted. This gives the volume of the soil solids.

3.2.2.6 Saturated hydraulic conductivity

The soil samples were collected using 10 cm to 12 cm cylindrical cores. Then, the sample was kept for saturation. After saturation it was placed in the permeameter mould assembly in the bottom tank and the bottom tank was filled with water up to its outlet. The water inlet nozzle of the mould was connected to the stand pipe filled with water. Water was permitted to flow till a steady state of flow was reached. The time interval required for water level in the standpipe to fall from a particular initial value (h_0) to a particular final value (h_1) was measured with the help of a stopwatch. Then the saturated hydraulic conductivity, Ksat (m s^{-1}), was calculated as,

$$K = \frac{2.3aL}{At} \log \left(\frac{h_1}{h_2} \right)$$

Where, a = area of stand pipe (m^2),

A = cross sectional area of the sample (m^2),

L = length of sample (m),

h_1 = initial head (m),

h_2 = final head (m),

t = time interval (s).

Plate 9 Soil sample kept for saturation in water plate

3.2.2.7 Infiltration

Infiltrometer is the device used to measure the rate of water infiltration into soil or other porous media. Commonly used infiltrometer are single ring or double ring infiltrometer, and also disc permeameter.

In this study, infiltration rate was studied using double ring infiltrometer. The experimental set up used in infiltration measurements are illustrated in plate 10. 25cm deep cylinders of diameter 30cm and 20cm are used for experiment. The cylinders are installed about 10cm deep in the soil. The cylinders are driven into the ground by a falling weight type hammer. The water level in the inner cylinder was read with metal steel placed in the inner cylinder. Then water is added to both cylinders. A stop watch started at the instant of the addition of water begins. The total quantity of water added to the inner cylinder was determined by counting the number of full containers of water and the fractional volume in the jar, which was added last. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reach the desired point was taken as the quantity of water that infiltrates during the time interval between the start of filling and the first measurement. After the initial reading the water level measurements are made at frequent intervals to determine the amount of water that has infiltrated during the time interval. Water was added quickly after each measurement so that a constant average infiltration head could be maintained. The buffer pond was filled with water immediately after filling the inner cylinder to have an equal water level. The experiment was followed till considerable readings are obtained. Then the readings (water level) at regular intervals are taken and are tabulated and infiltration rate is determined.

Using this data an equation of following form was developed to find functional relationship

$$Y = at^{\alpha} + b$$

Where

y = accumulated infiltration in cm

t = elapsed time

a, b, α = constant

Plate 10 Double ring infiltrometer set up in the field

3.3 Analysis of the data observed

Statistical analysis of the data obtained was done using RBD analysis in the computer package. Analysis of variance was done to find out the significant difference in the treatments. The level of significance used was 5%. Critical differences in treatments were also calculated for all the treatment means. The results are presented in next chapter.

RESULTS AND DISCUSSIONS

CHAPTER IV
RESULTS AND DISCUSSION

The study was conducted to evaluate the effect of tillage on soil hydraulic properties in sandy loam soil. The soil hydraulic characteristics such as bulk density, permeability, porosity, moisture content and infiltration were studied. Soil tillage was done with 35 hp tractor with attachments include mould board plough for primary tillage, cultivator and rotavator for secondary tillage.

The results obtained from the study were analyzed to provide basic information of effect of tillage on soil hydraulic properties. The results of the study were discussed in this chapter.

4.1 Evaluation of Soil Physical Properties

The results of the soil textural analysis are shown in APPENDIX I. The results of the mechanical analysis (both sieve and sedimentation) were plotted to get particle size distribution curve. In this curve percentage finer 'N' is taken as ordinate and particle diameter (mm) as the abscissa on logarithmic scale. The resulting curve is shown in figure 2. The figure showed that the soil sample consisted of 79.9% sand having size ranging from 2 to 0.05mm, 16.69% silt (0.05 to 0.002mm) and the remaining part 2.41 % clay. As per the USDA classification chart, the textural class of the soil was found to be sandy loam.

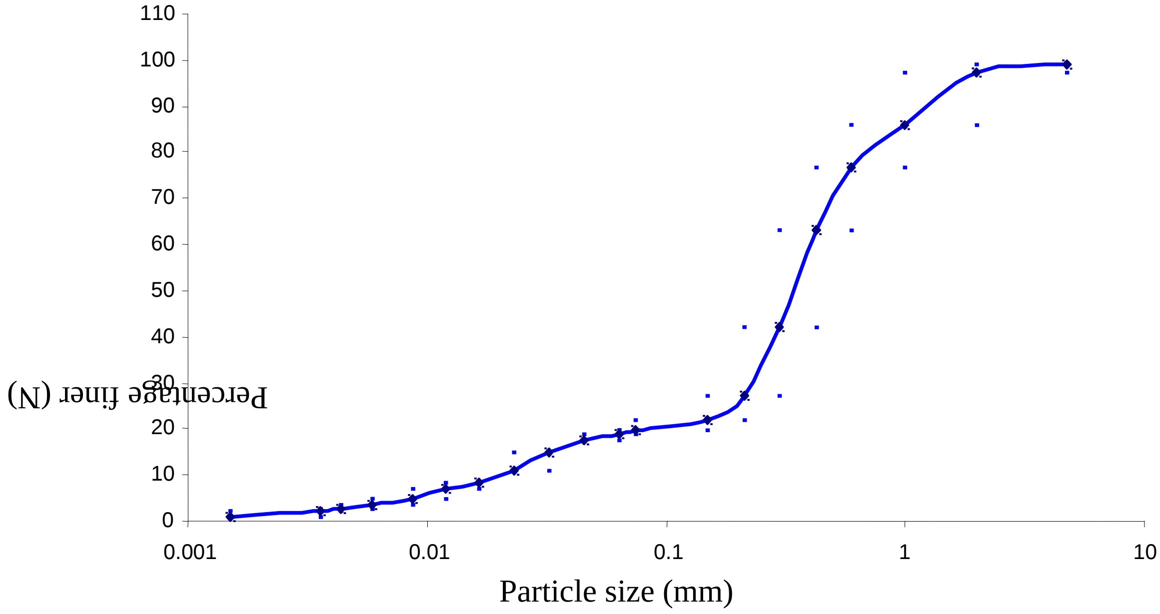

Fig.2. Particle size distribution curve

4.2 Moisture content

The moisture content of the soil from the experimental plots was found by gravimetric method. The rainfall data was collected during the study and is given in APPENDIX II. The soil samples were collected 3 week after tillage and the field data on moisture content determination is given in APPENDIX III.

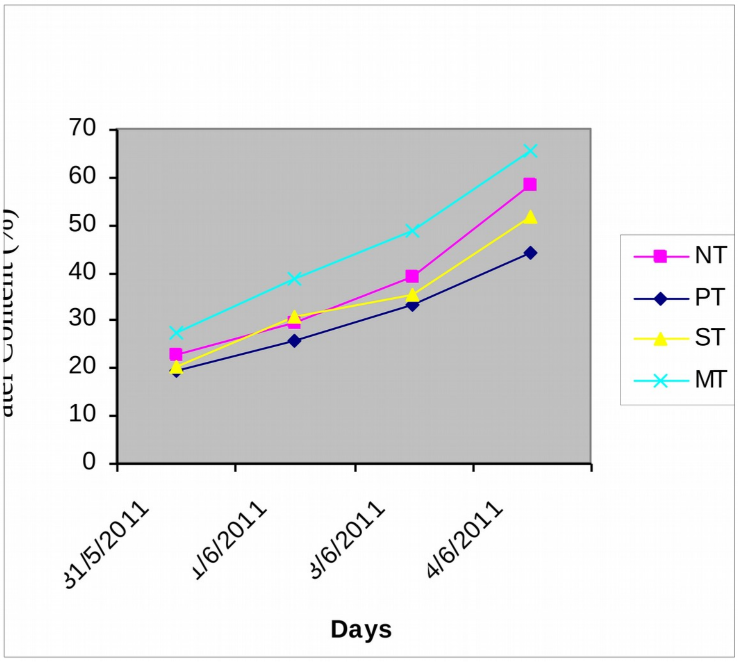

Fig. 3. Variation of water content with treatments and time

From the figure 3 it is clear that initially in all cases moisture content was within a range of 18-26 %. After 5 days, in mulched plot it was about 65 %, ie, moisture content of the mulched soil was comparatively higher than that of the other treatments. This is because of mulch reduces the evaporation of water from soil by reducing soil heating by sun radiation. Thus tillage with mulch can reduce the irrigation requirement of the soil.

Table 1. ANOVA table for moisture content of the soil

Source	df	SS	MS	F-cal	F-Tab	Remarks
Block	4	0.88	0.22	0.65	3.26	NS
Treatments	3	252.25	84.08	246.21	3.49	*
Error	12	4.10	0.34			
Total	19	257.23				

CD=0.81

* represents the value is significant at 5% significance level
NS represent the value is non significant at 5% significant level.

From the ANOVA table we can see that

1. There is no significant difference between replications for the moisture content parameter at 5% significant level.
2. The difference in moisture content between no tillage and primary tillage is insignificant.
3. It was also seen that there is highly significant difference among mulched tillage, secondary tillage and primary tillage for the moisture content parameter.

4.3 Bulk Density

The bulk density of the soil in the experimental field was found by core cutter method. The weight and volume of core cutter and weight of the soil samples are given in APPENDIX IV. The mean bulk densities of the soils from the four treatments are also given APPENDIX IV.

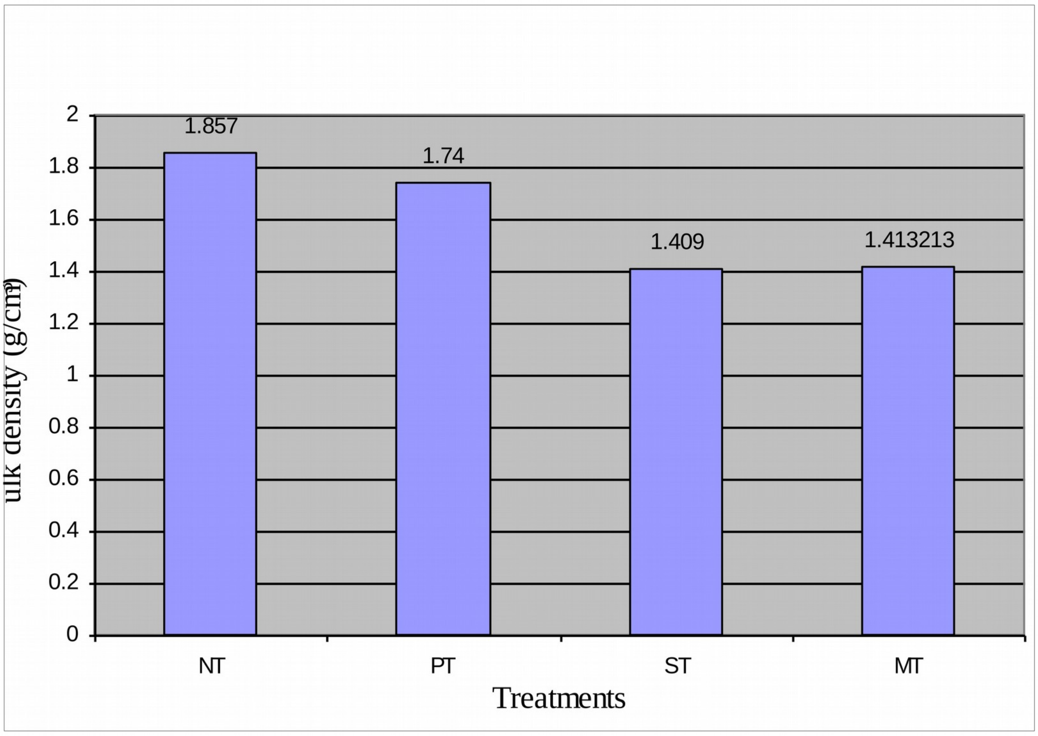

Fig. 4. Variation of bulk density with treatments

The bulk density of the soil is decreases with increases in porosity. From the figure 4, no tilled soil has more bulk density of 1.857 g/cm^3 that is because of its less porosity. Secondary tilled soil and mulch tillage has less bulk density because of its higher porosity. The bulk density decreases with tillage in the order NT>PT>MT≈ST

Table 2. ANOVA table for bulk density of soil

Source	df	SS	MS	F-cal	F-Tab	Remarks
Block	4	0.01	0.00	1.03	3.26	NS
Treatments	3	0.80	0.27	143.95	3.49	*
Error	12	0.02	0.00			
Total	19	0.83				

CD=0.06

* represents the value is significant at 5% significance level
NS represent the value is non significant at 5% significant level.

From the ANOVA table we can see that

1. There is no significant difference between replications for the bulk density parameter at 5% significant level.
2. The difference bulk density between secondary tillage and secondary tillage with mulch is insignificant.
3. It was also seen that there is highly significant difference among no tillage,

primary tillage and secondary tillage for the bulk density parameter.

4.4 Porosity

Particle density is calculated as mass of soil to the volume of soil solid for that the an amount of soil is kept for oven drying and the oven dried sample is added to a known volume of water and the increase in elevation of water level is noted . This gives the volume of the soil solids. The observations and calculations are presented in APPENDIX V. The mean porosity of the soil samples are calculated from the treatment replicas and it is given in APPENDIX V.

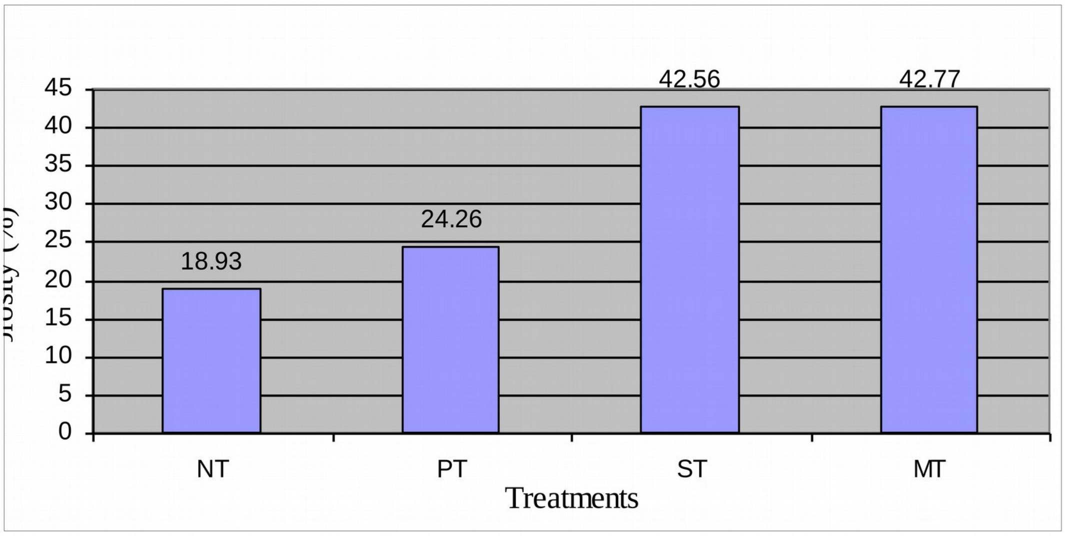

Fig. 5. Variation of porosity with treatments

The porosity is maximum ie,42.77 % in case of mulch tillage and 42.56 % for secondary tillage and least in case of no-tillage ie, about 18.93 %. In case of porosity, a high variation observed between no-tillage, mulch tillage and secondary tillage.

The figure 5 depicts that porosity increases with tillage. The porosity increases in the order NT<PT<ST≈MT. Porosity increases the volume of voids in the soil. Secondary tilled soil has more porosity compared to primary tillage and mulch. Porosity increases water holding capacity of the soil.

Table 3. ANOVA table for porosity

Source	df	SS	MS	F-cal	F-Tab	Remarks
Block	4	16.36	4.09	0.89	3.26	NS
Treatments	3	2279.16	759.72	164.76	3.49	*
Error	12	55.33	4.61			
Total	19	2350.86				

CD=2.96

* represents the value is significant at 5% significance level
NS represent the value is non significant at 5% significant level.

From the ANOVA table we can see that

1. There is no significant difference between replications for the porosity parameter at 5% significant level.
2. The difference porosity between secondary tillage and secondary tillage with mulch is insignificant.
3. It was also seen that there is highly significant difference among no tillage, primary tillage and secondary tillage for the porosity parameter.

4.5 Saturated Hydraulic conductivity or Permeability

The saturated hydraulic conductivity or permeability was experimentally found out and data is given in APPENDIX VI. The mean permeabilities of the four treatments are given in APPENDIX VI.

Fig. 6. Variation of permeability with treatments

Figure 6 depicts that the mean permeability of soil decreases in the order ST>MT>PT>NT. Secondary tilled soil has more permeability compared to the other treatment. This may be due to the increased porosity.

Table 4. ANOVA table for permeability

Source	df	SS	MS	F-cal	F-Tab	Remarks

Block	4	14.48	3.62	0.75	3.26	NS
Treatments	3	1943.46	647.82	133.42	3.49	*
Error	12	58.27	4.86			
Total	19	2016.20				

CD=3.04

* represents the value is significant at 5% significance level
NS represent the value is non significant at 5% significant level.

From the ANOVA table we can see that

1. There is no significant difference between replications for the permeability parameter at 5% significant level.
2. The difference permeability between secondary tillage and secondary tillage with mulch is insignificant.
3. Also there is no significant difference in permeability among primary tillage and no tillage treatments.
3. It was also seen that there is highly significant difference among primary tillage and secondary tillage, primary tillage and secondary tillage with mulch for the permeability parameter.

4.6 Infiltration

A double ring infiltrometer test was conducted to determine the infiltration rate of the soil in each treatment plots. The field data on cylinder infiltrometer from each treatment is given in APPENDIX VII.

4.6.1 No Tillage

The APPENDIX VII shows the readings obtained in the double ring infiltrometer experiment from no tilled land.

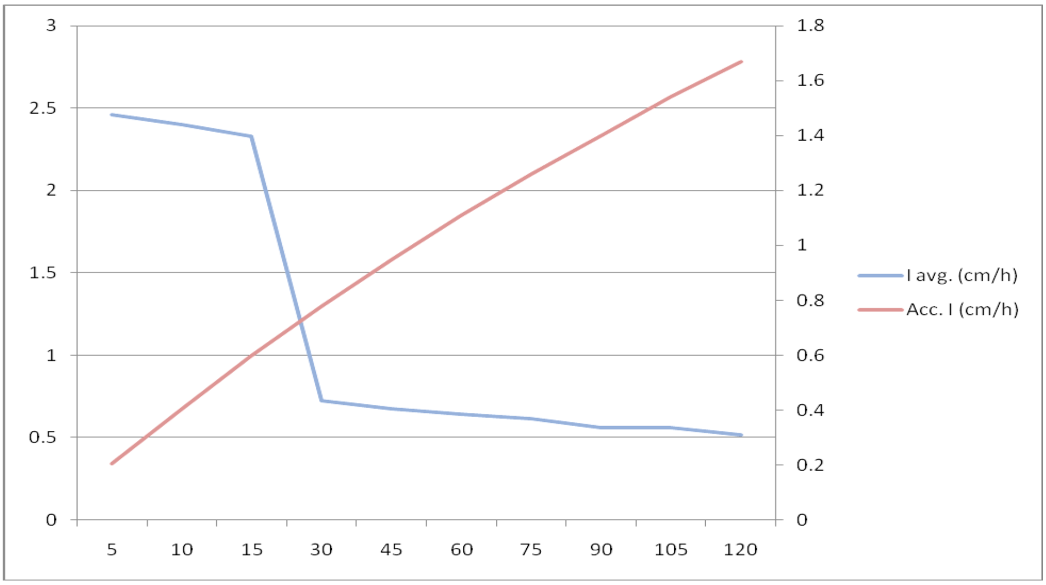

Fig. 7. Infiltration curves showing accumulated infiltration and infiltration rate of no tilled soil

The functional relationship between accumulated infiltration and time was fitted as

$$Y = 0.32028 * t^{0.3680} - 0.3685$$

It was observed that the average infiltration rate of no tilled soil was 1.1476 cm/hr.

4.6.2 Primary Tillage

The APPENDIX VII shows the readings obtained in the double ring infiltrometer experiment from primary tilled land.

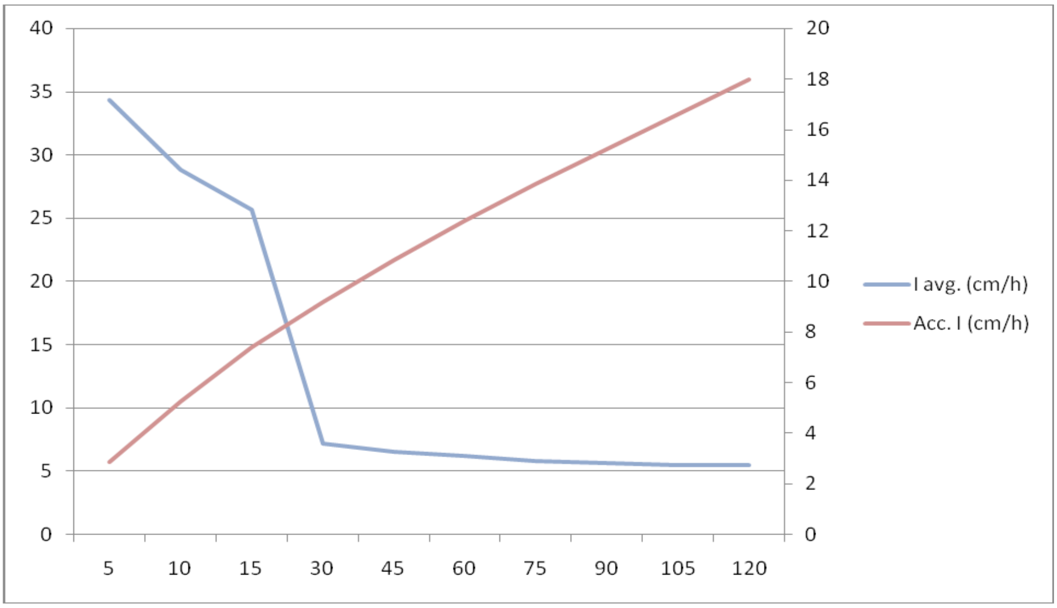

Fig. 8. Infiltration curves showing accumulated infiltration and infiltration rate

of primary tillage

The functional relationship between accumulated infiltration and time was fitted as

$$Y= 5.444*t^{0.3}-5.6952$$

The average infiltration rate of primary tilled soil was 13.1095 cm/hr.

4.6.3 Secondary Tillage

The APPENDIX VII shows the readings obtained in the double ring infiltrometer experiment from secondary tilled land.

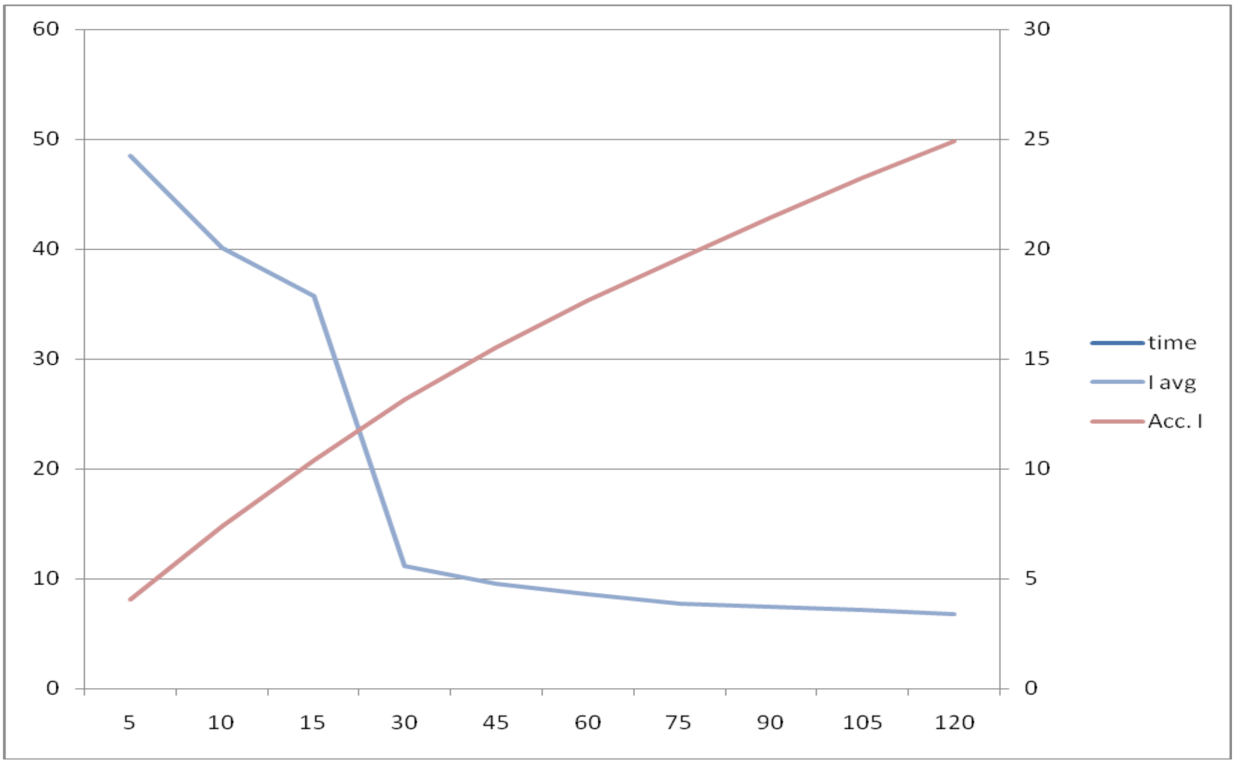

Fig. 9 Infiltration curves showing accumulated infiltration and infiltration rate of secondary tilled soil

The functional relationship between accumulated infiltration and time was fitted as

$$Y = 8.6728t^{0.2826}-9.5941$$

The average infiltration rate of secondary tilled soil was 18.248 cm/hr.

4.6.4 Secondary Tillage with Mulch

The APPENDIX VII shows the readings obtained in the double ring infiltrometer experiment from secondary tillage with mulch.

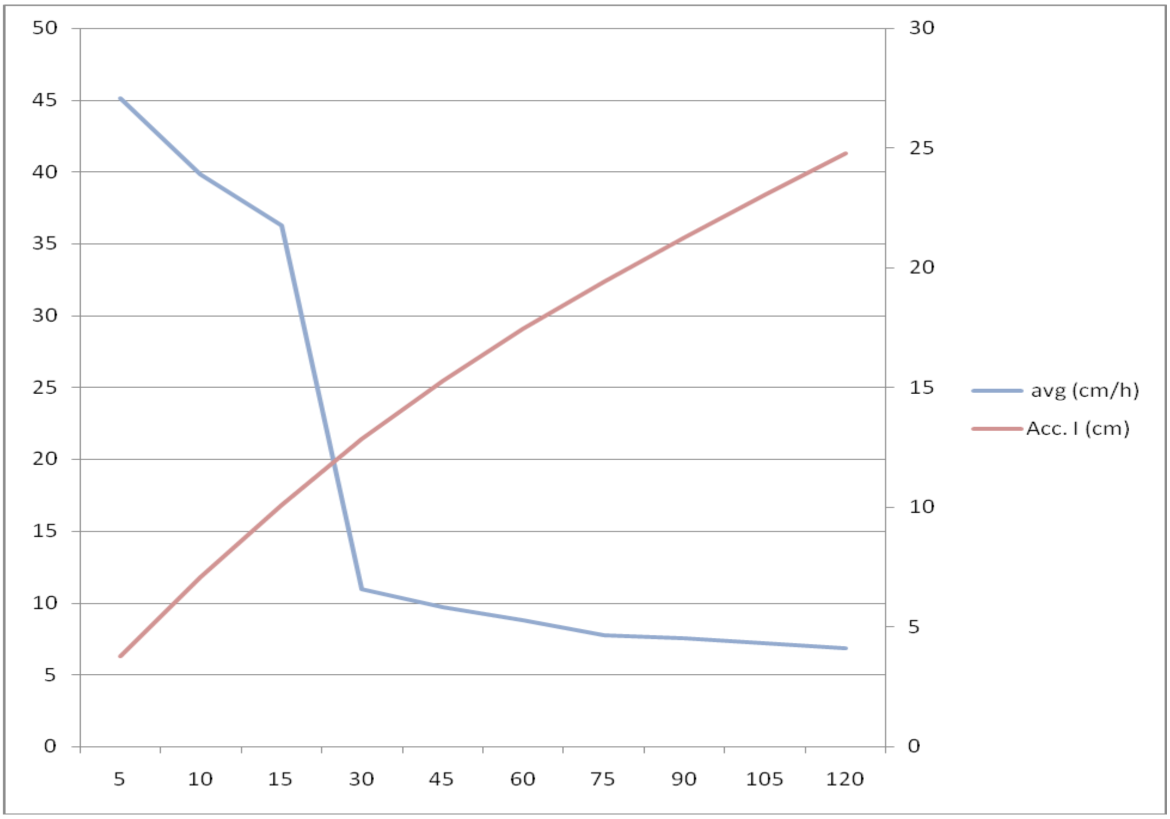

Fig. 10. Infiltration curves showing accumulated infiltration and infiltration rate of secondary tillage with mulch

The functional relationship between accumulated infiltration and time was fitted as

$$Y=9.1402t^{0.2738}-9.8395$$

It was observed that the average infiltration rate of secondary tillage with mulch soil was 17.9952 cm/hr.

4.6.5 Log –Log graph

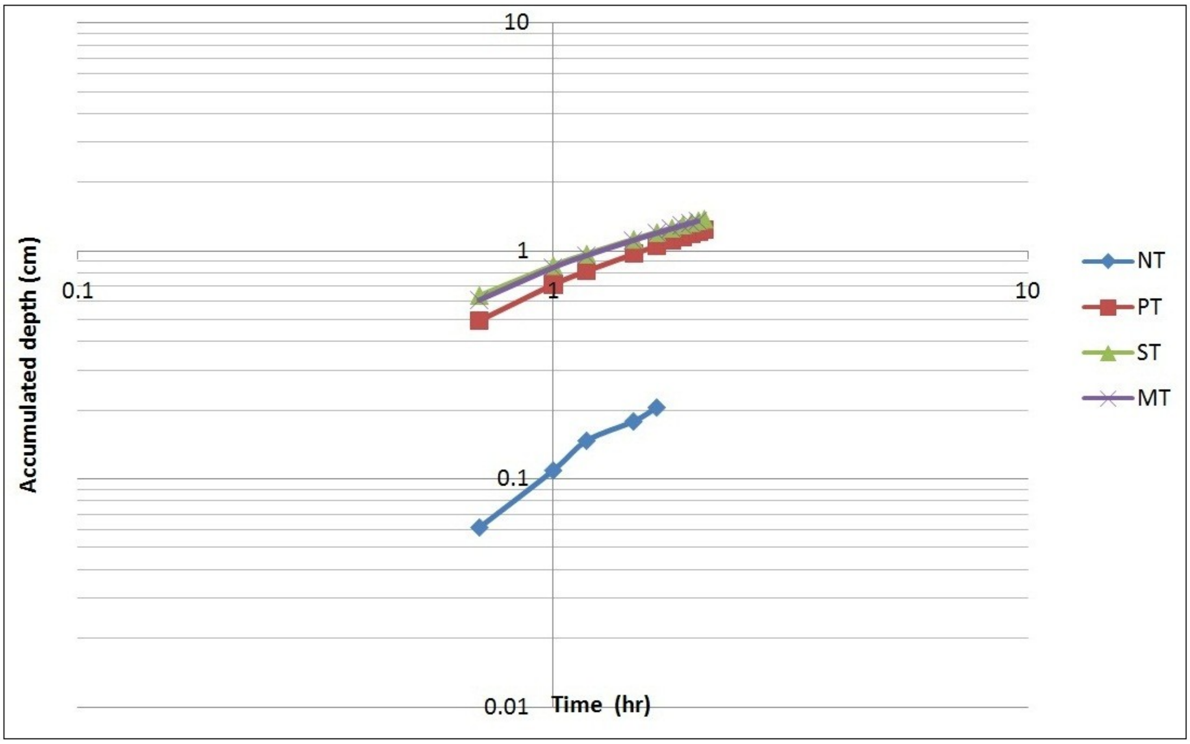

Fig. 11. Comparison of accumulated infiltration depths of treatments

The average infiltration rate is high in case of secondary tillage i.e., about 18.248 cm/hr followed by mulch tillage with 17.9952 cm/hr and primary tillage with 13.1095 cm/hr. the least was found in case of no-tillage of 1.1476 cm/hr. it reveals that tillage is having a very important role in movement of water through the soil.

By comparing the above accumulated infiltration curves, we can see that average infiltration rate of the soil increasing in the order NT<PT<MT≈ST. The treatment secondary tillage with mulch has almost infiltration rate with secondary tilled soil. The secondary tilled soil has more infiltration compared to no tilled and primary tilled soil, this may be due to the increased porosity in secondary tilled soil and mulched secondary tilled soil.

SUMMERY AND CONCLUSIONS

CHAPTER V
SUMMARY AND CONCLUSION

The study entitled "Effect of Tillage on Soil Hydraulic Properties" was aimed to asses the hydraulic properties such as moisture content, bulk density, porosity, saturated hydraulic conductivity and infiltration of soil under types of tillage. Tillage treatments include no tillage, primary tillage, secondary tillage, and secondary tillage with mulch.

Tillage operation is the mechanical manipulation of soil to develop a desirable soil structure for a seed bed and to establish specific surface configuration for planting, irrigation, drainage, harvesting operations etc

The average moisture content of soil increases in the order no tillage ≈ primary tillage < secondary tillage < secondary tillage with mulch. Secondary tillage with mulch has more moisture content, because of its reduced evaporation loss compared to the other treatments. Moisture content increases with tillage because of increase in the voids ratio.

The bulk density of the soil reduces with tillage because of its increase in its voids ratio. The bulk density determines the looseness of the soil. No tilled soil has more bulk density compared to the other treatments. It is because of its compacted nature. Tillage increases the total volume of the soil. Thus reduces the bulk density.

The porosity of the soil increases with tillage. Porosity increases in the order no tillage < primary tillage < secondary tillage ≈ secondary tillage with mulch. There is direct relationship between bulk density and degrees of tillage. Increase in porosity increase the water holding capacity of the soil. There is a significant increase in the porosity with tillage.

The saturated hydraulic conductivity plays a crucial role in issues connected with the flow of ground water, migration of fertilizers, pollutants and stability analysis. Tillage practices highly influence the saturated hydraulic conductivity of the soil. Saturated hydraulic conductivity increases in the order no tillage < primary tillage < secondary tillage ≈ secondary tillage with mulch. The higher saturated hydraulic conductivity was apparently caused by greater macro porosity whereas enhanced retention of water was likely caused by an organic layer overlying mineral soil or smaller hydraulic gradient in no tillage.

Infiltration rate of the soil determine the intake rate of water by the soil. Infiltration rate of the soil increases with tillage, because of increase in porosity. Increase in infiltration with tillage in the order no tillage < primary tillage < secondary tillage ≈ secondary tillage with mulch.

Tillage makes the soil suitable for cropping by enhancing the moisture availability to the plants. Also tillage enhances the ground water recharge by increasing the infiltration rate and saturated hydraulic conductivity of the soil. Thus tillage practices improve the overall hydraulic properties of soil.

REFERENCES

V

REFERENCE

Ahn, P.M. and Hintze, B. (1990). No tillage, minimum tillage, and their influence on soil properties. Organic-matter Management and Tillage in Humid and Sub-humid Africa. *IBSRAM Proceedings No.10. Bangkok:.* pp: 341-349

Antapa, P.L. and Angen, T.V. (1990). Tillage practices and residue management in Tanzania. In: Organic-matter Management and Tillage in Humid and Sub-humid Africa. *IBSRAM Proceedings No.10. Bangkok:* pp: 49-57.

Baldev Singh., Chanasyk, D. S., and W. B. McGill., (*1995).* Soil hydraulic properties of an Orthic Black Chernozem under long-term tillage and residue management. Canadian j. soil sci., 27:63-71.

Benjamin, J.G. (1993). Tillage effects on near-surface soil hydraulic properties. *Soil Till. Res*.26:27-288.

Blevins, R.L., D. Cook, S.H. Phillips and R.E. Phillips. 1971. Influence of No Tillage on Soil Moisture. *Agronomy Journal*, 63:593-596.

Boone, F.R. (1988). Weather and other environmental factors influencing crop responses to tillage and traffic. *Soil and Tillage Research*, 11:283-324.

Borresen, T. (1999). The effect of straw management and reduced tillage on soil properties and crop yields of spring-sown cereals on two loam soils in Norway. *Soil and Tillage Research*, 51: 91–102.

Carpenter, T.G., Fausey, N.R. and Reeder, R.C. (1985). Theoretical effect of wheel loads on subsoil stresses. *Soil & Tillage Research*, 6:179- 192.

Carter, M.R. (1988). Temporal variability of soil macroporosity in a fine sandy loam under mouldboard ploughing and direct drilling, *Soil Tillage Res*. 12:37-51.

Cesevičius, G., Feiza, V. & Feizienė, D. (2005). The effects of soil tillage systems of various intensity and plant residues on soil physical properties and barley yield. *Vagos: Scientific articles of Lithuanian University of Agriculture,* vol 69 (22):7–18.

Cresswell, H.P., Painter, D.J. and Cameron, K.C. (1991). Tillage and water content effects on surface soil physical properties. *Soil and Tillage Research*,21: 67-83.

Erbach, D.C., Benjamin J.G., Cruser R.M., Elamin M.A, Mukhtar S. and Choi C.H. (1992). Soil and corn response to tillage with para plow. *Transactions of the ASAE* 35(5), pp:1347-1354.

Ferreras, L.A., Costa, J.L., Garcia, F.O. and Pecorari, C. (2000). Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern "Pampa" of Argentina. *Soil & Tillage Research,* 54:31-39.

Głab, T. and Kulig, B. (2008). Effect of mulch and tillage system on soil porosity under wheat (*Triticum aestivum*). *Soil and Tillage Research*, 99: 169–178.

Greenland, D.J. (1981). Soil management and soil degradation. *J. Soil Science*, 32: 301-322.

Gupta, S. C. and Allmaras, R. R. (1987). Models to assess the susceptibility of soils to excessive compaction. *Adv. Soil Sci*. 6: 65-100.

Johnson, C.B., Mannering, J.V. and Moldenhauer, W.C. (1979). Influence of surface roughness and clod size and stability on soil and water losses. *Soil Sci. Soc. Amer. J*. 43:772-777.

Klute, A. (1982). Tillage effects on hydraulic properties of soil. A review. In: *Predicting Tillage Effects on Soil Physical Properties and Processes*. pp:1325-1334

Lal R., de Vleeschawer D.and Nganje R.M. (1980): Changes in properties of a newly cleared tropical alfisol as affected by mulching. *Soil Sci. Soc. Amer. J*, *44*: 827–833.

Lal, R. (1980). Crop residue management in relation to tillage techniques for soil and water conservation. In: Organic recycling in Africa 74-79. *Soils Bulletin 43*. FAO, Rome.

Lal, R. (1983). No-till farming: Soil and water conservation and management in the humid and sub-humid tropics. *IITA Monograph No. 2,* Ibadan, Nigeria.

Logsdon, S.D., Allmaras, R.R., Swan, J.B. and Randall, G.W. (1990). Macroporosity and its relation to saturated hydraulic conductivity under different tillage practices. *Soil Sci. Soc. Am. J.*, 54 (1990), pp: 1096–1101.

Lampurlanes, J. and Cantero-Martinez, C. (2003). Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barley root growth. Agron. J. 95:526-536.

Moret, D. and Arrúe, J.L. (2007). Characterizing soil water-conducting macro and mesoporosity as influenced by tillage using tension infiltrometry. *Soil Sci. Soc. Amer. J.,* 71:500-506.

Ohiri, A.C. and Ezumah, H.C. (1990). Tillage effects on cassava (*Manihot esculenta*) production and some soil properties. *Soil and Tillage Research,* 17:221-231.

Onstad, C.A., Wolfe, M.L., Larson, C.L. and Slack, D.C. (1984). Tilled soil subsidence during repeated wetting. *Trans. ASAE,* 27:733-736.

Osunbitan, J.A., Oyedele, D.J. and Adekalu, K.O. (2005). Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. *Soil Till. Res*. 82:57-64.

Parr, J.F., Papendick, R.I., Hornick, S.B. and Meyer, R.E. (1990). The use of cover crops, mulches and tillage for soil water conservation and weed control. In: Organic-matter Management and Tillage in Humid and Sub-humid Afric*a*. pp: 246-261. *IBSRAM Proceedings No.10. Bangkok: IBSRAM*

Pelegrin, F., Moreno, F., Martin-Aranda, J. and Camps, M. (1990). The influence of tillage methods on soil physical properties and water balance for a typical crop rotation in SW Spain. *Soil & Tillage Research,* 16: 345-358.

Reynolds, W.D.and Elrick, D.E., (1985). In-situ measurement of field-saturated hydraulic conductivity, sorptivity and α parameter using the Guelph permeameter. *Soil Sci.* 140: 292-302.

Sasal, M.C., Andriulo, A.E. and Taboada, M.A. (2006). Soil porosity characteristics and water movement under zero tillage in silty soils in Argentinian Pampas. *Soil and Tillage Research*, 87: 9–18.

Shafiq, M., Hassan, A. and Ahmad, S. (1994). Soil physical properties as influenced by induced compaction under laboratory and field conditions. *Soil Tillage Res.*, 29**,** pp: 13–22.

Shaykewich, C.F. (1970). Hydraulic properties of disturbed and undisturbed soils. *Can. J. Soil Sci.*, 50, pp: 431–437.

Tessier, S., Peru, M., Dyck, F.B., Zentner, R.P. and Campbell, C.A. (1990). Conservation Tillage for Spring Wheat Production in Semi-arid Saskatchewan. *Soil Tillage Research*, 18:73-89.

Unger, P.W., Langdale, G.W. and Papendick, R.I. (1988). Role of crop residues –

improving water conservation and use. In: Cropping Strategies for Efficient Use of Water and Nitrogen. *American Society of Agronomy Special Publication* No.51.69-100

Willis, W.O. and Amemiya, M. (1973). Tillage management principles. In: *Conservation Tillage* (Iowa, 1973) pp: 22-42.

APPENDICES

APPENDIX 1

Grain size distribution of the soil (Coarse Fraction)

Sl. No.	IS Sieve	Particle Size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer
1	4.72	4.75	3.50	1.17	1.17	98.93
2	2	2mm	4.80	1.60	2.77	97.23
3	1	1mm	42.90	14.30	17.07	82.93
4	0.60	0.6mm	18.57	6.19	23.26	76.74
5	0.425	0.425mm	40.470	13.47	36.73	63.27
6	0.3	0.3mm	63.32	21.10	57083	42.17
7	0.212	0.212mm	52.20	18.40	76.23	23.77
8	0.145	0.15mm	35.20	11.73	87.96	12.04
9	0.075	0.075mm	24.00	8.00	95.96	4.04
10	Pan	Pan	4.25	1.42	97.38	2.62

Grain Size Distribution of the soil (Fine fraction)

Mass of dry soil sample (M) =300 g

Mass of fraction passing 2 mm sieve (M’) =260 g

Mass of dry sample taken from minus 2 mm sieves (Md) =50 g

Specific gravity of soil particles of minus 75 micron, G =2.65

Date	Time	Elapsed Time	Temperature	Hydrometer reading	Rh	Effective Depth	Factor M	Particle Size, D(mm)	% finer (N)based on Md	% finer based on whole N=NxM/M
20-5-11	11.05am	½	32	6.75	7.25	14.2	1193	0.064	21.68	18.79
	11.06am	1	32	6.20	6.70	14.5	1193	0.045	19.92	17.33
	11.08am	2	32	6.25	6.75	14.6	1193	0.0322	20.08	17.47
	11.12am	4	32	5.00	5.50	14.8	1193	0.023	16.06	13.97
	11.18am	8	32	3.00	3.50	15.2	1193	0.0164	9.64	8.39
	11.33am	15	33	2.50	3.00	15.8	1180	0.0121	8.03	7.22
	12.03pm	30	33	1.75	2.25	16.0	1180	0.0087	5.63	4.89
	1.03pm	60	33	1.25	1.75	16.3	1180	0.0059	4.02	3.5
	3.03pm	120	36	1.00	1.50	16.5	1144	0.0044	3.21	2.79
	6.03pm	180	33	0.75	1.25	16.7	1180	0.0036	2.41	2.10
	3.05am	900	36	0.25	0.75	16.0	1144	0.0015	0.803	0.69

Calibration of Hydrometer

Volume of Hydrometer (vh) = 85ml

Height of Bulb = 14.8ml

Sectional area of the jar, A = 29.85 cm^2

Constant ½ (Vh-Vh/A) = 5.98cm

Hydrometer reading, Rh	H (cm)	Effective Depth, He (cm)
30	0.5	6.474
25	2.2	8.275
20	4.0	9.975
15	5.6	11.675
10	7.4	13.375
5	9.1	15.075
0	10.9	15.875
-5	12.6	18.675

APPENDIX II

Rainfall details

DATE	Rainfall (mm/day)
28/5/2011	0.7
29/5/2011	17.1
31/5/2011	61.15
1/6/2011	101.5
2/6/2011	10.6
3/6/2011	9.8
4/6/2011	8.5
5/6/2011	5.4
6/6/2011	4.6
7/6/2011	3.4

APPENDIX III

Determination of moisture content by gravimetric method

31/5/11

Treatments	Mass of can (g)	Mass of wet soil+can (g)	Mass of dry soil+can (g)	Mass of water (g)	Mass of dry soil (g)	Mass of water/Mass of soil	Water content, W (%)
No Tillage	38	76	69	7	31	0.225806	22.58065
Primary Tillage	38	81	74	7	36	0.194444	19.44444
Secondary Tillage	34.5	70.5	64.5	6	30	0.2	20
Mulched Tillage	36	71	63.5	7.5	27.5	0.272727	27.27273

1/6/2011

Treatments	Mass of can (g)	Mass of wet soil+can (g)	Mass of dry soil+can (g)	Mass of water (g)	Mass of dry soil (g)	Mass of water/Mass of soil	Water content, W (%)
No Tillage	38	88.5	77	11.5	39	0.294872	29.48718
Primary Tillage	38	109.5	95	14.5	57	0.254386	25.4386
Secondary Tillage	34.5	85.5	73.5	12	39	0.307692	30.76923
Mulched Tillage	36	84.5	71	13.5	35	0.385714	38.57143

3/6/2011

Treatments	Mass of can (g)	Mass of wet soil+can (g)	Mass of dry soil+can (g)	Mass of water (g)	Mass of dry soil (g)	Mass of water/Mass of soil	Water content, W (%)
No Tillage	38	86	72.5	13.5	34.5	0.391304	39.13043
Primary Tillage	38	128.5	106	22.5	68	0.330882	33.08824
Secondary Tillage	34.5	96	80	16	45.5	0.351648	35.16484
Mulched Tillage	36	108	84.5	23.5	48.5	0.484536	48.45361

4/6/2011

Treatments	Mass of can (g)	Mass of wet soil+can (g)	Mass of dry soil+can (g)	Mass of water (g)	Mass of dry soil (g)	Mass of water/Mass of soil	Water content, W (%)
No Tillage	38	86	72.5	13.5	34.5	0.391304	39.13043
Primary Tillage	38	128.5	106	22.5	68	0.330882	33.08824
Secondary Tillage	34.5	96	80	16	45.5	0.351648	35.16484
Mulched Tillage	36	108	84.5	23.5	48.5	0.484536	48.45361

APPENDIX IV

Determination of bulk density by core cutter method

No Tillage

Replications	Mass of core cutter (g)	Mass of core cutter + soil (g)	Volume of soil (cm^3)	Mass of the soil (g)	Bulk density (g/ cm^3)
R1	928	2735.8	982.5	1807.3	1.839491
R2	985	2817.5	982.5	1833	1.865649
R3	1077	2793.7	982.5	1865.2	1.898422
R4	985	2926	1021	1849	1.81097
R5	928	2823	982.5	1838.5	1.871247
				Avg. B.D	**1.857156**

Primary Tillage

Replications	Mass of core cutter (g)	Mass of core cutter + soil (g)	Volume of soil (cm^3)	Mass of the soil (g)	Bulk density (g/ cm^3)
R1	928	2679.5	982.5	1751.5	1.782697
R2	985	2708	982.5	1723	1.75369
R3	1077	2790	1021	1713	1.677767
R4	985	2726	982.5	1741	1.77201
R5	928	2660	982.5	1732	1.76285
				Avg. B.D	**1.749803**

Secondary Tillage

Replications	Mass of core cutter (g)	Mass of core cutter + soil (g)	Volume of soil (cm^3)	Mass of the soil (g)	Bulk density (g/ cm^3)
R1	928	2308	982.5	1380	1.40458
R2	985	2404.5	982.5	1419.5	1.444784
R3	1077	2485	1021	1408	1.37904
R4	985	2382	982.5	1397	1.421883
R5	928	2295	982.5	1367	1.391349
				Avg. B.D	**1.408327**

Secondary Tillage with Mulch

Replications	Mass of core cutter (g)	Mass of core cutter + soil (g)	Volume of soil (cm^3)	Mass of the soil (g)	Bulk density (g/ cm^3)
R1	928	2332	982.5	1404	1.429008
R2	985	2382	982.5	1397	1.421883
R3	1077	2485	1021	1408	1.37904
R4	985	2295	982.5	1310	1.333333
R5	928	2404.5	982.5	1476.5	1.502799
				Avg. B.D	**1.413213**

APPENDIX V

Porosity

No Tillage

Replications	Mass of soil (g)	Initial volume (ml)	Final volume (ml)	Change in volume (ml)	Particle Density (g/ cm^3)	Bulk density (g/ cm^3)	Porosity (%)
R1	30	40	53	13	2.307692	1.84	20.26667
R2	30	40	53	13	2.307692	1.86	19.4
R3	30	40	53.1	13.1	2.290076	1.89	17.47
R4	30	40	53.5	13.5	2.222222	1.81	18.55
R5	30	40	53	13	2.307692	1.87	18.96667
						Avg. Porosity	**18.93067**

Primary Tillage

Replications	Mass of soil (g)	Initial volume (ml)	Final volume (ml)	Change in volume (ml)	Particle Density (g/ cm^3)	Bulk density (g/ cm^3)	Porosity (%)
R1	30	40	53.1	13.1	2.290076336	1.78	22.2733333
R2	30	40	53.1	13.1	2.290076336	1.75	23.5833333
R3	30	40	52.5	12.5	2.4	1.67	30.4166667
R4	30	40	53.1	13.1	2.290076336	1.77	22.71
R5	30	40	53.1	13.1	2.290076336	1.76	23.1466667
						Avg. Porosity	**24.426**

Secondary Tillage

Replications	Mass of soil (g)	Initial volume (ml)	Final volume (ml)	Change in volume (ml)	Particle Density (g/ cm^3)	Bulk density (g/ cm^3)	Porosity (%)
R1	30	40	52.1	12.1	2.479338843	1.404	43.372
R2	30	40	52.4	12.4	2.419354839	1.445	40.2733333
R3	30	40	52.5	12.5	2.4	1.38	42.5
R4	30	40	52	12	2.5	1.42	43.2
R5	30	40	52.2	12.2	2.459016393	1.39	43.4733333
						Avg. Porosity	**42.56373**

Secondary Tillage with Mulch

Replications	Mass of soil (g)	Initial volume (ml)	Final volume (ml)	Change in volume (ml)	Particle Density (g/ cm^3)	Bulk density (g/ cm^3)	Porosity (%)
R1	30	40	51.8	11.8	2.542372881	1.425	43.95
R2	30	40	52	12	2.5	1.428	42.88
R3	30	40	51.8	11.8	2.542372881	1.425	43.95
R4	30	40	52.7	12.7	2.362204724	1.43	39.4633333
R5	30	40	51.7	11.7	2.564102564	1.445	43.645
						Avg. Porosity	**42.77767**

APPENDIX VI

Saturated Hydraulic conductivity or Permeability

No Tillage

Area of cross section of stand pipe, a = 0.48398 cm^2

Area of cross section of soil sample, A = 78.53 cm^2

Length of sample, l = 12.5cm

No Tillage- Replication 1

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	1.29	138.4	133.4	0.01598	3.66301E-05
2	1.77	133.4	128.4	0.016591	2.77165E-05
3	1.45	128.4	123.4	0.01725	3.51773E-05
4	1.91	123.4	118.4	0.017963	2.781E-05
				Kavg	3.18E-05

No Tillage- Replication 2

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	1.33	138.4	133.4	0.01598	3.55285E-05
2	1.82	133.4	128.4	0.016591	2.69551E-05
3	1.88	128.4	123.4	0.01725	2.71314E-05
4	1.5	123.4	118.4	0.017963	3.54114E-05
				Kavg	3.13E-05

No Tillage- Replication 3

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	1.3	138.4	133.4	0.01598	3.63484E-05
2	1.75	133.4	128.4	0.016591	2.80333E-05
3	1.77	128.4	123.4	0.01725	2.88175E-05
4	1.45	123.4	118.4	0.017963	3.66325E-05
				Kavg	3.25E-05

No Tillage- Replication 4

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	1.32	138.4	133.4	0.01598	3.57976E-05
2	1.79	133.4	128.4	0.016591	2.74068E-05
3	1.8	128.4	123.4	0.01725	2.83372E-05
4	1.47	123.4	118.4	0.017963	3.61341E-05
				Kavg	3.19E-05

No Tillage- Replication 5

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	1.29	138.4	133.4	0.01598	3.66301E-05
2	1.5	133.4	128.4	0.016591	3.27055E-05
3	1.7	128.4	123.4	0.01725	3.00041E-05
4	1.6	123.4	118.4	0.017963	3.31982E-05
				Kavg	3.31E-05

Average permeability of no tillage, K=3.21203E-05 cm/sec

Primary Tillage

Area of cross section of stand pipe, a = 3.14 cm^2

Area of cross section of soil sample, A = 78.53 cm^2

Length of sample, l = 10 cm

Primary Tillage- Replication 1

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	6.68	138.4	133.4	0.01598	0.002204026
2	8.52	133.4	128.4	0.016591	0.001794061
3	10.91	128.4	123.4	0.01725	0.0014567
4	7.96	123.4	118.4	0.017963	0.002079151
				Kavg	0.001883

Primary Tillage- Replication 2

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	7.01	138.4	133.4	0.01598	0.00210027
2	8.59	133.4	128.4	0.016591	0.001779441
3	9.32	128.4	123.4	0.01725	0.001705214
4	8.52	123.4	118.4	0.017963	0.001942493
				Kavg	0.001882

Primary Tillage- Replication 3

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	8.16	138.4	133.4	0.01598	0.001804276
2	9.05	133.4	128.4	0.016591	0.001688994
3	8.93	128.4	123.4	0.01725	0.001779686
4	10	123.4	118.4	0.017963	0.001655004
				Kavg	0.001732

Primary Tillage- Replication 4

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	7.42	138.4	133.4	0.01598	0.001984217
2	8.93	133.4	128.4	0.016591	0.001711691
3	8.92	128.4	123.4	0.01725	0.001781681
4	9.94	123.4	118.4	0.017963	0.001664994
				Kavg	0.001786

Primary Tillage- Replication 5

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	7	138.4	133.4	0.01598	0.00210327
2	8.16	133.4	128.4	0.016591	0.00187321
3	8.78	128.4	123.4	0.01725	0.001810091
4	9.3	123.4	118.4	0.017963	0.001779575
				Kavg	0.001892

Average permeability of primary tillage, K=1.834902E-03 cm/sec

Secondary Tillage

Area of cross section of stand pipe, a = 3.14 cm^2

Area of cross section of soil sample, A = 78.53 cm^2

Length of sample, l = 13 cm

Secondary Tillage- Replication1

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.12	138.4	133.4	0.01598	0.159497981
2	0.13	133.4	128.4	0.016591	0.152853965
3	0.14	128.4	123.4	0.01725	0.147574127
4	0.15	123.4	118.4	0.017963	0.143433715
				Kavg	0.15084

Secondary Tillage- Replication 2

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.12	138.4	133.4	0.01598	0.159497981
2	0.12	133.4	128.4	0.016591	0.165591796
3	0.14	128.4	123.4	0.01725	0.147574127
4	0.16	123.4	118.4	0.017963	0.134469108
				Kavg	0.151783

Secondary Tillage- Replication 3

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.13	138.4	133.4	0.01598	0.147228906
2	0.14	133.4	128.4	0.016591	0.141935825
3	0.13	128.4	123.4	0.01725	0.158925983
4	0.15	123.4	118.4	0.017963	0.143433715
				Kavg	0.14788

Secondary Tillage- Replication 4

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.13	138.4	133.4	0.01598	0.147228906
2	0.14	133.4	128.4	0.016591	0.141935825
3	0.15	128.4	123.4	0.01725	0.137735852
4	0.14	123.4	118.4	0.017963	0.153678981
				Kavg	0.145145

Secondary Tillage- Replication 5

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.12	138.4	133.4	0.01598	0.159497981
2	0.13	133.4	128.4	0.016591	0.152853965
3	0.15	128.4	123.4	0.01725	0.137735852
4	0.14	123.4	118.4	0.017963	0.153678981
				Kavg	0.150942

Average permeability of secondary tillage, K=1.49318179E-01 cm/sec

Secondary Tillage with Mulch

Area of cross section of stand pipe, a = 3.14 cm^2

Area of cross section of soil sample, A = 78.53 cm^2

Length of sample, l = 13 cm

Secondary Tillage with Mulch- Replication 1

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.12	138.4	133.4	0.01598	0.159497981
2	0.12	133.4	128.4	0.016591	0.165591796
3	0.14	128.4	123.4	0.01725	0.147574127
4	0.16	123.4	118.4	0.017963	0.134469108
				Kavg	0.151783

Secondary Tillage with Mulch- Replication 2

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.12	138.4	133.4	0.01598	0.159497981
2	0.13	133.4	128.4	0.016591	0.152853965
3	0.14	128.4	123.4	0.01725	0.147574127
4	0.15	123.4	118.4	0.017963	0.143433715
				Kavg	0.15084

Secondary Tillage with Mulch- Replication 3

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.13	138.4	133.4	0.01598	0.147228906
2	0.14	133.4	128.4	0.016591	0.141935825
3	0.13	128.4	123.4	0.01725	0.158925983
4	0.15	123.4	118.4	0.017963	0.143433715
				Kavg	0.147881

Secondary Tillage with Mulch- Replication 4

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.13	138.4	133.4	0.01598	0.147228906
2	0.14	133.4	128.4	0.016591	0.141935825
3	0.15	128.4	123.4	0.01725	0.137735852
4	0.14	123.4	118.4	0.017963	0.153678981
				Kavg	0.145145

Secondary Tillage with Mulch- Replication 5

Sl no.	Time (sec)	Hi	Hf	Log(Hi/Hf)	Permeability, K (cm/sec)
1	0.13	138.4	133.4	0.01598	0.147228906
2	0.14	133.4	128.4	0.016591	0.141935825
3	0.14	128.4	123.4	0.01725	0.147574127
4	0.16	123.4	118.4	0.017963	0.134469108
				Kavg	0.142802

Average permeability of secondary tillage, K=1.47690238E-01 cm/sec

APPENDIX VII

Infiltration

Observations on double ring infiltrometer

No Tillage

Time (Sec)	**R1 (cm)**	**R2 (cm)**	**R3 (cm)**	**R4 (cm)**	**R5 (cm)**	**Avg. R (cm)**	**$I_{avg.}$ (cm/hr)**	**Acc.I (cm)**
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5	0.21	0.2	0.2	0.205	0.2	**0.205**	**0.205**	**0.21**
10	0.2	0.205	0.205	0.2	0.195	**0.2**	**0.2**	**0.2**
15	0.19	0.19	0.19	0.19	0.2	**0.194**	**0.19**	**0.2**
30	0.18	0.19	0.19	0.18	0.18	**0.181**	**0.18**	**0.175**
45	0.15	0.17	0.17	0.17	0.18	**0.168**	**0.17**	**0.17**
60	0.14	0.16	0.16	0.17	0.17	**0.161**	**0.17**	**0.165**
75	0.11	0.16	0.16	0.155	0.18	**0.153**	**0.155**	**0.16**
90	0.12	0.14	0.14	0.14	0.16	**0.14**	**0.14**	**0.14**
105	0.11	0.14	0.14	0.14	0.17	**0.14**	**0.14**	**0.14**
120	0.1	0.13	0.13	0.13	0.15	**0.129**	**0.13**	**0.135**

Primary Tillage

Time (Sec)	**R1 (cm)**	**R2 (cm)**	**R3 (cm)**	**R4 (cm)**	**R5 (cm)**	**Avg. R (cm)**	**$I_{avg.}$ (cm/hr)**	**Acc.I (cm)**
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5	2.8	3	2.7	2.8	3	**2.86**	34.32	**2.86**
10	2.2	2.7	2	2.7	2.8	**2.4**	28.8	**5.26**
15	2	2.3	1.7	2.55	2.3	**2.1375**	25.65	**7.3975**
30	1.6	1.9	1.6	2.1	2	**1.8**	7.2	**9.1975**
45	1.4	1.7	1.55	1.9	1.65	**1.6375**	6.55	**10.835**
60	1.3	1.6	1.6	1.7	1.6	**1.55**	6.2	**12.385**
75	1.3	1.4	1.5	1.6	1.4	**1.45**	5.8	**13.835**
90	1.2	1.4	1.5	1.5	1.4	**1.4**	5.6	**15.235**
105	1.3	1.35	1.4	1.45	1.3	**1.375**	5.5	**16.61**
120	1.2	1.35	1.5	1.425	1.35	**1.36875**	5.475	**17.97875**

Secondary Tillage

Time (Sec)	**R1 (cm)**	**R2 (cm)**	**R3 (cm)**	**R4 (cm)**	**R5 (cm)**	**Avg. R (cm)**	**$I_{avg.}$ (cm/hr)**	**Acc.I (cm)**
0	0	0	0	0	0	0	0	
5	4	4.1	3.9	4.1	4.1	4.04	48.48	4.04
10	3.4	3.4	3.1	3.5	3.3	3.34	40.08	7.38
15	3	2.9	3	3	3	2.98	35.76	10.36
30	2.9	2.8	2.7	2.7	2.8	2.78	11.12	13.14
45	2.1	2.2	2.75	2.6	2.2	2.37	9.48	15.51
60	2.1	2	2.5	2.1	2	2.14	8.56	17.65
75	1.9	1.9	2	2	1.8	1.92	7.68	19.57
90	1.8	1.85	1.9	1.9	1.85	1.86	7.44	21.43
105	1.8	1.8	1.85	1.7	1.75	1.78	7.12	23.21
120	1.75	1.75	1.7	1.6	1.65	1.69	6.76	24.9

Secondary Tillage with Mulch

Time (sec)	**R1 (cm)**	**R2 (cm)**	**R3 (cm)**	**R4 (cm)**	**R5 (cm)**	**Avg. R (cm)**	**$I_{avg.}$ (cm/hr)**	**Acc.I (cm)**
0	0	0	0	0	0	0	**0**	**0**
5	3.7	3.9	3.9	3.6	3.7	3.76	**45.12**	**3.76**
10	3.2	3.4	3.1	3.5	3.4	3.32	**39.84**	**7.08**
15	3.1	2.9	3	3.1	3	3.02	**36.24**	**10.1**
30	2.7	2.8	2.7	2.7	2.8	2.74	**10.96**	**12.84**
45	2.1	2.2	2.75	2.6	2.5	2.43	**9.72**	**15.27**
60	2.1	2	2.5	2.1	2.3	2.2	**8.8**	**17.47**
75	1.9	1.9	2	2	1.9	1.94	**7.76**	**19.41**
90	1.8	1.85	1.9	1.9	1.95	1.88	**7.52**	**21.29**
105	1.8	1.8	1.85	1.7	1.8	1.79	**7.16**	**23.08**
120	1.74	1.75	1.7	1.6	1.75	1.708	**6.832**	**24.788**

EFFECTS OF TILLAGE ON SOIL HYDRAULIC PROPERTIES

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ABSTRACT

Tillage operation is the mechanical manipulation of soil to develop a desirable soil structure for a seed bed and to establish specific surface configuration for planting, irrigation, drainage, harvesting operations etc. Knowledge of variability of soil physical properties with tillage can assist in defining the best strategies for soil management and crop production. This leads to an increasing interest in the effect of different tillage treatments on soil hydraulic properties such as moisture content, bulk density, porosity, hydraulic conductivity and infiltration rate. Treatments include No Tillage (NT), Primary Tillage (PT), Secondary Tillage (ST) and Mulch after Tillage (MT). Moisture content of the mulched soil is comparatively higher than that of the other treatments. Increased tillage intensity decrease soil bulk density while increases the porosity. The porosity increase is in the order NT<PT<ST≈MT. The average infiltration rate of the soil also changes with the treatments in the order NT<PT<MT≈ST