EFFECT OF SEAL FORMATION DUE TO CATTLE MANURE APPLICATION ON INFILTRATION AND RUNOFF

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **'EFFECT OF SEAL FORMATION DUE TO CATTLE MANURE APPLICATION ON RUNOFF AND INFILTRATION'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled **'EFFECT OF SEAL FORMATION DUE TO CATTLE MANURE APPLICATION ON RUNOFF AND INFILTRATION'** is a record of research work done independently by **Sri.Rakesh,K.N**. 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 him.

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Abbreviations

%	= per cent
^oC	= degree centigrade
A	= Ampere(s)
B	= Boron
cm	= centimetre(s)
cm/h	= centimetre per hour
cm/s	= centimetre per second
Ca	= Calcium
Cl	= Chlorine
Cu	= Copper
C	= Carbon
COD	= Chemical Oxygen Demand
dS/m	= deci Siemens per meter
et. al	= and others
EC	= Electrical Conductivity
ESP	= Exchangeable Sodium Percentage
Fe	= Iron
FYM	= Farm Yard Manure
gm	= gram(s)
GI	= Galvanized Iron
H	= Hydrogen
ha	= hectare(s)
HP	= Horse Power
IPNS	= Integrated Plant Nutrient System
kg/cm^2	= kilogram per square centimetre
kN/m^3	= kilo Newton per cubic centimetre
kg/ha	= kilogram per hectare
kg/ha/m	= kilogram per hectare per metre
K	= Potassium
KCAET	= Kelappaji College of Agricultural Engineering and Technology

l	= litre(s)
m	= metre(s)
m^2	= square metre(s)
m/s	= metre per second
mm	= millimetre(s)
mm/h	= millimetre per hour
ml	= millilitre(s)
Mg	= Magnesium
Mb	= Molybdenum
Mn	= Manganese
M_{15}	= Manure equivalent to 15 t/ha
M_{20}	= Manure equivalent to 20 t/ha
M_{25}	= Manure equivalent to 25 t/ha
MS	= Mild Steel
Mg/m^3	= Milligram per cubic metre
N	= Nitrogen
O	= Oxygen
P	= Phosphorous
rpm	= revolutions per minute
t/ha	= tonnes pet hectare
TSS	= Total Suspended Sediments
V	= Volt(s)
Zn	= Zinc

INTRODUCTION

INTRODUCTION

Agriculture is the major occupation in India and about 44% of the total geographical area of the country (nearly 142.8 m ha) is occupied by various crops. In Kerala, nearly 59% of the total geographical area (nearly 2.27 m ha) is under cultivation and 38% of the working population depend on agriculture either as cultivators (12%) or as agricultural labourers (26%). These statistics exclude the small-scale homestead farming or domestic farming. Our agriculture is mainly concentrated in rural villages. Though we have advanced very much in technical know-how of various agricultural practices, majority of the village farmers are still following the conventional practices without proper scientific basis due to either ignorance or lack of facility.

Application of soil amendments is one of the major management practices for cultivation of any crop. Soil health is a term used synonymously with soil quality. The components of soil health are the biological processes that produce a balance of major and minor nutrients and freedom from plant diseases. It is known that at least 16 plant food elements (soil nutrients) are necessary for the growth of green plants and are called essential elements. In the absence of any of these elements, plants fail to complete its life cycle. Though the soil in its natural condition itself is rich in respect of various nutrient contents, it may not be sufficient to meet the specific requirements of specific crops. So, we may have to add various fertilizers in order to increase the production and thereby to economize the farming activities. The key role of fertilizers and their judicious use in crop husbandry are well understood when one is familiar with the general facts about the plant nutrition.

The green revolution had succeeded in popularising the chemical fertilizers and also in making them accessible to even remote areas. India remains as the 4th largest producer and user of fertilizers in the world. The annual production of nitrogenous fertilizers in the country is 8.21 million tonnes and that of phosphatic fertilizers is 2.77 million tonnes and potassium fertilizers is 1.81 million tonnes.

About 20 different fertilizers, carrying one or more of the macro nutrients (N, P, & K) are produced in India. In addition to these, about a dozen micro nutrient fertilizers are also produced on commercial scale. The total consumption of various fertilizers is 12.52 million tonnes, out of which 64 % (8021000 t) is nitrogenous fertilizers, 25% (3172000 t) is phosphatic fertilizers and 11 % (13330000 t) is potassium fertilizers. Kerala's position is 13^{th} among the states in respect of total fertilizer consumption (245000 t). The State consumes about 95,000 tonnes of both nitrogenous fertilizers and potassium fertilizers and 55,000 tonnes of phosphatic fertilizers annually. The average rate of application of fertilizer in the country is 72.4 kg/ha (nitrogenous fertilizers 46.4 kg/ha, phosphatic fertilizers 18.3 kg/ha and potassium fertilizers 7.7 kg/ha). In respect of application rate, Kerala's position is 10^{th} with an average of 84.4 kg/ha (nitrogenous fertilizers 32.6 kg/ha, phospatic fertilizers 32.9 kg/ha, and potassium fertilizers 32.9 kg/ha). During the last five decades, the use of synthetic fertilizers had increased by 198 folds.

Nevertheless, organic manure application is one of the most adopted soil treatment practice followed by the farmers all over the country. The practice of applying organic manure such as farm yard manure, green manure, night soil, bone ash, fish meal wood ash etc. to the soil for the purpose of increasing the crop yield is perhaps as old as the beginning of agriculture by man. In ancient times however, practices that were developed were based on experiences and observation. The most important part of any scientific work is to define the objectives. The objective of carrying out the crop production in a scientific manner with appropriate inputs is to overcome the constraints so that we can reliably produce maximum yield, which is set by the genetic capacity of that particular crop grown. Fertlizers are only one of the inputs needed to achieve the maximum yield, but because they remove all restrictions on supply of plant nutrients, they are the most important.

The Integrated Plant Nutrient System- IPNS- concept advocates the balanced use of chemical fertilizers, organic manure, crop residues, animal and human wastes and bio fertilizers. IPNS aims at sustainable productivity with minimum detrimental effect of chemical fertilizer on soil health and environment. Manure

application is now having greater significance due to the introduction of organic farming concept. Now-a-days, all are much aware of the environment and the hazards done to it by the increased use of chemicals and other synthetic amendments. Hence, environmentalists also preach for promoting bio-fertilizers and organic manure. Another salient feature of organic manure is that it can be applied to any crop and any soil and will decompose easily under varying climatic conditions.

The application of organic manure has much more significance as far as Indians, especially Kerala farmers are considered. India stands first in respect of population of cattle, buffalo and goats (16 %, 58%, and 20% share of world population respectively). Kerala support 16% of cattle population and 11 % of sheep and goat population of the country. On an average, Kerala have 2.42 cattle, 2.23 goats, 1.92 pigs and 9.72 poultry per household. So, there is much wider scope for manure application in Kerala. It has been proven undoubtedly that animal manure are rich in organic matter and other essential nutrients. Generally about $3/4^{th}$ of nitrogen, $4/5^{th}$ of phosphorous and $9/10^{th}$ of potassium ingested by live stock are excreted in manure. Organic matter addition is one of the main keys to improve soil fertility and productivity. It improves the biological and physico-chemical properties of the soil and thus helps to increase and conserve its productivity. Also, organic matter influences on soil wettability and aggregate stability. But, it is quite unfortunate that at present there is no scientific dosage for the manure application with respect to different soil types. The only available recommendations are with respect to different crop/plant varieties that have no reference to the type of soil on which it is applying.

Manures are rich in organic matter content and studies have proven that these organic matters are capable of forming a surface seal on the soil. These surface seals are capable of affecting the infiltration characteristics of the soil, by influencing its physical properties, which will in turn influences the runoff. Also excess application of organic manure may lead to increased amount of sediments and organic matter in the runoff water which will degrade the water bodies in the down stream. In other words, organic manures can turn as a major contributor to the non point source of pollution

reservoirs and other water storage structures. So, the application of organic matter without scientific basis may lead to detrimental effects to the environment and human habitats.

The present study is an attempt to develop scientific recommendations for the application of cattle manure for different types of soils. The study was undertaken under simulated rainfall conditions in the laboratory at K.C.A.E.T., Tavanur. Main objective of the study was to assess the effect of seal formation due to cattle manure application on infiltration and runoff for two soil types viz; sandy loam and clay loam under varying rainfall intensities and manure application rates.

The specific objectives of the study are:

i. To study the change in runoff rate from the soils
ii. To study the change in infiltration rate of the soil
iii. To study the change in total solid content of the runoff effluent
iv. To study the change in organic matter content of the runoff effluent
v. To study the change in total nitrogen content of the runoff effluent.

REVIEW OF LITERATURE

Review of Literature

Application of soil amendments is one of the significant farming operations in agriculture. Among various soil amendments, organic manures and bio- fertilizers are gaining more and more popularity due to their easy availability, cheap cost and high nutritive value. But the impact of addition of soil amendments upon various soil properties and crop yield should be taken into consideration before adopting any practices. The response of soil and crop yield to various soil amendments will greatly depend upon type of soil, rainfall characteristics and rate of application of soil amendments. Therefore, these parameters should also be considered while planning any soil amendment practices. The results of studies conducted in the past on these aspects are briefly reviewed in the forgoing section.

2.1 Soil

The term soil has different meanings and concept in different fields. It has originated from the latin word ‘solum’. To an agricultural scientist it means “the loose material on the earth’s crust consisting of disintegrated rock with an admixture of organic matter, which supports plant life”. Soil provides room for water to be used by the plants through the roots present in the same medium. From agricultural point of view, soil is considered as a three phase system comprising of the solid phase, liquid phase and gaseous phase.

The main component of the solid phase is the soil particles, the size and shape of which gives rise to pore spaces of different geometry. The most important soil properties influencing irrigation and cultivation are its infiltration characteristics, water holding capacities, texture, structure, capillary conductivity, profile conditions and depth of water table.

2.1.1 Soil Texture

The relative proportion of sand, silt and clay determines the soil texture. Texture is designated by using the names of predominant size fractions and the word loam is used, whenever all the major size fractions occur in sizeable proportions. Sandy soils are classified as coarse textured, loam soils as medium textured and clay soils as fine textured.

The least complex textural group is sand, which contains less than 15 % silt and clay. Such soils forms relatively simple capillary system with a large volume of non-capillary pore spaces, which ensures good drainage and aeration. Sandy soils are loose and non-cohesive and have a low water holding capacity. Sandy loam soils have 50-70% sand, 80-90% silt and 15-20% clay.

Sandy soils are intrinsically poorer than clay in all nutrients, cation exchange capacity and often in micronutrients too. They become arid quite quickly. Sand tends to contain smaller reserves of organic matter and nitrogen, because organic materials oxidize more quickly in the open texture of a coarse soil.

Clay soils are at the other extreme with reference to the size of particles and complexity. The clay particles are usually aggregated together into complex granules. Because of their plate like shape, clay particles have a much greater surface area than cubes or spheres of the same volume. Their extensive surface enables clay particles to hold more water and minerals than sandy soils.

Clay usually has large reserves of cations, that can be released by weathering for the use by plants and they contains more nitrogen and other organic matter.

Loamy soils contains more or less equal amount of sand, silt and clay. They have properties in between that of sand and clay. Such soils are considered most favourable for plant growth because they hold more available water and cations than sand and are better aerated and easier to work with than clay.

2.1.2 Soil Structure

Primary soil particles viz: sand, silt and clay are united together to form secondary soil particles, which are called soil aggregates. A naturally occurring soil aggregate is called a ped, where a clod is formed by artificially ploughing a dry clayey soil. The arrangements of peds with respect to each other determine soil structure.

2.1.2.1 Platy Structure

The horizontal axes of peds are much larger than their vertical axes. This means that the peds are in the form of thin plates.

2.1.2.2 Prismatic Structure

The vertical axes of peds are larger than their horizontal axes. Tall peds are bounded by plane faces intersecting each other at sharp angles. Prismatic structure has been subdivided into two sub types

i. Prismatic- the top of ped is flat
ii. Columnar- the top of the ped is rounded

2.1.2.3 Blocky Structure

Horizontal and vertical axes of peds are roughly equals, which means that the peds are roughly in the form of cubes. Blocky structure has been subdivided into two types.

i. Angular blocky – Peds are bounded by plane faces intersecting each other at sharp angles.

ii. Sub Angular blocky- Peds are formed by both plane faces intersecting each other at sharp and round faces.

2.1.2.4 Spheroidal Structure

The horizontal and vertical axes of the peds are more or less equal, peds are not in contact with each other so there is plenty of air spaces in between them because they are irregular in shape. Spheroidal structure have been sub divided into the following two types.

i. Granules are relatively less porous
ii. Crumbs are highly porous.

2.1.2.5 Formation of soil aggregates under natural conditions

Water molecules are dipolar. One side of the water molecule is positively charged and the other side is negatively charged. The opposite charged ends attracts each other and forms a long chain of water molecules. Positive cations are hydrated. They attract the negative ends of a chain of dipolar water molecules, the positive ends of which are attracted by a clay particles. Hence clay particles are held by bridges of oriented water molecules and positive cations.

When soil dries up, the chain of water molecules shortens more and more, so the clay particles are ultimately united. They are united together by some organic compounds formed during the decomposition of soil organic matter. Actually several clay particles are united in this way to form compound particles which in turn bound together by cementing agents like clay, iron and aluminum oxide to form the soil aggregate. Soil microorganisms decompose soil organic matter to form dark gummy substances, which bind the clay and sand and silt particles to form soil aggregates.

2.1.3 Pore Space

Pore space is that portion of the soil volume, which is not occupied by soil solid, but air and /or water. Pore spaces are of two kinds i) macro pores and ii) micro pores.

Macro pores occur between peds. They cannot retain water by capillary action and are usually filled with air. Excess water is usually drained down the spaces of average diameter greater than 60 micron. Micro pore spaces occur within the peds. They store water for plant growth. The average diameter of micro pores is less than 30 micron.

2.1.3.1 Factors affecting pore space of soils

i. Texture

Total and micro pore space of soil increases when their clay percentage increases, i.e., their texture becomes finer.

ii. Organic Matter

Organic matter is decomposed by soil microorganisms to form humus, which usually binds the sol particles to form aggregates. Besides this, humus also simulates the growth of soil microorganisms, which mechanically bind the soil particles to form aggregates within which micro pores occur.

iii. Nature of crops and cultivations

Excessive cultivation of soils increases the oxidation of humus, consequently total and micro pore spaces of soils are decreased.

2.1.4 Soil Erosion

Soil constitutes the physical basis for agriculture. One of the principle reasons for the low productivity in agriculture is the progressive deterioration of soil due to erosion. Soil erosion is the detachment and transportation of soil materials from one place to another through the action of wind, water in motion or by beating action of raindrops. Erosion is a primary source of sediments that pollutes streams and fills reservoir, thereby reducing their capacity and useful life. Erosion also adds to the removal of valuable plant nutrients with the runoff.

The sediment discharge component of a watershed simulation model called RUNOFF was developed by Borah (1989). The model uses a runoff simulation component and simulates space and time distributed soil erosion, sediment transport and sediment deposition and computes sediment discharge in a small watershed resulting from a single rainfall event. The model component has two parameters, raindrop detachment and flow detachment coefficients, which are calibrated based on observed sediment discharges.

Soil detachment by raindrop impact depends on soil cover and a variety of soil properties such as primary particle size distribution, soil structure, organic matter content etc. The rate of soil detachment due to raindrop impact may be expressed as:

$$Er = a_r \times I^2 (1 - D_c) \times (1 - D_g) \times \left[1 - \frac{(h + e)}{3 \times d_{50}}\right] \qquad \text{if} (h + e) < 3d_{50}$$

$$Er = 0 \qquad \text{if} (h + e) \geq 3d_{50}$$

Where

Er = The rate of soil detachment due to raindrop impact (m/s)

a_r = The raindrop detachment coefficient

I = The rainfall intensity (m/s)

D_c = The canopy cover density

Dg = The ground cover density

h = the water depth

e = the thickness of existing detachment soil on the bed (m)

d_{50} = The median raindrop diameter (m)

A study was conducted by Habbard *et al*. (1989) to determine the amount and rates of surface runoff, percolation and leaching of nitrate and phosphate from the upper root zone in three upland coastal plain soils. Extraction of agricultural chemicals, nutrients or pesticide from the soil surface into surface runoff and transport of chemicals by percolation from the root zone into ground water are of concern from both economical and environmental stand points. Determination of surface runoff, percolation and chemical transport from small landscape segments that comprise a watershed can be difficult because of limited control over the timing and sequence of rainfall events. One method for making such determination is to use a rainfall simulator over small area of the soil. The result showed that the surface runoff increases with rainfall intensities and reaches a steady state. Percolation was initially at a high rate, then decreased and after some time became constant. The observation of NO_3-N (nitrate) in the water phase of surface runoff water were related to rainfall intensity, time to ponding and soil properties. Nitrate concentration were greatest in the first four runoff samples and then decreased with time in all the soil types at all rainfall intensities

Lu *et al.* (1989) conducted a laboratory study using three size classes of uniform sand, sandy soil and silt loam to investigate the transportation and deposition and to test various sediment transport relationships. The result implies that rolling, sliding and hopping were the major modes of motion for the sandy soil particles under shallow flow conditions. For the silt loam soil, a power function of dimensionless shear stress with an exponent of about 1.5 gave a good prediction of sediment transport capacity. For sandy soils the power function is with an exponent of 1.27. For both the silt loam and sandy soils, low intensity rainfall which ranged from 0 to 50 mm/h on the depositional area not significantly changed the dimensionless sediment transport relationship.

Wallach *et al.* (1989) developed a model describing chemical transfer from soil to surface runoff and presented as convective mass transfer process through a boundary layer connecting a soil mixing cell to a runoff mixing cell. The boundary layer is assumed to be laminar above the soil surface, restricting chemical transport through this zone to molecular diffusion. The determined mass transfer coefficient is proportional

to the chemical diffusion coefficient and inversely proportional to the laminar boundary layer depth. It is increasing with the increase of soil surface roughness, runoff hydraulic gradient and runoff hydraulic radius. They also proposed a model for chemical runoff effluent concentration in which rainfall induced surface runoff is represented as a well mixed reactor. Transfer of soil solute to the reactor is assumed to occur by a rate limit process proportional to the soil concentration.

McGregore *et al.* (1990) conducted a laboratory study on silt loam soil to quantify the effect of various rate combination of incorporated and surface applied wheat straws on inter rill runoff and soil loss. Simulated rainfall was applied at a rate 64 mm/h to soil pan oriented on 2.5% slope. There was no significant effect on inter rill runoff or soil loss for either dry, wet or very wet runs for increasing rates of recently incorporated straw (1,3,5,7 t/ha) over two levels (1,3 t/ha) of surface straw. The increase in straw from 1 to 3 t/ha produced significant decrease in soil loss.

Bolton *et al.* (1991) found that the transport of sediments and nutrients from watershed slopes into adjacent water bodies degrades the watershed and badly affect the water bodies. Loss of sediments and nutrients through rainfall-runoff and erosion process may reduce watershed productivity and leads to further loss of vegetation and increased erosion. They conducted an experiment that addresses the organic matter and nutrient loading of waterbeds. They collected the data using spray down type rainfall simulator in a $1m^2$ plot. They found out the relationship between total suspended sediments (TSS) concentration (kg/ha/mm of runoff) in runoff and concentration (kg/ha/mm of runoff) of total phosphorous(TP) and total nitrogen (TN).

$$TP = 0.0013(TSS)^{0.83} \qquad r = 0.77$$
$$TN = 0.008(TSS)^{0.15} \qquad r = 0.11$$

Edward *et al.* (1996) studied the quality of runoff from northwest Arkansan pasture fields treated with organic and inorganic fertilizers. They found that the long term application of animal manure even at agronomic rate can promote accumulation of soil phosphorous which in turn can contribute to increased phosphorous leaching to down stream waters. The objective of the study was to assess the effects of

replacing animal manure as a soil amendment with inorganic fertilizer (ammonium nitrate) on fields that had been treated previously with animal manure on soil loss and run off. The result demonstrates the potential for positively influencing runoff quality in a relatively short duration by replacing animal manures with ammonium nitrate for fields already having sufficient soil phosphorous. The result of the study indicated that the fields receiving only inorganic nitrogen fertilizer exhibited decrease in both soil and runoff phosphorous concentration. However no significant increase in soil or runoff phosphorous concentration were observed for the fields that continued to receive animal manures. The significantly decreasing trend in soil and runoff phosphorous concentration during the study period suggests that the runoff quality benefit may be realized in a relatively short time by replacing animal manure with inorganic nitrogen fertilizers on fields that already having phosphorous

2.1.4.1 Factors affecting erosion by water

Erosion by water, known as water erosion is the removal of soil from the land's surface by water in motion. Water erosion is due to the dispensive action and transporting power of water – as it descends in the rain and leaves the land in the form of runoff. There is a direct relationship between total runoff and soil loss from agricultural lands. The major factors affecting water erosion are climate, topography, vegetation and soils.

The major climatic factor influencing runoff and erosion is rainfall. Rainfall and runoff are the two erosive agents responsible for erosion by water. The principle effect of raindrop is to detach the soil while that of surface flow of water is to transport the detached soil particles. The amount of soil detached by rain depends on the intensity of the rain, the character of the soil and the protective value of any cover present.

Most of the erosion by water occurs during and immediately following a relatively few rainstorms, which may occur almost at any time. Erosion researches under such conditions have numerous limitations. Simulated rainfall may be applied at selected intensities for known duration and land treatment conditions. Such a control is much more than an experiment with natural rainfall.

Rainfall simulators have gained much acceptance as a useful tool for infiltration and erosion research. Simulators produces rainfall events that may be

replicated at any desired time or location making it possible to collect data in a timely and cost effective manner. The use of rainfall simulators enables nearly immediate evaluation of carefully controlled plot conditions as well as observations of the erosion processes involved.

Rainfall simulators based on type of accessories fitted on them could be grouped into:

i. Pipes and orifices.
ii. Tubing tip/ Hanging yarn/ Hypodermic needles
iii. Rotating disc type
iv. Nozzle type
v. Air and water mixture system

2.1.5 Soil Nutrients

Plants, like animals and human beings require food for growth and development. This food is composed of certain chemical elements often referred to as plant nutrients.

For the past few hundred years agriculturists and scientists made vigorous attempt to find out the scientific principles and substances that makes plants to grow and rationalize farming as well as to improve soil management.

It is known that about ninety elements are found in crops, all of which are not essential to them. At least 16 plant food elements are necessary for the growth of green plants. These plant nutrients are called essential elements. The absence of any of these elements fails to complete its life cycle. They are C, H, O, N, P, S, K, Ca, Mg, Fe, Mn, Zn, Cu, Mb, B and Cl. An element is considered as essential for the crop only if it fulfils the following criteria.

i. The crop cannot grow normally and complete its life cycle in the absence of an essential element.

ii. The deficiency of an essential element can be corrected by supplying only that particular element to the crop.

iii. The concerned essential elements play a direct role in plant metabolism.

Among the essential elements N, P, K are primary plant nutrients are known as macro nutrients.

2.1.5.1 Nitrogen

Air is the primary source of nitrogen for plant nutrition and only leguminous crops can directly use this free nitrogen with the help of symbiotic bacteria of the genus Rhizobium. Other plants derive their nitrogen from the soil, in the form of nitrogen and ammonia. Nitrogen and ammonia are produced in the soil by the action of microorganisms. Non-symbiotic micro-organisms can fix free nitrogen of the air and make it available to the plants in ammonia nitrate form. Nitrogen encourages the vegetative development of plants by imparting a healthy green colour to the leaves. It also controls to some extent the efficient utilization of P & K. Its deficiency retards growth and root development, tuns the foliage yellowish or pale green, hastens maturity, causes the shriveling of grains and lowers crop yield. Nitrogen is an essential constituent of proteins and chlorophyll and is present in many other components of great physiological importance in plant metabolism such as nudes, tides, phosphatides, alkaloids, enzymes, hormones, vitamins etc. It is the very basic constituent of life. It improves quality of succulence of leafy vegetables and fodder crops and it increases protein content of food and fodder crops. An excess of nitrogen produces leathery (and some times crinkled) dark green leaves and succulent growth. It also decays maturation of plants, impairs quality of crops like barley, potato, tobacco, sugar cane and fruits, increases susceptibility to diseases and causes lodging of cereal crops by inducing and undo lengthening of stem inter nodes.

Shotliff (1990) found that nitrate is highly soluble and readily moves through the soil. Its movement is affected by its concentration, which among other parameters will be a factor of total amount of nitrogen applied, effective moisture content and soil permeability. The presence of plant roots, soil organisms, soil oxygen and organic carbon are factors which need to be taken into account. Compaction is not a problem with heavy soils alone and sandy soils are also vulnerable if worked in the wrong condition. Where compaction exists, water penetration will be slow to occur and the soil will not be recharged.

Ritter *et al.* (1991) found that nitrate concentration in soil profile are directly related to nitrogen application rate and not to the soil type. Nitrate leaching was higher in case of side dressing the nitrogen fertilizer compared to fertigation. Similarly nitrate leaching rate increased with full irrigation compared to partial irrigation. The nitrate leaching was highest during the winter season. In general the larger the drainage volume, the greater the mass of nitrogen leached.

2.1.5.2 Phosphorous

Phosphorous is a constituent of cell nucleus and metabolically active compounds like nucleic acids, adenosine di and tri phosphates etc. Phosphorus is essential for cell division and development of the merismatic tissues at the growing points and for root growth.

2.1.5.3 Potassium

Potassium plays a vital role in the formation of amino acids and proteins from ammonium ions, which are absorbed by roots from the soil. It is also responsible for the transfer of carbohydrates, proteins, etc. from the leaves to the roots. It also plays a vital role in the uptake of other elements. Potassium regulates the permeability of the cellular membrane. It increases the hydration of protoplasm, activates enzymes and its deficiency decreases photosynthesis. Potassium increases the resistance of crops to hot and dry conditions, insects, pests and diseases. It improves the quality of fruits and grains.

Fertilizer Association of India has compiled the data relating to the removal of major plant nutrients by field crops per tonne of harvest crop

Crop	Nutrients removed (kg/t)

	N	P	K
Paddy-Sona	9.74	3.12	3.26
Jaya & IET 2815	14.90	6.90	10.00
Ground nut	41.05	11.57	23.68
Rubber	143.75	17.50	66.56
Coffee	22.25	8.06	27.25
Tea	45.40	5.00	20.00
Coconut (70 nuts)	55.50	27.10	84.40

2.1.6. Soil Amendments

Soil is a complex medium supporting the growth of plants and providing the essential nutrients for their development. The ability of the soil to support the growth of plant is termed as the fertility of the soil.

Soil amendment practices are very significant in any cultivation practices. Proper amendment practice helps to improve the soil productivity and soil properties like water holding capacity, aeration, root growth etc., enhance the yield and helps to retain the fertile soil against the erosive agents either by covering it up or by improving the bindings. Under a given system of farming conditions, proper amendment practices also helps to replace the soil nutrients that are extracted by the plants for their growth or by leaching.

Unless the soil is replenished by natural or artificial means, the soil will continue to degrade in its quality and eventually plant growth will become partially or completely impossible. The methods for supplementary natural recuperation and for improving the productivity of the soil are

i. Addition of organic matter to the soil so that through decay it may furnish a more or less continuous supply of nutrients for the crops
ii. Restoration or increasing the amount of nutrients by the application of fertilizers.

2.1.6.1 Types of manures and Fertilizers

Indian soils are usually very poor in organic matter as well as in nitrogen. Phosphate deficiency is not common spread and potassium deficiency generally occurs in compact areas. Materials, which are commonly used to maintain and improve soil fertility, may be classified as follows:

i. Manures
ii. Fertilizers
iii. Concentrated organic matter
iv. Bulky organic matter.

2.1.6.1.1 Manures

These are relatively bulky materials such as animal or green manures, which are added mainly to improve the physical conditions of the soil, to replenish and keep up its humus status and to maintain optimum condition for the activities of micro organisms. They thus supply practically all the elements of fertility, which the crop requires. The plant food elements contained in manure are released in an

available form after it is applied to the soil and is decomposed by soil micro-organisms. Similarly green manures add not only substantial amount of organic matter but also nitrogen.

2.1.6.1.1.1 Farm Yard Manures

Good quality farmyard manure is perhaps the most valuable organic manure applied to the soil. It is the mixture of cattle dung, the bedding used in the stable and of any ramnants of straw and plant stalk food fed to the cattle. Organic manures contain much carbon. Organic manures supply nutrients for plants and the carbon containing compounds are food for small animals and micro organisms. Manures often improve the structure of the soil either directly through their action as bulky diluetents in compacted soils or indirectly when the waste products of animal or micro organisms cements soil particles together. These structural improvements increases the amount of water useful for the crops that soil can hold, improve aeration and drainage, encourage good root growth by providing enough pores of the right size and prevent soils from becoming too rigid when dry or completely water logged or devoid by air when wet.

There must be adequate moisture in the soil for proper decomposition of organic manures. Farm yard manures can therefore be applied to all crops grown in the rainy season or grown under irrigation.

The list of benefits of having organic matter in the soil are so varied and extensive.

i. Source of 90-95% the nitrogen in the unfertilized soils.

ii. Can be the major source of both available phosphorous and available sulphur when soil humus is present in appreciable amounts.

iii. Organic matter supplies directly or indirectly through microbial action the major soil aggregate forming cements

iv. Contributes to Cation Exchange Capacity, often furnishing 30-70 % of total amount.

v. Increases field capacity, available water content in sandy soils and both air and flow rates through fine textured soils. The latter effect is mainly due to soil aggregation which produces larger soil pores.

vi. Supplies carbon to the microbes that performs other beneficial functions.

vii. When left on the top soil as mulch, organic matter reduces erosion, shades the soil (which prevents rapid moisture loss) and keeps the soil cooler in very hot weather and warmer in winter.

viii. The quantity of manure to be applied to unirrigated crops varies from 0.75t/ha to 1 t/ha in areas of heavy rainfall. For irrigated crops the rate varies between 5 – 10 t/ha for sugar cane, maize and for yard crops like potato, vegetables and fruits still higher dozes of 7.5 – 12.5 t/ha.

From soil fertility point of view, the excreta of various farm animals is important for the supply of major constituents namely, N, P_2O_5, K_20 and organic matter. On an average a well rotted Farm Yard Manure contains 0.5% N, 0.2% P_2O_5 and 0.5 % K_2O. The use of farmyard manure alone causes an imbalance in nutrition owing to its relatively varying content of different nutrients. The percentage content of N,P and K in different Farm Yard Manures are given below.

Manure	Percentage content		
	Nitrogen (N)	Phosphoric Acid (P_20_5)	Potash K_2O
Cattle dung	0.3-0.4	0.1-0.2	0.1-0.3
Horse dung	0.4-0.5	0.3-0.4	0.3-0.4
Sheep dung	0.5-0.7	0.4-0.6	0.3-1.0
Farm yard manure-dry	0.4-1.5	0.3-0.9	0.3-1.9
Urban compost	0.7-2.0	0.9-3.0	1.0-2.0
Rural compost	0.5-1.0	0.4-0.8	0.8-1.2
Paddy straw	0.36	0.08	0.71

The fertilizing constituents (N, P_2O_5, K_20) of the excreta of various animals comes from the food eaten by them. Fodder and concentrates fed to the animals vary considerably in their richness of nutrients. As such the composition of dung and urine varies from day to day. Farm Yard Manures consists of two original compounds- the solid or the dung and the liquid or the urine. On an average an animal gives out three parts by weight of dung and one part by weight of urine.

Quantity of excreta produced by different classes of animals depends upon:

i. The age and weight of the animals

ii. Total quantity of fodder and concentrate food feed daily to the animal.

On an average the following amount of excreta is produced yearly by different animals. Approximate quantity of dung and urine produced per head annually by various animals are as follows

Animal	Dung produced Per year(kg)	Urine produced Per year (kg)
Bullock	7000	2600
Cow	5000	1900
Horse	9000	2000
Sheep	400	300
Pig	650	400

Approximate quantity of plant nutrients excreted per head annually by various animals are given in the following table.

Excreta of		Quantity in kg of		
		N	P_2O_5	K_2O
Cow	Dung	42.28	10.20	5.10
	Urine	20.41	Trace	29.52
	Total	21.87	10.20	34.62
Bullock	Dung	27.21	13.60	6.80
	Urine	29.16	Trace	39.36
	Total	56.37	13.60	46.16
Sheep &	Dung	2.84	1.89	1.71
Goat	Urine	2.52	0.09	3.93
	Total	5.36	1.98	5.64
Pig	Dung	3.74	3.40	2.72
	Urine	1.81	0.45	2.04
	Total	5.55	3.85	4.76
Horse	Dung	49.89	27.21	36.28
	Urine	30.61	Trace	28.35
	Total	80.50	27.21	64.63

It must be stressed that, the value of farm yard manure in soil improvement is due to its content of nutritive elements and its ability to:

i. Improve the soil tilth and aeration
ii. Improve the water holding capacity of the soil
iii. Simulate soil activities

iv. Simulate activities of micro organisms that makes the plant food elements in the soil readily available to crops

Felton and Ali (1992) studied the hydraulic parameter response to incorporated organic matter in the B- horizon. The study has shown that incorporation of organic matter into the soil results in improved moisture holding capacity and hydraulic conductivity and reduced bulk density and increased porosity. Incorporation of organic matter into the top 20 cm of the B-horizon of a mine soil can be accomplished its re-built without major changes in common mine operations. Bulk density was reduced by up to 25 %, porosity increased up to a point but additional organic matter did not continue to increase the porosity. Saturated hydraulic conductivity increased as much as 1400 % for silt loam soils.

Moore *et al.* (1995) studied the impact of poultry manure application to the environment and soil quality. The excess application of litter can cause environmental problems like nitrate leaching into ground water, non point source runoff into surface water bodies and releases of pathogenic micro organisms. There are many variables associated with poultry management system that can affect manure quality at the time of application. These include the type and amount of bedding materials used, accumulation time and type of feed. In addition to benefits that poultry litter and manure provide to crop production in the form of nutrients, these carbon bearing materials can build soil organic matter reserve which benefits the crop production via increase in soil water holding capacity, water infiltration rate, Cation Exchange Capacity and structural stability. Studies conducted in U.S. shown that 32% of water wells had high nitrate levels, (> 10 mg N L^{-1})due to improper poultry litter application. Also high loading rate of poultry litter resulted in build up of nitrate in the soil to 3 m depth or to bed area.

Nahar *et al.* (1995) studied the performance of wheat and some soil properties as affected by organic residues and inorganic nitrogen fertilizers. The study was conducted in silty clay loam soil. Due to the application of cow dung there was no significant variation in bulk density. The saturated hydraulic conductivity increased more than times

(from 2.60 x 10^{-4} cm/s to 1.69 x 10^{-3} cm/s) at the surface (0-5 cm), and nearly 20 times (from 4.12 x 10^{-7} cm/s to 8.60 x 10^{-8} cm/s) at a depth of 10-15 cm. But, the saturated hydraulic conductivity dropped from 2.59 x 10 $^{-6}$ to 0 at sub surface (20-25 cm). The organic carbon percentage increased nearly 1.5 % (0.48 to 0.73). Total nitrogen percentage increased 1.3 times (0.23 to 0.29) and available nitrogen 1.4 times (18.08 ppm to 25.30 ppm)

Davis *et al.* (1997) found that increased soil organic matter levels due to manure application are often associated with improved soil structure leading to increased infiltration. Therefore nitrate moving in soil water could infiltrate further and potentially shift nitrate losses from runoff towards leaching. The clay soils had significantly higher average electrical conductivities at all sampling depths, up to 1.6 dS/m on the soil surface to up to 2.0 dS/m at greater depths. But for sandy soils, the electrical conductivities are comparatively less i.e., 0.75 dS/m at surface to 0.3 dS/m at greater depths. There was no significant difference in organic matte content between sandy soils and clayey soils, 2.2% at surface and 0.75 % at greater depth for clay soils and 2.30 % at surface and 0.70 % at greater depths for sandy soils. The soil pH was also significantly higher in the clay soils than in sandy soils at all depths, 7.75 at the surface and 8.15 at greater depths for clay and 7.25 at surface and 7.65 at greater depths for sandy soils. In case of nitrate concentration, there was no significant difference between clay soils and sandy soils (50 and 40 ppm at surface and 15 and 10 ppm at greater depths)

Benbi *et al.* (1998) studied the effect of application of inorganic and organic fertilizers and manual versus chemical control of weeds on soil physical properties after 20 years of maize-wheat-fodder-cowpea cropping pattern. They selected five treatments viz. Control (no NPK), NPK + herbicide, NPK + hand weeding, NPK + FYM, NPK without any addition of sulphur. They found that none of the treatments significantly influenced the bulk density of the 0-15 cm layer. Application of farmyard manure every year for 20 years significantly increased the saturated hydraulic conductivity at both soil depths (0-15 cm and 15-30 cm). The increase in permeability due to farmyard manure resulted in a significantly higher infiltration rate. At suction ranging from 20-140 cm, there was a greater water retention in farm yard manure treated plots compared with the

control plots. More water retention in manured plots was due to larger organic matter, which leads to development of better physical condition through improved aggregation, greater soil water retention and water transmission and infiltration rate.

Walker *et al.* (1990) proposed a computer model to predict the effects of animal waste management practices on bacteria concentration of runoff from agricultural lands. The model outputs maximum and minimum bacteria concentration in runoff resulting from a storm assured to occur immediately after the manure is applied to the land. The model can simulate the effects of waste storage, filter strips and incorporation of manure into the soil.

Chenu *et al.* (2000) found that organic matter influences on clay wettability and soil aggregate stability. They found that the aggregate stability is generally strongly correlated with soil organic matter content. They analysed in the soil, the possible contribution of soil organic matter to aggregate stability by decreasing their wettability and evaluated the role of clay-associated organic matter in soil aggregate wettability and water stability. They found that the organic molecules adsorbed to clay decreases the wettability. The increasing hydrophobicity with increasing soil organic matter content in the clay function corresponds to

i. An increasing proportion of organic particles with hydrophobic character.
ii. Increasing coverage of clay minerals by hydrophobic organic coatings.

Also the water stability of aggregates and their drop penetration time generally incurred with hydrophobicity of clay fraction.

2.1.6.1.1.2 Composited Manure

By preparing compost from farm houses and cattle shed wastes of all types, good organic manure similar in appearance and fertilizer value to cattle manure can be produced from waste materials of various kinds such as cereal straw, crop stubble, cotton stalks, ground nut husk, farm weeds and grass, leaves, wood ashes etc.

Mostaghimi *et al.* (1989) studied the impact of land application of sewage sludge on runoff water quality. A rainfall simulator was used to study the effect of tillage system and sludge application method on rate of runoff, sediment and nitrogen loss from agricultural land. Surface application and incorporation of sludge were studied.

Anerobically digested sewage sludge was applied at the rates to supply 0, 75 and 150 kg/ha of plant available nitrogen. A total of 90 mm rainfall with an intensity of 40 to 45 mm/h was applied to sixteen 0.01 ha plots located on a silt loam soil. Runoff samples were collected from plot discharge and later analysed for sediment and nutrient contents. Runoff and sediment loss decreased as sludge application rate increased. The surface application of sludge was more effective in reducing sediment losses than sludge incorporation.

Skousen and Clinger (1993) studied the benefits of amending the soils and mine soils with sewage sludge. There had some potential hazards. Heavy metals in sludge (municipal sludge) are normally complexed in organic fraction of the soils and minor amounts are adsorbed to cation exchange and may be slowly available for plant uptake. Application of sludge to acid producing materials or acidic mine soils is a significant potential problem if heavy metals in the sludge are solublized and moved into ground and surface water supplies. In the study on a reclaimed surface 0, 15, 31, 64 dry mg/ha sewage sludge were applied and monitored for four years. Grass bio-mass increased and legume bio-mass decreased with increased sludge application. pH was not significantly affected while organic carbon increased from 15 g/kg to 22 g/kg , Cu, Zn and heavy metal concentration also increased with sludge application.

Bushee *et al.* (1998) analysed the quality of runoff plots treated with municipal sludge and horse bedding. They found that the presence of relatively mobile nitrogen(N), Phosphorous (P), organic matter, microbes and other materials near the soil surface following organic amendment application can decrease the quality of runoff. The primary environmental concern with regard to nutrients in runoff is related to eutrophication of downstream water bodies. Organic materials used in this study were selected because they have not received much attention in the context of runoff studies even though they are of interest in regions having significant carbon, urea and horse production.

2.1.6.1.1.3 Green Manure

Despite special efforts for increasing supplies of farm yard manure and compost, their supply is scarce and ever becoming more costly. Green manuring is the principle of

the supplementary means of adding organic manure to the soil. It consist of growing a quick growing crop and ploughing it to incorporate into the soil.

2.1.6.1.2 Fertilizers

Fertilizers are inorganic materials of concentrated nature. They are applied mainly to increase the supply of one or more of the essential nutrients. Fertilizers contain these elements in the form of soluble or readily available chemical compounds. Fertilizers are sometimes called as artificial or inorganic manures. Fertilizers have the advantage of smaller bulk, easy transport, quick availability of their plant food constituents and the possibility of application suited to the actual requirement of different crops and soils. Fertilizers are usually classified according to the particular plant food element which form their principle constituent viz. nitrogenous fertilizers, phosphatic fertilizers, potash fertilizes etc.

2.1.6.1.3 Concentrated organic manure

Some of the concentrated materials such as oil cakes, bone meal, urine and blood are of organic origin can also be used as good soil amendments.

2.1.6.1.4 Bulky Organic Manure

The effect of bulky organic manure is three folds.

i. Since they contain plant nutrients, they have a direct effect on plant growth, like any other commercial fertilizer. Bulky organic manure contains nutrients in small quantities, therefore large quantities of them need to be applied per acre. Bulky organic manure contains traces of micro nutrients also besides macro nutrients.

ii. They increases the organic matter and hence improves the physical properties. This effect is very much important in case of most of aerable lands. Such manures improve the humus content of the soils, at least temporarily and water holding capacity of the sandy soil is increased and drainage of clay soil is improved.

iii. They provides food for soil micro-organisms. This increases the activity of microbes, which in turn helps to convert plant nutrients into available forms.

2.1.6.1.5 Timing and methods of fertilizer and manure application

To obtain the maximum benefit from fertilizers, it is most essential that, the fertilizers be applied in proper time and at proper place. The fertilizers to be applied possess different qualities with regard to the solubility in water and movement into the soil solution. Similarly soils are of different nature from sandy to clay. The nature of soils governs the movement of applied fertilizer. Again the requirement of plants for different plant nutrients varies in relation to their stage of growth. Thus the time and method of fertilizer application will vary in relation to

i. Nature of fertilizer
ii. The type of soil
iii. The difference in nutrient requirement and nature of field crops.

2.1.6.1.5.1 Different methods of applying fertilizers

1) Solid form
   a) Broad cast
      i) Broad casting at planting
      ii) Top Dressing
   b) Placement
      i) Plough sole placement
      ii) Deep placement
      iii) Sub soil placement
   c) Localised placement
      i) Central placement
      ii) Bund placement
      iii) Pellet application
      iv) Side Dressing
2) Liquid Form
   a) Starter solution
   b) Foliar Application of spray application
   c) Direct application to the soil
   d) Application through irrigation water.

2.1.6.2 Surface seal formation due to addition of amendments and its effect on runoff and infiltration

Barrington and Madramotoo (1989) found that total solid content of the manure slurry is more important than the soil permeability in reducing infiltration over time. The physical mechanism were identified as the primary sealing process where as the biological mechanism were observed to further reduce infiltration rate only when temperature exceeds 15ºC and the manure was relatively high in biodegradable components. Bio chemical mechanisms have been known to develop within the soil over several month and to intervene by destroying all the macro structures by process known as gieization.

Darcy's law can be applied to manure slurries infiltration as long as the following process are considered.

1. As manure infiltrates into the soil, i) two distinct layers are formed above that of the soil, a soil surface organic mat of manure particles too large to move through the medium's pores, along the liquid infiltrates ii) a manure soil interface, where manure particles gets lodged inside the soil pores.

2. Along with the soil, these two modified layers form three porous media, each medium demonstrating a distinct permeability.

3. Considering the particle size analysis for all types of manures, the liquid flowing through these three media have lost more than 60 % of their total solids, thus exhibiting a total solid content of less than 3% and viscosity similar to that of water (manures with less than 5 % total solid demonstrates viscous properties similar to that of water).

Nabh *et al.* (1989) found that broad cast burning a harvested site in US increased the water repellence and decreased the infiltration rate of surface soil for about five months. Both infiltration rate and water repellency returned to nearly pre-burn levels after that period. The moisture content of the soil in the burned plot was higher than that in the unburned plots at all depths up to 30 cm.

A study was undertaken by Hamlet *et al.* (1990) to determine the effects of soil conditioners, ammonium laureth sulphate and vehicle compaction on soil properties. There was no statistically significant effect of ammonium laureth sulphate

on soil water infiltration, soil penetration resistance, soil bulk density, soil water content or crop yield. Additionally there was no interaction effects of the soil conditioner with the level of compaction caused vehicular traffic. However increased trafficking did not cause increase soil compaction with resultant significant effect on penetration resistance, soil bulk density, soil water content and soil water infiltration.

Trout (1990) studied the surface seal formation on surge flow furrow infiltration. Surge irrigation is the intermittent application of surface irrigation of water. Under some conditions the technique reduces the application time and volume required to advance flow across the field surface and thus improves irrigation water distribution uniformity. The intermittent flow can increase the degree of soil aggregate breakdown and the amount of sediment erosion and deposition in furrows and thus a formation of depositional surface seal. Surging increases the infiltration rate and thus reduces the advance time. When surface sealing was prevented with cheesecloth layer surging consistently reduced steady state and cumulative infiltration by 25%. However infiltration was still much higher in these surged, no seal furrows than in the conventional furrows.

Eisenhauer *et al.* (1992) used a numerical model to simulate one dimensional infiltration of overland flow into surface sealed soils. Surface sealing did not always influence infiltration. Sealing had the most control on infiltration when the seal was already present at the beginning of irrigation. When the soil surface was not protected, the impact of water drops apparently caused significant sealing of the soil surface layer, which resulted in over prediction of infiltration. The development of the compact surface layer (surface seal) was attributed to the structural disturbance of soil aggregates by raindrop impact and the sorting action of water as it flowed over and through the surface thus fitting fine particles and aggregates between the large ones. The cumulative infiltration was not significantly affected by the transient seal formation. The effect was less than 1% reduction in cumulative infiltration. The rate of the seal formation was slow enough and infiltration was high enough so that the top soils saturated rapidly. The constant seal had more influence on infiltration that the infiltration reduced from 3.4 % to 20.2 %.

Ghobar (1993) studied the influence of irrigation water on soil infiltration. The sequence of events, which occur under different application rate, is as follows. To begin with water infiltrates into the soil very rapidly and totally absorbed particularly with first runs. As all the soil particles in the surface layer becomes wetted, the rate of infiltration declines and a thin layer of water forms on the surface and accumulates in very small depressions. Once these depressions are full, run off commences. He found that the infiltration rate is decreased as the amount of water applied (cumulative infiltration) increased. The reduction in infiltration is attributed to the formation of a crust. The stage of crust formation is the factor which determines the infiltration rate of bare soils. Infiltration rate decreases as the number of runs or the amount of water applied increases. Apparently mechanical action of the applied water greatly enhances the rate of exchangeable cation and soil solution on swelling and dispersion at the soil surface which in turn has a large effect on infiltration rates. The greater reduction in infiltration rate under the treated waste water application resulted in an increase in soil sodicity compared to clean water and the clogging of soil particle pores by suspended solids, which restricts water flow and thereby effectively reduces the soil infiltration rate.

Stone and Ekwue (1993) measured the maximum dry bulk density and corresponding critical moisture content in the laboratory condition of soil mixed with three organic materials peat, farmyard manure and filter press mud at four levels 0, 4, 8, 12% by mass and compacted using 5,15 and 25 hammer blows. The experiment was conducted for both clay and sandy loam soils. While the mean maximum dry bulk density declined significantly from 1.51 to 1.26 mg/m^3 , the mean critical moisture content decreased with increasing compaction efforts. The bulk density was increased by the concentration of organic material but it reduced by the compaction rate for both types of the soils like clay and sandy loam. The effectiveness organic material in terms of reducing maximum dry bulk density and increasing critical moisture content was in the decreasing order of peat, farmyard manure and filter press mud.

Wang *et al.* (1994) developed an event based simulation model to describe the runoff transport of solids (soil and manure particles) and nutrients (nitrogen and

phosphorous) from areas treated with animal manure. Runoff losses of land applied animal manure constituents can adversely affect the quality of downstream water. The resulting model consist of a linked hydrology, soil/manure transport and nutrient transport components in process oriented and uses measurable parameters to greatest degree possible. The three components of the model were calibrated sequentially (hydrology, soil/manure transport and nutrient transport in order) using data from plot scale field experiments involving grassed plots treated with poultry litter. Transport of total suspended solids, ammonia, nitrogen and dissolved phosphorous were well predicted by the model.

Chaubey *et al.* (1995) conducted an experiment to determine the effectiveness of vegetative filter strips in controlling losses of surface applied poultry litter constituents. Land application of animal manure is generally regarded as an economic means of making beneficial use of manure constituents. Runoff from land application sites however is a potentially significant source of pollution since it can contain undesirable constituents of sediment, organic matter, nutrients and micro organisms. Use of vegetative filter strips has received considerable attention for removing impurities in runoff from crop land and areas of live stock activity. Vegetative filter strips consists of grass and other cover and are emplaced downslope of pollutant sources to remove sediment, nutrients and other materials from the incoming runoff. The objective of the study was to test the effectiveness of vegetative filter strips for removing sediment, nutrients and organic matter from land areas amended with poultry litter. It was found that vegetative filter strips removed significant quantities of Total Nitrogen, ammoincal nitrogen, total phosphorus, total suspended solids, COD and PO4-P from incoming runoff by 39, 47, 40 35 and 51 % respectively.

Williams *et al.* (1995) studied the microphytic influence on inter rill erosion and infiltration capacities. They found that microphytes – mosses, lichens and algae contributes to the development of microphytic crusts on range land soils. Undisturbed microphytic crusts reportedly enhanced infiltrability at some sites. This enhancement was attributed to the ability of microphytes to reduce the development of physico- chemical

rain crusts. Soil surface structure and thus macro pores (0.75 mm in diameter) might also be maintained by well developed microphytic crusts.

Microphytes are not always associated with superior infiltration capacity. For example basidomycetous fungi encase sand grains in organic material and creates hydrophobic conditions in the inter spaces between vascular plants. Microphytic crusts potentially influence infiltration in similar manner through a combination of concentrated fine particles and hydrophobic organic matter at the soil surface. It was found that the microphyte are disintegrated and the resulting collapse slaking and temporary sealing of the soil surface promotes rapid ponding. Microphytes in control and chemically treated conditions significantly reduce time to ponding and time to runoff apparently due to structural and textural differences at the soil air interface. Inter rill erosion was greatest in the field when microphytes are absent (due to chemically killing) and lowest in the control plots. But mocrophyte crusts did not significantly influences the infiltration capacity.

Crust is the general term used to describe a soil surface that has become hard or impervious upon after being compacted by water droplets or subjected to surface irrigation. Fattah and Upadhyaya (1996) studied two types of crusts, i)structural crusts induced by translocation of fine particles and seals up to 13.5 mm thickness which are termed thin crusts and ii) depositional crusts induced by translocation of fine particles and their subsequent deposition at a certain depth below their original location which are greater than 13.5 mm in thickness. Soil compaction and soil crusting are the major management created layers which influences water infiltration significantly. Surface seals are formed under the influence of external forces such as raindrop impact and mechanical compaction or through slaking and breakdown of soil aggregates during wetting.

Three types of soil surface seals are found when thin sections of soil crust formed due to simulated raindrop impact were studied.

i. Washed-in-zone with a low porosity but to a lesser degree than the surface seal, which reached a depth of 2 mm and was due to the downward movement of colloidal materials.

ii. Washed-out zone that resulted from mobilisation of clay and movement of colloids with 0.5 mm thickness of packed silt size grains.

iii. A thin surface seal of less than 0.1mm thickness.

It was found that very thin surface crusts (soil surface seals less than 6 mm thickness), whether dry or wet did not appear to reduce infiltration rates. This is most likely due to the presence of cracks that developed in the crust immediately upon wetting the surface. A thick depositional crust reduces the final infiltration rate significantly. The initial infiltration rate depended upon the type of the crust. The initial infiltration rate increased significantly for a wet crust.

Flanagan *et al.* (1997) studied the effect of water chemistry and soil amendments on a silt loam soil. The main hypothesis of the study was that surface sealing and infiltration on an initially dry silt loam soil could be significantly affected by the type of applied water and soil surface treatment combinations. Tap water and de-ionized water were tested. It was found that the use of water with different electrolyte concentration on silt loam soils does not adversely affect the infiltration and runoff response. Infiltration, runoff and soil loss are processes that occur when rainfall and runoff water interact with the structure and physical and chemical bonds of the soil surface. A well aggregated soil which is porous strongly resistant to dispersion and aggregate breakdown will typically have greater infiltration rates and less runoff and soil loss than a poorly aggregated soil that is easily dispersed to seal the crusts. Soil surface seal formation results from physical aggregates due to rain drop impact and/or chemical dispersion which is dependent upon soil properties.

Heil *et al.* (1997) classified surface seals as either structural or sedimentary seals. Structural seals forms insitu as result of disaggregation upon raindrop impact or rapid wetting. Redistribution of soil particles results in a decreased number and/or continuity of macro pores and formation of several micro layers. Fine (clay and silt sized) particles may move as a front into the soil, forming a thin (0.1 to 1 mm) dense, disruption “ washed in layers”. As the seal develops, coarse and fine sands are sorted at the surface and form additional micro layers above the “washed in layers”. Later these layers may be

eroded. Seal formation is a dynamic process and should always be observed as a function of time.

The two main properties influencing soil sealing are generally particle size distribution and aggregation. In a single grained soil or soils with little or no aggregation, soil texture may be the dominant factor affecting soil sealing. Medium textured soils with high silt content and sandy soils with low silt content were found to be most prone to sealing. Other soil properties such as organic matter type and content, inorganic amorphous cements, mineralogy, salt content and flocculation/dispersion conditions may influence soil sealing directly or through their effect on aggregate stability. The influence of soil properties on seal formation were studied with specific objectives to describe the occurrence of surface seals in selected soils and to characterise seal morphology, genesis, hardens and effect on infiltration. The texture of the soil were examined and found that soil sealing is most severe on sandy loam soils, where in at a lower degree in loamy sand soil. Infiltration rate was found to decrease by 95 % for sandy loam soils, 30-50% for sandy soils and 45% for loamy sand soils.

Zhang *et al.* (1998) assessed the effects of surface treatment on surface sealing, runoff and inter rill erosion. Surface treatment influences the nature and extent of seal/crust formation, which affects runoff and erosion. The study evaluated the effect and longevity of soil amendments, tillage and screen cover on runoff and inter rill erosion. Three treatments (control, screen cover, crust breaking shallow tillage) and another three amendments (control, anionic, poly acrilamide (PAM), phosphogypsum) were studied under natural rainfall conditions. Total runoff and soil losses were 69, 61, 47 mm and 5.3, 1.6, and 4.3 mg/ha for control, screen cover and tillage treatments respectively. Compared with control, screen cover reduced soil loss significantly but not runoff, while tillage reduced runoff more than soil loss. Total runoff and soil loss for control, gypsum and PAM treatments were 146, 48 and 81 mm and 3.6, 2.6 and 2.5 mg/ha respectively. Runoff was reduced by 67 % and 44 % for the gypsum and PAM relative to control and soil loss was reduced by 16 % and 19%, showing gypsum and PAM were more effective in reducing runoff than soil loss. Runoff was significantly reduced in gypsum and PAM treatments following surface application. Results showed that screen cover and tillage

temporarily reduced or delayed seal/crust formation, while effects of gypsum or PAM were more persistent. Surface sealing and soil crusting are common to many agricultural soils, which often increase surface runoff and erosion. Surface seals substantially reduce water infiltration because of their low hydraulic conductivity. It has been reported that soil cover and chemical amendments such as gypsum and organic polymer are effective in reducing seal crust formation and increasing final infiltration rate.

During seal formation, soil bulk density and shear strength in the vicinity of soil surface increase and subsequently soil splash or splash detachment decreases. In general sealing tends to increase inter rill soil loss by increasing runoff, because inter rill erosion is often limited by the transport capacity of shallow overland flow. However, decrease of inter rill soil loss with seal formation have also been reported. This discrepancy is because seal formation affects both processes like detachment by raindrop impact and transport by thin overland flow. Because detachment decreases as a seal form, seal formation may reduce the total soil loss if detachment is limiting. Conversely, larger runoff volumes produced under salient conditions coupled with enhanced transport capacity by raindrop impact may increase inter rill soil loss rate if shallow overland transporting is limiting.

Seal formation involves two major complementary mechanisms i) physical disintegration of soil aggregates by raindrop impact and slaking upon wetting followed by consolidation at the soil surface ii) chemical dispersion of surface clay particles into region immediately beneath the surface, where dispersed clay particles clog pores and form an illuviated zone. Physical process denominates when soils with high electrical conductivity of low exchangeable sodium percentage are exposed to high intensity rains. Otherwise, chemical processes supplement or enhance the physical processes. The interaction between the two mechanisms becomes significant when soils with low ESP and EC and a dominant 1:1 clay minerals are exposed to rain.

Chenu *et al.* (2000) found that the main process by which soil aggregates are disrupted upon rainfall are i) slaking ii) differential swelling iii) mechanical dispersion and iv) physico chemical dispersion. Soil organic matter is assumed to stabilize aggregates against these disruptive processes by two major actions. At first organic matter increases the cohesion of aggregates and then organic matter may decrease the wettability of aggregates by slowing down their rate of wetting and thus the extent of slaking. In some soils, organic substance induce very severe water repelling. Strongly hydrophobic organic coating can prevent water from entering the aggregates or the horizon, restrict infiltration and cause intense surface runoff.

Apart from the case of strongly hydrophobic soils, soil organic matter may impart partial repellence to soil aggregates and thereby contribute to their stability. Dried aggregates from pasture soils which are rich in organic matter were more stable than moist ones and it was opposite for aerable soils with low carbon content. The slower re-wetting of pasture aggregates as compared to aerable counterparts was ascribed to hydrophobic properties of soil organic matter.

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter describes the materials used and methodology adopted for carrying out the study.

3.1 Rainfall Simulator

The oscillating tubing tip type rainfall simulator fabricated by Sajeena and Kurien (1999) was used for the experiment. The tubing tip is a precise method of making water drops. The hypodermic needles could produce drop sizes up to 5.8 mm. The drop size can be varied by changing the pressure of the water supplied to the needles. The oscillating mechanism helps to avoid the falling of drops at the same spot continuously. Fig.1 shows the schematic diagram of the rainfall simulator. The overall view of the experimental set is shown in Plate. 1

3.1.1 Components of Rainfall Simulator

3.1.1.1 Drop Former Unit

The drop former unit consists of 0.89 mm hypodermic needles and a net work of 1.8 cm diameter GI pipes. The net work has an inlet for water and two valves for releasing entrapped air. The transverse pipe of the net work were drilled at 5 cm interval to accommodate the heads of the 18 gauge hypodermic needles. The needles wee fitted in the holes by soldering. Each transverse pipe was fitted with 44 needles. The drop former unit thus has 176 needles, 44 needles each on 4 transverse pipes. For the oscillating movement of the drop former unit, four cast iron wheels of 5 cm diameter were provided on both longitudinal sides of drop former unit. The close up view of the drop-forming unit is shown in Plate. II.

3.1.1.2 Supporting Frame Work

The entire drop former unit was supported by a rectangular frame work of 4.6 m x 2.2 m made of angle iron pieces having size 50 mm x 50 mm x 6 mm. MS flat of 25 mm x 2 mm were welded on both sides of the flat surface of the angle iron placed on longitudinal sides of the frame work, to form channel for the movement of the wheels.

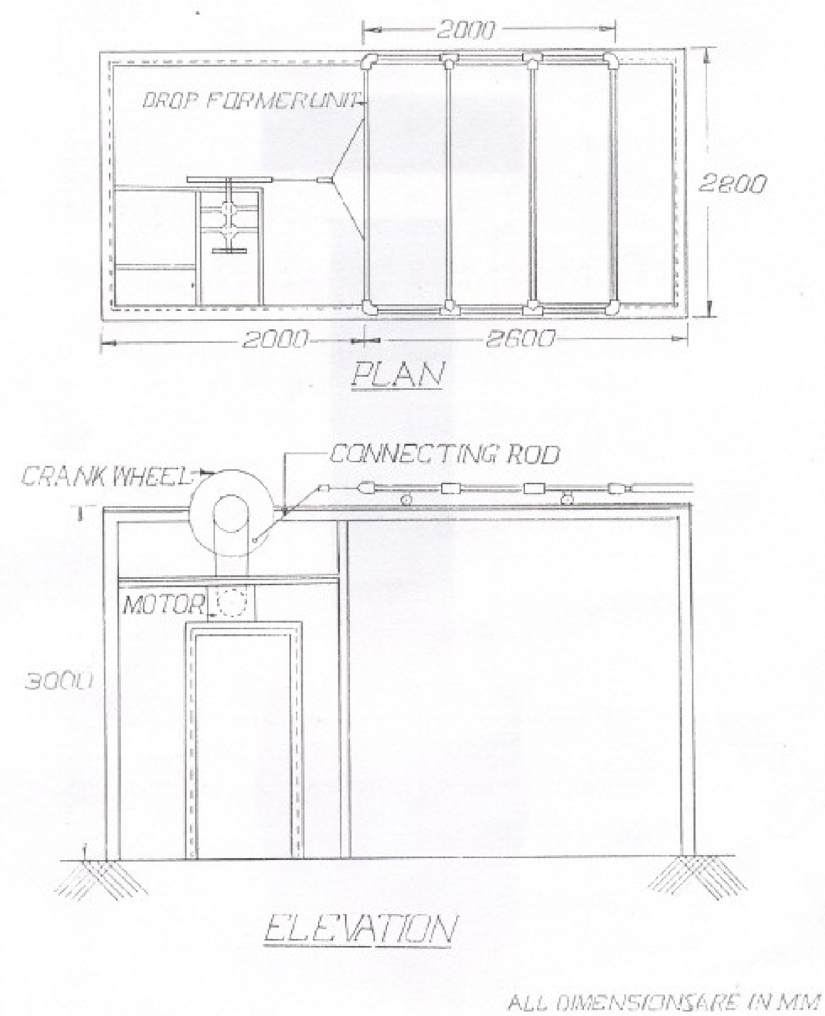

Fig 1. Schematic diagram of the rainfall simulator.

Plate I. Overall view of the experimental setup

Plate II. Close view of the drop forming unit.

The pulley and the cranking mechanism of the drive unit were fitted on the frame work of size 1.15 m x 1 m fitted on the main frame work. The framework was supported by seven legs of 3 m long 25 mm MS pipes. The legs were welded to the frame. The foot of each leg was fitted with 30 mm to 5 mm horizontal MS flats, 30 cm in length to provide stability to the structure.

3.1.1.3 Power Transmission System

The power required to oscillate the drop former unit was taken from a three phased geared motor. The specifications of the motor are given below.

Speed: 45 rpm HP: 3

Voltage: 415 V Current: 3.4 A

The out put shaft of the motor was fitted with a 75 mm V pulley (A), above which a 305 mm V pulley (B) which reduces the speed to 13 rpm. A crank wheel of 660 mm diameter was fixed on the shaft of the pulley B. The connecting rod between the crank wheel and the drop former unit converts the rotary motion of the crank wheel to a reciprocatory motion of the drop former unit, thus forcing it to oscillate at the rate of 13 oscillations per minute. The details of the power transmission system is shown in Fig. 2 A view of the power transmission is shown in Plate. III.

3.1.1.4 Water Supply to the Rainfall Simulator

A centrifugal pump operated by an electric motor was used to lift the water from a storage tank of 500 l capacity and to develop the required pressure for working the rainfall simulator. The discharge line includes a valve. A pressure gauge of 0-6 kg/cm^2 was fixed in the discharge line after the valve. The supply to the discharge line was controlled by means of the valve.

Specifications of the pump are:

Head : 15 m HP : 0.5 Operating conditions: 230V, 2.0 A 50 Hz

The tank got supply of water from the main pipe line in the campus. The water was filtered through fine cloth filters before collecting in the tank. This was done to prevent the clogging of the needles by fine particles. Water was supplied to the simulator through a 1.8 cm diameter flexible hose.

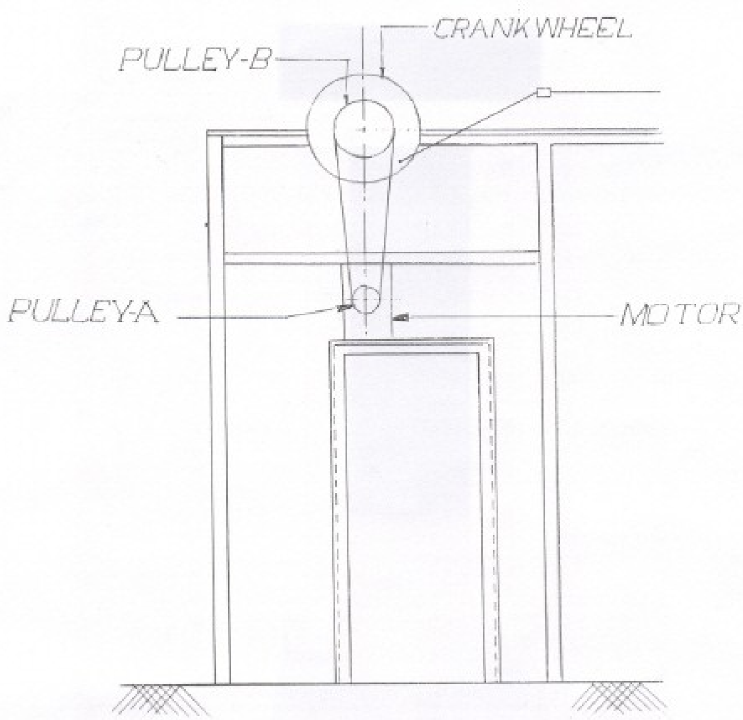

Fig 2. Power trasmission system of the rainfall simulator.

Plate III. Power transmission system of the rainfall simulator

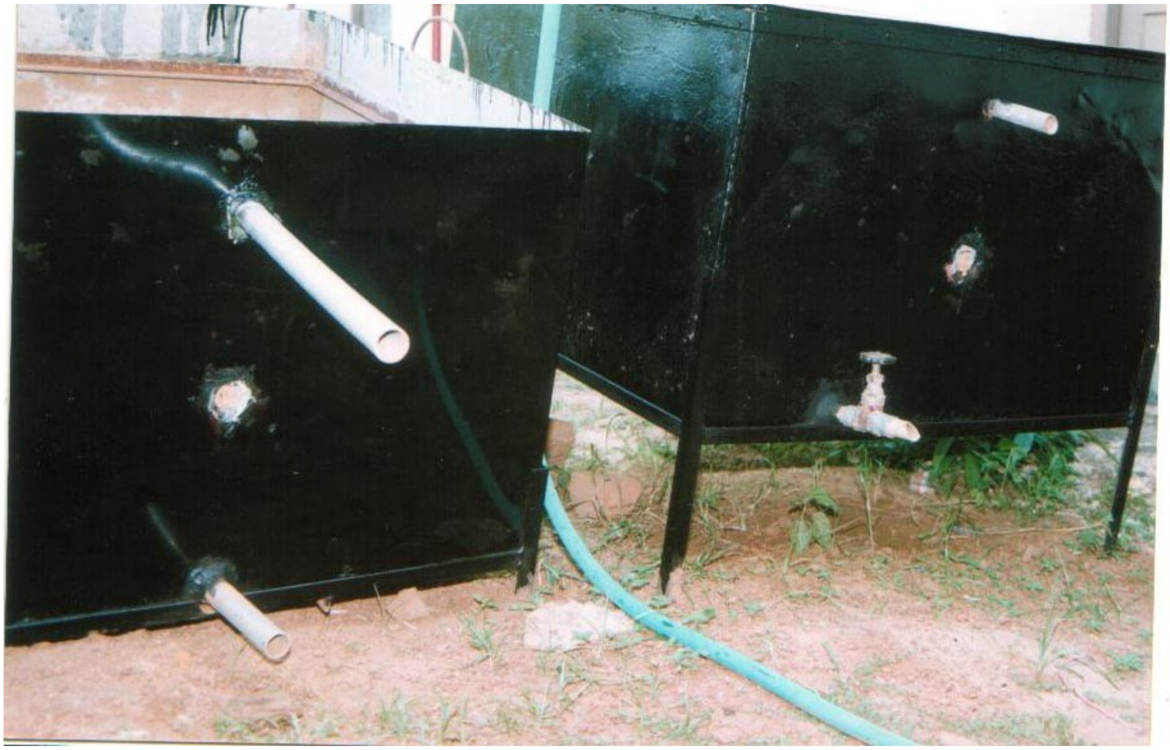

Plate IV. Soil trough with stand.

3.1.2 Calibration of the Rainfall Simulator

The rainfall simulator was operated for different operating pressures in the range 0.2 – 1.0 kg/cm^2. Catch cans were placed at 650 mm x 550 mm grid, thus forming a total of 16 catch cans (4 x 4). The simulator was operated for 30 minutes. The volume of water collected in each can was recorded and this volume was converted into its equivalent depth. The test was repeated for 0.2, 0.4, 0.6, 0.8, and 1 kg/cm^2. The intensity was calculated for each supply pressure of water and calibration curve was plotted.

3.2 Study Location

The rainfall simulator was installed in the open area in between the laboratories and the smithy shop of KCAET, Tavanur. The wind velocity was minimum in the selected area. Hence the site was selected for the study.

3.3 Uniformity of Rainfall

The simulator was operated at 0.2 kg/cm^2. Catch cans were placed at 16 grid points as detailed in calibration procedure. The simulator was operated for 30 minutes. The volume of water collected in each can was recorded. The uniformity coefficient (Cu) was calculated using the Christainsen's formula.

$$\mathrm{Cu} = 100\left(1 - \frac{\Sigma x}{mn}\right)$$

Where:

Cu = Uniformity coefficient, %

m = Average volume of all observations, mm

n = Number of observations

x = Numerical deviation of observations from the average application rate.

The experiment was repeated for various intensities of rainfall.

3.4. Soil trough

A soil trough of inner dimension 900 mm x 900 mm x 300 mm was fabricated with 0.89 mm GI sheet. The tank has provision for collecting the runoff water and infiltrated water. A supporting frame was also fabricated by welding 25 mm x 25 mm x 5 mm MS angle iron pieces. The height of the frame was adjusted in such a way that it gives 10 % slope towards the outlet side (Plate. IV).

3.5 Soil Analysis

The soil samples were taken from two locations of the instructional farm, KCAET, Tavanur. One sample from the mango orchard and one sample from the were used for the study.

3.5.1 Textural Analysis

Textural analysis of the soil was done by determining the particle size distribution. The percentage of various sizes of particles in a given dry soil sample was found by a particle size analysis. It was performed in two stages.

1. Sieve Analysis 2. Sedimentation Analysis

The first stage was meant for coarse grained soils only while the second stage was performed for the fine grained soils.

3.5.1.1 Sieve Analysis

The complete sieve analysis can be divided into two parts- the coarse analysis and the fine analysis. An oven dried sample of soil was separated into two fractions by sieving it through a 4.75 mm IS sieve. The portion retained on it (+ 4.75 mm) is termed as the gravel fraction and was kept for coarse analysis, while the portion passing through it (- 4.75 mm) was subjected to fine analysis.

The following set of sieves were used for coarse sieve analysis IS: 100, 63, 20, 10, and 4.75 mm. The sieves used for fine sieve analysis were 2mm, 1mm, 600, 425, 300, 212, 150, and 75 micron IS sieves.

The percentage of soil retained on each sieve was calculated on the basis of total mass of soil samples taken and from these results, the percentage passing through each sieve was calculated.

3.5.1.2 Sedimentation Analysis

In the sedimentation analysis the soil fractions finer than 75 micron was kept under suspension in water. The analysis was based on Stoke's law, according to which the velocity, at which grains settle out of suspension, all other factors being equal, is dependant on the shape, weight and size of the grain. The coarser particles being spherical and having the same specific gravity settles more quickly than the finer ones. the terminal velocity 'v' of sinking of a spherical particle is given by:

$$v = \frac{1}{18} D^2 \frac{(G - 1)\gamma w}{\eta}$$

Where,

D = Diameter of the spherical particles (m)

V = terminal velocity (m/sec)

γw = unit weight of water (kN/m^3)

from this expression, if the diameter of particle, D is in mm and if the particle falls through a height He cm in t minutes,

$$D = \sqrt{\frac{3000\,\eta}{(G - 1)\,\gamma w}} \times \sqrt{\frac{He}{t}}$$

The hydrometer and the sedimentation jar were calibrated before the start of the analysis.

After calibration, a graph was plotted between the effective depth (He) and the density reading (Rh) of the hydrometer. The necessary correction to be made were also determined. Hundred grams of the soil was first treated with hydrogen peroxide solution to remove organic materials. Next, the soil was treated with 0.2 N hydrochloric acid to

remove carbon compounds if any. After washing the mixture with warm water, the oven dried soil was weighed and 100 ml dispersing agent (sodium hexameta phosphate) was added. The soil suspensions was washed through a 75 micron IS sieve, the mass of those passing through the 75 micron sieve was transferred to 1000 ml measuring cylinder making up the volume accurately to 1000 ml. The hydrometer was immersed in it and the reading were taken at different time intervals. The percentage finer (N) was determined and the particle distribution curve was plotted. The texture of the soil was determined with the help of textural triangle.

3.6 Preparation of soil samples for the experiment

The soil samples were taken from the locations mentioned above. The soils were filled in plastic bags in the reverse order of their profile distribution. The soils were transported to the study area. The soils were air dried and filled in the soil trough according to their profile distribution.

Roughly powdered cattle manure were surface applied and incorporated by stirring the surface. The application of manure were in four levels.

Control = No manure application

M_{15} = Manure equivalent to 15 tones/hactre

M_{20} = Manure equivalent to 20 tones/hactre

M_{25} = Manure equivalent to 25 tones/hactre

3.7 Collection of runoff and infiltration samples

The simulator was operated at a pressure of 0.4 kg/cm^2 initially. The pressure was maintained constant by adjusting the valve. The 0.4 kg/cm^2 pressure gives the rainfall equivalent to 30 mm/h. The unit was operated for 30 minutes continuously and collection pans were put at runoff and infiltration outlets. After 30 minutes of operation the unit was switched off. The runoff seizes soon after the rainfall was stopped. The volume of collected samples were measured and recorded. The samples were transferred to plastic containers and closed tightly for further analysis. The infiltration continued for nearly 3-4 hours. The volume of infiltrated water for each 30 minutes were measured and recorded for a duration of four hours.

Each treatment was continued for 7 continuous days and simulated rainfall was applied every day at same time. All the four treatments (Mc, M15, M20, M25) were replicated three times. The same procedure was repeated for 0.6 and 1 kg/cm^2 pressure, which gives 45 and 60 mm/h rainfall respectively.

3.8 Analysis of samples

3.8.1 Engineering Properties

3.8.1.1 Total solid content

The runoff samples collected were stirred well and a uniform sample of 50 ml was taken in a sample pot. The weight of the sample was noted and was kept in a hot air oven at 105^0 C for 24 hours. The dry weight of the sample and empty weight of the pot were also recorded. From these data, the total solid contents were determined.

3.8.1.2 Bulk density of the soil sample

After seven days treatment, the soil samples were allowed to dry for 24 hours in the trough. Then the soil samples were collected from three profile levels. The volume and initial weights were recorded and the samples were, dried in hot air oven at 105 ^{o} C for 24 hours. The dry weight was also recorded and the bulk density was determined from the available data.

3.8.2 Chemical Properties

3.8.2.1 Total Kjeldahl Nitrogen

The total nitrogen in the runoff samples were determined by macro kjeldahl method.

3.8.2.2 Total Organic Matter

The total organic carbon content in the runoff samples were determined by Walkley and Black's Titration method. The total organic matter content were determined from the total carbon content.

RESULTS AND DISCUSSIONS

Results and Discussion

The results obtained from the study are discussed in this chapter.

4.1 Soil Analysis

From the textural analysis, it is observed that the soil from the mango orchard is sandy loam soil (sand 69 %, silt 12 % and clay 16 %) and the soil from the paddy field is clay loam soil (sand 42%, silt 25% and clay 33%).

4.2 Calibration of the rainfall simulator

The rainfall simulator was calibrated for determining the application uniformity and intensity of the rainfall at different operating pressures. The results are presented in Figures 1 and 2 and the corresponding values are given in Appendix I.

4.3 Infiltration

The results of infiltration study are as given below.

4.3.1 Sandy Loam Soil

The results of infiltration study shows that the infiltration rate decreases at a steady rate with time in all treatment combinations. From the daily trend, it is seen that the infiltration rate is low on the first day, then increases and again decreases from 2nd or 3rd day onwards. The low infiltration rate during the first day may be because of the presence of un-decomposed manure particles in the soil surface. The solid particles will block the entry of water into the soil profile. For all the treatment combinations there was no appreciable difference among daily infiltration rate after 150 minutes. For all the cases, the highest infiltration rate was obtained for the control and the infiltration rate was observed to decrease with increase in manure concentration.

4.3.1.1 30 mm/h rainfall intensity

The infiltration rate recorded under various manure treatments with 30 mm/h rainfall intensity are given in Appendix II and are shown graphically in Figures 3 to 7.

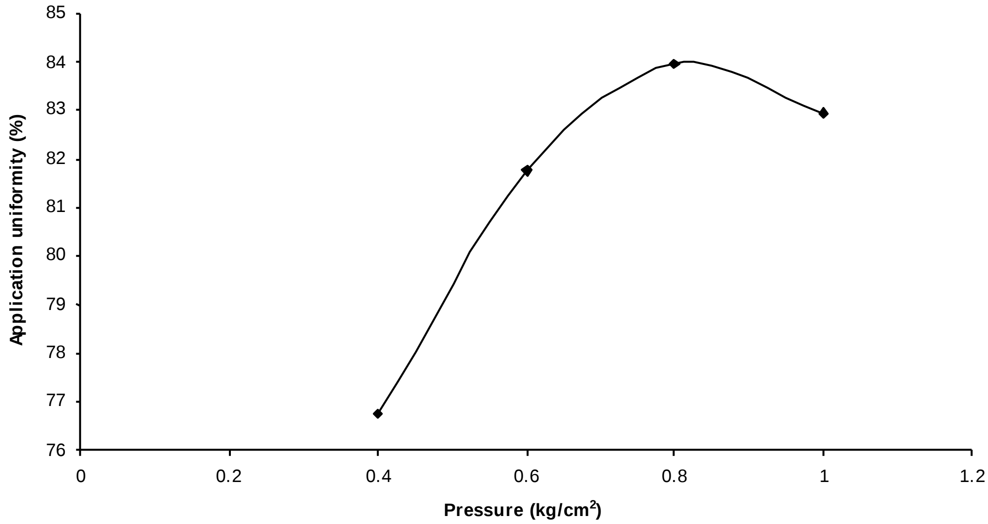

Fig.1 Calibration curve for application uniformity of the rainfall simulator

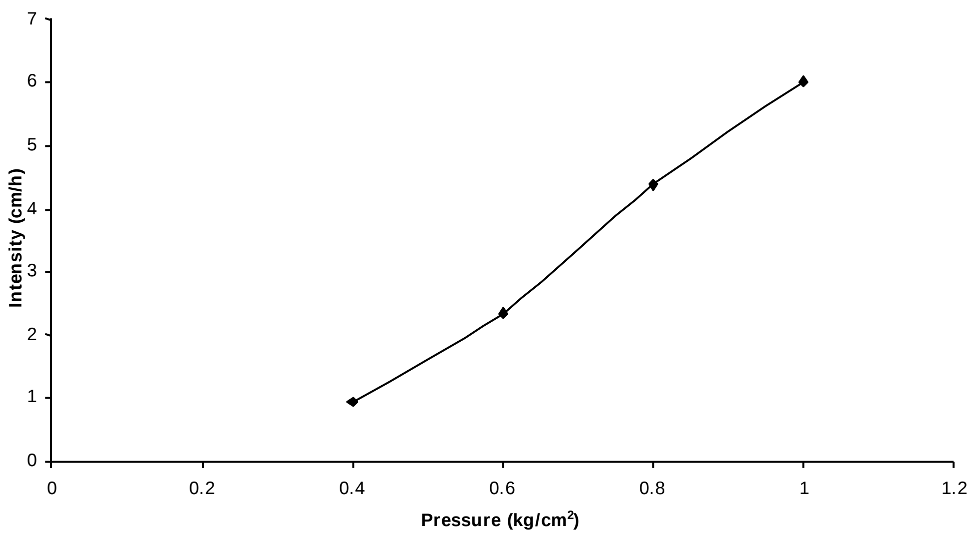

Fig. 2 Calibration curve for rainfall intensity of the simulator.

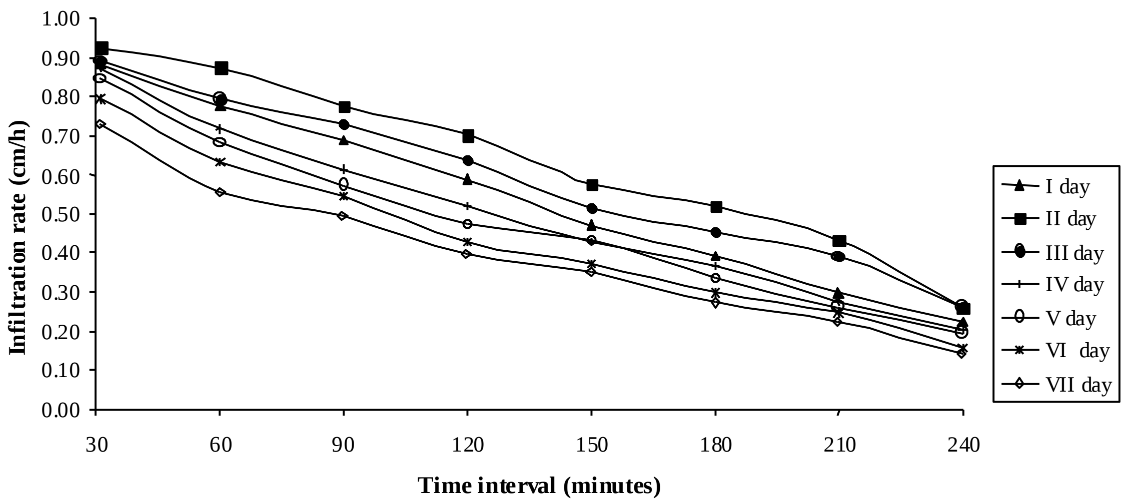

Fig.3 Infiltration rates of sandy loam soil at 30mm/h rainfall intensity without manure.

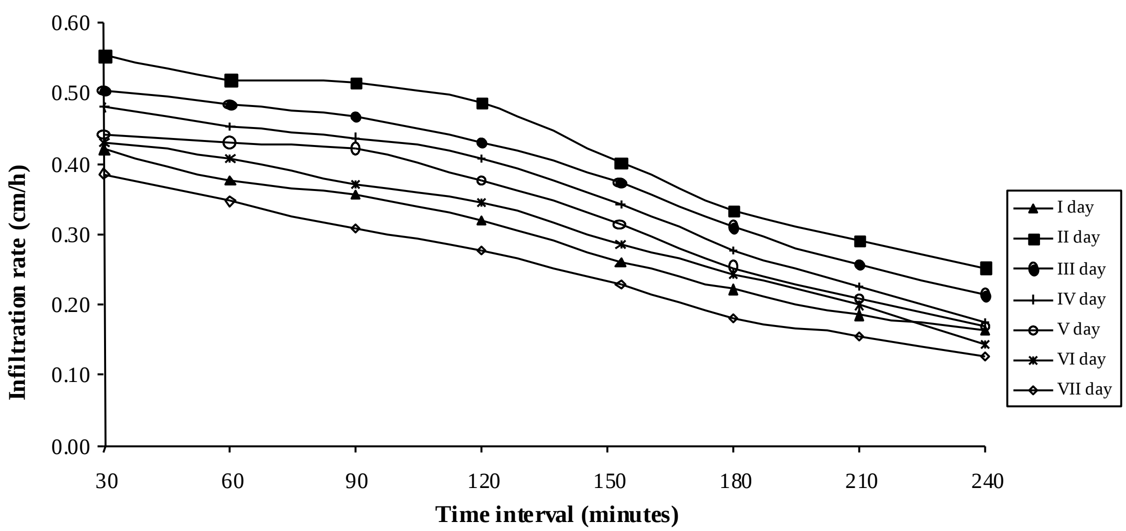

Fig.4 Infiltration rates of sandy loam soil at 30 mm/h rainfall intensity with 15 t/ha manure application rate.

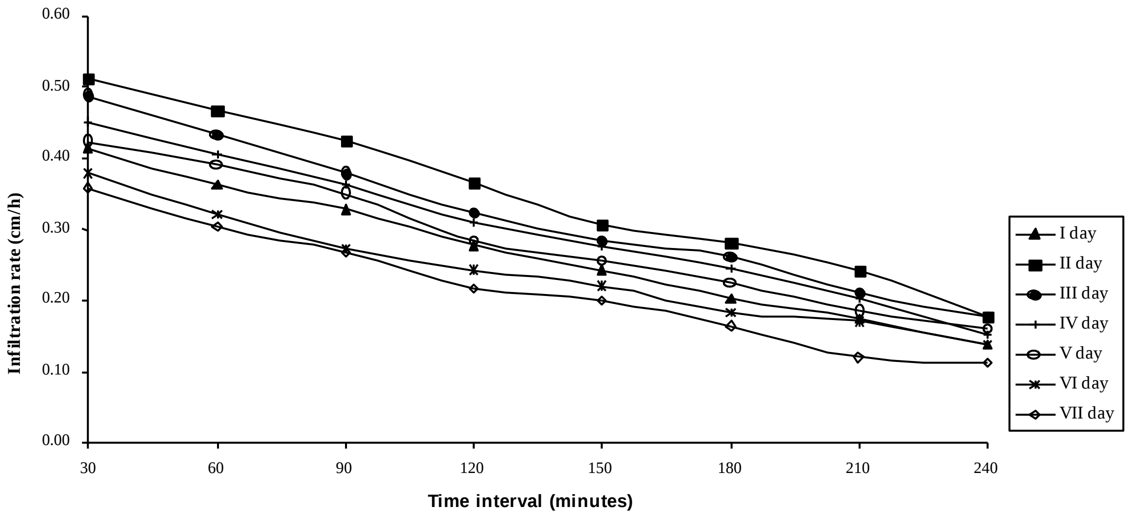

Fig.5 Infiltration rates of sandy loam soil at 30 mm/h rainfall intensity with 20 t/ha manure application rate.

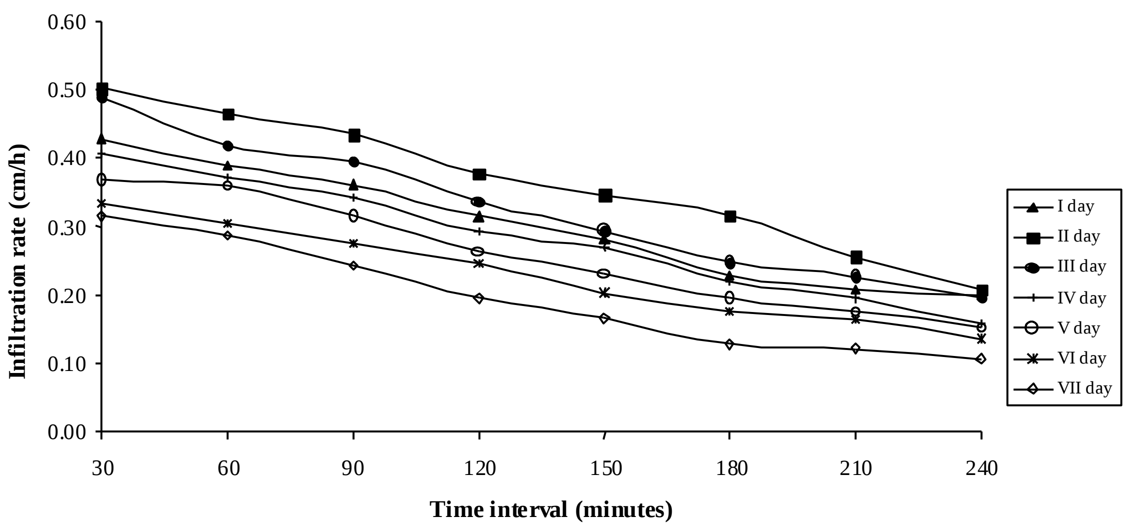

Fig.6 Infiltration rates of sandy loam soil at 30 mm/h rainfall intensity with 25 t/ha manure application rate.

The average infiltration rate for control was 0.509 cm/h, whereas the infiltration rates were 0.331, 0.283 and 0.276 cm/h respectively for M_{15}, M_{20} and M_{25} levels.

4.3.1.2 45 mm/h rainfall intensity

The results of the infiltration study at 45 mm/h rainfall intensity for the sandy loam soil are illustrated in Figures 8 to 12 and the values are given in Appendix III. The average infiltration rate for control was 0.608 cm/h. The same was 0.563 cm/h, 0.515 cm/h and 0.405 cm/h respectively for M_{15}, M_{20} and M_{25} treatments.

4.3.1.3 60 mm/h rainfall intensity

The daily infiltration values at 60 mm/h rainfall intensity are tabulated in Appendix IV and shown in Figures 13 to 17. The average infiltration rate was 1.298 cm/h for the control. The values were 0.745cm/h, 0.652 cm/h and 0.649 cm/h for M_{15}, M_{20} and M_{25} treatments respectively

From the above results it is clear that the infiltration rate decreases with time and also towards the end of seven days observation period. Therefore the obtained results agree with the Horton's model for infiltration which states that the rate of infiltration continues to decrease with time. The analysis done by Ghobar (1993) also gave similar result, that initially the water infiltrates into the soil very rapidly and once the soil became saturated the infiltration rate declined.

As stated by Barrington and Madramoottoo (1989) when organic manure is applied to the soil, there will be an organic bedding on the soil surface. This may be the reason for a decline in infiltration rate towards the end of observation period when daily average values are considered.

Also, it was found that, the infiltration rate is decreasing with the manure concentration, with the highest infiltration rate for control. Lucius and Van Slyke (1993) found that when the organic manure is applied on the soil, minor solid particles may clog the macro pores, restricting the downward flow of water and thus the infiltration rate may drop down. Hence, it can be concluded that the application of organic manure will reduce infiltration rate of coarse textured soils.

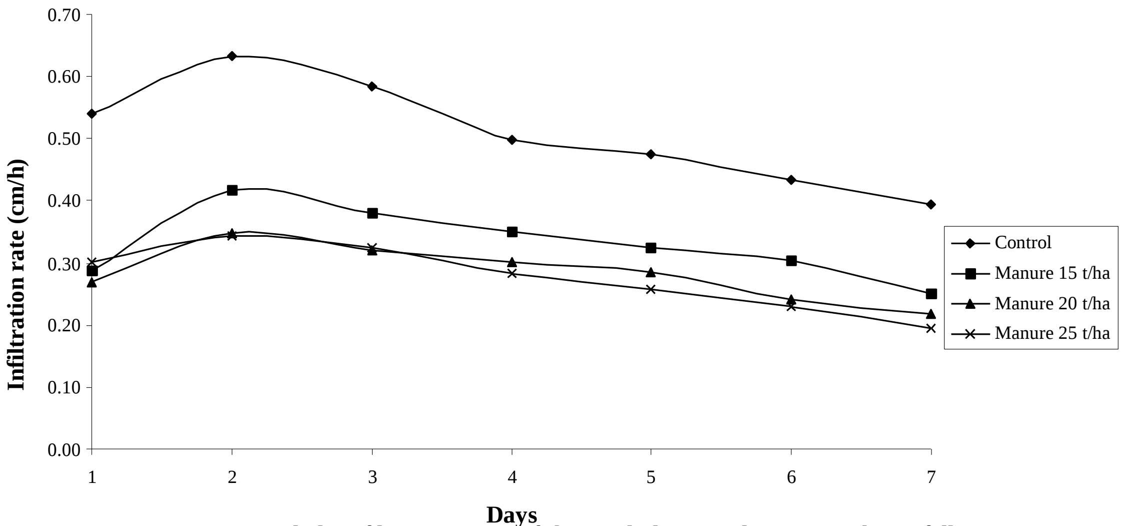

Fig.7 Average daily infiltration rates of the sandy loam soil at 30 mm/h rainfall intensity.

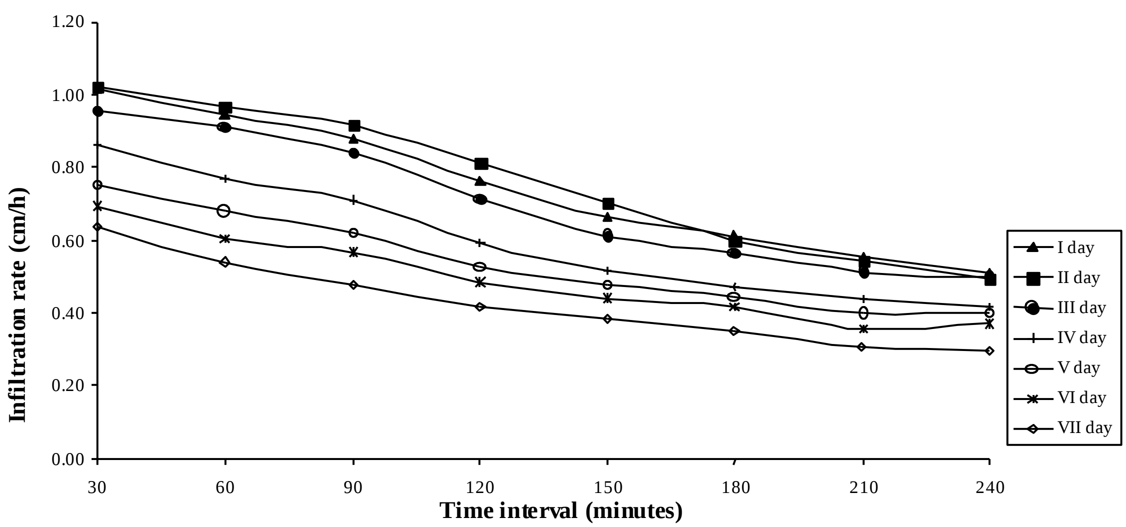

Fig.8 Infiltration rates of sandy loam soil at 45mm/h rainfall intensity without manure.

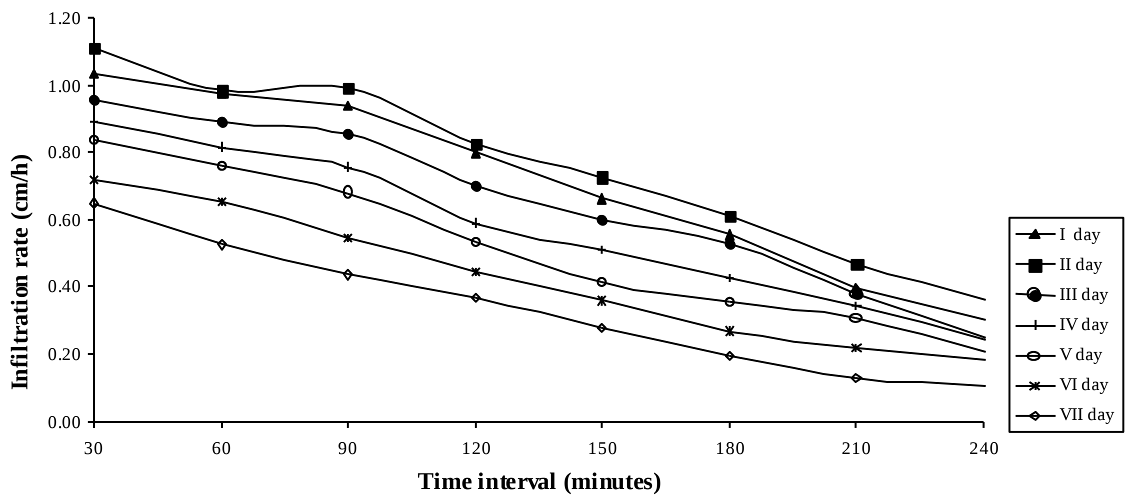

Fig.9 Infiltration rates of sandy loam soil at 45 mm/h rainfall intensity with 15 t/ha manure application rate.

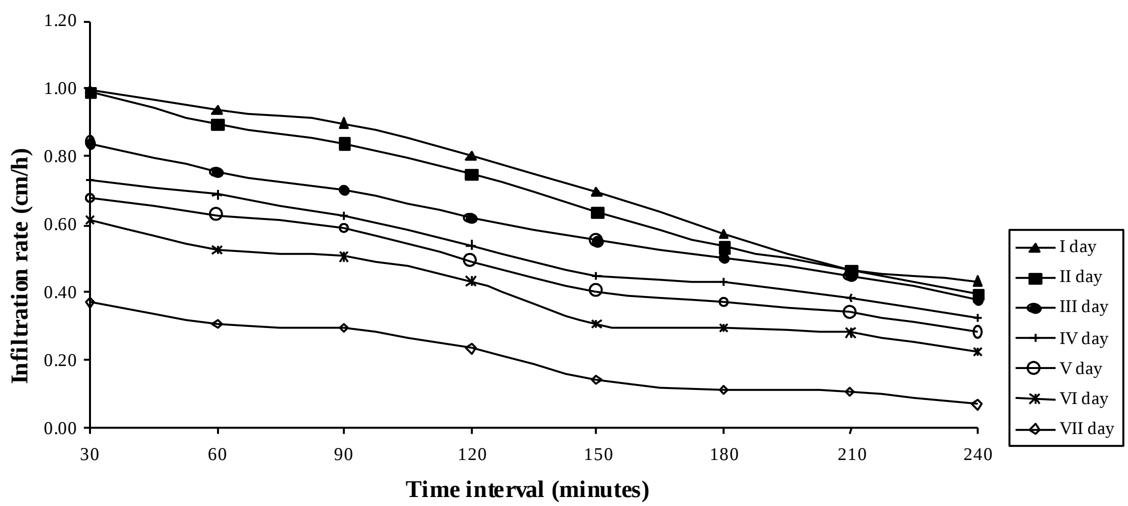

Fig.10 Infiltration rates of sandy loam soil at 45 mm/h rainfall intensity with 20 t/ha manure application rate.

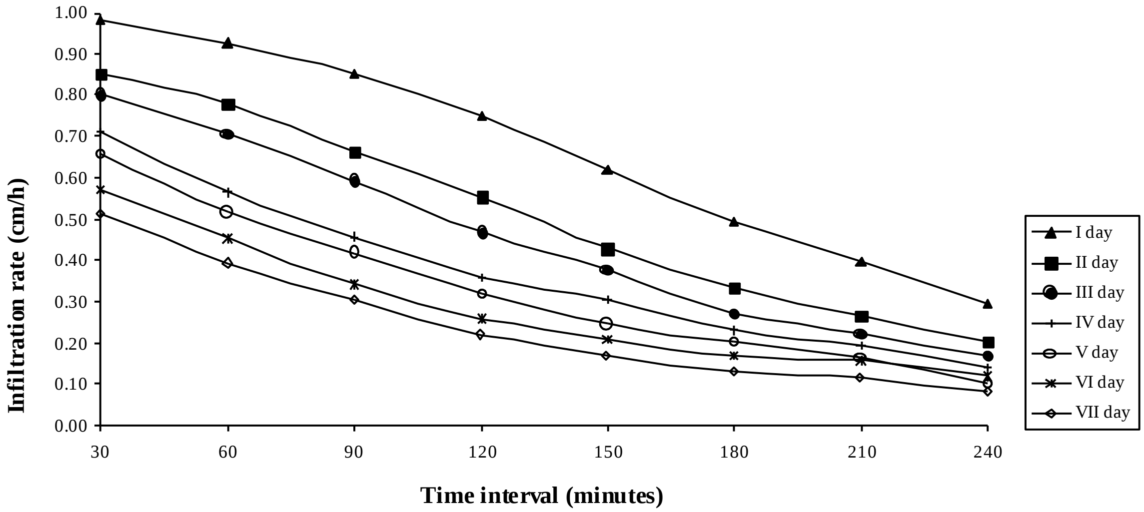

Fig.11 Infiltration rates of sandy loam soil at 45 mm/h rainfall intensity with 25 t/ha manure application rate.

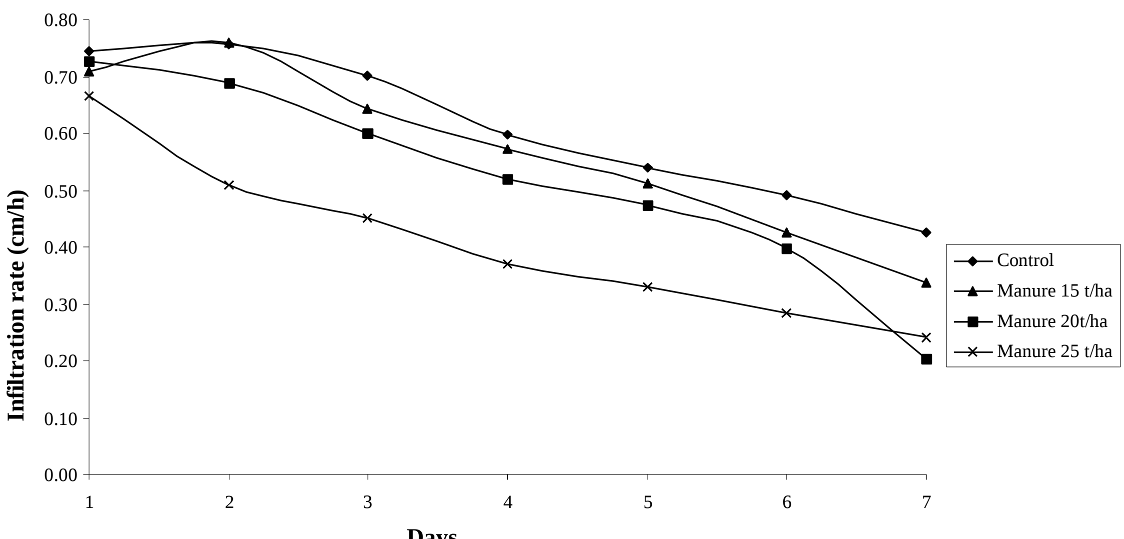

Fig.12 Average daily infiltration rates of sandy loam soil at 45 mm/h rainfall intensity.

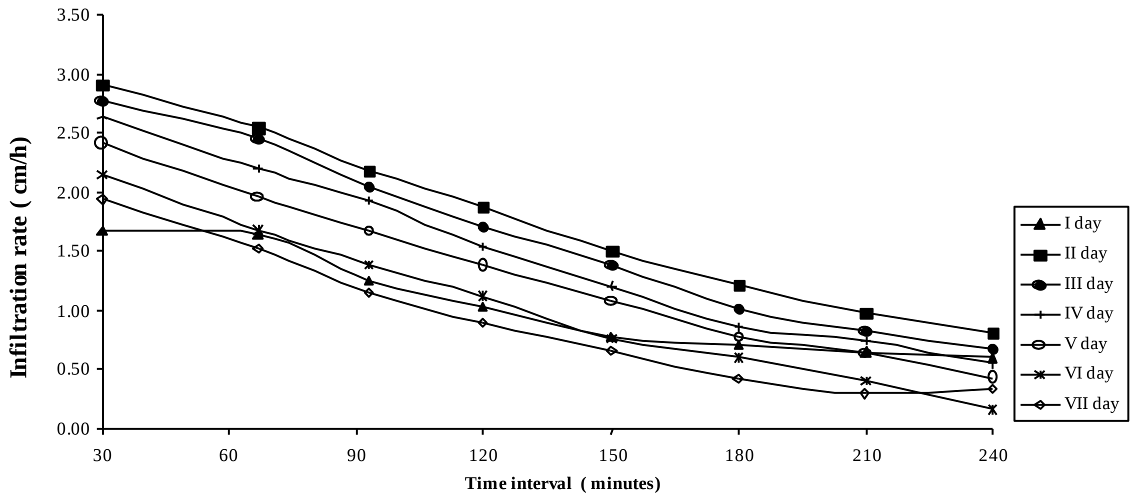

Fig.13 Infiltration rates of sandy loam soil at 60mm/h rainfall intensity without manure.

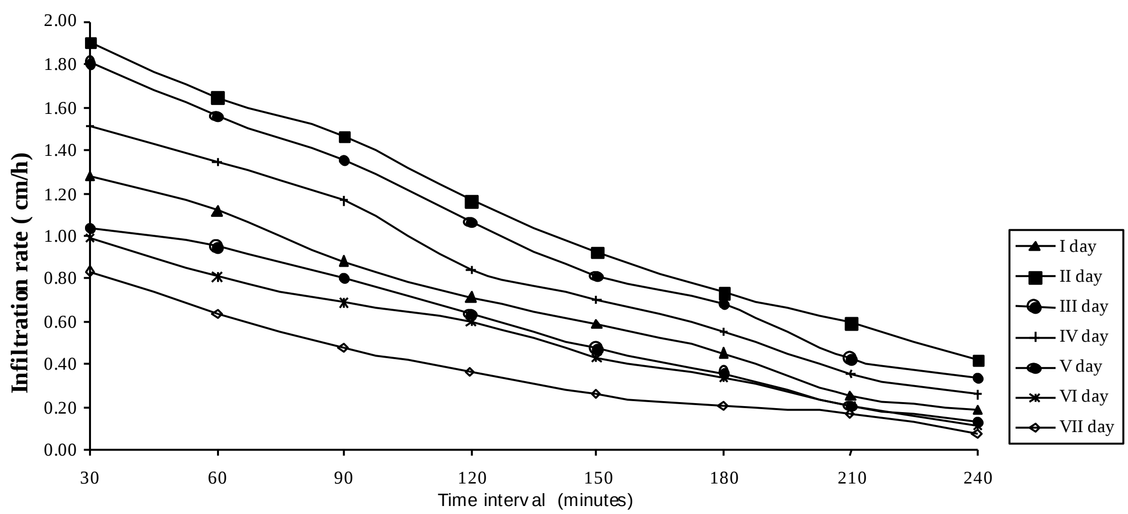

Fig.14 Infiltration rates of sandy loam soil at 60 mm/h rainfall intensity with 15 t/ha manure application rate.

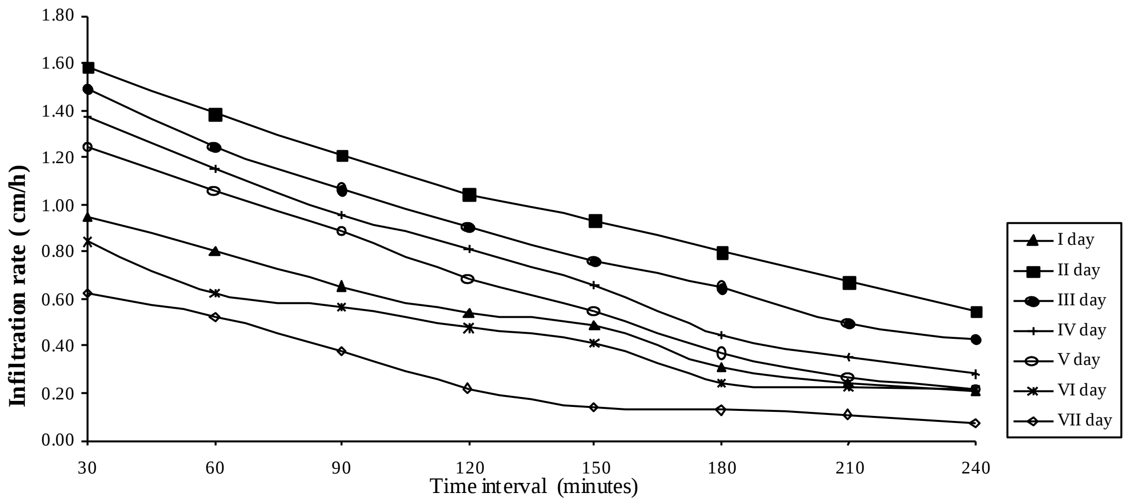

Fig.15 Infiltration rates of sandy loam soil at 60 mm/h rainfall intensity with 20 t/ha manure application rate.

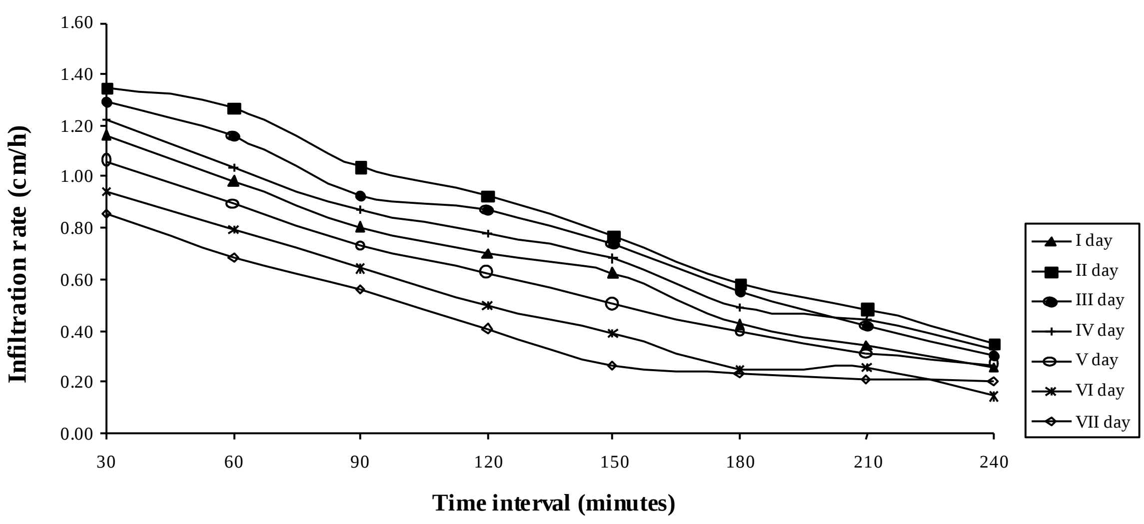

Fig.16 Infiltration rates of sandy loam soil at 60 mm/h rainfall intensity with 25 t/ha manure application rate

The functional relationship connecting the infiltration rate against rainfall and manure concentration for sandy loam soil was given by

$$IR = -1.62\times10^{-2}R + 1.49\times10^{-2}M + 6.41\times10^{-2}$$

Where,

IR = Infitration rate (cm/h)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

Statistical analysis show that when manure is considered as the dependant variable there is no significant difference in infiltration rate with varying manure concentration at 5 % significance level. When the rainfall is considered as the dependant variable it is seen that rainfall intensity significantly affects the infiltration rate. The mean infiltration rate obtained for different rainfall intensities also differ significantly from each other. The treatment interaction proved to be not significant.

4.3.2 Clay Loam Soil

The infiltration rate was low on the first day then made a sudden increase, again showed a decreasing trend in coming days. In all the cases, the daily infiltration rate converged to a common region after 150-180 minutes of observation. At all the rainfall intensities, the infiltration rate increased with manure concentration, hence the lowest level of infiltration rate was recorded for the control.

4.3.2.1 30 mm/h rainfall intensity

The infiltration rates observed for the clay loam soil at 30 mm/h rainfall intensity are given in the Tables 14 to 17 and the daily infiltration curves are shown in Figures 18 to 22. The average infiltration rate for the control was 0.008 cm/h where as that for the other manure treatment levels were 0.075, 0.132 and 0.186 cm/h respectively for M_{15}, M_{20}, M_{25} treatments.

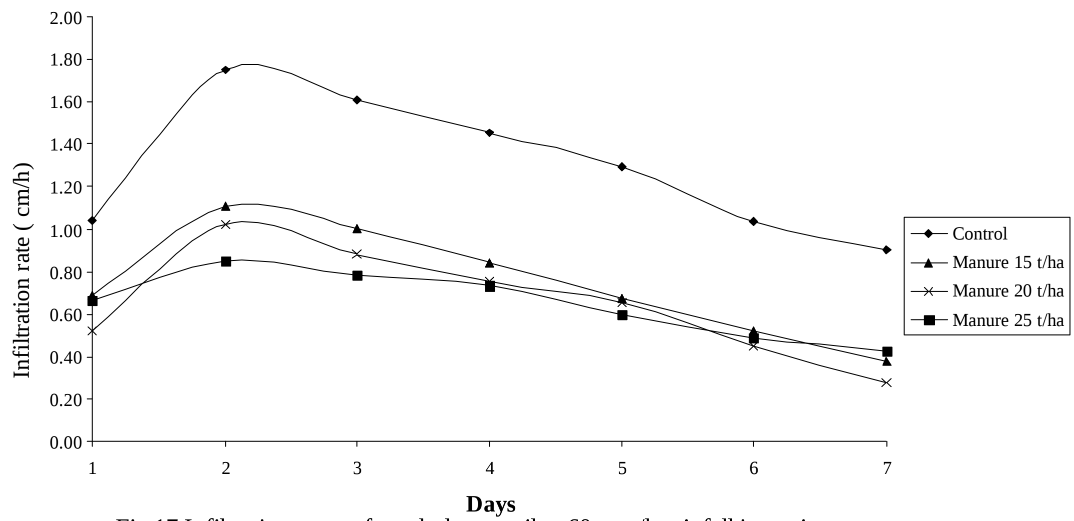

Fig.17 Infiltration rates of sandy loam soil at 60 mm/h rainfall intensity.

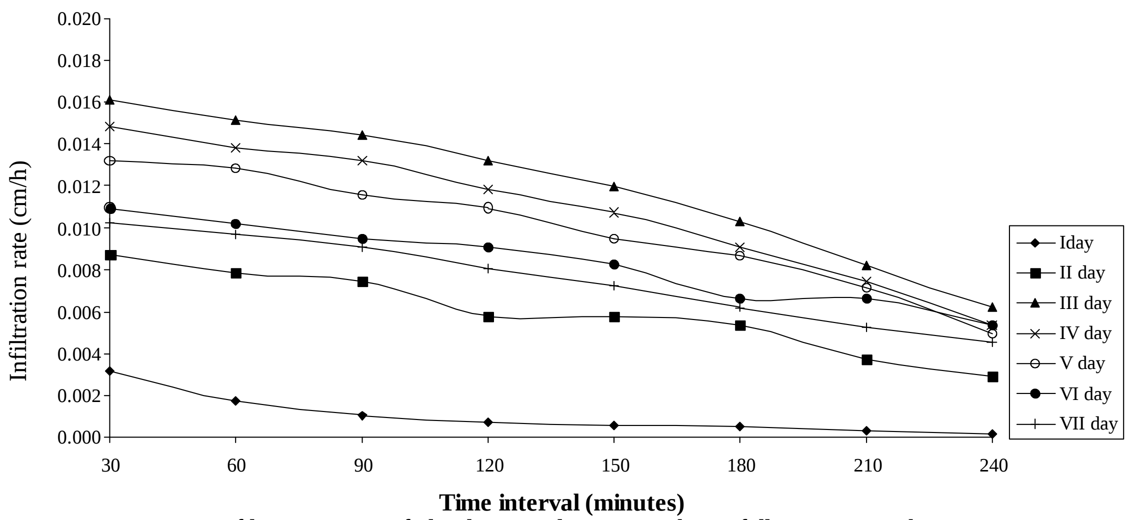

Fig.18 Infiltration rates of clay loam soil at 30 mm/h rainfall intensity without manure.

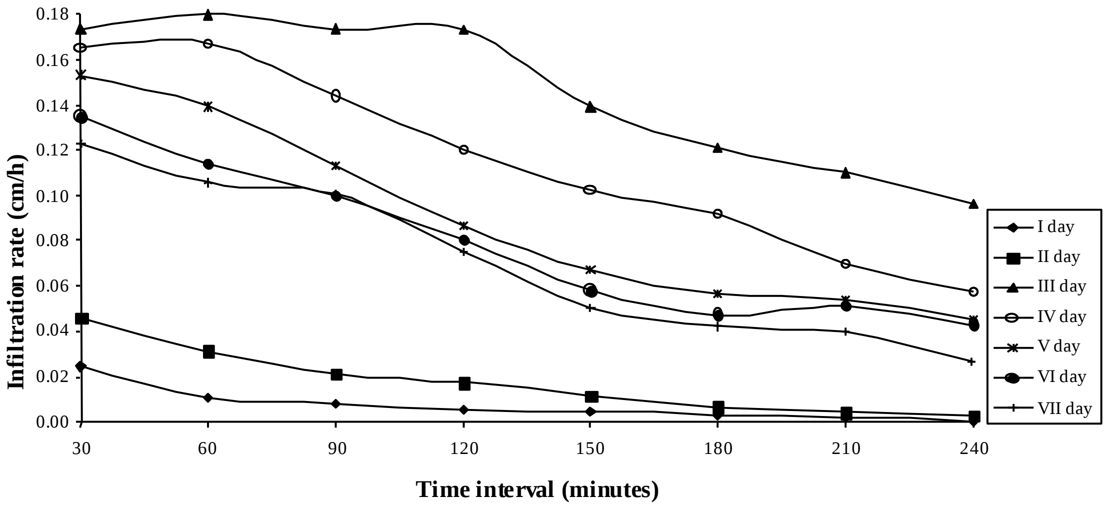

Fig.19 Infiltration rates of clay loam soil at 30 mm/h rainfall intensity with 15 t/ha manure application rate

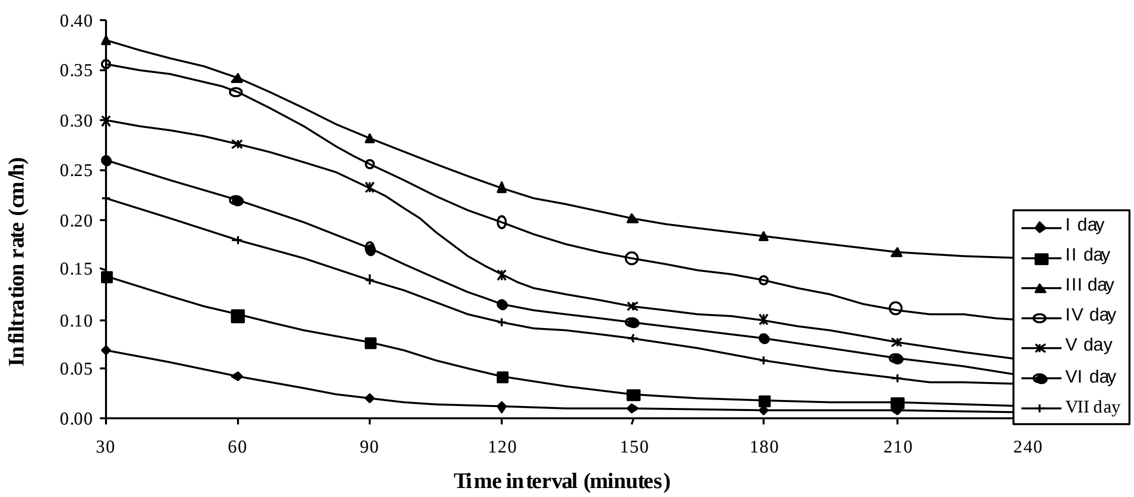

Fig.20 Infiltration rates of clay loam soil at 30 mm/h rainfall intensity with 20 t/ha manure application rate

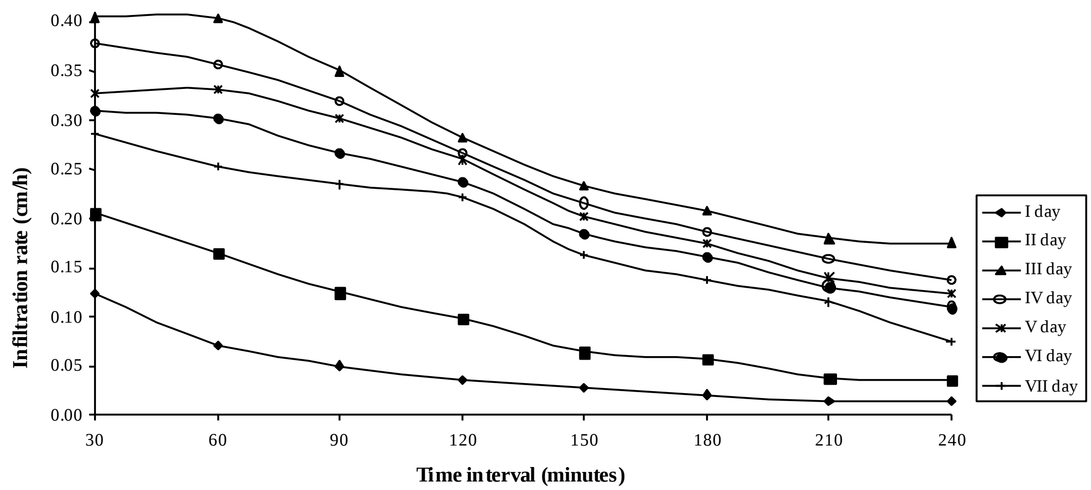

Fig.21 Infiltration rates of clay loam soil at 30 mm/h rainfall intensity with 25 t/ha manure application rate

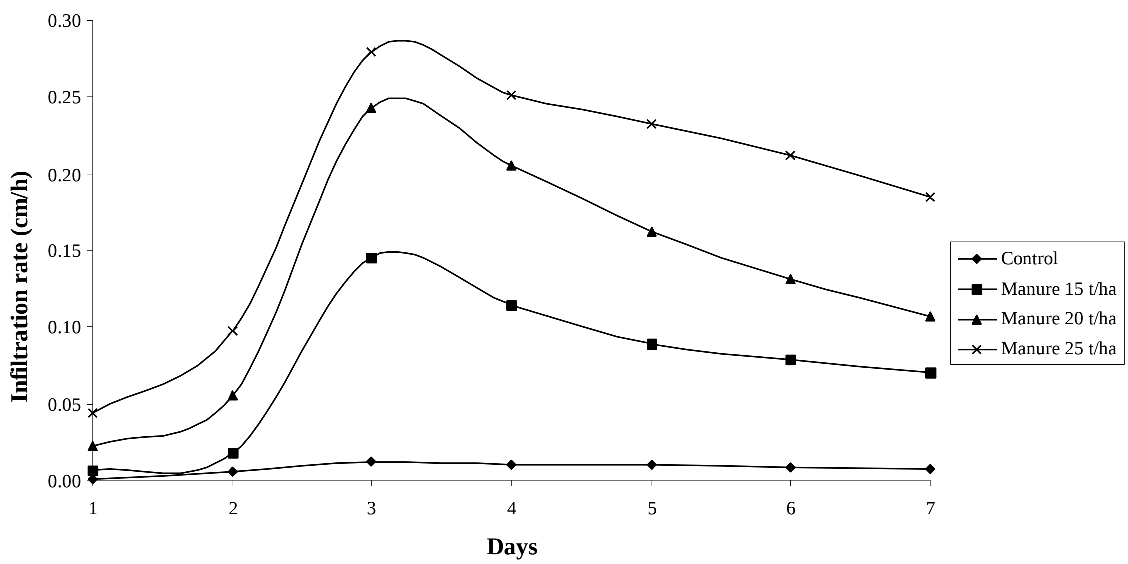

Fig.22 Average daiy infiltration rates of clay loam soil at 30 mm/h rainfall intensity

4.3.2.2 45 mm/h rainfall intensity

The average infiltration values recorded of 45 mm/h rainfall intensity are given in Appendix VI and are shown graphically in Figures 23 to 27. The average infiltration rate for control was 0.021 cm/h. The values were 0.052, 0.109 and 0.071 cm/h respectively for M_{15}, M_{20} and M_{25} treatments

4.3.2.3 60 mm/h rainfall intensity

The results of the infiltration study at 60 mm/h rainfall intensity for clay loam soil are given in Appendix VII and are graphically shown in Figures 28 to 32. The average infiltration rate was 0.036 cm/h for control condition. The other treatments recorded 0.042, 0.068, 0.125 cm/h for M_{15}, M_{20} and M_{25} treatments respectively.

For all rainfall intensities, the infiltration rate was very low during the first two days, increased upto the third day and then again decreased gradually. Since the manure is surface applied without incorporation, there will be an initial restriction to the movement of water into the soil profile. This may be the reason for the low infiltration rate during the first two days. The rainfall and the runoff will take away the large manure particles remained on the surface and also the organic matter gets decomposed. Hence there was a gradual increase in the infiltration rate on subsequent days. Ghobar (1993) had stated that at the beginning the water will infiltrate into the soil very rapidly and is totally absorbed particularly during the first run. He added that, as the soil particles on the surface become wetted, the rate of infiltration declines. A similar result was obtained from this study also. The rate of infiltration starts decreasing with time. A reduction towards the end of seven days observation period may be due to the effect of organic matter bedding on the top of the soil (Barrington and Madramoottoo, 1989). It can also be seen that the infiltration rate improves with the manure concentration level. The reason is that the organic matter level increases with the increased manure application rate. The more the organic matter gets decomposed in the soil, the more will be the influence of organic matter

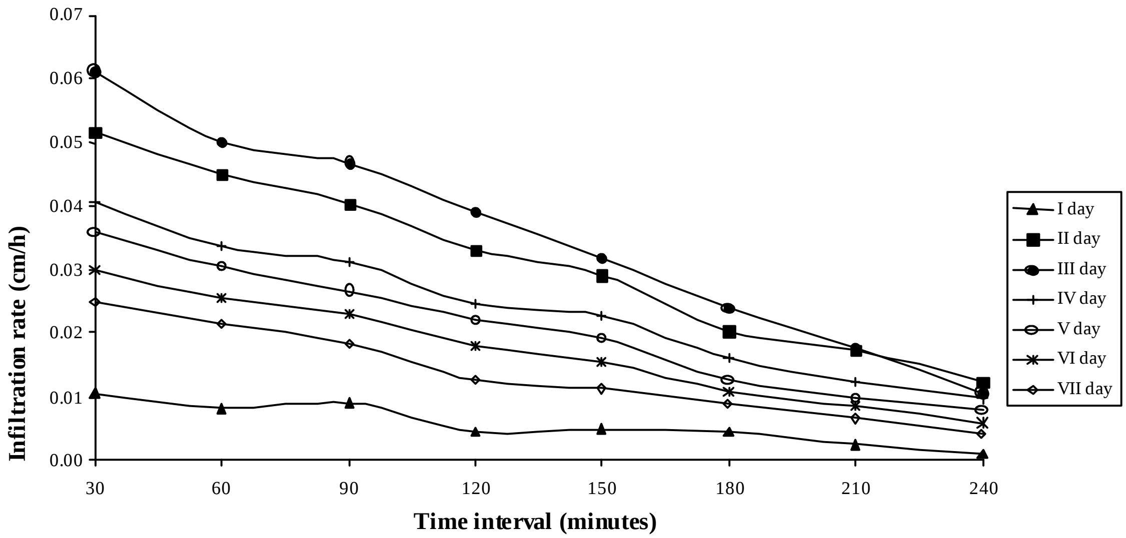

Fig.23 Infiltration rates of clay loam soil at 45 mm/h rainfall intensity without manure.

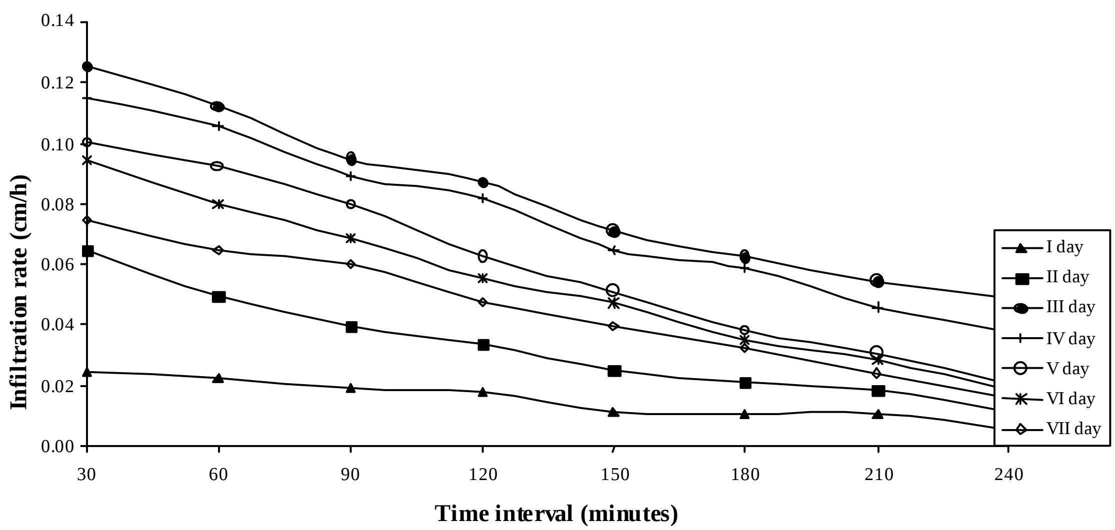

Fig.24 Infiltration rates of clay loam soil at 45 mm/h rainfall intensity with 15 t/ha manure application rate

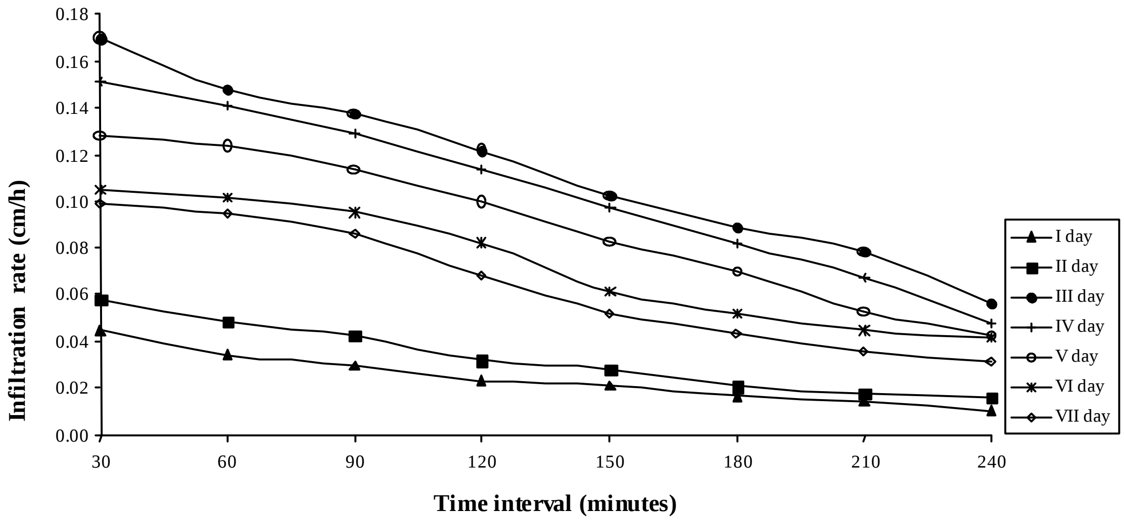

Fig.25 Infiltration rates of clay loam soil at 45 mm/h rainfall intensity with 20 t/ha manure application rate.

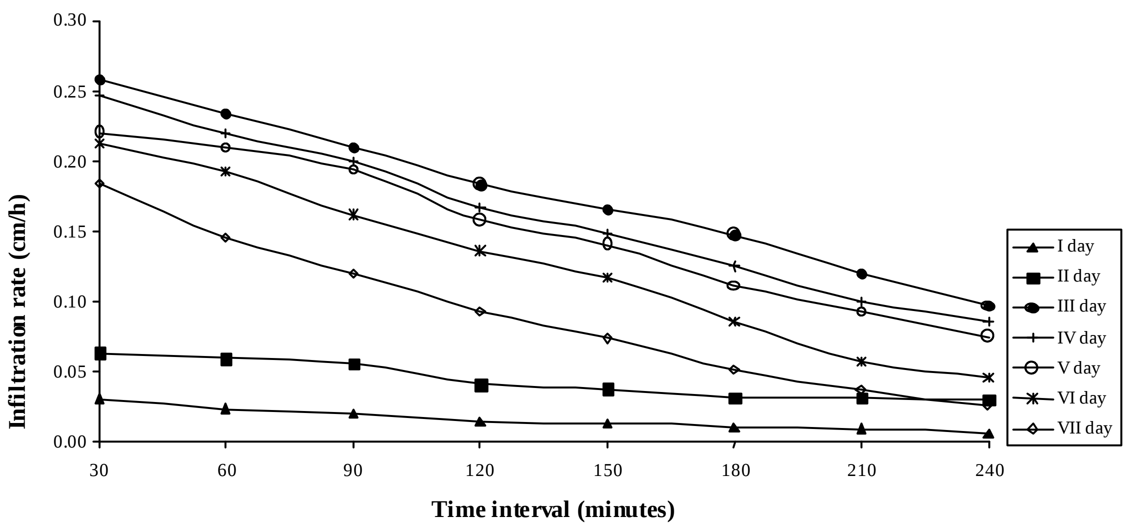

Fig.26 Infiltration rates of clay loam soil at 45 mm/h rainfall intensity with 25 t/ha manure application rate.

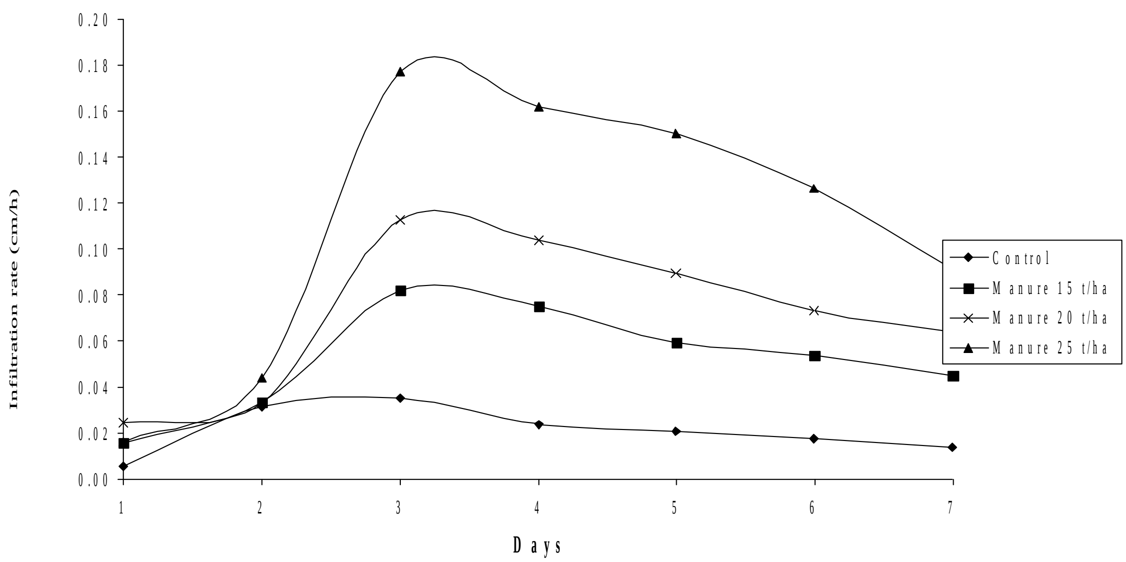

Fig.27 Infiltration rates of clay loam soil at 45 mm/h rainfall intensity.

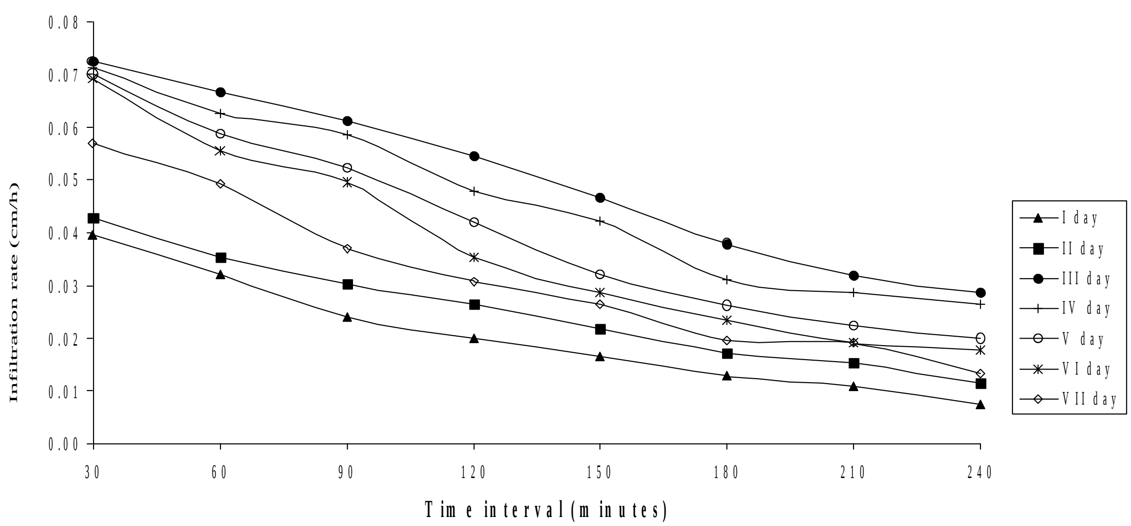

Fig.28 Infiltration rates of the clay loam soil at 60 mm/h rainfall intensity without manure.

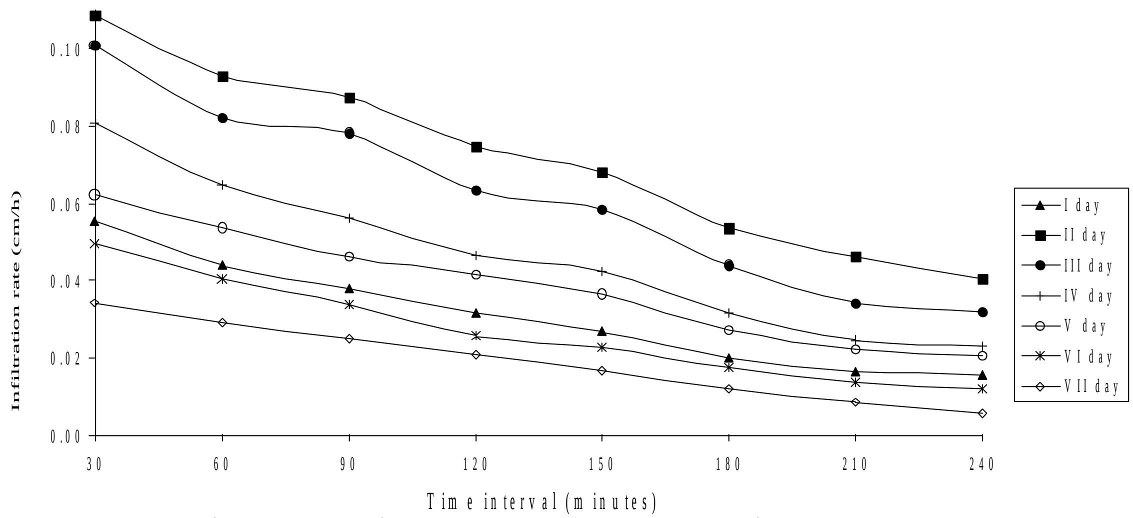

Fig.29 Infiltration rates of the clay loam soil at 60 mm/h rainfall intensity with 15 t/ha manure application rate.

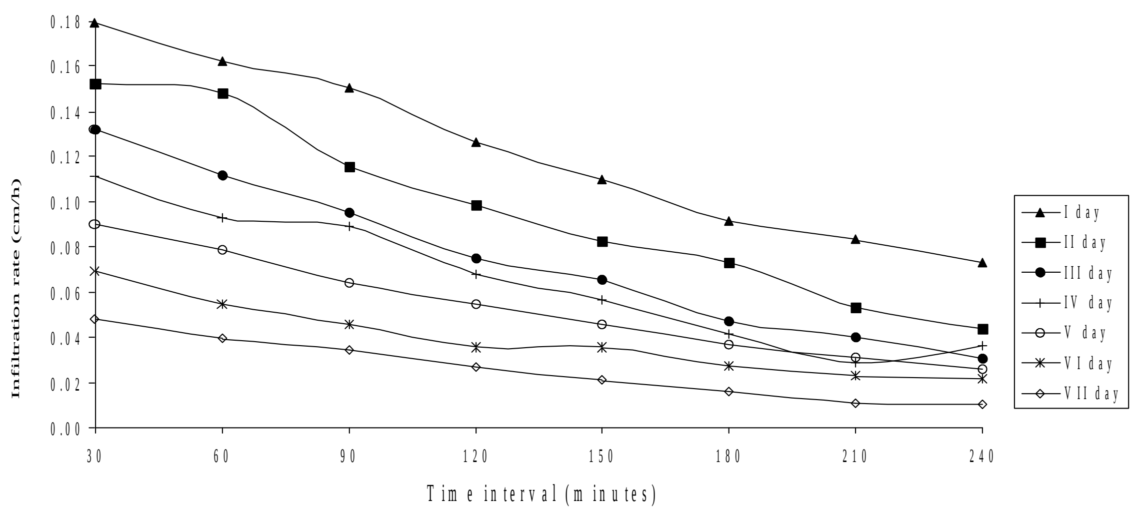

Fig.30 Infiltration rates of the clay loam soil at 60 mm/h rainfall intensity with 20 t/ha manure application rate.

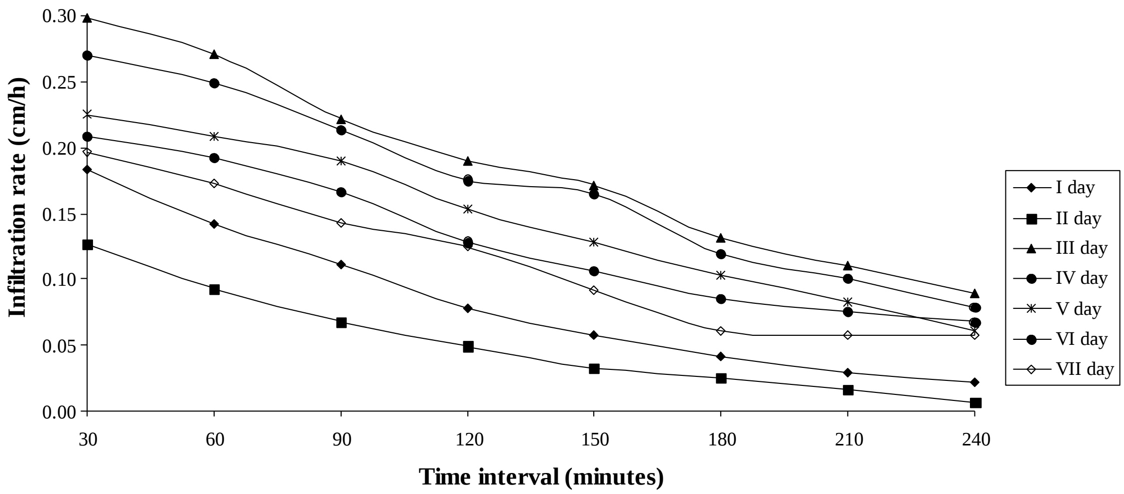

Fig.31 Infiltration rates of the clay loam soil at 60 mm/h rainfall intensity with 25 t/ha manure application rate.

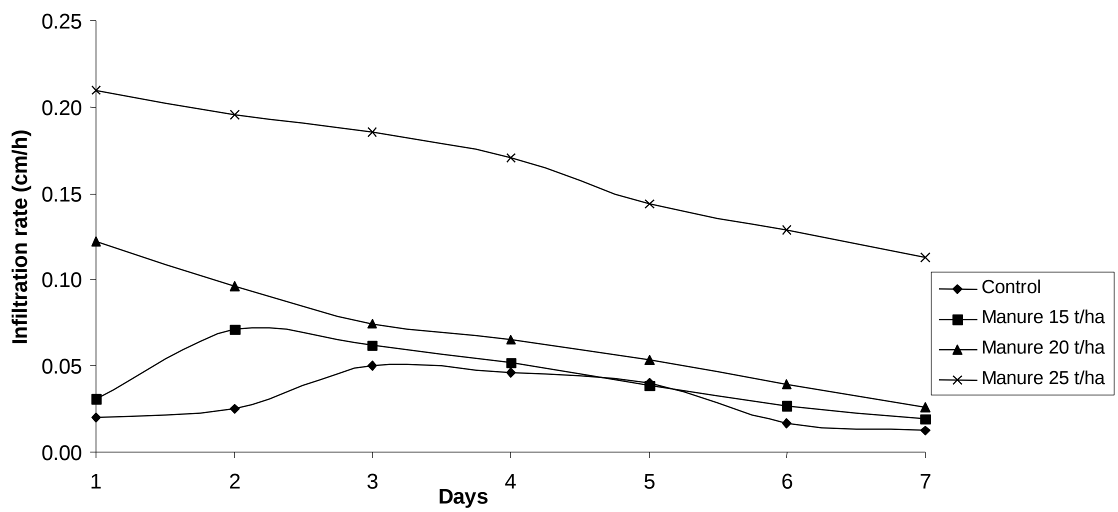

Fig.32 Average daily infiltration rate of clay loam soil at 60 mm/h rainfall intensity.

bedding. Organic matter improves the structure of the soil and the physical properties like pore space and water holding capacity (Lucius and Slyke, 1983).

A relationship between infiltration rate against rainfall intensity and manure concentration for the clay loam soil of the following form was obtained;

$$IR = -1.08 \times 10^{-3} R + 4.18 \times 10^{-3} M + 6.31 \times 10^{-2}$$

Where,

IR = Infitration rate (cm/h)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

Statistical significance of the results obtained were tested by F-Test. It was found that when manure is treated as the dependant variable it is seen that manure concentration significantly affects the infiltration rate. When rainfall is treated as the dependant variable there is no significant difference in infiltration rate with increase in the rainfall intensity. The combined effect of manure and rainfall on infiltration was tested by factorial analysis. If was found that the manure-rainfall combination have greater influence on the infiltration rate.

4.4 Runoff

The results of the analysis of runoff for various treatments are discussed in the subsequent sections.

4.4.1 Sandy Loam Soil

The analysis of runoff depth from the sandy loam soil showed that, the runoff increases with the increase in manure concentration and thus M_{25} recorded the highest runoff, followed by M_{20}, M_{15} and Control in the descending order.

Details of the depth of runoff collected at 30 mm/h rainfall intensity are given in Appendix VIII and shown in Fig. 33. The runoff depth for control was 2.09 cm. The corresponding values were 6.49, 7.83, 8.31 cm for M_{15}, M_{20} and M_{25} respectively.

The runoff depth collected at 45 mm/h rainfall intensity are shown in Fig. 34 and the values are given in Appendix IX. The runoff depth for control was11.35 cm. The corresponding values were 12.57, 13.87, 16.99 cm for M_{15}, M_{20} and M_{25} respectively.

The runoff depth collected at 60 mm/h rainfall intensity are given in Appendix X and shown in Fig. 35. The runoff volume for control was 36.26 cm. The corresponding values were 45.34, 54.93 and 63.62 cm for M_{15}, M_{20} and M_{25} respectively .

From these results, it is clear that as the manure concentration increases, the amount of water infiltrating down will decrease and this in turn will increase runoff loss. This was primarily due to the blocking of the large sized pores by the minor solid particles contained in the organic manure (Robberts and Clanton, 1992). Since the sandy soils have less number of micro pores, there is only a less chance for the water to move downward since the macro pores will get blocked by the manure particles (Barrington and Madramootoo,1989). This effect is more pronounced at higher intensities of manure application rates. But the difference of runoff volume among the different levels of manure treatments is becoming lesser at higher intensities of rainfall.

The relationship of runoff depth against rainfall intensity and manure concentration is given by;

$$R = 2.09 \times 10^{-1} R + 7.17 \times 10^{-2} M - 7.14$$

Where,

RO = Runoff depth (cm)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

From the statistical analysis of the results it was found that when manure is treated as the dependant variable there is no significant difference in runoff volume with the manure concentration. When the rainfall is treated as the dependant variable it was found that rainfall intensity significantly affects the runoff volume at 5% significance level. The mean runoff volume at different rainfall intensities also differ significantly. The factorial analysis showed that the different treatment combination have a significant influence upon the runoff volume.

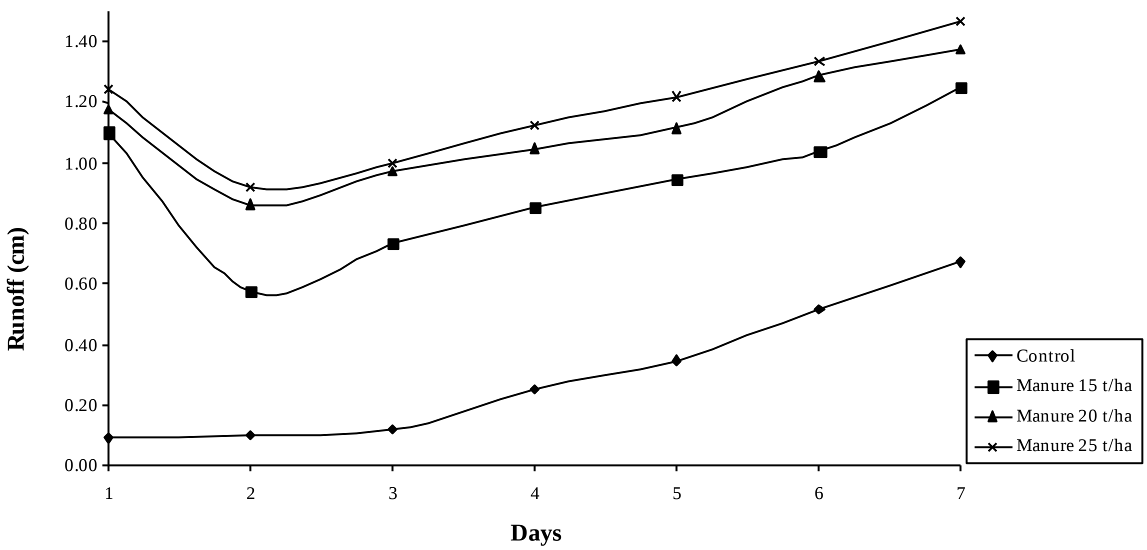

Fig.33 Runoff depth from sandy loam soil at 30 mm/h rainfall intensity

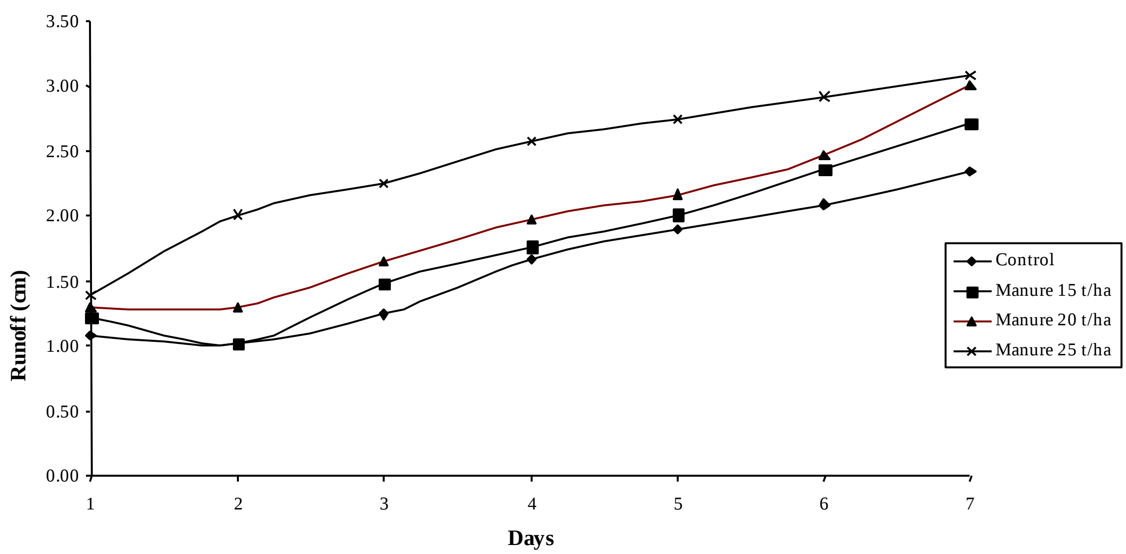

Fig.34 Runoff depth from sandy loam soil at 45 mm/h rainfall intensity

4.4.2 Clay Loam Soil

Among all the treatments the control recorded the highest level of runoff followed by M_{15}, M_{20} and M_{25} in the descending order.

Details of the runoff depth collected at 30 mm/h rainfall intensity are shown in Fig.36 and the corresponding values are given in Appendix VIII. The runoff volume for control was10.64 cm. The corresponding values were 8.41, 6.80, and 5.30 cm for M_{15}, M_{20} and M_{25} respectively.

The runoff volume depth at 45 mm/h rainfall intensity are given in Appendix IX and shown in Fig. 37. The runoff volume for the control was 26.34 cm. The corresponding values were 25.45, 24.82 and 23.85 cm for M_{15}, M_{20} and M_{25} respectively.

The runoff depth collected at 60 mm/h rainfall intensity are given in and shown in Fig. 38 and Appendix X. The runoff volume for the control was 44.58cm. The corresponding values were 44.27, 43.58 and 42.75 cm for M_{15}, M_{20} and M_{25} respectively.

The above results leads to the inference that the loss of water as runoff decreases with the increase of manure level. From the infiltration data, it was observed that the infiltration rate and hence the infiltration volume increase with increase in the manure levels. The organic bedding formed as a result of manure application increases the water holding capacity of the soil by improving its properties like micro pore spaces, structure etc. Also the manure particles shows a high affinity to water particles, and hence will retain more water than the control (Lucius and Slyke 1983).

The relationship of runoff depth against rainfall intensity and manure concentration was obtained in following form;

$$R = 1.72 \times 10^{-1} R - 1.75 \times 10^{-2} M - 3.80$$

Where,

RO = Runoff depth (cm)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

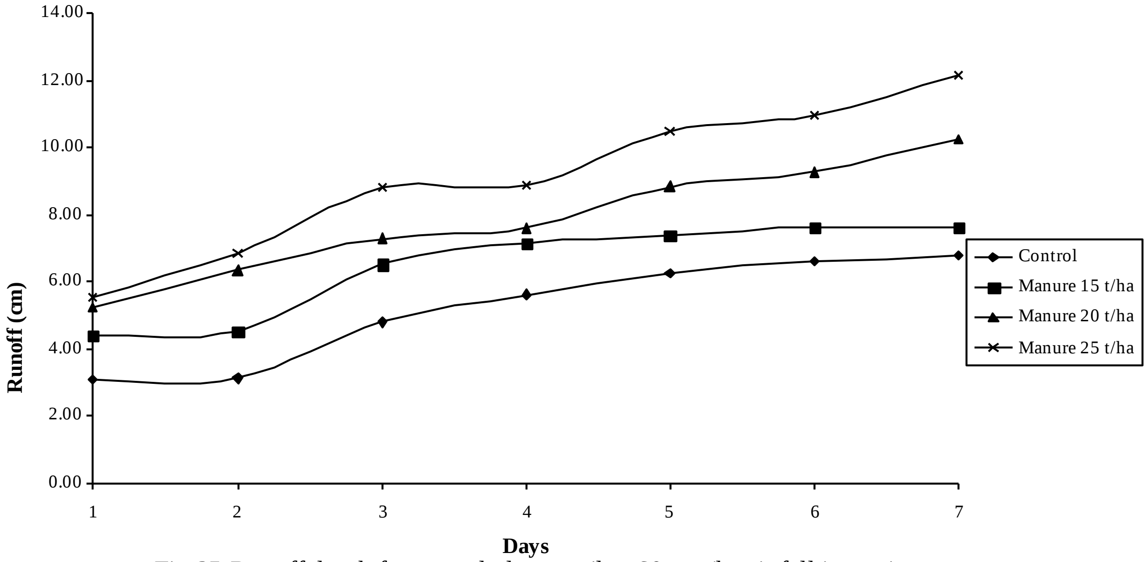

Fig.35 Runoff depth from sandy loam soil at 60 mm/h rainfall intensity

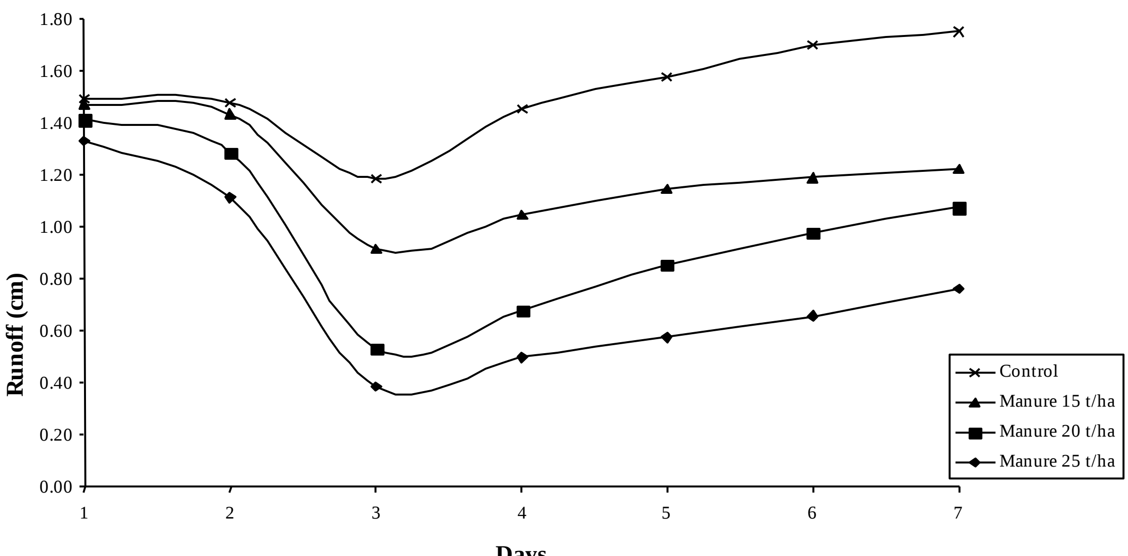

Fig.36 Runoff depth from clay loam soil at 30 mm/h rainfall intensity

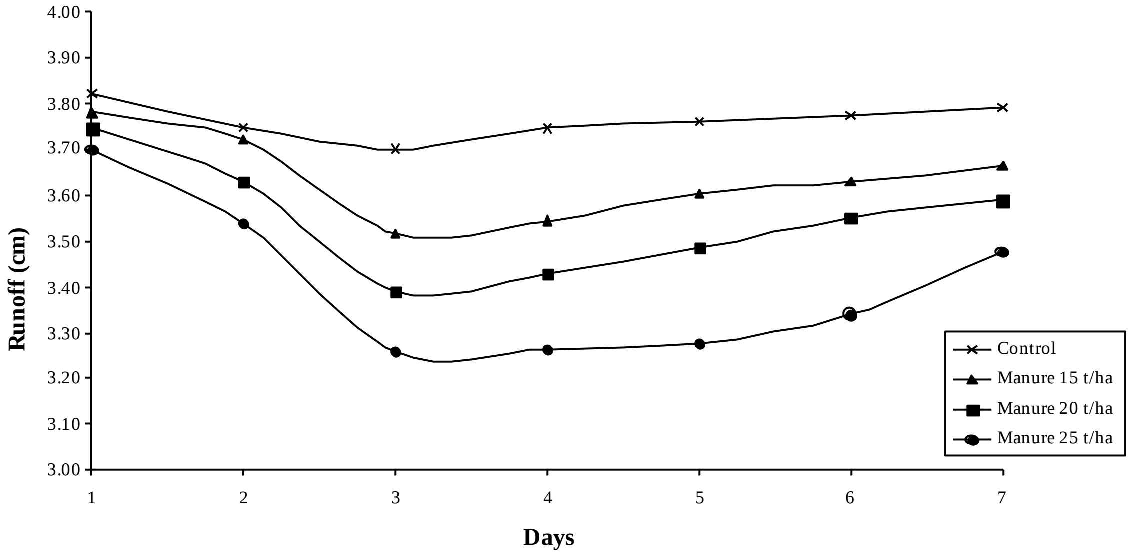

Fig.37 Runoff depth from clay loam soil at 45 mm/h rainfall intensity

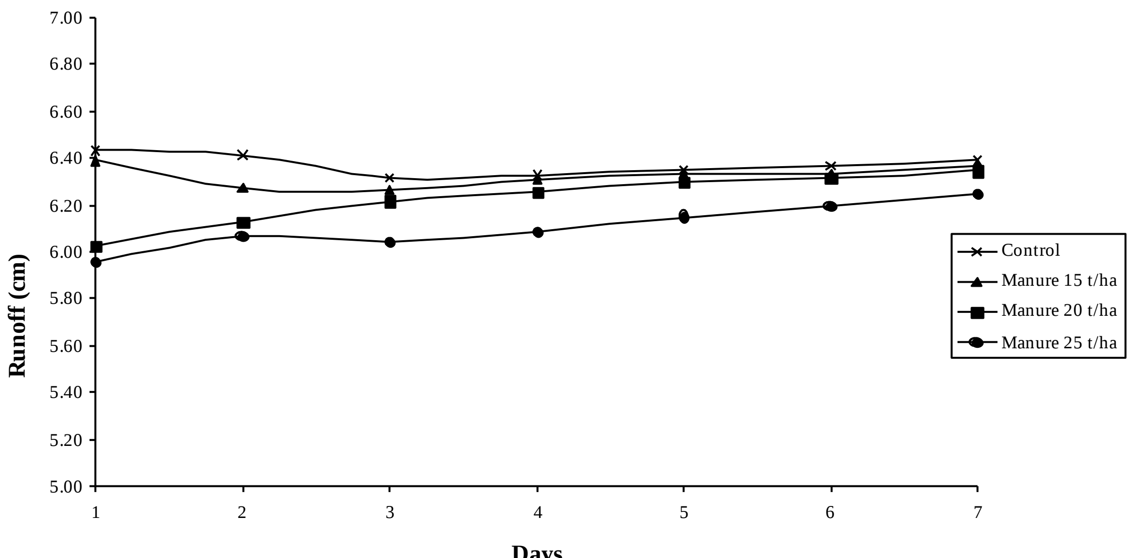

Fig.38 Runoff depth from clay loam soil at 60 mm/h rainfall intensity

The statistical significance of the results were tested by F-Test. It was seen that when manure is treated as the dependant variable there is no significant difference in runoff volume with increase in the manure concentration. When the rainfall is treated as the dependant variable it was seen that rainfall intensity significantly affects the runoff volume. It was also observed that the runoff volume obtained for all the three rainfall intensities differ from each other significantly. The factorial analysis showed that, the combination of manure and rainfall treatments together have very much influence on the runoff volume

4.5 Total Solids

The runoff samples were analysed for the total solid content and the results are discussed below.

4.5.1 Sandy Loam Soil

The following results were obtained when the runoff water from the sandy loam soil was analysed for total solid content.

Appendix XI shows the percentage of total solids at 30 mm/h rainfall intensity and the same results are illustrated in Fig. 39. The percentage of total solids were 0.213, 0.283, 0.279 and 0.444 percent respectively for the control, M_{15}, M_{20} and M_{25} treatments respectively.

The results at 45 mm/h rainfall intensity are given in Appendix XII and in Fig.40. The percentage of total solids was 0.295 % at the control. The values for other treatments were 0.311, 0.318 and 0.469 percent for M_{15}, M_{20} and M_{25} respectively.

The percentage of total solid at 60 mm/h rainfall intensity are given in Appendix XIII and in Fig. 41. At 60 mm/h rainfall intensity the percentage of total solids at the control was 0.325 %, and the values were 0.368, 0.399 and 0.497 percent at M_{15}, M_{20} and M_{25} respectively.

When the total solid percentage in the runoff water from sandy loam soil were analysed, they gave similar results as that of other parameters. The percentage of total solids increases with the increase of manure concentration and with rainfall intensity. The seven days of observation period gave, almost a constant value, with few exceptions.

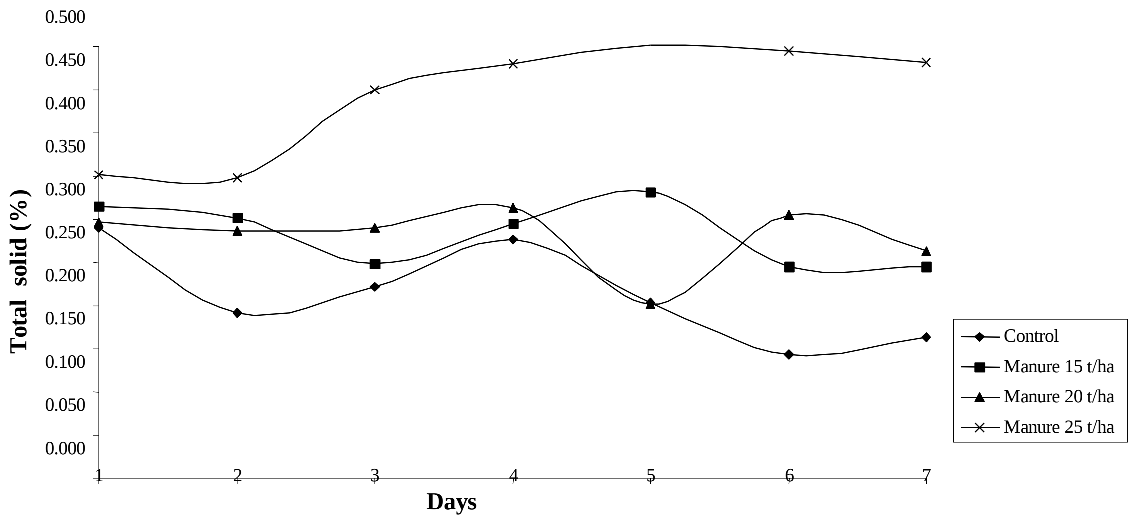

Fig.39 Percentage of total solids in the runoff water from sandy loam soil at 30 mm/h rainfall intensity.

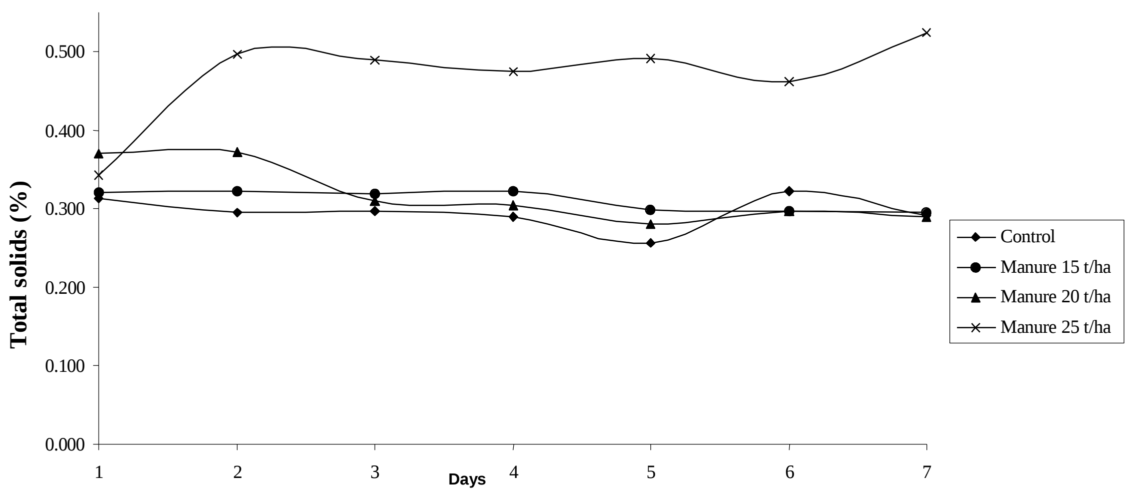

Fig.40 Percentage of total solids in the runoff water from sandy loam soil at 45 mm/h rainfall intensity.

The average values of individual treatments gave a clearer trend i.e., the total solid percentage is highest for the M_{25} treatment and the value decreased in the order M_{20}, M_{15} and the control.

Since the manure is applied in the dried and powdered form, it contains a lot of minor solid particles. The content of minor particles will increase with the level of application of manure on the soil. Hence the total solid percentage in the manure increases with the level of manure concentration. Khaleel *et al.* (1980) reported that runoff loss of solid is influenced by the rate and method of manure application.

A high intensity rainfall will have a higher erosive power. Hence the runoff will carry more suspended matter, which resulted in the increase in solid percentage with the increase in rainfall intensity. This agrees with the findings of Bolton *et. al.* (1991), that is total suspended sediment increases with runoff concentration.

The general equation developed for the total solid percentage for sandy loam soil against rainfall intensity and manure concentration is;

$$S = 3.08 \times 10^{-3} R + 6.27 \times 10^{-3} M + 1.18 \times 10^{-2}$$

Where,

S = Total solids (%)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

The statistical significance of the results were tested by F-Test. It was found that when rainfall is treated as the dependant variable there is no significant difference in the total solid percentage with change in rainfall intensity . When manure is treated as the dependant variable, it was found that manure concentration significantly affects the total solids percentage. The percentage of total solids in the runoff water at all the manure concentrations differ significantly, except that between M_{15} and M_{20} treatments. The factorial analysis showed that manure and rainfall together have no influence on the total solid content.

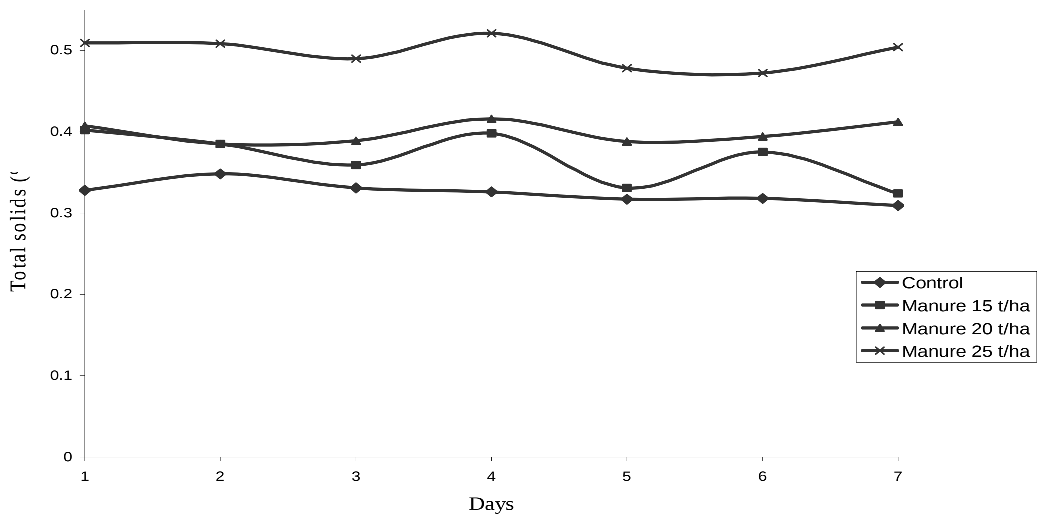

Fig.41 Percentage of total solids in the runoff water from sandy loam soil at 60 mm/h rainfall intensity.

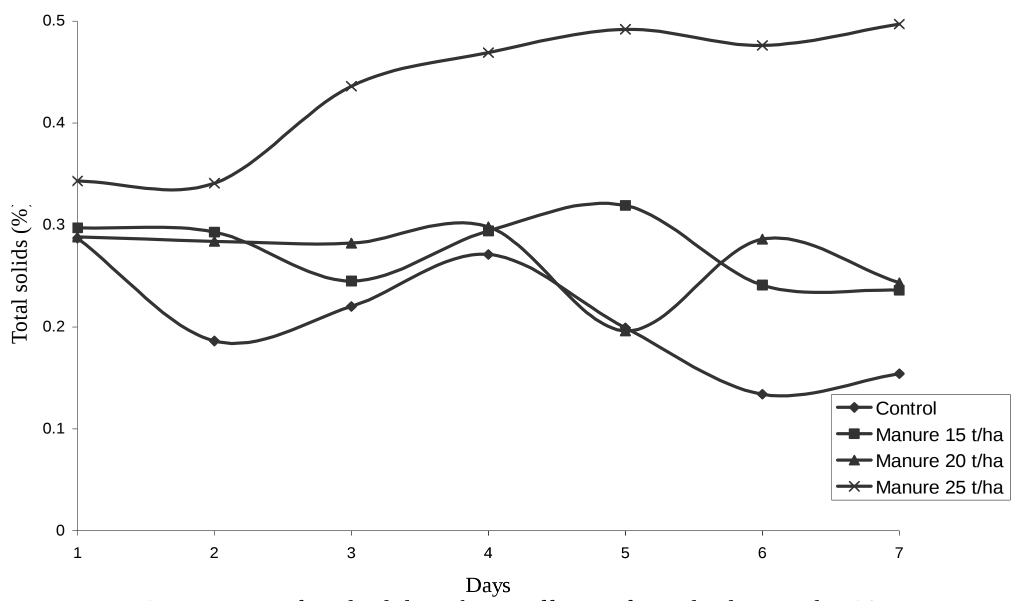

Fig. 42 Percentage of total solids in the runoff water from clay loam soil at 30 mm/h rainfall intensity.

4.5.2 Clay Loam Soil

The percentage of total solids content in the runoff water from the clay loam soil at various manure concentration and rainfall intensities are given below.

Fig.42 gives the total solid content at 30 mm/h rainfall intensity and values are given in Appendix XI. At 30 mm/h rainfall intensity the solids percentage for the control M_{15}, M_{20} and M_{25} treatments were 0.207, 0.275, 0.268 and 0.436 percent respectively.

The results of the analysis at 45 mm/h rainfall intensity are given in Appendix XII and are shown in Fig. 43. The total solids percentage for the control treatment was 0.289% and it was 0.300, 0.312 and 0.454 percent respectively for M_{15}, M_{20} and M_{25} treatments.

The total percentage of solids obtained at 60mm/h rainfall intensity are given in Appendix XIII and are shown graphically in Fig.44. The values were 0.320 % for the control and 0.358, 0.390 and 0.486 percent for M_{15}, M_{20} and M_{25} respectively.

Bolton *et al*. (1991) reported that the sediment loss is proportional to the rainfall intensity and Khaleel *et al*. (1980) reported that runoff loss of solids is influneced by the rate and method of manure application. In this study also similar results were obtained. The total solid percentage contained in the runoff water from clay loam soil has also shown a trend similar to the earlier findings. There was a clear increase in the percentage of solids with the increase in manure concentration and of rainfall intensity. The shift from control to M_{15} treatment was very clear at all the rainfall intensities. But the values not varied much between M_{15} and M_{20} treatments.

As the manure concentration increases the loose solid –manure- particles on the surface of the soil also increases and which can be easily eroded away by the rainfall. Hence there was an increase in solids content with the increase of manure concentration. When the manure concentrations are low, they will be incorporated to the soil surface almost completely and hence there is less chance for getting eroded.

As the intensity of rainfall increases, the velocity of runoff also increases, which in turn will increase the suspended load that can be carried away with the runoff water. So there was a corresponding increase in solids concentration with the rainfall intensity.

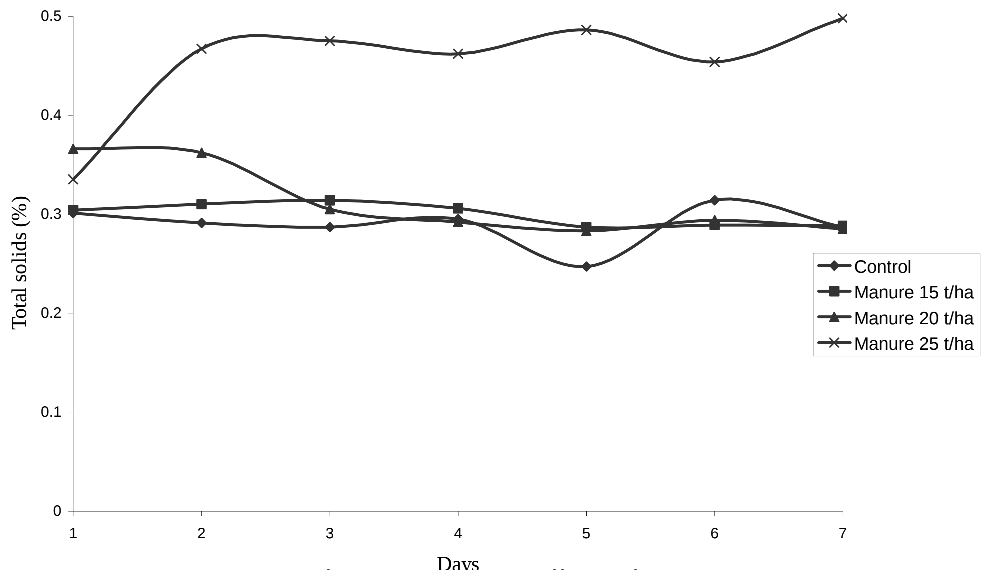

Fig. 43 Percentage of total solids in the runoff water from clay loam soil at 45 mm/h rainfall intensity.

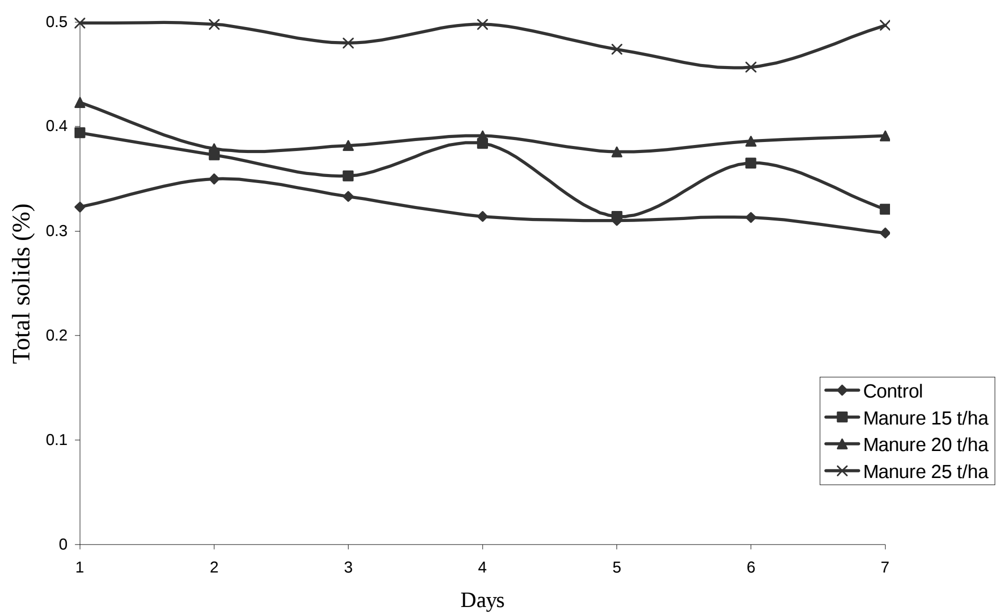

Fig.44 Percentage of total solids in the runoff water from clay loamsoil at 60 mm/h rainfall intensity.

The general equation developed for the total solid percentage for the clay loam soil against the rainfall intensity and manure concentration is of the form;

$$S=3.07 \times 10^{-3} R + 6.07 \times 10^{-3} M + 1.1 \times 10^{-2}$$

Where,

S = Total solids (%)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

The statistical significance of the results were tested by F-Test. It was found that when rainfall is treated as the dependant variable there is no significant difference in total solids percentage with change in the rainfall intensity. When the manure is treated as the dependant variable it was found that manure concentration significantly affects the percentage of total solids. When the amount of total solids obtained at different levels of manure concentrations were analysed, it was found that all the values differ significantly from each other except for the combination M_{20}-M_{15} and M_C-M_{15} . The manure concentration and rainfall together have no significant influence on the percentage of total solids

4.6 Organic Matter

The runoff water is analysed for total organic matter content and the results are given below.

4.6.1 Sandy Loam Soil

The results of the analysis for sandy loam soil at 30 mm/h rainfall intensity are given in Appendix XIV and are shown in Fig. 45. The average percentage of organic matter was 0.0108 at the control while that for M_{15}, M_{20} and M_{25} were 0.2229, 0.0325, 0.0395 % respectively.

The result of organic matter analysis at 45 mm/h rainfall intensity are as given in Appendix XV and are shown in Fig.46. At the control the percentage of organic matter was 0.0073. and the same value was 0.0200, 0.0288 and 0.0302 % respectively for M_{15}, M_{20} and M_{25} treatments.

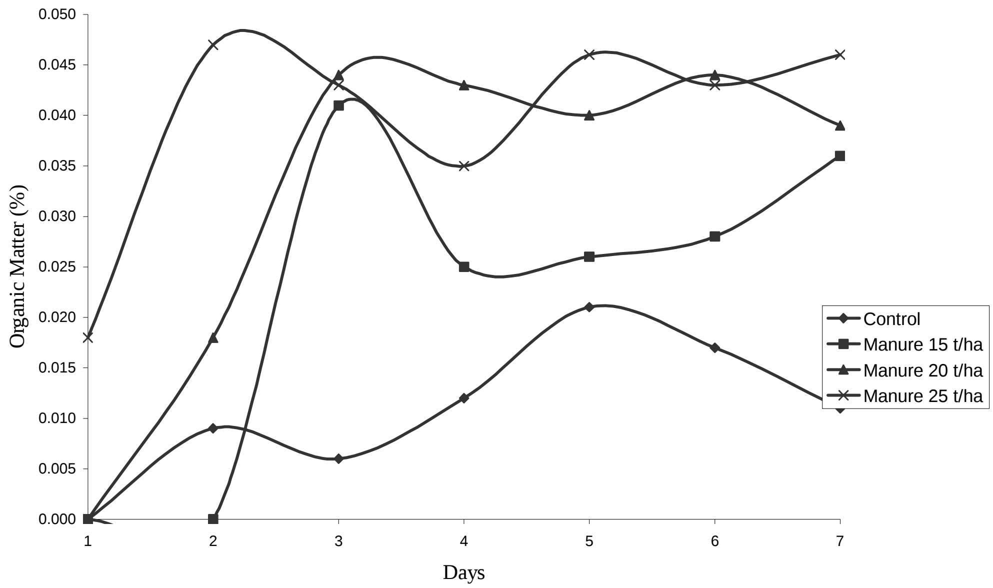

Fig.45 Pecentage of organic matter in the runoff water from sandy loam soil at 30 mm/h rainfall intensity.

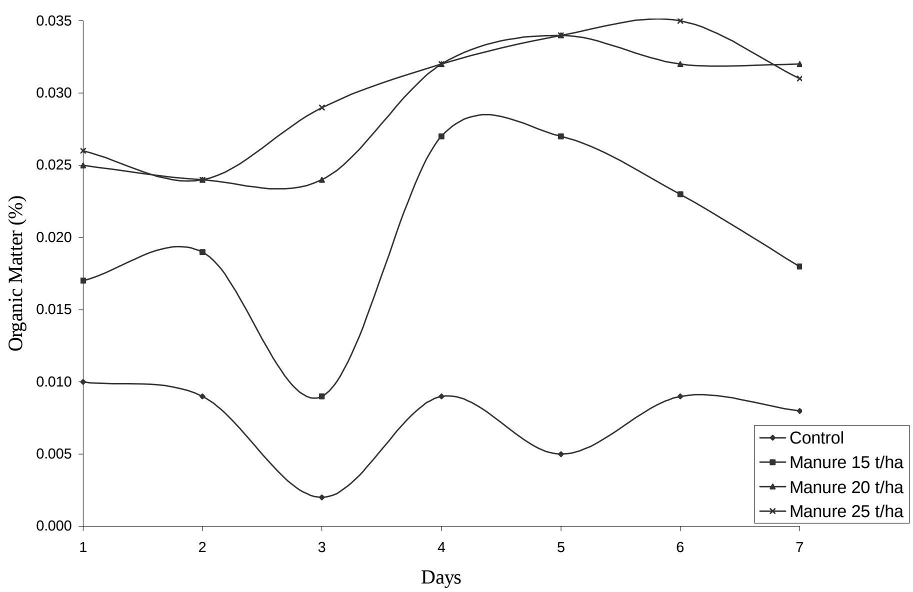

Fig. 46 Percentage of organic matter in the runoff water from sandy loam soil at 45 mm/h rainfall intensity.

The results at 60 mm/h rainfall intensity are given in Appendix XVI and are shown in Fig.47. The values were 0.0025 % for the control and 0.0069, 0.0203 and 0.0283 % for M_{15}, and M_{20} M_{25} respectively.

When the application rate of manure increases the organic matter content also increases. Hence, the organic matter percentage was also increasing with the manure concentration (Chisci and Spallacci ,1984). Since the decomposition of organic matter is a slow process, there will be higher amount of residual organic matter on the surface soil at higher manure application rate. These will be taken away by the flowing water, and hence the organic matter content of runoff water will be increasing with manure application rate.

The percentage of organic matter was decreasing with increase in the rainfall intensity. The sandy soils contains more number of macro pores and hence the leaching will be high. Tandon (1989) reported that the leaching rate will be proprotional to rainfall intensity in sandy soils. So at higher rainfall intensities the organic matter taken into the soil profile will be more and hence there is less chance for the loss through runoff water and at top soil layer a mat of organic manure will be formed (Barrington and Madramootto, 1989). When the intensity of rainfall is further increased more and more manure particles will be pushed into the pore space and hence only a small quantity of manure will be left at the surface to be taken away by the runoff water. This may be the reason for the reduction of organic matter content in runoff water with increase in rainfall intensity.

The regression equation obtained for the organic matter percentage for the sandy loam soil against the rainfall intensity and manure concentration is;

$$O = -3.91 \times 10^{-4} R + 1.03 \times 10^{-3} M + 2.3^{-2}$$

Where,

O = Organic Matter content (%)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

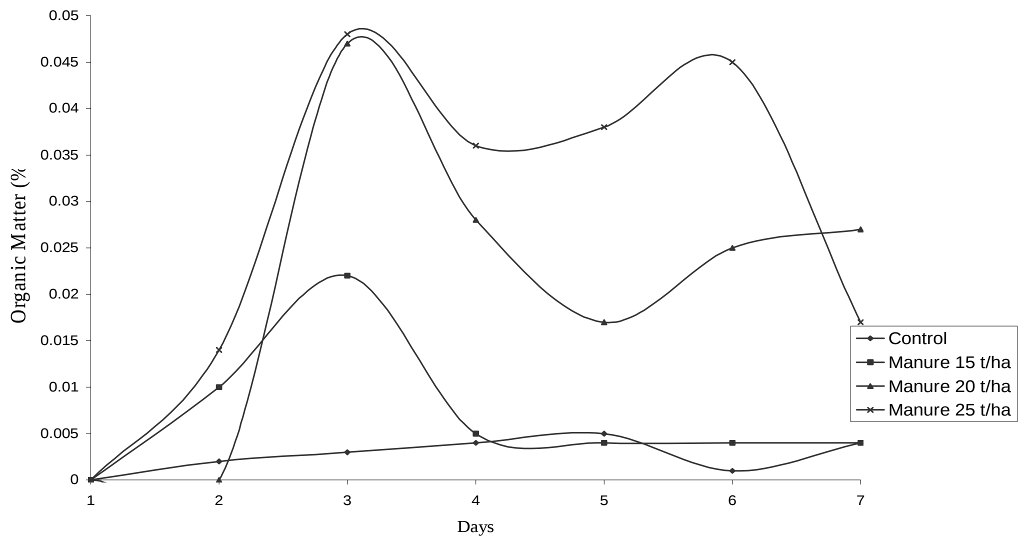

Fig. 47 Percentage of organic matter in the runoff water from sandy loam soil at 60 mm/h trainfall intensity.

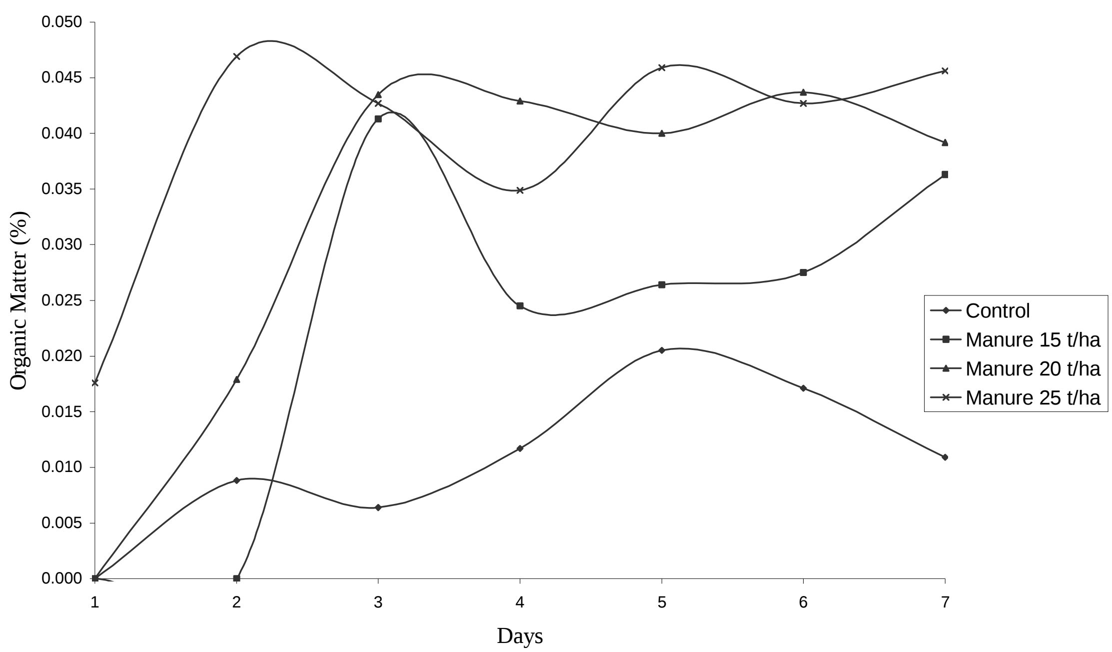

Fig.48 Percentage of organic matter in the runoff water from clay loam soil at 30 mm/h rainfall intensity.

The statistical significance of the results were tested by F-Test. It was noted that when rainfall is treated as the dependant variable there is no significant difference in organic matter percentage with change in the rainfall intensity. When the manure is treated as the dependant variable it was noted that manure application levels significantly affects the organic matter percentage. The organic matter content in the runoff matter obtained from different manure treatments differ significantly. The factorial analysis showed that the manure and rainfall together have no influence on the loss of organic matter.

Clay Loam Soil

The analysis for organic matter content was done for the runoff water from the clay loam soil and the following results were obtained.

The percentage of organic matter content at 30 mm/h rainfall intensity are shown in Fig.48 and the values are given in Appendix XIV. The average percentage of organic matter content was 0.0029, 0.0038, 0.0033 and 0.0045 % for the control, M_{15}, M_{20} and M_{25} treatments respectively.

The organic matter content at 45 mm/h rainfall intensity are shown in Fig.49 and the values are given in Appendix XV. The average organic matter content for control was 0.0047 % and the value for M_{15}, M_{20} and M_{25} treatments were 0.0052, 0.0062 and 0.0077 % respectively.

The values corresponding to 60 mm/h rainfall intensity are shown in Fig.50 and the same is also given in Appendix XVI. The average values were 0.0054 % for the control and 0.0062, 0.0074 and 0.0087 for M_{15}, M_{20} and M_{25} treatments respectively.

On analyzing the general trend of the organic matter content in the runoff water from clay loam soil, it was found that the percentage organic matter content increases with the manure concentration and also with the rainfall intensity. The organic matter content increases with the rainfall intensity because, at high intensity rainfall, the erosion will be severe, when erosion is severe it may cause loss of much of the top soil, which in turn leads to loss of nutrients (Yawalkar *et al*.1992). Chisci and Spallacci (1984) also found that the loss of organic matter content increases with the rainfall intensity. A high intensity rainfall will have a higher carrying capacity. So more manure particles will be

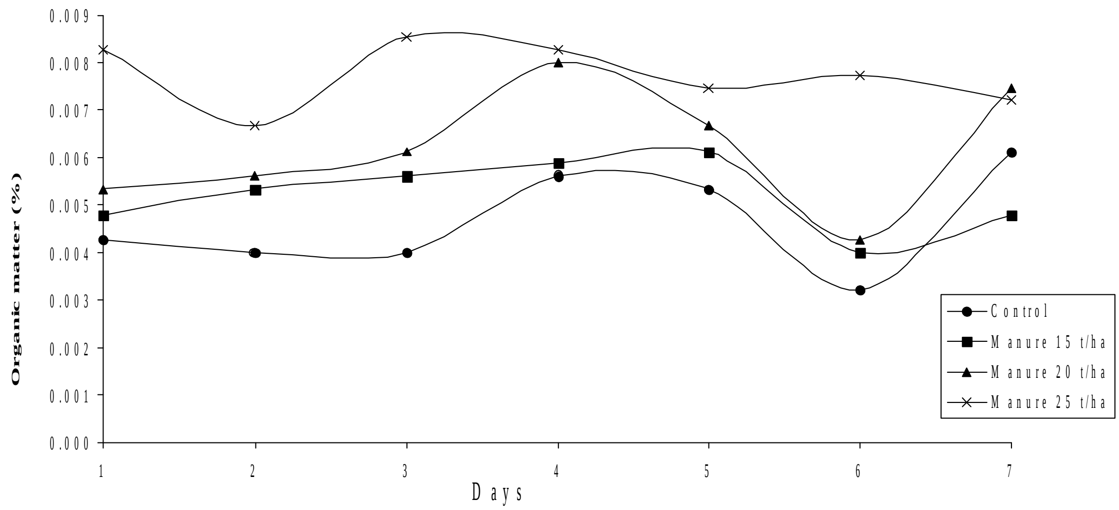

Fig. 49 Percentage organic matter content in the runoff water for clay loam soil at 45 mm/h rainfall intensity.

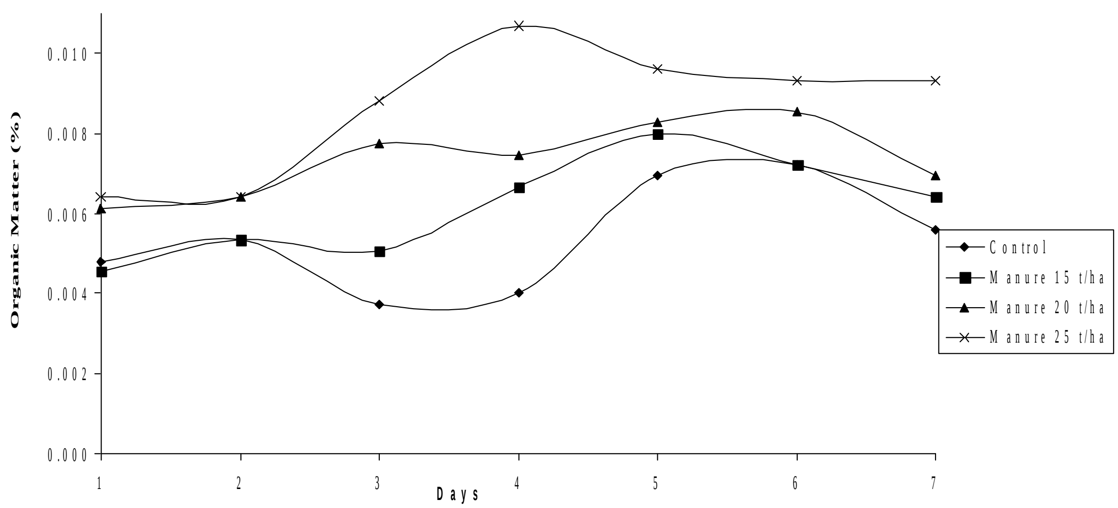

Fig. 50 Percentage organic matter content in the runoff water for clay loam soil at 60 mm/h rainfall intensity.

taken away by the higher intensity rainfall. Since the pore space of clay loam soils are small in size, the solid particles could not be taken into the pores, so the flowing water will carry it away. Hence higher organic matter percentage was observed at higher intensity rainfalls. The variation is only between different treatments and there is no clear cut variation between daily values. The daily values are highly fluctuating with ups and downs. The reason is that the decomposition of organic manure is a slow process and only a long term observation can give any notable trend (Brady 1989). But when the average out put for each treatments was considered the highest level of organic matter was noted for the M_{25} treatment followed by M_{20}, M_{15} and the control in the descending order. The results were similar at all the rainfall intensities.

As the decomposition of organic matter is a long term process if the quantity of manure is higher, there will be more residual organic matter which is left undecomposed and hence the organic matter percentage is increasing with the manure concentration (Chisci and Spallacci 1984). Barrington and Madarmooto (1989) reported that manure application on the top of the soil leads to the formation of surface organic mat of manure particles.

The mathematical expression for the organic matter percentage for clay loam soil against the rainfall intensity and manure concentration is given below;

$$O = 3.07 \times 10^{-3} R + 6.07 \times 10^{-3} M + 0.112$$

Where,

O = Organic Matter content (%)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

The statistical significance of the results were tested by F-Test. It was found that when manure is treated as the dependant variable there is no significant difference in the percentage of organic matter with change in manure application rate. When the rainfall is treated as the dependant variable, it was found that rainfall intensity significantly affects the percentage of organic matter in the runoff. The organic matter content percentage for all the three rainfall intensities differ from each other significantly except for the combination R_{60}-R_{45}. On factorial analysis it was found that the combination of manure rainfall does not have any influence on the percnetage of organic matter.

4.7 Total Nitrogen

The total nitrogen content of the runoff samples collected from various treatments are discussed below.

4.7.1 Sandy Loam Soil

The runoff water obtained from the sandy loam soil for varying combination of treatments were analysed for total nitrogen content and the following results were obtained.

The amount of total nitrogen (in ppm) obtained at 30 mm/h rainfall intensity are given in Appendix XVII and shown in Fig. 51. At 30 mm/h , the amount of total nitrogen was 0.176 ppm for the control and the same value for M_{15}, M_{20} and M_{25} treatments were 0.225, 0.251 and 0.267 ppm respectively.

Table 45 gives the values of total nitrogen in ppm obtained at 45 mm/h rainfall intensity, the same results are shown in Appendix XVIII. The amount of total nitrogen for 45 mm/h rainfall intensity for various treatments were 0.725 ppm for the control and 0.961, 1.121 and 1.528 ppm respectively for M_{15}, M_{20} and M_{25}.

The results obtained at 60 mm/h rainfall intensity are shown in Fig.53 and the corresponding values are given in Appendix XIX. The values were 1.225 ppm for the control and 1.310, 1.441 and 1.732 ppm for M_{15}, M_{20} and M_{25} treatments respectively.

On analyzing the runoff water for the total nitrogen content, it was seen that the percentage of total nitrogen content increases with the concentration of manure and also with the rainfall intensity. Though there is difference in amount of nitrogen between different levels of treatments, no such demarcation was visible between the daily values during the seven day trial of each treatment. The reason is that the manure matter and other chemical compounds will decompose very slowly and hence any significant change within each treatment may be visible only if the observation period is extended. Brady (1989) found that only 1/5th to 1/2 of the nutrient supplied by animal manure is recovered by the first crop following the application. The elements are released only very slowly, at the rate of 2-4 % per year being common. The findings of this experiment also agree with this statement.

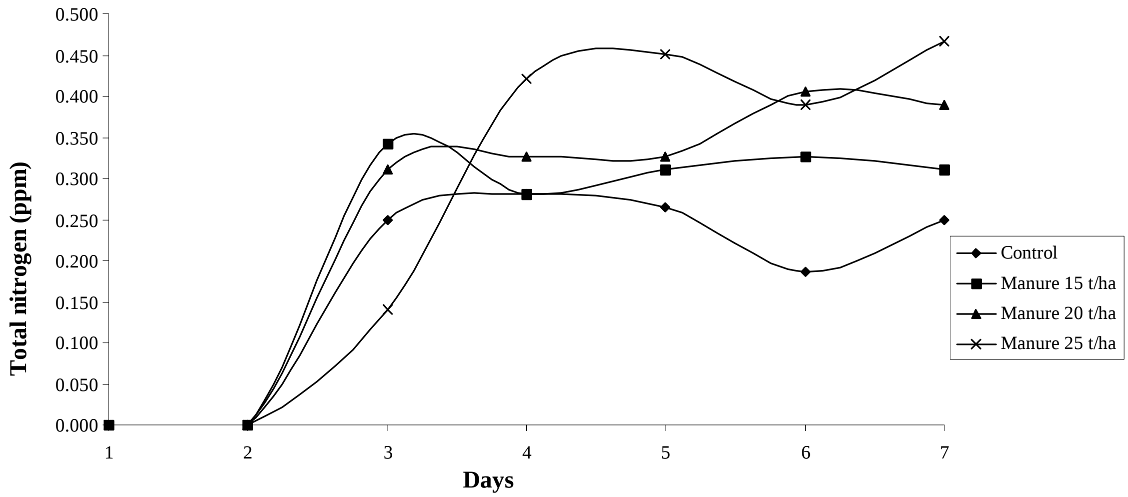

Fig.51 Total nitrogen content of runoff water of the sandy loam soil
at 30 mm/h rainfall intensity.

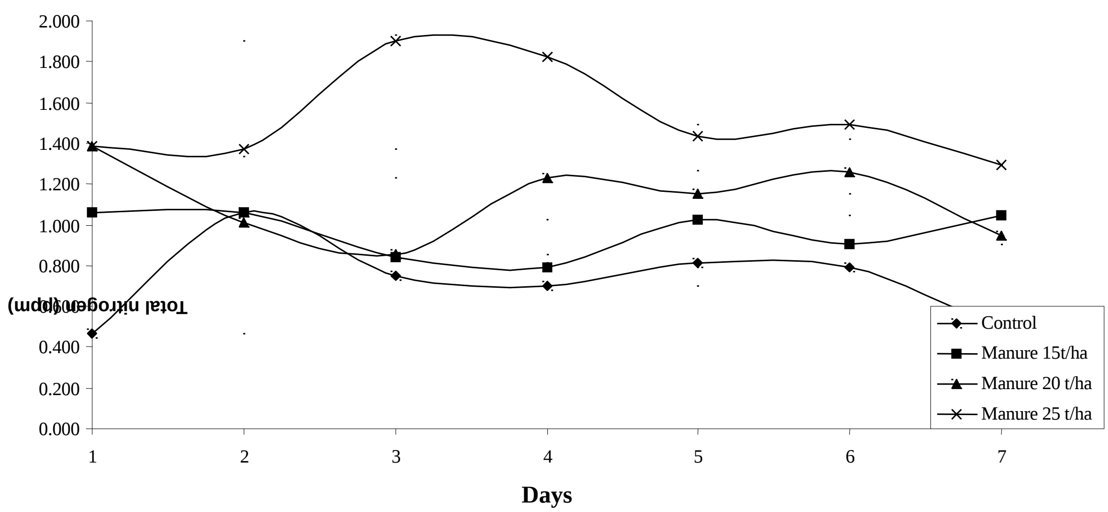

Fig.52 Total nitrogen content of the runoff water of sandy loam soil
at 45 mm/h rainfall intensity.

Chisci and Spallacci (1984) found that the losses of nutrients are minimal at control since all the available nitrogen was quickly taken up. Manure increases the supply of nitrogen in the soil, but the slow release by microbial activities increases the concentration. A similar result was obtained in this study also. When the manure concentration increases, it will take more time to decompose completely. This means that, there will be more amount of residual organic matter at the surface soil. Hence there will be a chance for the runoff water to take away more quantity of nitrogen from the surface soil. Similarly when the rainfall intensity increases the volume and velocity of runoff water will also increase. Hence more manure particles and other suspended matter will be taken away with the runoff water, which will results in the increase of nitrogen concentration.

The relationship between the total nitrogen content against the rainfall intensity and manure concentration for the sandy loam soil is given below;

$$N = 3.99 \times 10^{-2} R + 1.66 \times 10^{-2} M - 1.13$$

Where,

N = Total Nitrogen content (ppm)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

The statistical significance of the results were tested by F-Test. It was found that when manure is treated as the dependant variable there is no significant difference in total nitrogen content with manure concentration. When the rainfall is treated as the dependant variable it was found that rainfall intensity significantly affects the total nitrogen percentage. The difference of nitrogen loss between different rainfall intensities was higher than the critical value in all the treatment combinations. Hence nitrogen loss at all rainfall intensities differ significantly. A two way factorial analysis was conducted to study the combined effect of manure and rainfall upon the total nitrogen loss. It was found that the combined treatments influence the nitrogen loss significantly.

4.7.2 Clay Loam Soil

The runoff water collected from clay loam soil was analysed for total nitrogen content and the following results were obtained.

The results obtained at 30 mm/h rainfall intensity are given in Appendix XVII and are shown in Fig.54. At 30 mm/h rainfall intensity, the amount of total nitrogen was 0.111 ppm for the control, and the same value for M_{15}, M_{20} and M_{25} treatments were 0.127, 0.129 and 0.205 ppm respectively.

The total nitrogen content, in the runoff sample at 45 mm/h rainfall intensity are given in Fig. 55 and Appendix XVIII. The amount of nitrogen was 0.271 ppm for the control and 0.345, 0.443 and 0.680 ppm respectively for M_{15}, M_{20} and M_{25} treatments.

The results obtained at 60 mm/h rainfall intensity are given in Appendix XIX and Fig.56a. The values were 0.658 ppm for the control and 0.847, 0.990 and 1.130 ppm for M_{15}, M_{20} and M_{25} treatments respectively.

The total nitrogen percentage in the runoff water showed an increasing trend both with the increase of manure concentration and rainfall intensity. But the curves never kept a uniform pattern for any treatment. However as rainfall intensity increases the demarcation between individual curves becomes more and more clear.

The individual daily values within each treatment did not show any definite pattern. The reason is that for the leaching and decomposition of chemical compound a seven day observation may not be adequate. Hence the average values were taken into consideration. The results of the analysis done by Brady (1984) also agree with these results. So at higher concentration of organic manure, there will be higher amount of residual chemicals on the soil surface and these will be taken away by the flowing water. That is why the concentration of total nitrogen increases with the manure concentration (Chisci and Spallacci, 1984). In the same way the total nitrogen also increases with the intensity of rainfall.

The relationship between the nitrogen content against the rainfall intensity and manure concentration for clay loam soil is given by;

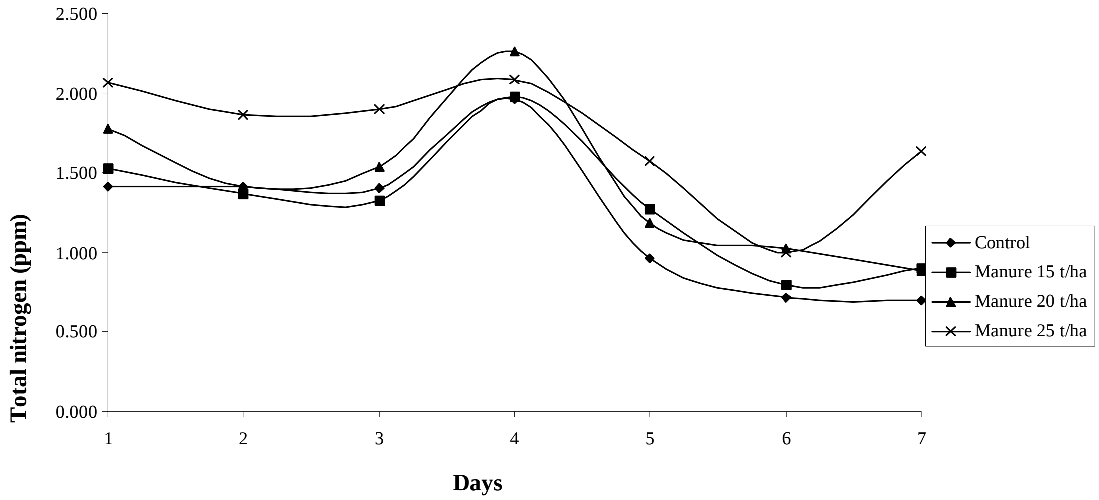

Fig.53 Total nitrogen content of the runoff water of sandy loam soil at 60 mm/h rainfall

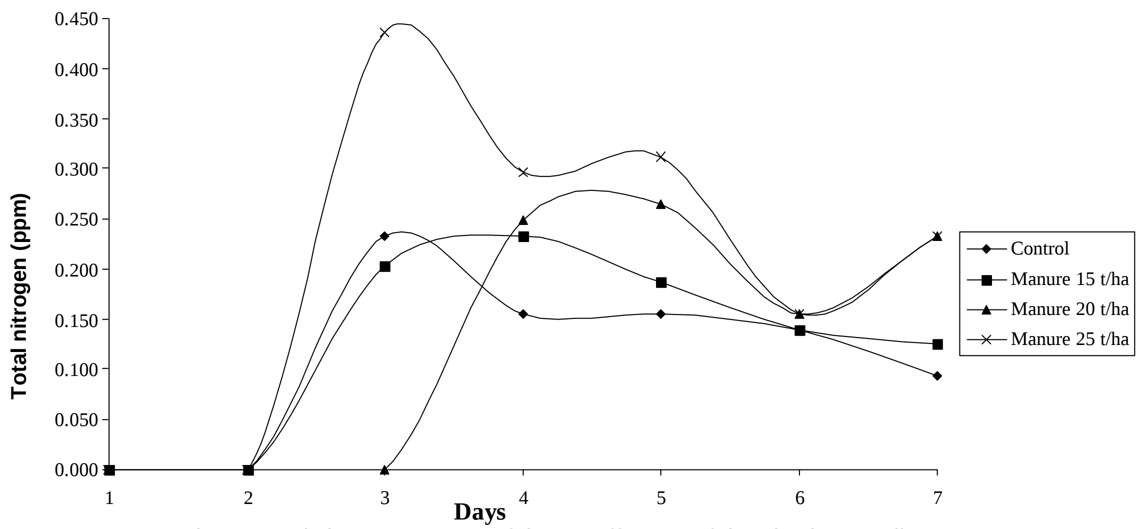

Fig.54 Total nitrogen content of the runoff water of the clay loam soil at 30 mm/h rainfall intensity.

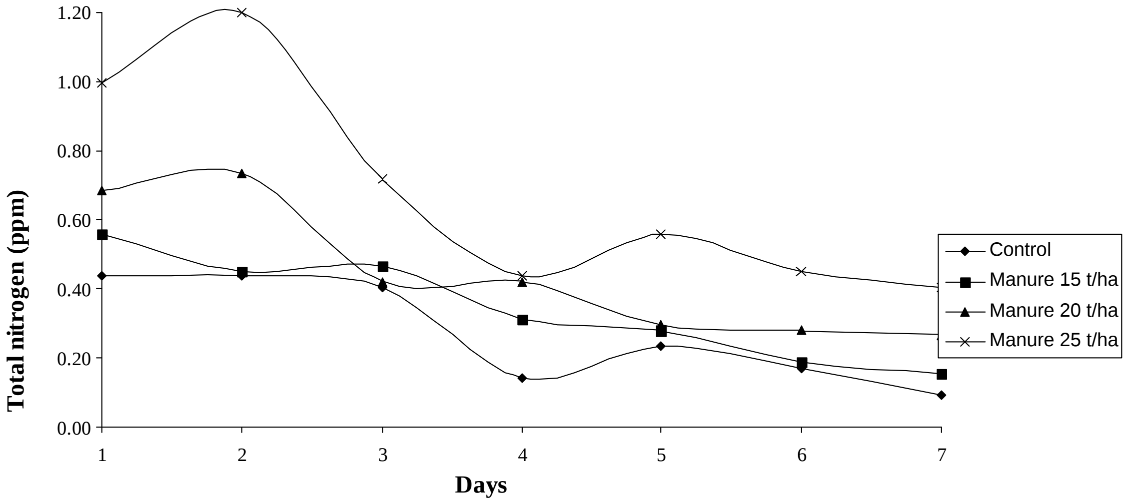

Fig.55 Total nitrogen content of the runoff water of clay loam soil at 45 mm/h rainfall intensity.

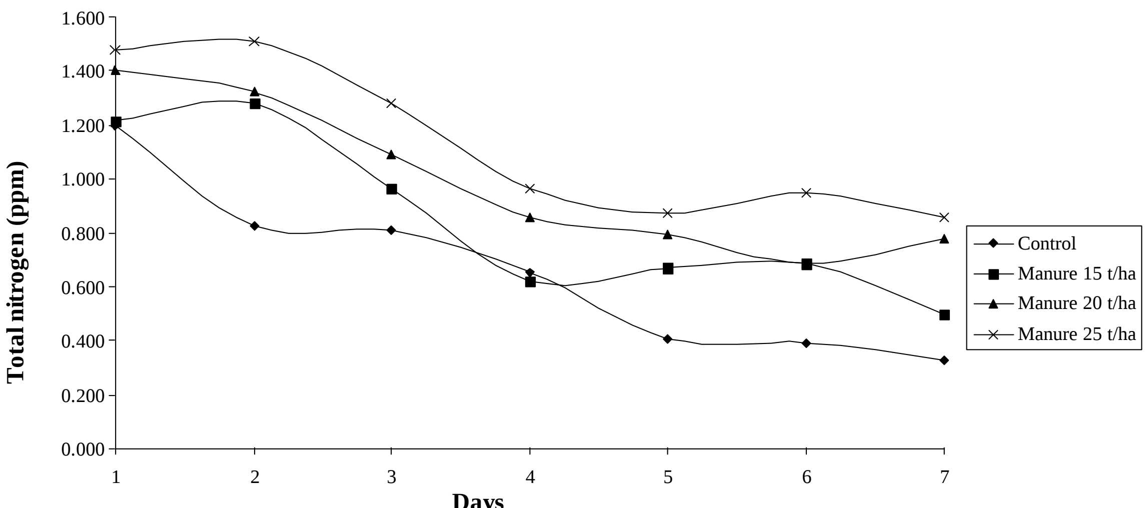

Fig.56 Total nitrogen content of the runoff water for clay loam soil at 60 mm/h rainfall intensity.

$$N = 2.54 \times 10^{-2} R + 1.13 \times 10^{-2} M + 0.827$$

Where,

N = Total Nitrogen content (ppm)R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

The statistical significance of the results were tested by F-Test. It was noted that when manure is treated as the dependant variable there is no significant difference in total nitrogen content with change in the manure application rate. When the rainfall is treated as the dependant variable, it was found that rainfall intensity significantly affects total nitrogen percentage. There was significant difference among the values of total nitrogen obtained from all the rainfall intensity treatments. A two way factorial analysis was conducted to study the combined effect of manure and rainfall upon the total nitrogen loss. It was found that the combined treatment influences the nitrogen loss significantly.

4.8 Bulk Density

The bulk density of the soil was determined at three profile levels. The results are given below.

4.8.1 Sandy Loam Soil

The bulk density values of sandy loam soil at 30 mm/h rainfall intensity are given in Appendix XX and are shown in Fig. 57. The values at the control were 1.601, 1.776 and 1.968 g/cc respectively at different profile levels. Different manure treatments recorded lower values. The values were 1.498, 1.750 and 1.870 g/cc for M_{15}, 1.490, 1.680 and 1.910 g/cc for M_{20} and 1.444, 1.621 and 1.908 g/cc for M_{25} respectively.

Bulk density values at 45 mm/h rainfall intensity are given in Appendix XX and are shown in Fig.58. The values for the control were 1.595, 1.786 and 1.923 g/cc. The values for various treatments were 1.602, 1.702 and 1.999 g/cc for M_{15}, 1.590, 1.600 and 1.824 g/cc for M_{20} and 1.589, 1.611 and 1.721 g/cc for M_{25} respectively.

The bulk density values at 60 mm/h rainfall intensity were 1.865, 1.912 and 2.084 g/cc for the control, 1.723, 1.832 and 1.822 g/cc for M_{15}, 1.714, 1.645 and 1.710 g/cc for M_{20} and 1.697, 1.544 and 1.617 g/ccfor M_{25} respectively. The values are given in Appendix XX and shown in Fig. 59

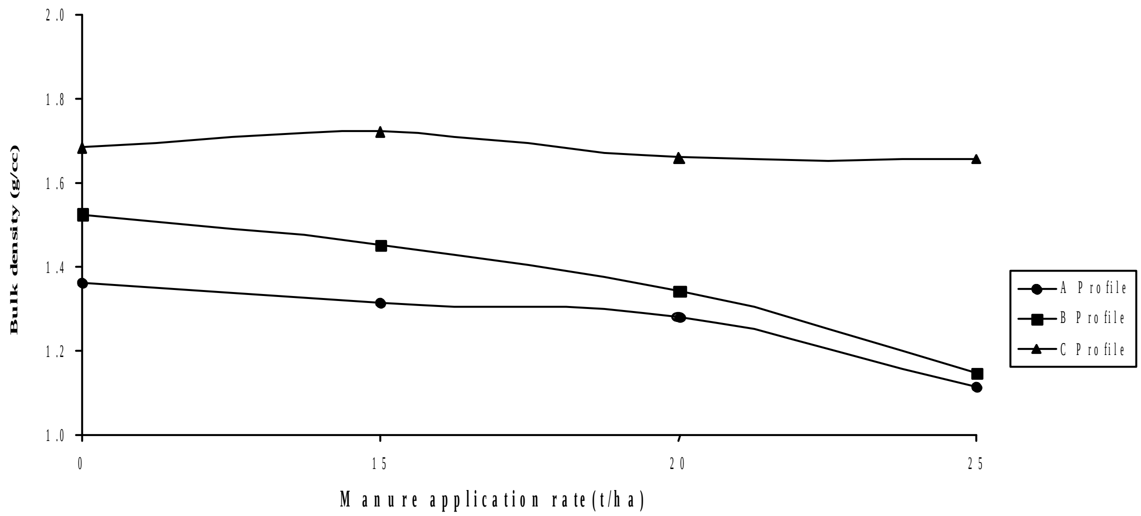

Fig.57 Bulk density values at different profile levels for sandy loam soil at 30 mm/h rainfall intensity.

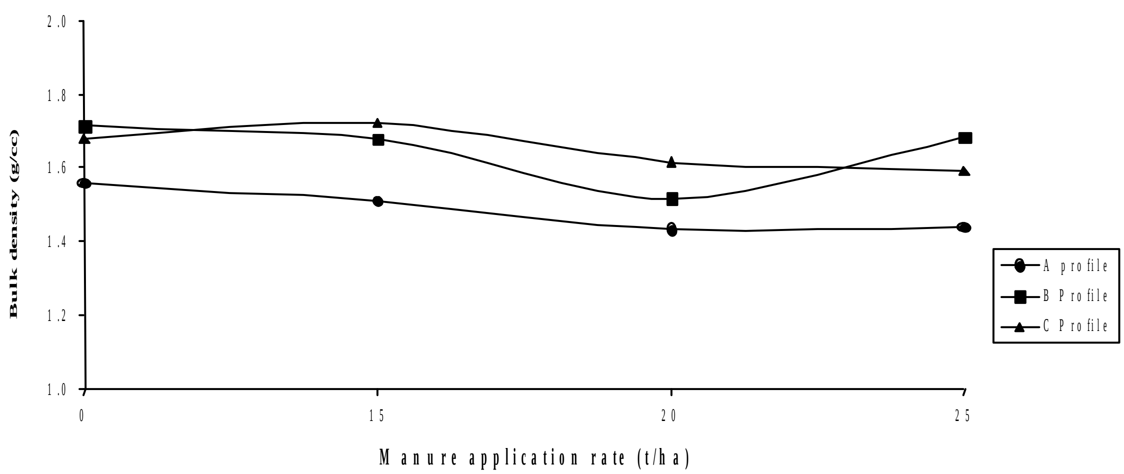

Fig.58 Bulk density values at different profile levels for sandy loam soil at 45 mm/h rainfall intensity.

The results shows that, the bulk density values are increasing with profile depth, this agrees with the findings of Brady (1995) which states that the bulk density values increases with the profile depth due to lower content of organic matter, less aggregation and higher compaction. Again he stated that the organic matter binds and lightens the soil, which in turn tends to lower the weight of the soil. This may be reason for the lowering the bulk density values with the manure concentration.

A functional relationships giving values of bulk density for various combinations of rainfall intensity and manure application rate were derived, which are follows:

Profile A: $BD = 1.56 \times 10^{-2} R – 5.66 \times 10^{-3} M + 0.94$

Profile B: $BD = 1.16 \times 10^{-2} R – 8.66 \times 10^{-3} M + 1.04$

Profile C: $BD = 1.31 \times 10^{-3} R – 3.49 \times 10^{-3} M + 1.68$

Where,

BD = Bulk Density (g/cc)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

F- test was conducted to analyse the statistical significance of the results. From the test it was found that different levels of manure application rates have significant effect on bulk density and the variation of rainfall intensity has no significant effect on bulk density. The two way analysis also showed that, the rainfall intensity and manure application rate together have no significant effect on bulk density

4.8.2 Clay Loam Soil

The bulk density of clay loam soil corresponding to 30 mm/h rainfall intensity are given in Appendix XXI and are presented graphically in Fig. 60. The bulk density values for the control were 1.362, 1.525 nd 1.683 g/cc respectively at the different profile levels of 0 cm, 10 cm and 20 cm depth from the surface. The values were 1.313, 1.215 and 1.713 g/cc for M_{15}, 1.115, 1.125 and 1.165 g/cc for M_{20} and 1.283, 1.038 and 1.661 g/cc for M_{25} respectively

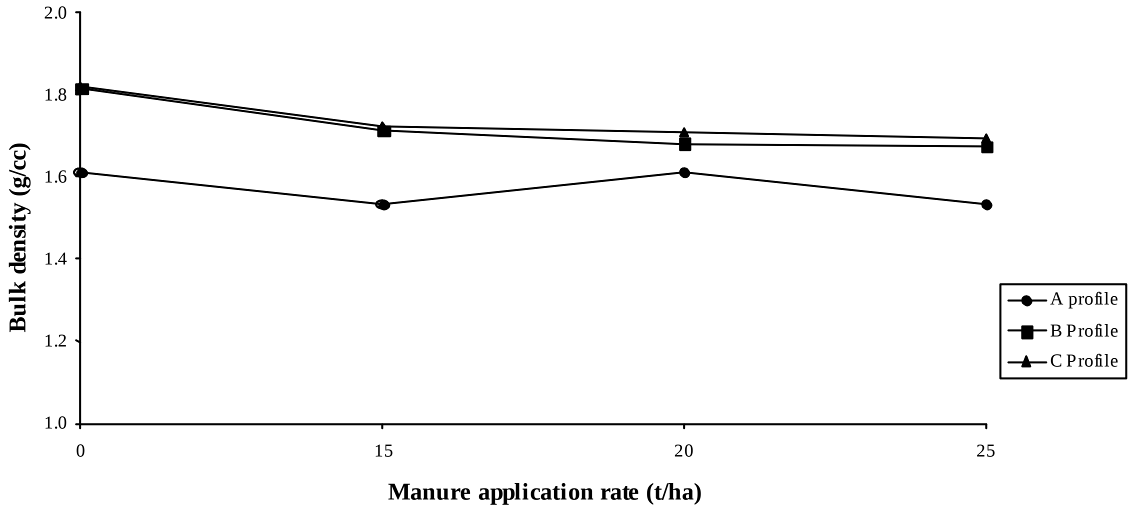

Fig.59 Bulk density values at different profile levels of sandy loam soil at 60 mm/h rainfall intensity.

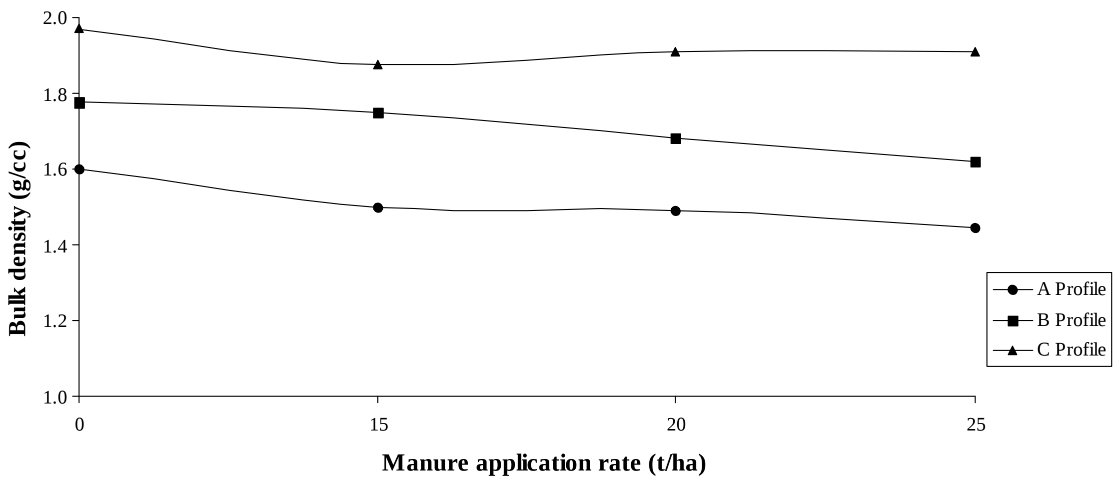

Fig. 60 Bulk density values at different profile levels of clay loam soil at 30 mm/h rainfall intensity.

The details of the bulk density values at 45 mm/h rainfall intensity are given in Appendix XXI and Fig.61. When the rainfall intensity increased to 45 mm/h the bulk density values recorded for control was 1.715, 1.558 and 1.678 g/cc respectively at three profiles levels, the corresponding values were 1.678, 1.510, and 1.723 g/cc respectively for M_{15}, 1.519, 1.430 and 1.615 g/cc for M_{20} and 1.683, 1.439 and 1.541 g/cc for M_{25}respectively.

The bulk density values at 60 mm/h are given in Appendix XXI and Fig. 62. The bulk density values were 1.821, 1.612 and 1.814 respectively at three profile levels for the control. The values were 1.723, 1.535 and 1.712 g/cc for M_{15}, 1.710, 1.610 and 1.680 g/cc for M_{20} and 1.693, 1.532 and 1.673 g/cc for M_{25} respectively.

The results show a similar trend as that for sandy loam soil, i.e., the bulk density values decrease with the increase in manure concentration and rainfall intensity. The above results show that the bulk density values decrease with the increase in manure concentration and rainfall intensity. These finding agree with the results reported by Felton and Ali(1992) and Stone and Ekwue(1993).

Brady (1995) stated that the bulk density values will increase with profile depth due to lower content of organic matter, less aggregation and higher compaction; a similar result was also found in these studies. Brady again proved that, the organic matter binds and also lightens the soil, which in turn tends to lower the weight of the soil. This may be the reason for lowering the bulk density values with the manure concentration

Tisdale *et al.* (1998) found that smaller the amount of pore space present in the soil, higher the bulk desnsity values. In the present study also, the bulk density values obtained for the clay loam soil were lower than the sandy loam soil.

A functional relationships giving values of bulk density for various combinations of rainfall intensity and manure application rate were derived, which are follows:

Profile A: $BD = 8.05 \times 10^{-4} R - 4.44 \times 10^{-3} M + 1.33$

Profile B: $BD = 8.83 \times 10^{-4} R - 9.26 \times 10^{-3} M + 1.80$

Profile C: $BD = -3.55 \times 10^{-3} R - 9.47 \times 10^{-3} M + 2.17$

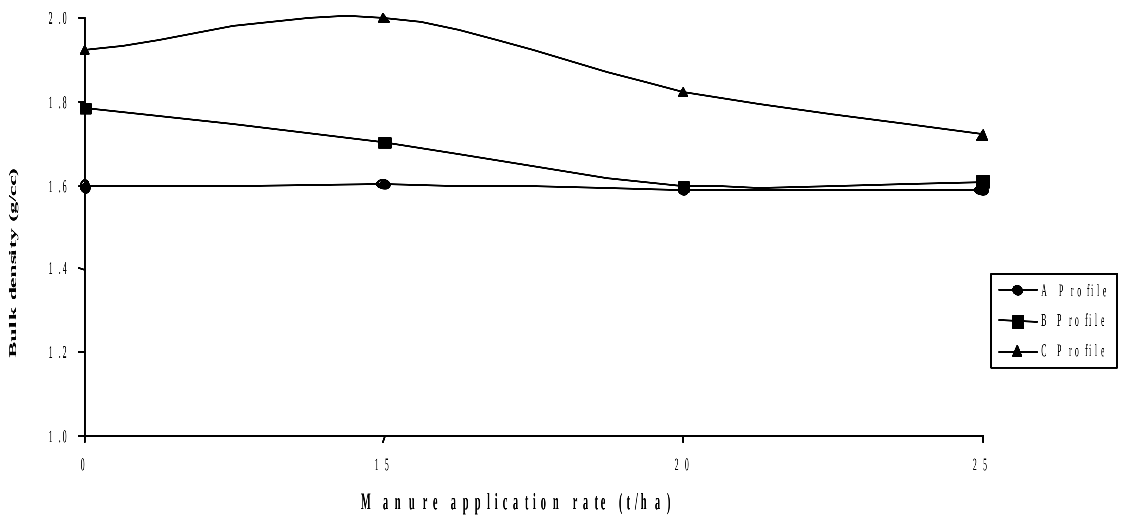

Fig.61 Bulk density values at different profile levels for the clay loam soil at 45 mm/h rainfall intensity.

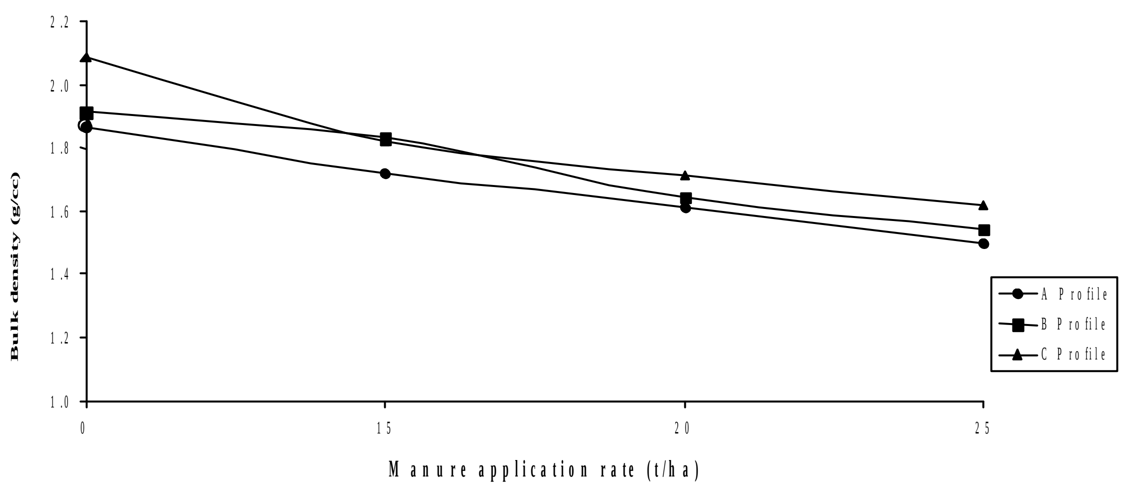

Fig.62 Bulk density values at different profile levels for the clay loam soil at 60 mm/h rainfall intensity.

Where,

BD = Bulk Density (g/cc)

R = Rainfall intensity (mm/h)

M = Manure application rate (t/ha)

From the statistical analysis it was found that, if manure is taken as the dependant variable, the different levels of manure application have no significant effect on the bulk density. When rainfall is considered taking as taking as the dependant variable, the change in intensities of rainfall has got significant influence on the bulk density values. On analyzing the combined effect of manure and rainfall, no significant effect was noticed.

SUMMARY

Summary

Agriculture is the major source of income in India and especially in Kerala. Though we have advanced very much regarding the technical know how in agricultural sector, still majorities of the village farmers follow conventional practices due to either ignorance or lack of facility. Application of soil amendments is one of the major management practices for the cultivation of any crop. The role of soil amendment is to supply various soil nutrients, inorder to maintain the soil productivity and to ensure higher yield. Though fertilizers are one of the major soil amendments, organic manure application is also popular especially among the rural farmers, all over the country. Now- a-days manure application has got greater significance due to the introduction of organic farming concept and economical benefit as compared to the use of inorganic fertilizers.

Manures are rich in organic matter content and studies have proved that these organic matters are capable of forming a seal on the soil surface which influences the soil characteristics like infiltration, water holding capacity, runoff etc. Excess application of organic manure will result in increased amount of sediments, organic matter and other chemicals in the runoff water, which will degrade the water bodies in the down stream and deposit residual chemicals on the soil surface.

The present study was aimed to assess the effect of seal formation due to cattle manure application on infiltration and runoff in different types of soils viz: sandy loam and clay loam. The manure application levels were fixed as control, 15 t/ha, 20 t/ha and 25 t/ha under rainfall intensities of 30, 45 and 60 mm/h. Each treatment was continued for 7 days and was repeated with three replications.

The major findings of the study are as follows:

- It was observed that the addition of organic manure in coarse textured soil would reduce infiltration rate. In coarse textured soil, the number of macro pores are more and when the organic matter is applied on the soil, minor solid particles may clog the macro pores, restricting the downward flow of water and hence the infiltration rate decreases. It was seen that high intensity rainfall is more effective in transporting the solid particles to the pore space, which brings down the infiltration rate.

- In a fine textured soil, addition of organic manure forms organic bedding on the topsoil surface. This organic bedding can hold more amount of water and thus can improve the water holding capacity. This inturn was resulted in increased infiltration rate. The infiltration rate noted was proportional to the rainfall intensity.
- It was observed that runoff increased with the manure concentration for the sandy loam soil. On analysing the infiltration rates, it was found that the infiltration is reducing with manure concentration since the macro pores are blocked. Obviously the runoff will increase with manure concentration and rainfall intensity.
- On the other hand, the manure forms organic bedding in the clay loam soil, which can retain more amount of water. This has resulted in reduced runoff at higher manure application levels. But, the runoff volume was more at higher intensities of rainfall.
- The total nitrogen content in the runoff water was analysed and it was found that the nitrogen content is increased with both manure application rate and rainfall intensity in sandy loam soil. As the manure application rate increases, the amount of residual nitrogen on the surface soil also increases. A higher intensity rainfall will have a high erosive capacity. The above two factors are responsible for the increased nitrogen content with respect to the manure concentration and rainfall intensity
- In clay loam soil also the total nitrogen content increased with manure application rate and rainfall intensity. The reasons are the same as that stated for sandy loam soil.
- The organic matter content also increased with the manure application rate in sandy loam soil, but at the same time decreased with the increase of rainfall intensity. The fine manure particles from soil surface will be taken to the pore spaces of sandy loam soil during rainfall and hence the amount of manure particles left on the surface, which can be washed away, by the runoff water will be less. This has resulted in reduced organic matter content at higher intensity rainfall.
- In clay loam soil, the total organic matter content increased with both manure application rate and rainfall intensity.
- The total solids in the runoff water from sandy loam soil increased with the manure application rate and rainfall intensity. Since the manure was applied in dry powder form and also it was applied on the surface, the solid particles can easily get eroded. A high intensity rainfall will have a high erosive power and carrying capacity. This has resulted in higher solid percentage with heavier rainfall intensity.

- The total solids in the runoff water from clay loam soil also increased with manure application rate and rainfall intensity. The reasons are the same as that explained for the sandy loam soil.
- The bulk density of both soils increased with the increase in manure concentration and rainfall intensity.

The final conclusion is that, though the manure application is one of the best management practices, its excess application will results in detrimental effects by polluting the environment and nearby water bodies. While considering the manure application rate, the texture of the soil should also be considered with equal importance as that of the crop cultivating.

RECOMMENDATIONS

RECOMMENDATIONS

Recommendations for future studies in the area:

1. This was only a lab study conducted in a controlled enviornment. Hence the results obtained may not be conclusive, but can give an insight to, what will be the impact of cattle manure application on different soil properties and runoff. The result in actual field condition may be different from that of lab study. Hence, impact of cattle manure application on differennt soil properties in acutal field condition with respect to different crops must be studied.

2. For the thorough decomposition of organic manure and nutrients, a longer observation period may be required, which can be finalised only after knowing the crops intended to grow and the soil type.

3. Studies may be conducted by varying the intensity and duration of the rainfall.

4. Studies may be conducted to assess the effect of different types of manure application methods viz. incorporation, surface application, top dressing, liquefied application etc. on the soil properties.

5. Studies may be conducted by changing the trough slope to assess the effect of change in slope on the results.

6. Studies may be conducted in actual farming situations, as farmers are the ultimate beneficiaries and attempt may be made to recommend manure application rates with respect to crop and soil type.

REFERENCES

REFERENCE

Anonymous. (2000). *Data Book on Agricultur*. Agricultural Division, State Planning Board, Kerala.

Anonymous. (1995). *Handbook of Agriculture*. ICAR, New Delhi.

Assouline,S. and Mualem,Y. (1997). Modelling the dynamics of seal formation and its effect on infiltration as related to soil and rainfall characteristics. Water Resources Research. **33**(7): 1527-1536.

Barrington,S.F. and Madramootoo,C.A. (1989). Investigating Seal Formation from Manure Infiltration into Soils. *Trans. ASAE*. **32**(3): 851-856.

Benbi,D.K., Biswas,C.R., Bava,S.S. and Kumar,K. (1998). Influence of Farm Yard Manure, Inorganic Fertilizers and Weed Control Practices on Soil Physical Properties in a long term Experiment. *Soil Use and Mangagement.* **14**(1):52-54.

Beringer,H. (1984). Prospects and Limitations of Soil and Plant Analysis for Establishing Nutrient Balances for Mango Crops. Proceedings of 18th colloquin of the International Potash Institute, International Potash Institute, Switzerland. pp: 291-298.

Bolton,S.M., Ward,T.J. and Cole, R.A. (1991). Sediment Related Transport of Nutrients from South Western Watersheds. *J. of Irrig. and Drainage Engg*. **117**(5): 736-747.

Borah,D.K. (1989). Sediment discharge model for small watersheds. *Trans. ASAE*. **32**(3): 874-880.

Brady,N.C. (1995). *The Nautre and Properties of Soils*. Prentice-Hall of India Pvt. Ltd., New Delhi. pp: 35-70.

Bushee,E.L., Edward,D.R. and Moore.P.A. (1998). Quality of Runoff From Plots Treated with Municipal Sludge and Horse Bedding. *Trans. ASAE.* **41**(4):1035-1041.

Chaubey,I., Edward,D.R., Moore,P.A. and Nicholas,D.J. (1995). Effectiveness of vegetative filter strips in controlling losses of surface applied poultry litter constituents. *Trans. ASAE*. **38**(6): 1687-1692.

Chenu,C., Bissonnais,Y.L. and Arrouays,D. (2000). Organic Matter Influence on Clay Wettability and Soil Aggregate Stability. *Soil. Sci. Soc. Am. J*. **64**:1479-1486.

Chisci, G. and Spallacci. (1984). Nutrient Losses by leaching and runoff and possibilities of their control. . Proceedings of 18th colloquin of the International Potash Institute, International Potash Institute, Switzerland. pp: 323-346.

Cookee,G.W. (1982). *Fertilizing for Maximum Yield*. Granandа Publishers, New York. pp:3-9, 253-255.

Davis,G., Young,M. and Bret,A. (1997). Soil Characteristics of crop land fertilized with feed lot manure in the south plate river basin of Colarado. J. of Soil and Water Cons. **52**(5). 327-331.

Edward,D.R., Daniel,T.C., Murdoch,J.F. and Moore,P.A. (1996). Quality of Runoff from Far North West Arkansas Pasture Fields Treated with Organic and Inorganic Fertilizers. *Trans. ASAE*. 39(5):1689-1698.

Eisenhauer,D.E., Heerman,D.F. and Klute,A.K. (1992). Surface Sealing Effects on Infiltration with Surface Irrigation. *Trans. ASAE*. **35**(6):1799-1807.

Fattah,H.A. and Upadhyaya,S.K. (1996). Effect of Soil Crust and Soil Compaction on Infiltration in a Yoyo Loam soil. *Trans. ASAE*. **39**(1):79-84.

Felton,G.K. and Ali,M. (1992). Hydraulic Parameter Response to Incorporated Organic Matter in the B Horizon. *Trans. ASAE*. **35**(4): 1153-1160.

Flangan,D.C., Norton,L.D. and Shainbey,I. (1997). Effect of Water Chemistry and Soil Amendments on a Silt Loam Soil- Part.I. Infiltration and Runoff. *Trans. ASAE*. **40**(6):1549-1554.

Hamlet,J.M., Melvin,S.W. and Horton,R. (1990). Traffic and Soil Amendment Effects on Infiltration and Compaction. *Trans. ASAE*. **33**(3): 821-826.

Heil,J.W., Anthony,S.R. and Kevin,M.M. (1997). Soil Properties Influencing Surface Sealing of Some Sandy Soil in the Sahel. *J. Soil Science*. **162**(7):459-469.

Hesse,P.R. (2001). A Text Book of Soil Chemical Analysis. CBS Publishers & Distributors. New Delhi. pp: 27-95

Jessica,G.D., Young,M. and Abnstedt. (1997). Soil Characteristics of Crop Land Fertilized with feedlot manure in the south river basin of Colorado. *J. Soil and Water Cons.* **52**(5): 327-331.

Lu,J.Y., Cassol,E.A. and Hauer,W.C.M. (1989). Sediment Transport Relationship for Sand and Silt loam Soils. *Trans. ASAE*. **32**(6): 1923-1931.

Lucius,L. and Slyke,V. (1993). *Fertilizer and Crop Production*. Agro Biotical Publishers, Bikner. pp: 69-101.

McGregore,K.C., Bengtson,R.L. and Mutchler,C.K. (1990). Surface and Incorporated Wheat Straw Effects on Interrill Runoff and Soil Erosion. *Trans. ASAE*. **33**(2): 469-474.

Moore,P.A., Daniel,T.C., Sharpley,A.N. and Wood,C.W. (1995). Poultry Manure Management-Envirornmentally Sound Options. *J. of Soil and Water Cons.* **50**(3): 321-327.

Mostaghimi,S., Deizman,M.M., Dillaha,T.A. and Heatwole,C.D. (1989). Impact of Land Application of Sewage Sludge on Runoff Water Quality. *Trans. ASAE*. **32**(2): 491-496.

Nabh,D.H., Gaweda,F. and Froehlich,H.A. (1989). Infiltration, Water Repellency and Soil Moisture Content after broad cast burning a forest site in Southwest Oregon. *J. of Soil and Water Cons*. **44**(1): 87-89.

Nahar,K., Haider,J. and Karim,A.J.M.S. (1995). Residual Effect of Organic Manure and Influence of Nitrogen Fertilizer on Soil properties and Performance of Wheat. *Ann. Bangladesh Agric*. **5**(2):73-78

Rao,S.N.S. (1997). *Soil Microorganism and Plant Growth*. Oxford & IBH Publishing Co, New Delhi. pp: 22-103

Ritter,W.F., Scarbrough,R.W. and Chirnside,A.E. (1991). Nitrate Leaching under Irrigation on Coastal Plain Soil. *J. I rrig. and Drainage Engg*. **117**(4): 490-502.

Robberts,R.J. and Clanton,C.J. (1992). Plugging Effects from Live Stock Waste Application on Infiltration and runoff. *Trans. ASAE*. **35**(2): 515-522.

Sajeen,S. and Kurien,E.K. (1999). Erodibility and runoff potential of laterite soils under simulated rainfall conditions. *Unpublished M.Tech Thesis*, KCAET, Tavanur.

Shotliff,J. (1990).Nitrate and Soil Compaction.*The Agricultural Engineer*.**45**(1):21-23.

Skousen,J. and Clinger,C. (1993). Sewage Sludge Application Programme in West Virginia. *J.Soil and Water Cons*. **48**(2): 145-151.

Stone,R.J. and Ekwue,E.I. (1993). Maximum Bulk Density Achieved During Soil Compaction as Affected by the Incorporation of Three Organic Materials. *Trans. ASAE*. **36**(6):1713-1719.

Tandon,H.L.S. (1985). *Fertilizer Marketing Systems in India*. Fertilizer Development and Consultation Organization, New Delhi. pp: 1-17.

Tandon,H.L.S. (1991). *Fertilizer Guide*. Fertilizer Development and Consultation Organization, New Delhi. pp:1-36

Tisdale,S.L., Nelson,W.L., Beaton,J.D. and Havlin,J.L. (1998). *Soil Fertility and Fertilizers*. Oxford & IBH Publishing Co. New Delhi. pp: 45-80, 101-176.

Trout,T.J. (1990). Surface Seal Formation on Surge Flow Infiltration. *Trans. ASAE*. **33**(5):1583-1593.

Walker,S.E., Mostaghimi,S., Dillaha,T.A. and Woeste,F.E. (1990). Modelling Animal Waste Management Practices: Impacts on Bacteria Levels in Runoff from Agricultural Land. *Trans. ASAE*. **33**(3):807-817.

Wallach,R., Jury,W.A. and Spencer,W.F. (1989). The Concept Of Convective Mass Transfer For Prediction Of Surface Runoff Pollution By Soil Surface Applied Chemicals. *Trans. ASAE*. **32**(3): 1923-34.

Wang,Y., Edward,D.R., Daniel,T.C. and Scott,H.D. (1994). Simulation of Runoff Transport of Animal Manure Constituents. *Trans. ASAE*. **39**(4):1367-1379.

Williams,J.D., Dobrowolski,J.P. and West,N.E. (1995). Microphytic Crust Influence on Inter rill Erosion and Infiltration capacity. *Trans.ASAE*. 38(1): 139-146.

Yawalkar,K.S., Agarwal,J.P. and Bokde,S. (1992). *Manures and Fertilizers*. Agri-Horticulutural Publishing House, Nagpur. pp: 8-29, 265.

Zhang,X.C., Miller,W.P., Neering,M.A. and Norton,L.D. (1998). Effects of Surface Treatment on Surface Sealing, Runoff and Inter rill Erosion. *Trans. ASAE*. **41**(4):989-994.

APPENDIX

APPENDIX 1.

Calibration table for rainfall uniformity and intensity

Operating Pressure (kg/cm^2)	Application Uniformity (%)	Rainfall Intensity (cm/h)
0.4	76.74	0.93
0.6	81.77	2.34
0.8	83.97	4.37
1.0	82.95	6.01

APPENDIX II. Infiltration rates of sandy loam soil at 30mm/h rainfall intensity.

a. Without manure.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.882	0.776	0.688	0.588	0.471	0.393	0.298	0.226	0.540
II	0.928	0.875	0.776	0.703	0.577	0.519	0.434	0.258	0.633
III	0.893	0.794	0.728	0.636	0.514	0.452	0.393	0.261	0.584
IV	0.871	0.717	0.616	0.520	0.426	0.368	0.276	0.201	0.499
V	0.847	0.684	0.574	0.474	0.434	0.335	0.263	0.194	0.476
VI	0.796	0.632	0.544	0.426	0.371	0.299	0.247	0.157	0.434
VII	0.726	0.555	0.493	0.397	0.349	0.272	0.224	0.140	0.395

b. Manure application rate 15 t/ha .

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.419	0.375	0.356	0.319	0.261	0.221	0.185	0.165	0.288
II	0.552	0.518	0.514	0.485	0.401	0.334	0.291	0.251	0.418
III	0.504	0.483	0.467	0.430	0.373	0.309	0.256	0.213	0.379
IV	0.480	0.452	0.436	0.408	0.342	0.276	0.225	0.174	0.349
V	0.440	0.428	0.420	0.375	0.313	0.252	0.209	0.168	0.326
VI	0.430	0.408	0.371	0.344	0.286	0.244	0.198	0.143	0.303
VII	0.386	0.346	0.307	0.276	0.228	0.180	0.156	0.128	0.251

c. Manure application rate 20 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.416	0.362	0.329	0.277	0.243	0.203	0.174	0.139	0.268
II	0.513	0.468	0.425	0.366	0.307	0.282	0.240	0.177	0.347
III	0.489	0.433	0.379	0.324	0.285	0.262	0.210	0.176	0.320
IV	0.452	0.405	0.364	0.310	0.276	0.244	0.203	0.151	0.301
V	0.424	0.392	0.351	0.284	0.255	0.225	0.184	0.161	0.285
VI	0.380	0.321	0.273	0.243	0.220	0.182	0.170	0.137	0.241
VII	0.359	0.305	0.268	0.217	0.201	0.165	0.119	0.112	0.218

d. Manure application rate 25 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.428	0.388	0.361	0.315	0.281	0.229	0.208	0.198	0.301
II	0.501	0.466	0.435	0.378	0.346	0.317	0.256	0.208	0.343
III	0.489	0.417	0.394	0.336	0.294	0.248	0.228	0.196	0.325
IV	0.407	0.371	0.342	0.292	0.268	0.221	0.196	0.156	0.282
V	0.367	0.359	0.314	0.265	0.231	0.195	0.177	0.152	0.258
VI	0.334	0.304	0.275	0.245	0.204	0.177	0.163	0.136	0.230
VII	0.315	0.287	0.243	0.195	0.166	0.128	0.122	0.107	0.195

APPENDIX III. Infiltration rates of sandy loam soil at 45mm/h rainfall intensity.

a. Without manure.

Day	Infiltration rate (cm/h) during the time interval (minutes)

	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	1.020	0.943	0.880	0.761	0.663	0.613	0.558	0.508	0.743
II	1.022	0.967	0.916	0.813	0.703	0.600	0.545	0.494	0.758
III	0.955	0.912	0.842	0.714	0.613	0.566	0.514	0.497	0.701
IV	0.861	0.770	0.711	0.592	0.519	0.475	0.440	0.418	0.598
V	0.754	0.680	0.620	0.529	0.478	0.446	0.400	0.403	0.539
VI	0.695	0.604	0.568	0.486	0.442	0.418	0.355	0.371	0.492
VII	0.636	0.541	0.478	0.418	0.383	0.350	0.309	0.297	0.426

b. Manure application rate.15 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	1.033	0.974	0.941	0.800	0.660	0.556	0.397	0.301	0.708
II	1.110	0.940	0.991	0.774	0.726	0.612	0.470	0.360	0.748
III	0.957	0.888	0.853	0.699	0.596	0.530	0.380	0.249	0.644
IV	0.893	0.816	0.756	0.591	0.506	0.427	0.343	0.244	0.572
V	0.837	0.760	0.677	0.532	0.413	0.353	0.307	0.209	0.511
VI	0.717	0.653	0.547	0.444	0.360	0.270	0.218	0.184	0.424
VII	0.649	0.525	0.436	0.367	0.278	0.196	0.129	0.106	0.336

c. Manure application rate 20 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.998	0.935	0.900	0.803	0.696	0.574	0.468	0.433	0.726
II	0.992	0.895	0.839	0.751	0.636	0.535	0.466	0.394	0.688
III	0.840	0.755	0.700	0.619	0.551	0.500	0.449	0.377	0.599
IV	0.729	0.686	0.622	0.538	0.448	0.430	0.383	0.321	0.520
V	0.680	0.628	0.589	0.492	0.403	0.373	0.339	0.280	0.473
VI	0.615	0.526	0.505	0.433	0.306	0.295	0.281	0.223	0.398
VII	0.369	0.307	0.292	0.232	0.138	0.111	0.107	0.068	0.203

d. Manure application rate 25 t/ha

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.983	0.927	0.854	0.749	0.620	0.495	0.362	0.226	0.652
II	0.854	0.780	0.661	0.556	0.429	0.314	0.251	0.192	0.505
III	0.800	0.707	0.592	0.467	0.376	0.272	0.205	0.161	0.447
IV	0.711	0.564	0.456	0.360	0.303	0.230	0.192	0.140	0.370
V	0.660	0.516	0.418	0.320	0.244	0.202	0.164	0.154	0.334
VI	0.571	0.453	0.340	0.258	0.209	0.169	0.157	0.118	0.284
VII	0.512	0.394	0.303	0.220	0.167	0.129	0.116	0.110	0.244

APPENDIX IV. Infiltration rates of sandy loam soil at 60mm/h rainfall intensity.

a. Without manure.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	1.670	1.650	1.260	1.020	0.780	0.710	0.641	0.600	1.041

II	2.910	2.544	2.180	1.880	1.500	1.220	0.980	0.800	1.752
III	2.780	2.445	2.050	1.710	1.390	1.010	0.830	0.670	1.611
IV	2.630	2.194	1.930	1.540	1.210	0.850	0.740	0.550	1.456
V	2.410	1.960	1.670	1.380	1.090	0.780	0.630	0.430	1.294
VI	2.150	1.682	1.390	1.120	0.760	0.600	0.400	0.160	1.033
VII	1.940	1.520	1.150	0.890	0.660	0.410	0.290	0.330	0.899

b. Manure application rate 15 t/ha.

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	1.280	1.120	0.880	0.716	0.589	0.455	0.254	0.187	0.685
II	1.900	1.649	1.466	1.165	0.920	0.736	0.593	0.421	1.106
III	1.806	1.560	1.351	1.064	0.818	0.680	0.427	0.341	1.006
IV	1.512	1.344	1.164	0.844	0.705	0.556	0.352	0.261	0.842
V	1.040	0.950	0.800	0.635	0.473	0.360	0.210	0.136	0.676
VI	0.990	0.807	0.686	0.605	0.433	0.341	0.209	0.114	0.523
VII	0.836	0.635	0.474	0.368	0.263	0.207	0.172	0.080	0.379

c. manure application rate 20 t/ha .

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.946	0.805	0.654	0.537	0.486	0.312	0.244	0.207	0.524
II	1.586	1.385	1.207	1.043	0.934	0.800	0.671	0.549	1.022
III	1.489	1.245	1.062	0.903	0.760	0.647	0.494	0.427	0.878
IV	1.373	1.153	0.960	0.812	0.659	0.445	0.354	0.280	0.755
V	1.245	1.056	0.885	0.683	0.549	0.366	0.268	0.220	0.659
VI	0.840	0.620	0.565	0.476	0.416	0.244	0.224	0.214	0.450
VII	0.622	0.525	0.378	0.222	0.139	0.128	0.112	0.073	0.275

d. Manure application rate 25 t/ha.

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	1.164	0.985	0.806	0.699	0.626	0.427	0.343	0.259	0.664
II	1.346	1.270	1.042	0.931	0.774	0.582	0.488	0.351	0.848
III	1.292	1.160	0.926	0.874	0.738	0.554	0.418	0.302	0.783
IV	1.225	1.037	0.873	0.776	0.680	0.490	0.440	0.330	0.731
V	1.063	0.895	0.733	0.627	0.502	0.400	0.313	0.268	0.600
VI	0.940	0.794	0.644	0.497	0.392	0.250	0.257	0.147	0.490
VII	0.856	0.688	0.560	0.406	0.263	0.236	0.211	0.199	0.427

F Value:- Rainfall:6.267 Manure:1.063 Cd Value:0.272

APPENDIX V. infiltration rates of clay loam soil at 30mm/h rainfall intensity.

a. Without manure.

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
II	0.009	0.008	0.007	0.006	0.006	0.005	0.004	0.003	0.006
III	0.016	0.015	0.014	0.013	0.012	0.010	0.008	0.006	0.012
IV	0.015	0.014	0.013	0.012	0.011	0.009	0.007	0.005	0.010

V	0.013	0.013	0.012	0.011	0.010	0.009	0.007	0.005	0.010
VI	0.011	0.010	0.010	0.009	0.008	0.007	0.007	0.005	0.008
VII	0.010	0.010	0.009	0.008	0.007	0.006	0.005	0.005	0.008

b. Manure application rate 15 t/ha

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.024	0.010	0.008	0.005	0.005	0.003	0.002	0.000	0.007
II	0.046	0.031	0.021	0.017	0.012	0.006	0.004	0.003	0.017
III	0.174	0.180	0.174	0.173	0.139	0.121	0.110	0.096	0.145
IV	0.165	0.167	0.144	0.120	0.102	0.091	0.070	0.057	0.115
V	0.153	0.139	0.113	0.087	0.067	0.057	0.054	0.045	0.089
VI	0.135	0.114	0.100	0.080	0.058	0.047	0.051	0.042	0.078
VII	0.123	0.105	0.100	0.075	0.050	0.042	0.040	0.026	0.070

c. Manure application rate 20 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.070	0.043	0.020	0.012	0.010	0.008	0.008	0.007	0.022
II	0.143	0.104	0.076	0.044	0.025	0.019	0.016	0.013	0.055
III	0.380	0.342	0.281	0.232	0.201	0.183	0.168	0.160	0.243
IV	0.357	0.328	0.255	0.197	0.160	0.139	0.110	0.100	0.206
V	0.299	0.276	0.233	0.145	0.113	0.100	0.076	0.058	0.163
VI	0.260	0.219	0.171	0.116	0.097	0.081	0.060	0.043	0.131
VII	0.223	0.170	0.140	0.097	0.081	0.060	0.041	0.035	0.107

d. manure application rate 25 t/ha

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.123	0.070	0.050	0.035	0.027	0.020	0.012	0.012	0.044
II	0.205	0.164	0.124	0.097	0.063	0.056	0.036	0.035	0.098
III	0.404	0.403	0.349	0.281	0.233	0.207	0.179	0.175	0.279
IV	0.377	0.357	0.318	0.266	0.214	0.186	0.158	0.136	0.252
V	0.327	0.332	0.302	0.259	0.202	0.174	0.140	0.122	0.232
VI	0.309	0.302	0.266	0.236	0.183	0.160	0.130	0.108	0.212
VII	0.286	0.253	0.235	0.221	0.162	0.137	0.114	0.073	0.185

Appendix VI. Infiltration rates of clay loam soil at 45mm/h rainfall intensity

a. Without manure.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	Average
I	0.012	0.008	0.009	0.005	0.005	0.005	0.003	0.001	0.006
II	0.052	0.045	0.040	0.033	0.029	0.020	0.017	0.012	0.031
III	0.061	0.050	0.047	0.039	0.032	0.024	0.018	0.011	0.035
IV	0.041	0.034	0.031	0.025	0.023	0.016	0.013	0.010	0.024
V	0.036	0.031	0.027	0.022	0.019	0.013	0.010	0.008	0.021
VI	0.030	0.026	0.023	0.018	0.016	0.011	0.009	0.006	0.017
VII	0.025	0.021	0.018	0.013	0.011	0.009	0.007	0.004	0.014

b. manure application rate 15 t/ha .

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.025	0.023	0.019	0.018	0.012	0.011	0.011	0.006	0.015
II	0.065	0.050	0.040	0.033	0.025	0.022	0.018	0.011	0.033
III	0.126	0.112	0.095	0.087	0.071	0.063	0.054	0.049	0.082
IV	0.115	0.105	0.089	0.082	0.065	0.059	0.046	0.038	0.075
V	0.101	0.092	0.080	0.063	0.051	0.038	0.031	0.021	0.060
VI	0.094	0.079	0.069	0.055	0.047	0.035	0.029	0.019	0.053
VII	0.075	0.065	0.060	0.048	0.040	0.032	0.024	0.016	0.045

c. Manure application rate 20 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.031	0.024	0.021	0.015	0.013	0.010	0.009	0.007	0.016
II	0.064	0.060	0.055	0.041	0.038	0.032	0.031	0.030	0.044
III	0.258	0.233	0.210	0.183	0.165	0.148	0.119	0.096	0.177
IV	0.247	0.219	0.200	0.167	0.148	0.125	0.101	0.086	0.162
V	0.220	0.210	0.193	0.157	0.140	0.112	0.094	0.075	0.150
VI	0.212	0.193	0.162	0.136	0.117	0.086	0.057	0.046	0.126
VII	0.184	0.145	0.120	0.093	0.074	0.052	0.037	0.026	0.091

d. manure application rate 25 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.045	0.034	0.029	0.023	0.021	0.017	0.014	0.011	0.024
II	0.058	0.049	0.042	0.032	0.028	0.021	0.018	0.016	0.033
III	0.170	0.147	0.137	0.122	0.103	0.089	0.079	0.057	0.113
IV	0.151	0.141	0.129	0.114	0.097	0.081	0.067	0.048	0.104
V	0.128	0.124	0.114	0.100	0.083	0.070	0.053	0.043	0.089
VI	0.105	0.102	0.096	0.082	0.061	0.052	0.045	0.042	0.073
VII	0.099	0.095	0.086	0.068	0.052	0.044	0.036	0.031	0.064

Appendix VII. Infiltration rates of clay loam soil at 60mm/h rainfall intensity

a. without manure.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.040	0.032	0.024	0.020	0.017	0.013	0.011	0.007	0.020
II	0.043	0.035	0.030	0.026	0.022	0.017	0.015	0.012	0.025
III	0.073	0.067	0.061	0.054	0.047	0.038	0.032	0.029	0.050
IV	0.071	0.063	0.058	0.048	0.042	0.031	0.029	0.026	0.046
V	0.070	0.059	0.052	0.042	0.032	0.026	0.022	0.020	0.040
VI	0.069	0.056	0.049	0.035	0.029	0.023	0.019	0.018	0.037
VII	0.057	0.049	0.037	0.031	0.026	0.020	0.019	0.013	0.032

b. Manure application rate 15 t/ha.

Day	Infiltration rate (cm/h) during the time interval (minutes)								
	0-30	**30-60**	**60-90**	**90-120**	**120-**	**150-**	**180-**	**210-**	**Average**

					150	180	210	240	
I	0.055	0.044	0.038	0.032	0.027	0.020	0.017	0.016	0.031
II	0.109	0.093	0.087	0.075	0.068	0.054	0.046	0.040	0.071
III	0.101	0.082	0.078	0.063	0.058	0.044	0.034	0.032	0.062
IV	0.080	0.065	0.056	0.046	0.042	0.032	0.024	0.023	0.046
V	0.062	0.054	0.046	0.042	0.036	0.027	0.022	0.021	0.039
VI	0.049	0.040	0.034	0.026	0.022	0.018	0.014	0.012	0.027
VII	0.034	0.029	0.025	0.021	0.017	0.012	0.009	0.006	0.019

c. Manure application rate 20 t/ha.

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.179	0.162	0.151	0.127	0.110	0.091	0.083	0.073	0.122
II	0.152	0.148	0.116	0.098	0.083	0.073	0.054	0.044	0.096
III	0.132	0.112	0.096	0.075	0.066	0.047	0.040	0.031	0.075
IV	0.112	0.093	0.089	0.068	0.056	0.041	0.029	0.036	0.066
V	0.091	0.079	0.064	0.055	0.046	0.037	0.031	0.026	0.054
VI	0.070	0.055	0.046	0.035	0.035	0.027	0.023	0.021	0.039
VII	0.049	0.040	0.035	0.027	0.021	0.016	0.011	0.010	0.026

d. Manure application rate 25 t/ha.

Day	**Infiltration rate (cm/h) during the time interval (minutes)**								
	0-30	**30-60**	**60-90**	**90-120**	**120-150**	**150-180**	**180-210**	**210-240**	**Average**
I	0.183	0.142	0.111	0.078	0.058	0.041	0.029	0.022	0.083
II	0.126	0.093	0.068	0.049	0.033	0.025	0.016	0.007	0.052
III	0.298	0.271	0.222	0.190	0.171	0.131	0.111	0.090	0.185
IV	0.269	0.249	0.213	0.174	0.165	0.119	0.100	0.079	0.171
V	0.225	0.208	0.190	0.153	0.128	0.102	0.083	0.061	0.144
VI	0.208	0.192	0.165	0.128	0.106	0.085	0.075	0.068	0.129
VII	0.196	0.172	0.143	0.124	0.091	0.061	0.058	0.058	0.113

F value:- Rainfall: 0.544 Manure:0.233 Cd Value:0.065

Appendix VIII. Runoff depth (cm) at 30 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.089	1.099	1.178	1.244
II	0.100	0.577	0.861	0.917
III	0.119	0.733	0.971	1.001
IV	0.253	0.853	1.048	1.123
V	0.347	0.948	1.112	1.220
VI	0.514	1.038	1.287	1.331
VII	0.672	1.247	1.377	1.469

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	1.497	1.473	1.412	1.326
II	1.477	1.431	1.281	1.111
III	1.185	0.918	0.528	0.385
IV	1.458	1.042	0.678	0.495
V	1.577	1.143	0.851	0.572
VI	1.698	1.187	0.977	0.653
VII	1.748	1.220	1.073	0.761

Appendix IX. Runoff depth (cm) at 45 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	1.081	1.224	1.296	1.394
II	1.024	1.017	1.301	2.014
III	1.248	1.479	1.659	2.252
IV	1.662	1.766	1.976	2.576
V	1.899	2.011	2.162	2.742
VI	2.085	2.358	2.462	2.917
VII	2.349	2.712	3.012	3.094

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	3.819	3.780	3.745	3.698
II	3.747	3.721	3.630	3.537
III	3.702	3.514	3.391	3.259
IV	3.747	3.543	3.428	3.263
V	3.760	3.604	3.486	3.277
VI	3.773	3.628	3.550	3.338
VII	3.788	3.662	3.587	3.477

Appendix X. Runoff depth (cm) at 60 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	3.076	4.413	5.253	5.531
II	3.121	4.544	6.366	6.852
III	4.790	6.547	7.319	8.782
IV	5.630	7.173	7.584	8.872
V	6.284	7.366	8.856	10.485
VI	6.593	7.641	9.280	10.944
VII	6.765	7.659	10.277	12.152

Fvalue:- Rainfall:55.76
Manure:0.017
Cd Value: 1.565

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	6.430	6.388	6.024	5.957
II	6.412	6.272	6.128	6.069
III	6.312	6.265	6.213	6.046
IV	6.328	6.306	6.250	6.088
V	6.350	6.332	6.298	6.151
VI	6.363	6.336	6.317	6.195
VII	6.386	6.370	6.346	6.248

F Value: Rainfall:25.79
Manure: 0.13
Cd Value: 2.34

Appendix XI.Percentage of total solids in the runoff matter at 30 mm/h rainfall intensity.

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.291	0.314	0.297	0.351
II	0.192	0.302	0.286	0.349
III	0.221	0.249	0.290	0.450
IV	0.277	0.295	0.314	0.479
V	0.203	0.332	0.201	0.501
VI	0.144	0.245	0.304	0.495
VII	0.163	0.246	0.263	0.482

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.287	0.297	0.288	0.343
II	0.186	0.293	0.284	0.341
III	0.220	0.245	0.282	0.436
IV	0.271	0.294	0.298	0.469
V	0.199	0.319	0.196	0.492
VI	0.134	0.241	0.286	0.476
VII	0.154	0.236	0.243	0.497

Appendix XII. Percentage of total solids in the runoff soil at 45 mm/h rainfall intensity.

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.313	0.321	0.371	0.343
II	0.296	0.323	0.372	0.497
III	0.297	0.318	0.311	0.489
IV	0.289	0.323	0.305	0.475
V	0.256	0.299	0.280	0.492
VI	0.323	0.296	0.297	0.461
VII	0.292	0.295	0.290	0.525

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.301	0.304	0.366	0.335
II	0.291	0.310	0.362	0.467
III	0.287	0.314	0.305	0.475
IV	0.295	0.306	0.292	0.462
V	0.247	0.287	0.283	0.486
VI	0.314	0.289	0.294	0.454
VII	0.287	0.288	0.285	0.498

Appendix XIII.Percentage of total solids in the runoff matter at 60 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.328	0.402	0.407	0.509
II	0.348	0.385	0.385	0.508
III	0.331	0.359	0.389	0.490
IV	0.326	0.398	0.416	0.521
V	0.317	0.331	0.388	0.478
VI	0.318	0.375	0.394	0.472
VII	0.309	0.324	0.412	0.504

F Value:- Rainfall:1.192
Manure:8.592
Cd Value: 0.038

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.323	0.394	0.423	0.499
II	0.350	0.373	0.379	0.498
III	0.333	0.353	0.382	0.480
IV	0.314	0.384	0.391	0.498
V	0.310	0.314	0.376	0.474
VI	0.313	0.365	0.386	0.457
VII	0.298	0.321	0.391	0.497

F Value:- Rainfall:1.234
Manure:8.189
Cd Value: 0.039

Appendix XIV. Percentage of organic matter content in the runoff water at 30 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.000	0.000	0.000	0.018
II	0.009	0.000	0.018	0.047
III	0.006	0.041	0.044	0.043
IV	0.012	0.025	0.043	0.035
V	0.021	0.026	0.040	0.046
VI	0.017	0.028	0.044	0.043
VII	0.011	0.036	0.039	0.046

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.0000	0.0000	0.0000	0.0176
II	0.0088	0.0000	0.0179	0.0469
III	0.0064	0.0413	0.0435	0.0427
IV	0.0117	0.0245	0.0429	0.0349
V	0.0205	0.0264	0.0400	0.0459
VI	0.0171	0.0275	0.0437	0.0427
VII	0.0109	0.0363	0.0392	0.0456

Appendix XIV. Percentage of organic matter content in the runoff water at 30 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.010	0.017	0.025	0.026
II	0.009	0.019	0.024	0.024
III	0.002	0.009	0.024	0.029
IV	0.009	0.027	0.032	0.032
V	0.005	0.027	0.034	0.034
VI	0.009	0.023	0.032	0.035
VII	0.008	0.018	0.032	0.031

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.0096	0.0173	0.0245	0.0264
II	0.0093	0.0187	0.0237	0.0235
III	0.0019	0.0093	0.0235	0.0285
IV	0.0091	0.0272	0.0317	0.0323
V	0.0048	0.0267	0.0341	0.0344
VI	0.0085	0.0232	0.0323	0.0352
VII	0.0077	0.0176	0.0317	0.0309

Appendix XIV. Percentage of organic matter content in the runoff water at 30 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.000	0.000	0.000	0.000
II	0.002	0.010	0.000	0.014
III	0.003	0.022	0.047	0.048
IV	0.004	0.005	0.028	0.036
V	0.005	0.004	0.017	0.038
VI	0.001	0.004	0.025	0.045
VII	0.004	0.004	0.027	0.017

F Value:- Rainfall: 1.010
Manure:9.896
Cd Value: 0.005

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	**15**	**20**	**25**
I	0.0000	0.0000	0.0000	0.0000

II	0.0016	0.0099	0.0000	0.0144
III	0.0032	0.0221	0.0467	0.0477
IV	0.0040	0.0048	0.0275	0.0357
V	0.0045	0.0035	0.0165	0.0379
VI	0.0008	0.0037	0.0245	0.0451
VII	0.0035	0.0043	0.0272	0.0171

F Value:- Rainfall: 2.375
Manure: 0.313
Cd Value: 0.005

Appendix XVII.Total nitrogen content (ppm) of runoff water at 30 mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	0.000	0.000	0.000	0.000
II	0.000	0.000	0.000	0.000
III	0.249	0.342	0.311	0.140
IV	0.280	0.280	0.327	0.420
V	0.265	0.311	0.327	0.451
VI	0.187	0.327	0.405	0.389
VII	0.249	0.311	0.389	0.467

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	0.000	0.000	0.000	0.000
II	0.000	0.000	0.000	0.000
III	0.234	0.202	0.000	0.436
IV	0.156	0.234	0.249	0.296
V	0.156	0.187	0.265	0.311
VI	0.140	0.140	0.156	0.156
VII	0.093	0.125	0.234	0.234

Appendix XVIII.Total nitrogen content (ppm) of runoff water at 30mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	0.467	1.059	1.385	1.385
II	1.059	1.059	1.012	1.370
III	0.747	0.841	0.856	1.899
IV	0.701	0.794	1.230	1.821
V	0.809	1.027	1.152	1.432
VI	0.794	0.903	1.261	1.494
VII	0.498	1.043	0.950	1.292

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	0.436	0.560	0.0685	0.996
II	0.436	0.451	0.732	1.199
III	0.405	0.467	0.420	0.716
IV	0.140	0.311	0.420	0.436
V	0.234	0.280	0.296	0.560
VI	0.171	0.187	0.280	0.451
VII	0.093	0.156	0.265	0.405

Appendix XIX.Total nitrogen content (ppm) of runoff water at 30mm/h rainfall intensity

Sandy Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	1.417	1.526	1.775	2.070
II	1.417	1.370	1.417	1.868
III	1.401	1.323	1.541	1.899
IV	1.961	1.977	2.257	2.086
V	0.965	1.276	1.183	1.572
VI	0.716	0.794	1.027	0.996
VII	0.701	0.903	0.887	1.635

F Value:- Rainfall:27.66
Manure:0.29
Cd Value: 0.306

Clay Loam

Day	Manure Application Rate (t/ha)			
	Control	15	20	25
I	1.199	1.214	1.401	1.479
II	0.825	1.276	1.323	1.510
III	0.809	0.965	1.090	1.276
IV	0.654	0.623	0.856	0.965
V	0.405	0.669	0.794	0.872
VI	0.389	0.685	0.685	0.950
VII	0.327	0.498	0.778	0.856

F Value:- Rainfall: 23.83
Manure: 0.35
Cd Value:0.19

Appendix XX. Bulk density values at different profile levels for sandy loam soil at different rainfall intensity and manure application rate

Profiles	30 mm/h rainfall intensity				45 mm/h rainfall intensity				60 mm/h rainfall intensity			
	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha
A	1.362	1.313	1.283	1.115	1.715	1.678	1.519	1.683	1.821	1.723	1.710	1.693
B	1.525	1.215	1.038	1.125	1.558	1.510	1.430	1.439	1.612	1.535	1.610	1.532
C	1.683	1.723	1.661	1.655	1.678	1.723	1.615	1.591	1.814	1.712	1.680	1.673

Appendix XXI. Bulk density values at different profile levels for clay loam soil at different rainfall intensity and manure application rate

Profiles	30 mm/h rainfall intensity				45 mm/h rainfall intensity				60 mm/h rainfall intensity			
	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha	Without manure	Manure @ 15 t/ha	Manure @ 20 t/ha	Manure @ 25 t/ha
A	1.601	1.498	1.49	1.444	1.595	1.602	1.59	1.589	1.865	1.723	1.714	1.697
B	1.776	1.75	1.68	1.621	1.786	1.702	1.6	1.611	1.912	1.832	1.645	1.544
C	1.968	1.873	1.91	1.908	1.923	1.999	1.824	1.721	2.084	1.822	1.71	1.617

EFFECT OF SEAL FORMATION
DUE TO CATTLE MANURE APPLICATION
ON INFILTRATION AND RUNOFF

By

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ABSTRACT OF THESIS

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Abstract

The application of soil amendment is one of the major management practices in farming operations. Nowadays, the importance of manure application as a soil amendment is increasing due to the increased concern for the ecology and environment its abundance in availability and low cost. The manures are rich in organic matter content and other nutrients. It changes the physical properties of the soil. But the excess application of organic manure may lead to detrimental results due to the surface seal formation. Hence, the present study attempts to assess the effect of seal formation due to cattle manure application on infiltration and runoff.In the coarse textured soils, like sandy loam soil the infiltration rate will be reduced and runoff will be increased. But in the fine textured soils, like clay loam soil, the infiltration rate will be increased and runoff will be reduced. The contents of the nutrients like nitrogen, organic matter and total solids in the runoff water and the physical properties like bulk density will increase with the increase in manure application and rainfall intensity. Hence it was concluded that, while applying manure on the field, the rate of application of the manure can be determined only after determining the soil texture and rainfall intensity. Otherwise, the manure application will be results in pollution of nearby water bodies.