EVALUATION OF RUNOFF AND SOIL LOSS IN PLOTS UNDER DIFFERENT PLANT DENSITIES OF AMARANTHUS

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CERTIFICATION

This is to certify that this work was carried out by Mr DAODU, Ajayi John (AGE/86/710) in the Department of Agricultural Engineering, Federal University of Technology, Akure, in partial fulfillment of the requirements for the award of Master of Engineering (M.Eng.), in the Department of Agricultural Engineering of the Federal University of Technology, Akure

It has not been submitted elsewhere for the award of any other Degree or Diploma

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DEDICATION

This work is dedicated to the Glory of God, to my late father Mr Momoh Andrew Daodu, my mother, Mrs. Olupele Comfort Daodu and to my future progress in Agricultural Engineering profession.

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ABSTRACT

This study was conducted to evaluate runoff and sediment yield as affected by different plant densities of Amaranthus at the Agricultural Engineering Experimental Farm, Federal University of Technology, Akure.

Treatments were based on four plant densities: A (97 plants/m^2), B (42 plants/m^2) C (125 plants/m^2), D (69 plants/m^2). Runoff depths and sediment yields were measured during the months of August to November, 1999. A complete randomised block design was used to evaluate treatment methods on the basis of sediment yield and runoff depth. A Rainfall-Runoff model was established to enable future occurrence to be predicted. The water balance equation was used to compute the evapotranspiration (ET) for each plot.

There were significant differences in sediment yields and runoff depths among the treatments at 5% level of significance. Treatments A (97 plants/m^2) and C (125 plants/m^2) were found to have the least amount of runoff and sediment yield, while treatments B (42 plants/m^2) and D (69 plants/m^2) had the highest amount of runoff and sediment yield.

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CHAPTER ONE

1.0 INTRODUCTION

Runoff of a catchment is the total quantity of water draining into a stream or into a reservoir at any point in time. It can also be stated that runoff is the excess of rainfall.

Runoff will occur when Infiltration, Evaporatranspiration (ET), and other parameters such as depression storage and surface inflow have been satisfied during precipitation.

This can be related by the water balance equation (Hillel, 1980).

$$P = ET + R + D \pm \Delta S + \text{Rin} \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

$$ET = P - R - D \pm \Delta S - \text{Rin} \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

where

P = Precipitation (mm)
ET = Evapotranspiration (mm/day)
R = Runoff (mm)
D = Drainage (mm)
ΔS = Change in water storage
Rin = Surface inflow

For this study, drainage and surface inflow are assumed to be negligible.

Equation (2) then reduces to:

$$ET = P - R + \Delta S \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

Information on Runoff and Evapotranspiration [equation (3) is needed to be able to know the water-use-efficiency (WUE) and water-use-patterns (WUP) of crops in order to develop appropriate packages of agronomy practices, in particular, amaranthus cropping system.

Surface runoff plays a critical role in determining the rate of soil loss from agricultural lands. This is especially the case during large events with high stream power (Watson and Laflen, 1986).

Runoff is a major factor causing land degradation and environmental quality deterioration. It is often triggered and accelerated by inappropriate land use and poor management.

To effectively control soil erosion and wisely manage land resources, erosion mechanisms must be well understood and the effectiveness of management practices must be assessed. Erosion rainfall -runoff prediction models offer a powerful way to make informed land management decisions. Thus, development of up-to-date prediction technology is of great importance in preserving land productivity.

The major variables affecting runoff are:- climate, vegetation, and topography. Out of these, vegetation, and to some extent, soil factors may be controlled. The climatic factors and topographic factors except slope length are beyond the power of man to control (Lal and Greenland, 1979). Hence, for a given geographic region with its characteristic climate and land form, erosion control may be achieved by manipulating vegetation and soil factors. Thus, a study needs to be conducted so as to create awareness in the minds of people why a particular planting pattern/densities needs to be adopted for a particular soil.

1.1 OBJECTIVES

The objectives of this study were:

(1) To compare runoff under different plant densities of amaranthus.

(2) Determination of soil loss in relation to precipitation at different plant densities.

(3) To model the incidence of runoff under Amaranthus cropping system.

1.2 JUSTIFICATION OF THE STUDY

Most farmlands were cultivated by farmers without knowing the extent of damage caused yearly by runoff. Information on surface runoff volume /depth is needed for several purposes:

In soil and water management, it is needed in the design of soil conservation structures and for studying and planning supplemental irrigation facilities.

In the tropics, there exist few runoff records which cover sufficient duration of the rainy season to enable accurate assessment of runoff characteristics of the watersheds. On the other hand daily rainfall records that are representative of watersheds are usually available or can be estimated from near by raingauges. Therefore, models that are capable of utilising these rainfall records to simulate runoff will be of great utility.

CHAPTER TWO

2.0 LITERATURE REVIEW

Many studies have been conducted to examine erosion and sedimentation from agricultural lands. Globally, nearly two billion hectares or about 13% of the earth's land surface suffered some types of human-induced land degradation (Oldeman et al, 1991). Water erosion has been the main cause of this land degradation. Effective methods to control erosion from farm plots would therefore directly influence planting pattern.

Runoff and rainfall of an area are influenced by the following factors:

- Precipitation characteristics
- Shape and size of catchment
- Geological characteristics
- Meteorological characteristics
- Storage characteristics.

Aneke (1982), reported that for a given catchment the topography (slope), vegetative cover and rainfall form the major factors in runoff and sediment yield. Erosion has been divided into interrill, rill and gully components. Interrill erosion consists of soil particle detachment by raindrop impact and particle transport by splash and shallow overland flow.

Splash detachment and transport are major components of interrill erosion, but have not always been separated from overland flow transport in interrill erosion research (Grosh and Jarrett, 1994). Splash detachment is considered to be the primary factors in soil availability for interrill flow transport, thus, it is impossible to consider runoff and soil loss without detachment.

Interrill erosion research has been conducted on small plots to measure soil loss in runoff and on splash cups and boxes to measure splash detachment and transport (Grosh & Jarrett, 1994). Both soil - loss and runoff transport were considered in this present study.

2.2 DAMAGE DONE BY EROSION

There are many ways in which water erosion causes damage. Soil is lost, plant nutrients are leached, texture is changed, structure deteriorates, productive capacity is reduced and fields are isolated. The sediments produced pollute streams and lakes and pile up on bottom land in stream channels and reservoirs (Frederick et al, 1980).

2.2.1 SOIL LOSS

The most apparent damage caused by water erosion is the removal of soil from the eroding surfaces. Grant (1975) reported that erosion from land covered with perennial vegetation amounts to only a fraction of a ton per hectare annually, that from bare cultivated fields may exceed 450 metric tons a year. At this rate it would take only forty five years (45years) to wash away about 17cm deep furrow slice if the loss were uniform over the land.

For soil conservation planning and erosion impact evaluation, the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and more recently, RUSLE (Revised Universal Soil Loss Equation) (Renard et al, 1997) have been widely used to predict long term average soil loss from agricultural lands. In recent years, process-based erosion models such as WEPP (Water Erosion Prediction Project) (Nearing and Lane, 1995), and GUEST (Griffith University Erosion System Template) (Misra and Rose, 1996) were developed for soil loss predictions.

Misra and Rose (1996), reported that sediment concentration is related to the stream power which in turn depends on the runoff rate. For a storm event the flow - weighted average sediment concentration is related to an effective runoff rate q_e (Rose, 1994), defined as

$$q_e = \left(\frac{\Sigma\, qi^{1.4}}{\Sigma qi} \right)^{2.5} \qquad \text{.. (4)}$$

where q_i is the runoff rate for the time interval i and the summation applies for the duration of the runoff event. The product of runoff depth and the average sediment concentration will then give the amount of soil loss per unit area for the event. Both the peak runoff rate and the effective runoff rate in the physically-based models can be an equivalent steady- state runoff rate for soil erosion prediction purposes (Yu et al, 1998).

2.2.2 SEDIMENT CONTINUITY EQUATION

The WEPP erosion model computes estimates of net detachment and deposition using a steady state sediment continuity equation (Nearing et al, 1989). Which is

$$^{d_G}/_{d_x} = D_f + D_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where

$X(m)$ = distance down slope

$G(kgS^{-1}\,m^{-1})$= Sediment load

$D_i\,(KgS^{-1}\,m^{-2})$ = Interill erosion rate

$D_f\,(KgS^{-1}\,m^{-2})$ = rill erosion rate

Interill erosion D_i is considered to be independent of X_L. Rill erosion, D_L is positive for detachment and negative for deposition for purpose of calculation, both D_f and D_i are computed on a per rill area basis, thus, G is solved on a per rill width basis (Nearing et al. 1989).

2.2.3 SEDIMENT TRANSPORT CAPACITY

Nearing et al. (1989) reported that sediment transport capacity, as well as sediment load, is calculated on a unit channel width basis within the erosion component. Sediment yield load is converted to a unit field width basis when the calculations are completed. The transport capacity, Tc as a function of X is calculated using a simplified transport equation of the form

$$T_c = K_t \tau_f^{3/2} \quad \text{..................................(6)}$$

where τ_f is the hydraulic shear acting on the soil, and K_t is a transport coefficient

2.3 RUNOFF

For a given runoff plot, water balance for time interval can be written as (Yu et. al. 1998).

$$q_1 = r_1 - f_1 - e_1 - \frac{\Delta S_i}{\Delta t} \quad \text{..(7)}$$

where

r_i, f_i and e_i are average rainfall, infiltration and evaporation rates for the time interval, respectively q_i is the average runoff rate at the plot exit, Δ_{si} is the change in storage during the time interval Δt. Evaporation is negligible during a runoff event. The storage term can be ignored in the equation when the interval is large relative to the hydrologic lag of the plot. As data are accumulated at large time intervals the storage effect decreases and the difference between rainfall intensity and actual infiltration rate becomes an increasingly accurate estimate of the runoff rate at the plot outlet.

Under these simplified conditions runoff rate estimation can be reduced to determining actual rate of infiltration for the plot, fi in mm/h for each time interval of the event, so that the runoff rate at the plot scale can be estimated by (Yu et al, 1998).

$$q_i = r_i - f_i \tag{8}$$

where

r_i is the rainfall rate in mm/h. The unknown rate of infiltration is subjected to the following two constraints:

$$\sum_{i=1}^{n}(r_i - f_i)\,\Delta t = Qt \tag{9}$$

$$\text{and} \quad f_i < r_i \tag{10}$$

where Qt is the total runoff depth in mm for the event. Δt in hours is the time interval at which rainfall rate is measured.

Runoff is a process where there is a flow of water over the surface with

$$R_{off} = P - SS_D - I \tag{11}$$

where R off is the runoff, SSD is the surface storage and detention and I is the infiltration. Three parameters are involved:

- Rainfall reaching the soil surface
- Infiltration of water into the soil profile
- The static and dynamic storage capacity of the soil surface depending on slope and roughness/configuration of the surface (Hoogmoed et. al., 1991). These three parameters are dynamic and not independent of each other; for example, surface roughness and infiltration capacity may both decrease under rainfall.

The ability to estimate runoff rates when rainfall rates and total runoff amount are known would facilitate wide - spread application of process-based soil erosion models (Yu et. al., 1998).

It is the purpose of this project to model the incidence of runoff when rainfall amount and runoff amount are known under a cropping system for use in future erosion prediction.

2.4 AGENTS ACTIVE IN WATER EROSION

Two major agents are active in water erosion; falling raindrops and running water. Both of these derive the energy needed to detach and transport soil grains from the force of gravity (Fredrick et. al., 1980). This type of movement, while spectacular and important when it occurs in the aggregate, is less important than the direct movement of soil by runoff.

2.4.1 ENERGY OF FALLING RAINDROPS

The kinetic energy of a falling body can be calculated from the equation

$$E = 2\,MV^2 \qquad \text{.......................................(12)}$$

where

E = Kinetic energy of the raindrop

M = Mass of falling drop

V = Velocity of falling drop

Air friction slows down the fall of water drops and prevents each drop from exceeding a terminal velocity that is related to its mass (Laws, 1941).

2.5 RAINSTORM INTENSITY AND ENERGY

Laws and Parsons (1943) found that natural rain contains a range of drop diameters from less than 0.25 mm to 7 mm. In general, drop size increases as storm intensity increases up to 150 mm/h but a range of sizes is present in each storm.

Hudson (1971) and McGregor and Muthcler (1996) corroborate the increase in drop size for low and intermediate intensity storms, but show that above about 75 mm/h the median drop diameter decreases with increasing intensity.

Wischmeier and Smith (1958) used Laws and Parsons data to develop an equation for predicting rainstorm energy

$$e = 11.89 + 87.3 \log_{10} I \qquad \text{.........................} (13)$$

where

e = Total energy in units of 10^3J/ha for each millimeter of rainfall

I = rainfall intensity (mm/hr)

2.6 VEGETATION AND RAINDROP ENERGY

The amount of rainfall or precipitation reaching the ground surface is dependent upon the nature and density of vegetation and ground cover. All raindrops do not strike the soil at terminal velocity and so do not always release maximum energy. Shaw (1959) showed that a given corn crop intercepts and holds 3 to 5 mm total rainfall from a storm that exceeds 7.5 mm total rainfall.

This water never reaches the ground to beat the soil and cause erosion. Many drops that strike plants eventually reach the ground but the short fall from the canopy reduces their velocity and energy level. Other drops strike vegetation and break into smaller drops that continue falling, but with reduced energy. The importance of vegetative cover in intercepting raindrops was first reported by (Baver and Wollny, 1939).

The greatest deterrent to soil erosion is plant cover. Crop cover influences both infiltration rate and susceptibility of soil to erosion. The most effective cover is a well managed sod.

Fields easily eroded are those in poorly managed cultivated crops. The severest erosion occurs when erosive rainstorms coincide with periods of cultivation when the soil is essentially bare. Vegetation and land use influence erodibility by influencing one or more of the following soil parameters: (i) Organic matter content (ii) Permeability (iii) Infiltration (iv) Water stable aggregate (Lai and Greenland, 1979).

Savabi and Stott (1994) showed that total soil and water loss from agricultural areas can be reduced significantly by interplanting legumes between corn rows. Plant cover offers potential for erosion control in conservation tillage system (McGregor et. al., 1999).

Dabney et al (1996), in their studies with the use of grass hedges to control erosion, described grass hedges as narrow strips of strive erect dense grass planted close to the contour. They noted that coarse hedges forming grasses can withstand concentrated flows that would bend and overlap finer vegetation. Dabney et. al. (1995) conducted flume experiments using several combinations of four stiff-grass species, four types of sediment and eight flow rates ranging from 0.33 to 2.33m^2 (m.n.m)-1 sediment trapping was caused by deposition in the back water upstream of the grass rather than by filtration in the grass.

Establishment of plant and litter cover was found to be the most important deterrent to surface erosion (Berglund, 1976). Effectiveness of grass -legumes mixtures and mulch application in control depended on fast initial vegetation growth and cover (Grace et al, 1998). The effect of surface cover types, their combinations, and percent ground coverage on soil loss were studied by Benkobi et. al., (1993) with a rotating boom rainfall simulator. They found that a combination of rock cover and vegetation litter may offer effective erosion control.

Grace et al, (1998) in their studies on the evaluation of erosion control techniques on forest roads, reported that erosion material and exotic grass had a greater amount of vegetation cover as opposed to mulch cover. This would result in greater interception, decreased raindrop energy and decreased runoff due to increased canopy in the erosion material and exotic grass treatment. Erosion control can be achieved by interception of rainfall, increasing resistance to detachment, or reducing the transport capacity of the runoff.

2.7 METHOD USED FOR MEASURING RUNOFF/SOIL LOSS

Runoff can be measured by delineating a certain area of a field and collecting and measuring the volume of water passing the down slope border of that area. The main differences in methods of measuring runoff are a matter of scales, the collecting area is the main determinant for the type of information and for the required methodology. Hoogmoed et.al. (1991), in their studies, reported that, runoff collecting areas in agricultural research may range from complete watersheds down to area of less than $1m^2$. In this case the information relates not only to soils but also to surface shape and roughness and vegetation cover. Runoff collected from small areas provides more information on the soils and their behavoiur under rainfall. Basically, three classes of plot sizes may be distinguished small plots, USLE (Wischmeier plots) and watershed-type plots.

2.7.1 SMALL PLOTS

These plots usually ($1 - 2m^2$) are used commonly in combination with rainfall simulators but can also be used under natural rainfall (Hoogmoed et al, 1991). The processes studied are those that are directly tied to the effects of rainfall like sealing or aggregate break down and not to process induced by water flowing over the surface. These are cheaper, all runoff water and sediment can be collected but border or edge - effects may be serious. Since variability on the fields will have a much bigger influences the choice of locations is more critical and more replication may be needed.

2.7.2 WISCHMEIER OR USLE PLOTS

The size of these plots is large enough to permit study of the combined processes of rainfall, runoff and erosion standard plots are 1.8m wide and 22m long. Such plots cover 0.04 ha and have the dimensions most commonly encountered. Wischmeier and Smith (1978) in the work leading to the formulation of the Universal Soil Loss Equation (USLE).

The runoff volume can be measured using large vessels (200 litres) (In this study 15 litres container was used) installed in a hole in the ground (Hoogmoed et al, 1991). Continuous registration of runoff can take place using any type of discharge measurement method. Care must be taken that silt and debris coming off the plots do not interfere with the measurement of the runoff.

Though construction of such plots is not all that expensive their operation can be rather time consuming. Also very sizeable areas are required. The fact that the plot is cut off from the (up slope) area may influence the representation of the measurement.

2.7.3 WATERSHED-SIZE PLOTS

These plots may comprise agricultural fields plus natural drainage ways. The field area or natural vegetation or a combination of both preferable, the area should be under only one type of cover or treatment. The size and shape of watershed permit the evaluation of conservation measures on a larger than field scale. The major disadvantage is that the results obtained form these plots cannot easily be reproduced.

2.7.4 UNBOUNDED RUNOFF PLOTS

These are recent developments in overland flow measurement (Hoogmoed et al, 1991). Runoff collection troughs are installed in a cascade system in such a way that surface inflow to one unbounded plot may be considered to be the same as runoff into the adjacent.

Differences between surface inflow and runoff for a plot bounded only at its lower end can thus, be calculated. The problem of bounding a plot at its upper end and along its sides is limited. Unlike conventional runoff plots, tillage farm operations along the contour are not restricted in unbounded plots. In all other respects an unbounded runoff plot is much like a conventional runoff plot.

2.8 AGRONOMIC CHARACTERISTICS OF AMARANTHUS

Amaranthus caudautus are used frequently in the tropics as boiled vegetables. They are often added to soups and stews and have high nutritional value. They grow rapidly and may be harvested within a few weeks of planting.

Amaranthus are short-lived annuals growing and are sometimes grooved. Leaves are variable in shape green or purple and normally alternate (Rice et. al., 1994).

Rainfall both the total annual amount and the monthly distribution should be considered carefully in selecting the site for Amaranthus. Many crops are sensitive to excessive water in the root zone and the rainfall pattern is therefore, likely to determine the range of crops which can be grown (Rice et al, 1994). Some Amaranthus are damaged by heavy rainfall and a site which is exposed to periods of prolonged wet weather may not be suitable for these crops.

2.9 MODELING

The WEPP model is divided into six conceptual components: climate generation, plant growth and residue decomposition (Savabi and Stott, 1994). The hydrologic component include simulation of storm runoff, snow melt ,soil water evaporation, plant transpiration, percolation, irrigation, surface drainage and subsurface flow (Savabi et al, 1989)

Surface runoff is calculated as the difference between rainfall and infiltration. The infiltration equation used in the WEPP model is a solution of the single layer Green and Ampt (1911) equation for unsteady rainfall as presented by Chu (1978)

$$F_t = K_s\left[1+\frac{Ns}{F}\right] \quad \text{................................(14)}$$

where:

f = Infiltration rate (mm/h)

Ks = Saturated hydraulic conductivity (mm/h)

T = Time

Ns = Effective matric potential (mm)

F = Cumulative infiltration depth (mm)

The effective matric potential Ns is given by $Ns = \psi\,(1-Se)Ne$ ....(15)

where:

Ne = Effective porosity of 0 to 20 cm of soil (mm/mm)

Se = Initial effective saturation of 0to 20cm of soil (mm/mm)

ψ = The average wetting front capillary potential (mm).

The relationship between rainfall depth and runoff depth for different plant densities can be expressed by the equation,

$$Y = a_0 + b_i X \qquad \text{..........................(16)}$$

where:

Y = runoff depth (mm)

X = rainfall depth (mm)

a and b are the best-fit coefficients

a_0 is the intercept of the line on the runoff axis.

b_i is the gradient of the line.

2.10 WATER BALANCE

An accurate estimate of soil water balance is essential for any watershed modeling effort (Savabi and Stott, 1994). To model the soil water balance accurately all factors affecting soil water need to be considered.

$$ET = P + I \pm R \pm D \pm \Delta S \qquad \text{..........................(17)}$$

where:

ET = Evapotranspiration

P = Precipitation

I = Infiltration

R = runoff

D = Depression storage

ΔS = Change in depth of water stored.

In this study, parameters like inflow, infiltration and depression storage are considered to be negligible. Equation (17) then becomes.

$$ET = P - R \pm \Delta S \tag{18}$$

The moisture content was computed on volume basis using the equation below

$$Mc(vol) = Mc \times B.D \tag{19}$$

where,

$Mc(vol)$ = Moisture content on volume basis

Mc = Moisture content as percentage.

$B.D$ = Bulky density of the soil.

$$\text{Depth of water stored} = Mc(vol)Dw \tag{20}$$

Dw = Depth of water in the soil.

CHAPTER THREE

3.0 METHODOLOGY AND MATERIALS

3.1 STUDY SITE

The experiment was conducted at the Agricultural Engineering Experimental Farm of the Federal University of Technology, Akure. The annual rainfall in Akure ranges between 1000 mm to 1500 mm.

The soil at the experimental farm was a combination of sandy- clayey-loamy soils. The surface layer was of silt loam over a red clay loam subsoil. The infiltration rate ranges from 9.60 cm/hr to 24.0 cm/hr. The average slope of the land was 7.6% (Malumi, 1997).

3.2 EXPERIMENTAL DESIGN

The experimental design was a complete randomized block design. There were four treatments A, B, C, and D, based on plant densities: 125 plants/m^2, 97 plants/m^2, 69 plants/m^2, and 42 plants/m^2. There were three replicates. A total of 12 plots were established, each of size 1.2 m x 1.2 m (Fig.1).

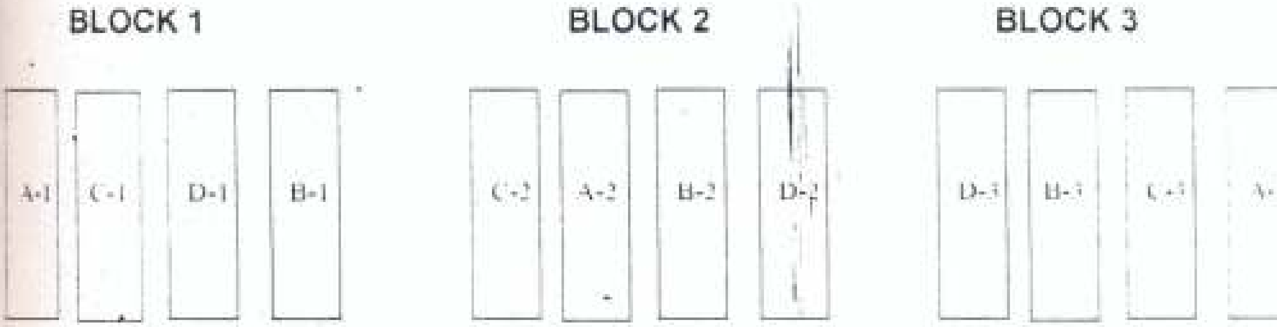

Fig. 1: Experimental design layout showing each treatment in blocks 1,2,and 3

Fig. 2: The Layout of the Experimental Farm

Amaranthus was manually sown on the 12 plots on 18th August 1999. Figure 2 shows the layout of the experimental farm. Each plot was bounded by wooden boards 250 mm high, driven approximately 30 mm into the slope surface (fig 3), to insure that rainfall and surface runoff within each plot were isolated from the adjacent plot. A 100 mm diameter PVC pipe was connected at the bottom of the wooden board and leads to an excavated ditch in which was placed 15 litres storage plastic container. The plastic container and the PVC pipe were covered with polythene to prevent the direct entry of rainfall into the containers (fig. 3).

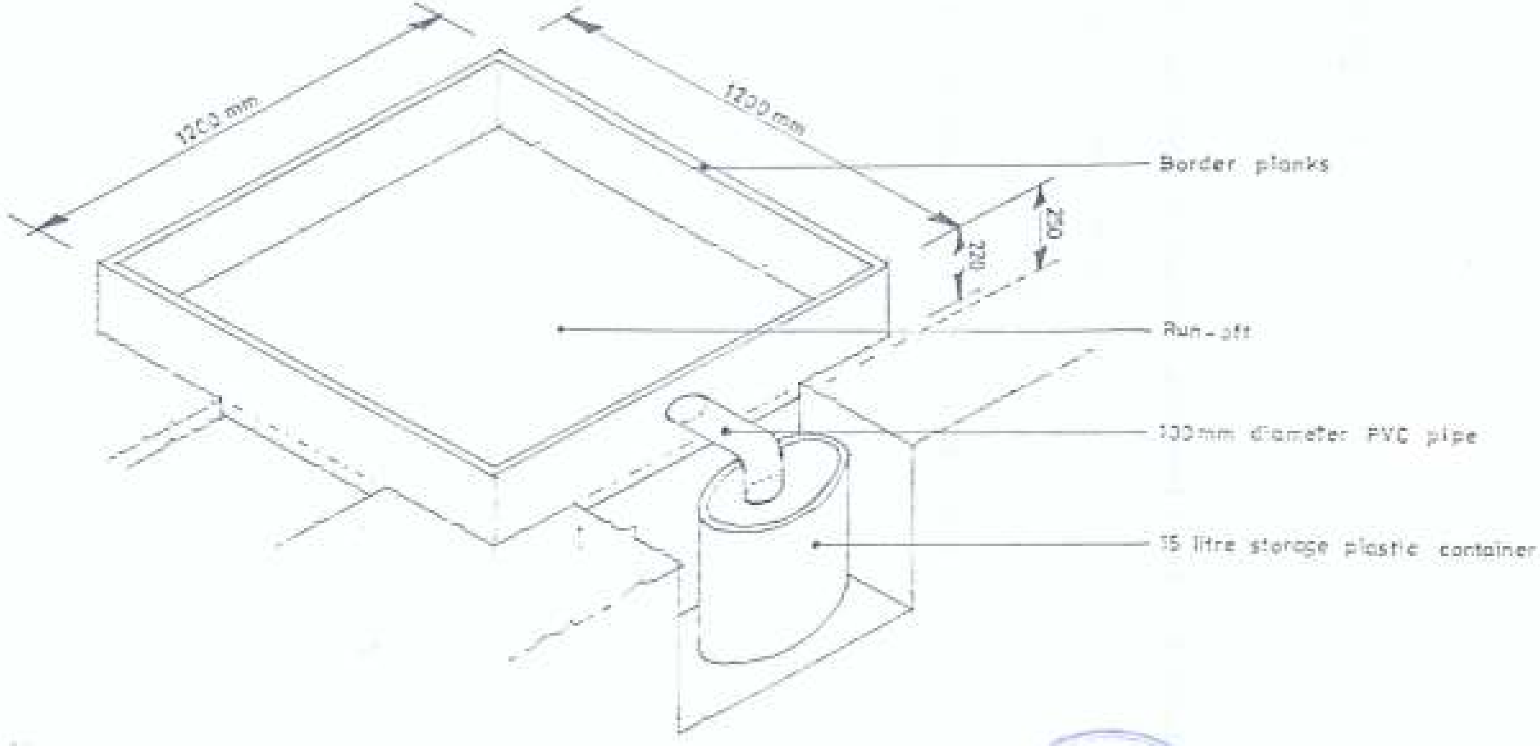

Fig. 3a A RUN-OFF PLOT SHOWING THE PLASTIC CONTAINER IN THE eCAVATED dITCH

3.3 MEASUREMENTS

3.3.1 Rainfall

The major variable influencing sediment yield and runoff volume measured in this study was rainfall amount. Monitoring of treatments began a week after establishment of the plants. During rainfall events, rainfall amounts were recorded with rainguage located on the site (Table1).

Table 1: **Rainfall Measurement**

Obs. No.	Sampling Period (August-November 1999)	Precipitation (mm)
1	25-8-99	64.0
2	27-8-99	67.4
3	30-8-99	142.8
4	3-9-99	10.3
5	6-9-99	37.4
6	10-9-99	64.0
7	13-9-99	24.0
8	15-9-99	32.8
9	17-9-99	56.2
10.	21-9-99	21.6
11.	24-9-99	9.9
12.	29-9-99	23.5
13.	5-10-99	56.8
14.	11-10-99	47.5
15.	12-10-99	49.4
16.	14-10-99	48.5
17.	18-9-99	13.0
18.	19-10-99	18.0
19.	21-9-99	31.4
20.	25-10-99	11.8
21.	3-11-99	11.0
22.	10-11-99	12.0

3.3.2 RUNOFF

Two variables were examined: plot runoff depth and plot sediment yield. Plot runoff volume was directly measured as the amount of water in the storage containers. The runoff depth (mm) was calculated from equation (21)

where

$$H = V/A \qquad \text{.........................(21)}$$

H is the runoff depth (mm)

V is volume of runoff in the storage container (mm^3)

A is the area of the runoff plot (mm^2). The average runoff for the whole period is shown in Table 2.

Table 2. Average runoff depth (mm)

S/N	Date	A ($\bar{x}$) (mm)	B () ($\bar{x}$)(mm)	C ($\bar{x}$) (mm)	D ($\bar{x}$) (mm)
1	25-8-99	9.6	12.8	9.6	11.5
2	27-8-99	10.1	13.5	8.8	12.1
3	30-8-99	21.4	28.7	18.6	25.7
4	3-9-99	1.5	2.1	1.3	1.9
5	6-9-99	5.6	7.5	4.9	6.7
6	10-9-99	9.6	12.8	8.3	11.5
7	13-9-99	3.8	4.8	3.1	4.3
8	15-9-99	4.9	6.5	4.3	5.9
9	17-9-99	8.4	11.2	7.3	10.1
10.	21-9-99	3.2	4.3	2.8	3.9
11.	24-9-99	1.5	2.0	1.3	1.8
12.	29-9-99	3.5	4.70	3.1	4.2
13.	5-10-99	8.3	11.4	7.4	10.2
14.	11-10-99	7.0	9.5	6.2	8.6
15.	12-10-99	6.4	9.8	6.4	8.9
16.	14-10-99	7.0	9.70	6.3	8.7
17.	18-9-99	2.0	2.6	1.7	2.3
19.	21-9-99	4.7	5.7	4.1	5.7
20.	25-10-99	1.7	2.5	1.5	2.1
22.	10-11-99	1.6	2.2	1.4	2.0

Table 3: Average Sediment yield for the study period

S/N	Date	A($\bar{x}$)(g)	B($\bar{x}$)(g)	C($\bar{x}$)(g)	D($\bar{x}$)(g)
1	25-8-99	279.2	344.9	277.4	319.0
2	27-8-99	253.2	270.5	307.8	377.3
3	30-8-99	227.4	220.5	215.3	231.4
4	3-9-99	160.1	202.0	150.1	201.0
5	6-9-99	77.2	101.1	76.4	73.5
6	10-9-99	151.6	290.5	247.9	244.9
7	13-9-99	76.7	201.1	62.1	147.0
8	15-9-99	165.3	213.6	132.3	212.8
9	17-9-99	115.0	400.0	175.4	267.1
10.	21-9-99	195.6	335.8	257.1	307.1
11.	24-9-99	7.8	17.2	11.3	10.5
12.	29-9-99	43.6	48.1	42.1	42.5
13.	5-10-99	16.7	22.5	42.1	42.5
14.	11-10-99	46.1	48.4	33.1	43.9
15.	12-10-99	180.9	35.9	43.3	45.4
16.	14-10-99	49.5	61.9	40.5	76.8
17.	18-9-99	11.2	18.5	8.0	15.5
18.	19-10-99	7.2	14.5	7.3	13.0
19.	21-9-99	31.7	29.6	6.6	14.9
20.	25-10-99	8.1	15.6	5.6	15.3
21.	3-11-99	6.4	10.8	4.8	9.4
22.	10-11-99	6.8	9.5	5.4	6.4

3.3.4. SOIL MOISTURE CONTENT AND SOIL STORAGE DETERMINATION

Soil moisture Content was measured gravimetrically at weekly intervals at depths 10cm, 20 cm and 30 cm. One location was sampled in each plot at each time of measurement (Fig 4). The soil sample was taken and its weight determined in the laboratory. The soil sample is then oven dried and reweigh, this is repeated until constant weight is obtained. The difference in weight was then converted to volume basis, as shown below:

$$M.C. = \frac{\text{Wt. Of wet soil} - \text{wt. of dried soil}}{\text{Wt. of wet soil}}$$

$$M.C. = \frac{\text{Wt. Of wet soil} - \text{wt. of dried soil}}{\text{Wt. of wet soil}} \times \underline{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots(22)$$

Where M.C. is the moisture content

$$M.C. = \frac{\text{Vol. of water}}{\text{Vol. of soil}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(23)$$

$$M.C. = \frac{Mw}{Dw} \Big/ \frac{Ms}{Ds}$$

$$M.C. = \frac{Mw}{Dw} \cdot \frac{Ds}{Ms} \cdot \frac{cm^3}{cm^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots(24)$$

where M.C. = Moisture content

Mw = Mass of water

Dw = Density of water

Ds = Density of soil

Ms = Mass of dry soil

Fig. 4 The plots when they are fully grown and method of collecting soil for analysis.

3.3.4 PLANT MEASUREMENT

Plant height, numbers of leaves, leaf area index, depth root zone and biomass yield were determined. These plant measurements started 6 weeks after planting. The plants were randomly selected from each plot

3.3.6 INFILTRATION

A double ring infiltrometer arrangement was used. Cylinders of 30 cm and 60 cm diameters and 30 cm high, made of 16 gauge iron sheet, constituted the inner and outer parts of the infiltrometers, respectively. Infiltration measurements were made 4 weeks after establishment.

Water levels in the inner ring of the infiltrometer were recorded at intervals of 5, 10, and 15 minutes within the first hour, then 20 minutes after (Table4). When the water level in the cylinders dropped to between 3.5 cm and 5 cm, sufficient water was added to return the surface to almost its initial elevation. Receding water levels against time at suitable intervals were plotted (Fig.5) using Kostiakov (1932) empirical equation for infiltration under pounded condition

$$f = at^{b} - 26 \qquad \text{..........................(24)}$$

where a and b are constants that depend on soil type. For sandy loamy soil a = 38.536 b= - 0.3087 and $R^2 = 0.91$ (Ahaneku and Sangodoyin, 1997).

Table 4 **INFILTRATION DATA FOR THE EXPERIMENTAL FARM**

SN	TIME INTERVAL	FINAL READING	INITIAL READING	INFILTRATION DEPTH	CUM INFILTRATION DEPTH	INFILTRATION RATE
	Min.	(Cm)	(Cm)	(Cm)	(Cm)	(Cm/hr)
1.	5	21.00	23.00	2.00	2.00	24.00
2.	10	21.50	23.00	1.50	3.50	18.00
3.	20	20.20	23.00	2.80	6.30	16.80
4.	30	20.80	23.00	2.20	8.50	13.20
5.	45	19.90	23.00	3.10	11.60	12.40
6.	60	20.20	23.00	2.80	14.40	11.20
7.	75	20.40	23.00	2.60	17.00	7.80
8.	95	20.00	23.00	3.00	20.00	9.00
9.	115	19.80	23.00	3.20	23.20	9.60
10.	135	19.80	23.00	3.20	26.40	9.60

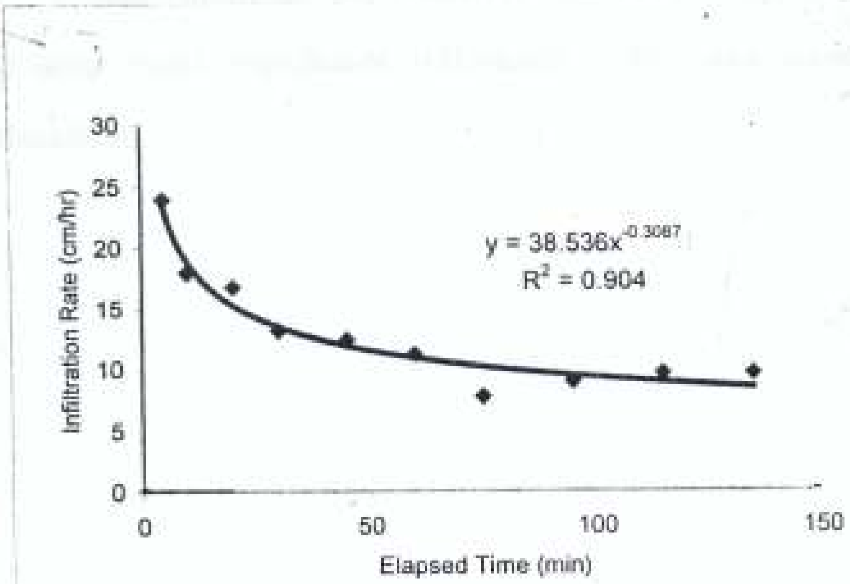

Fig5: Infiltration Curve of the Experimental Soil

3.3.6 STATISTICAL ANALYSIS

Two statistical tests were used to analyse erosion data: Correlation analysis and Analysis of Variance (ANOVA). A Pearson's correlation analysis was used to test for correlation among runoff depth and total sediment yield and rainfall. ANOVA was used to test the treatment effect for sediment yield and runoff depth. Where analysis of variance indicates significant treatment differences, Fisher least significant difference (LSD) was used to compare individual differences.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RAINFALL

Table1 presents the twenty-two (22) sample events monitored during the study period. Immediately after the initiation of the study, the highest storm event of 142 mm was recorded on the 30th August, 1999. Although, this storm event was expected to produce the highest runoff depth and sediment yield, it was not so, since it occurred when the soil was still very porous and loose due to the tillage operation. Apparently the greater proportion of rain water infiltrated into the soil. This is in conformity with Jarvis et. al., (1985) which established that infiltration and rate of wetting-front migration were consistently faster on the most disturbed conventional tillage treatment than indirect drilling (no-till).

4.2 RUNOFF

Table 2 shows average runoff for each of the sample event for each plot. Table 5a, shows that treatments A and C had less runoff compared to treatments B and D. This is probably due to the differences in surface coverage (i.e. differences in plant densities). Treatment A and C had relatively higher proportion of vegetation cover, and hence greater interception, decreased raindrop energy and decreased runoff when compared to treatments B and D. Similar observations were made by (Grace et, al; 1998). Interception is increased as foliar development in treatments A and C, which leads to reduction in runoff in the case of treatment A and C. This is in agreement with observations made by (Chandiler and Water, 1998).

Statistical analysis of variance results indicated that plant densities had a significant effect on runoff (Table 5b) at 0.05 level of significance. Further analysis, using Fisher's Least Significant Difference (LSD) procedure also indicated that the average total runoff is significantly higher for treatments B, D, A and C in order of plant densities (Table 5c). Plant densities had a direct effect on the total runoff depth for all treatments tested.

Figure 6 shows the effect of plant densities on runoff for the eleven weeks study period. Treatment B have the highest value as shown in the Figure. This is followed by D, A, and C, in order of plant densities.

RESULTS OF STATISTICAL ANALYSIS FOR RUNOFF

Table 5a **SUMMARY**

Treatment	Count	Sum	Average	Variance
A	3	380.9	126.9667	0.763333
B	3	510.1	170.0333	2.212333
C	3	336.9	112.3	1.09
D	3	460.4	153.4667	0.723333

Table 5b **ANOVA TABLE**

Source of Variation	df	SS	MS	F	P-value	F crit
Treatment	3	6055.789	2018.596	1717.954	1.42E-11	4.06618
Error	8	9.400	1.175			
Total	11	6065.189				

Table 5c **Result of the Fisher's Least Significant Difference (LSD)**

Treatment	Mean*
B	170.03a
D	153.47b
A	126.97c
C	112.30d

*Means followed by the same letter are significantly different (p>0.05)

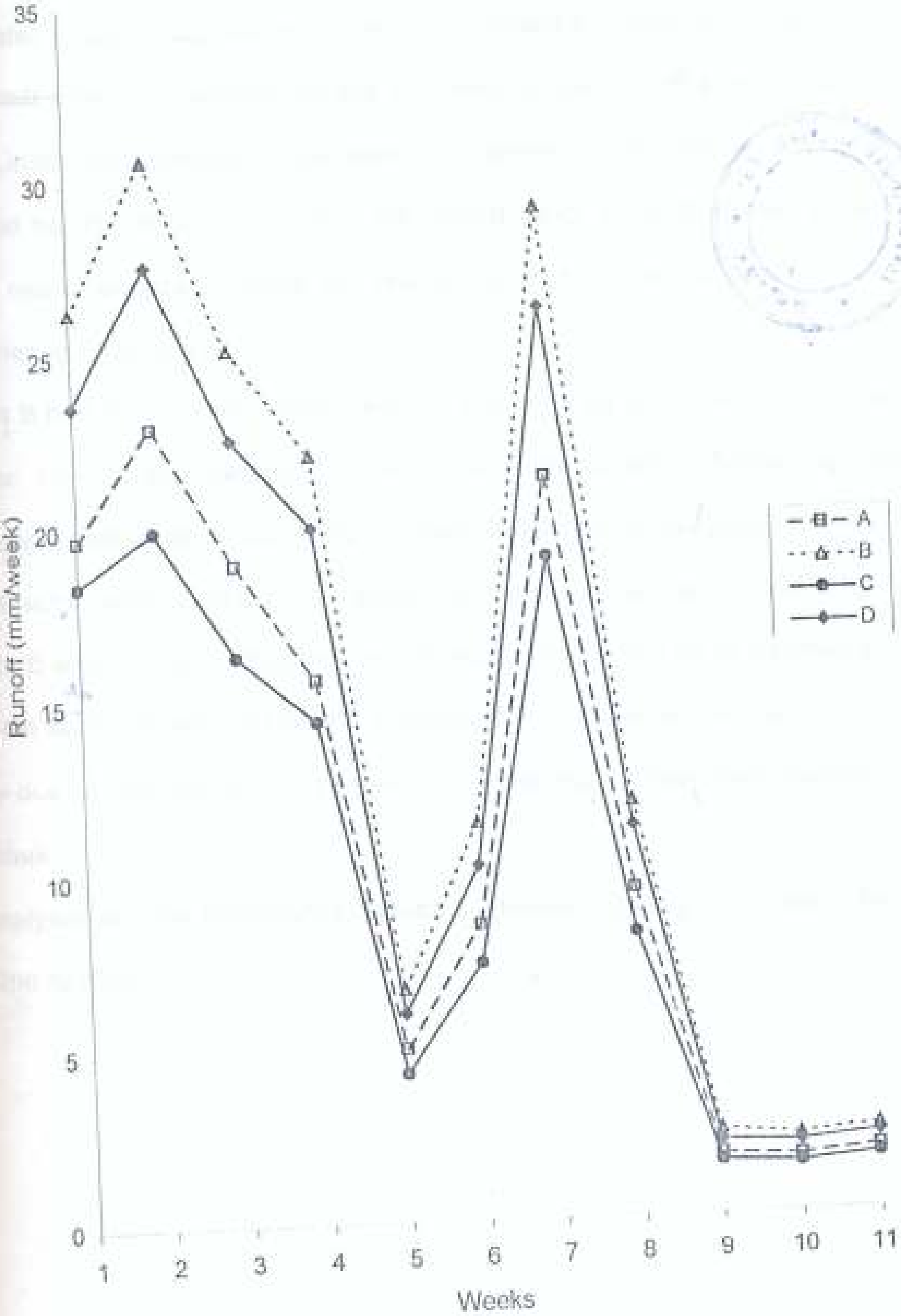

Fig 6. Runoff for the 11 weeks.

RAINFALL - RUNOFF RELATIONSHIP

Rainfall - Runoff relationships were developed for each plot (Table 6). The riod runoff total was plotted versus the sum of the runoff producing rainfall ig. 7). Linear relationships were found to provide the best fit line between nfall and runoff. Within each plot, the runoff ratio (ratio of runoff to rainfall) mained nearly constant (Table 6). The amount of rainfall to produce surface noff varied among plots.

eatment B had the highest runoff (Fig. 6), followed by treatment D, A, and C in at order. The rainfall needed to initiate surface runoff is always greater in nsely populated plots as compared to those with less population. The increase runoff with rainfall 'depth is remarkably similar for each plot (Table 6). eatment B and D had the highest runoff depth as compared to treatment A and under the same amount of rainfall. Treatment A and C lower amount of runoff is obably due to interception of raindrops by the high population density of the maranthus.

Analysis on the treatments Table 7, showed strong correlation between n-off and rainfall.

Table 6: Rainfall – Runoff Relationships

Treatment (Plot)	Total Average Runoff (mm)	Total Rainfall Amount (mm)	Runoff Ratio (mm)/Rainfall (mm)	Observation	Regression Co-efficient r^2
A	126.3	853.20	0.15	22	0.996
B	170.02	853.20	0.20	22	0.9996
C	112.2	853.20	0.13	22	0.9956
D	153.4	853.20	0.18	22	0.9819

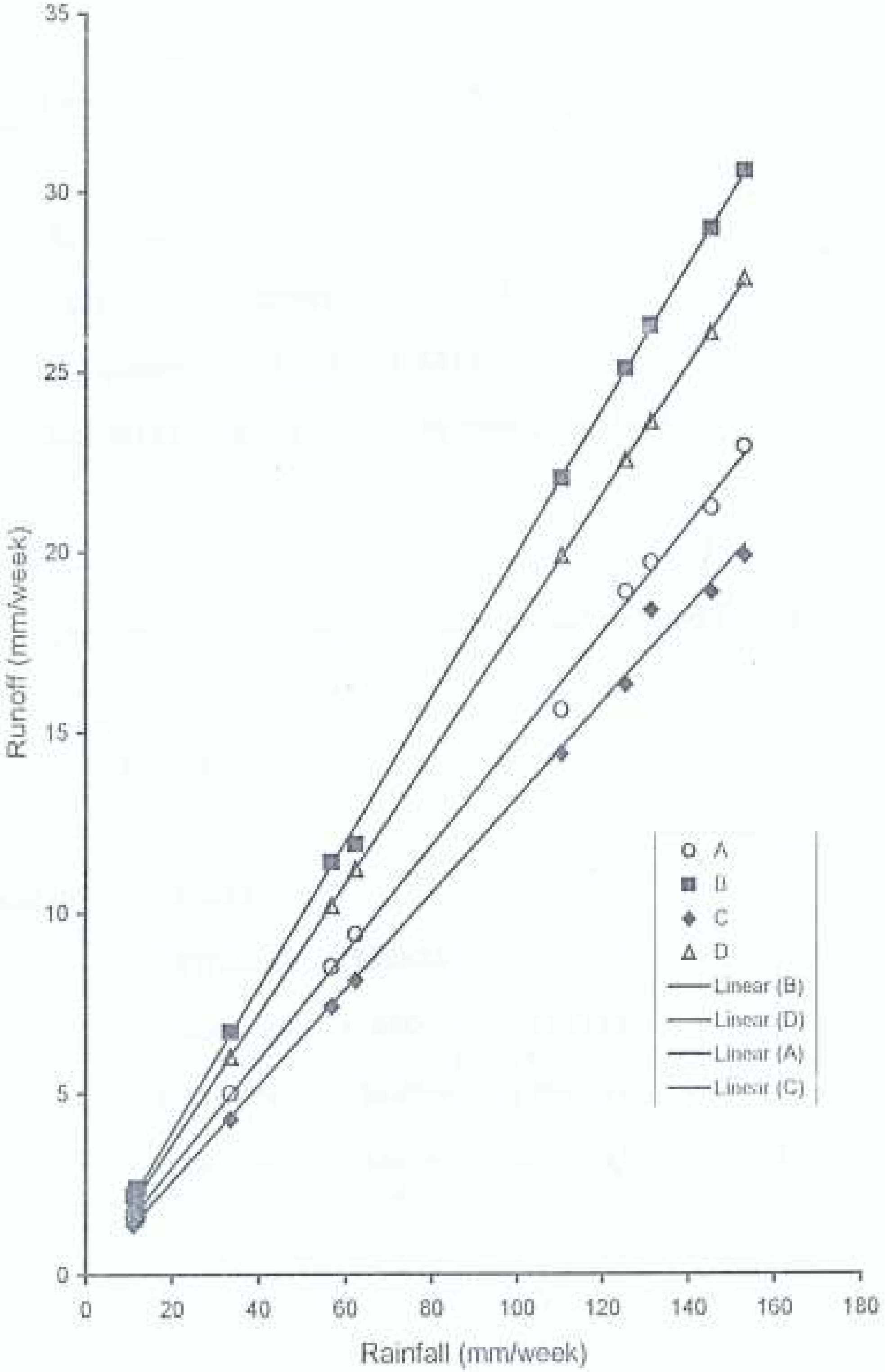

Fig.7: Linear Relationship between runoff and rainfall

able 7: Correlation coefficients for rainfall and runoff depth

	Rainfall	A	B	C	D
ainfall	1				
	0.615066	1			
	0.4552063	0.923302	1		
	0.4706969	0.888133	0.941328	1	
	0.4556151	0.92638	1.987606	0.954823	1

able 8: Correlation coefficients for rainfall and sediment weight

D	Rainfall	A	B	C	D	
D	1					
Rainfall	0.4556151	1				
A	0.5709056	1.598835	1			
B	0.5598495	0.43081	0.794129	1		
C	0.5167292	0.546888	0.906131	0.909877	1	
D	0.5674896	0.485161	0.888749	0.966051	0.971736	1

Table 9: Correlation coefficients between sediment weight and runoff depth

A	A		B	B	
A	1		B	1	
A	0.5423333	1	B	0.547853	1

D	D		C	C	
D	1		C	1	
D	0.5674896	1	C	0.595001	1

4.4 SEDIMENT YIELD

Table 3 shows average sediment yield from each of the sample event for each plot. The measured total soil loss of the event attained its peak immediately after the establishment of the plots and then decreased when the crop began to grow. Similar observation were made during the study on erosion control techniques on forest roads, with erosion material treatment and exotic grass treatment (Grace et al, 1998).

It was noted that, the sediment yield reduced as the amaranthus developed, interception is increased by foliar development and detachment is reduced as the root net work develops. In other words, sediment yields in treatment A and C were lower than in treatments B and D which have lesser plant densities.

Statistical analysis as shown in Tables 8 and 9, showed strong Correlation among rainfall, runoff, and sediment yield Runoff depth was correlated with sediment yield and rainfall was correlated with sediment yield. Figure 8, shows the linear relationship between sediment yield and rainfall during the study period.

Treatment B had the highest sediment yield Table 10a, and as shown in Fig. 9. It also had the least plant density among the treatments. During storm event, water which was supposed to hit the soil directly and caused runoff and sediment yield were intercepted by the canopy of the Amaranthus in treatment A and C. This results in greater water infiltration into the soil, greater water retention and evapotranspiration to take place.

Analysis of Variance (ANOVA) result indicated that plant densities had a significant difference on sediment yield (Table 10b). Further analysis using Fisher's Least Significant Difference (LSD) indicated that the average total sediment yield was significantly higher for treatment B and D than for treatment A and C tested (Table 10c). However the difference between mean total sediment yield for treatment A and C were not statistically different at a 95% probability level

RESULTS OF STATISTICAL ANALYSIS FOR SEDIMENT YIELD

Table 10a Anova: for Total Sediment Weight for the period

SUMMARY

Groups	Count	Sum	Average	Variance
A	3	6360.9	2120.3	28.3024
B	3	8737.5	2912.5	28.3024
C	3	6375.3	2125.1	28.3024
D	3	7923.9	2641.3	28.3024

Table 10b ANOVA

Ce of Vari	SS	d/f	MS	F	P.Value	D crit
Between	1394292	3	464764	16421.4	1.7E-15	4.06618
Within Gr	226.419	8	28.3024			
Total	1394518	11				

Table 10c Fisher's least significant difference

Groups	Average
B	2912.5a
D	2641.3b
C	2125.1c
A	2120.3c

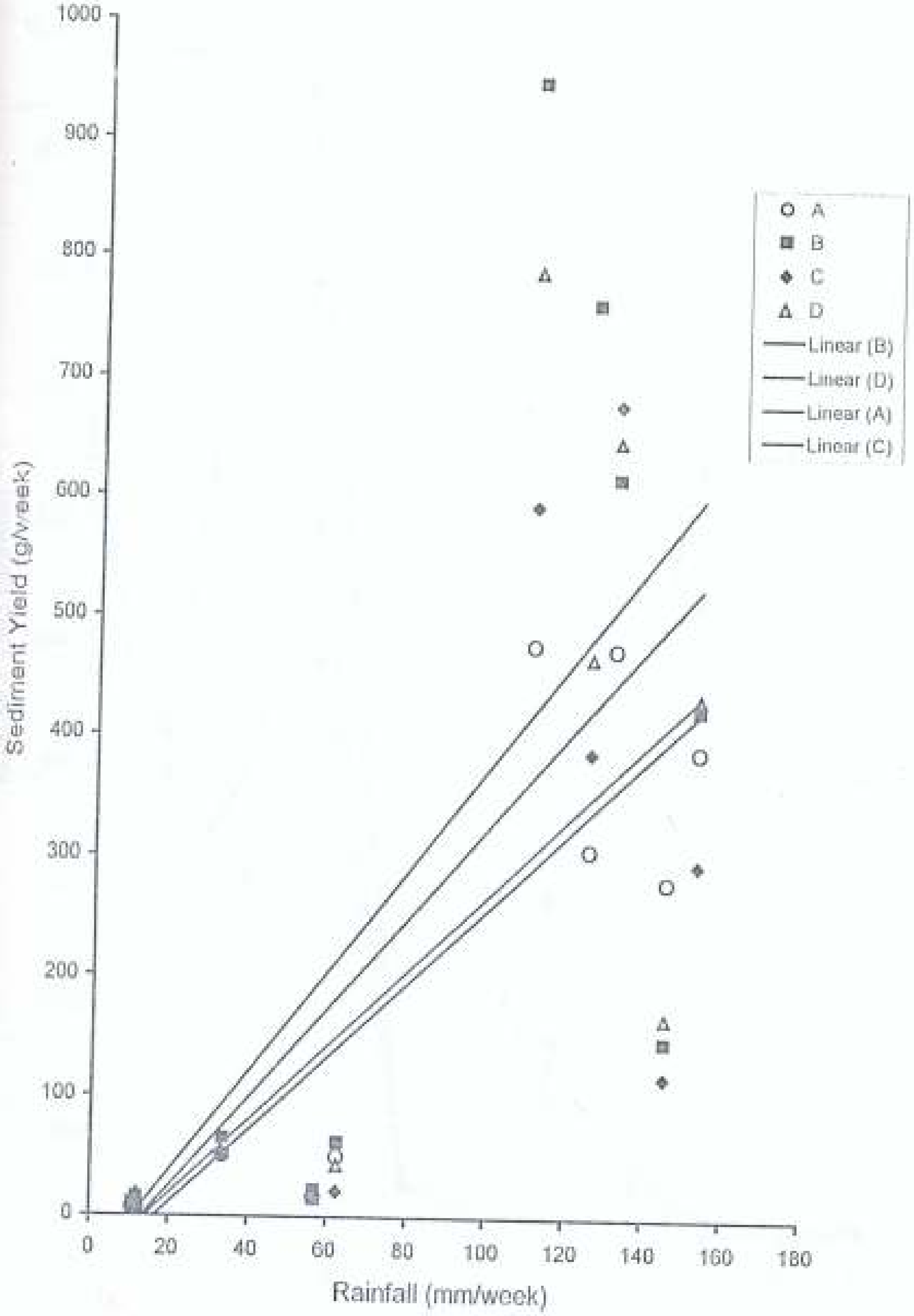

Fig. 8 Linear Relationship between sediment yield and rainfall

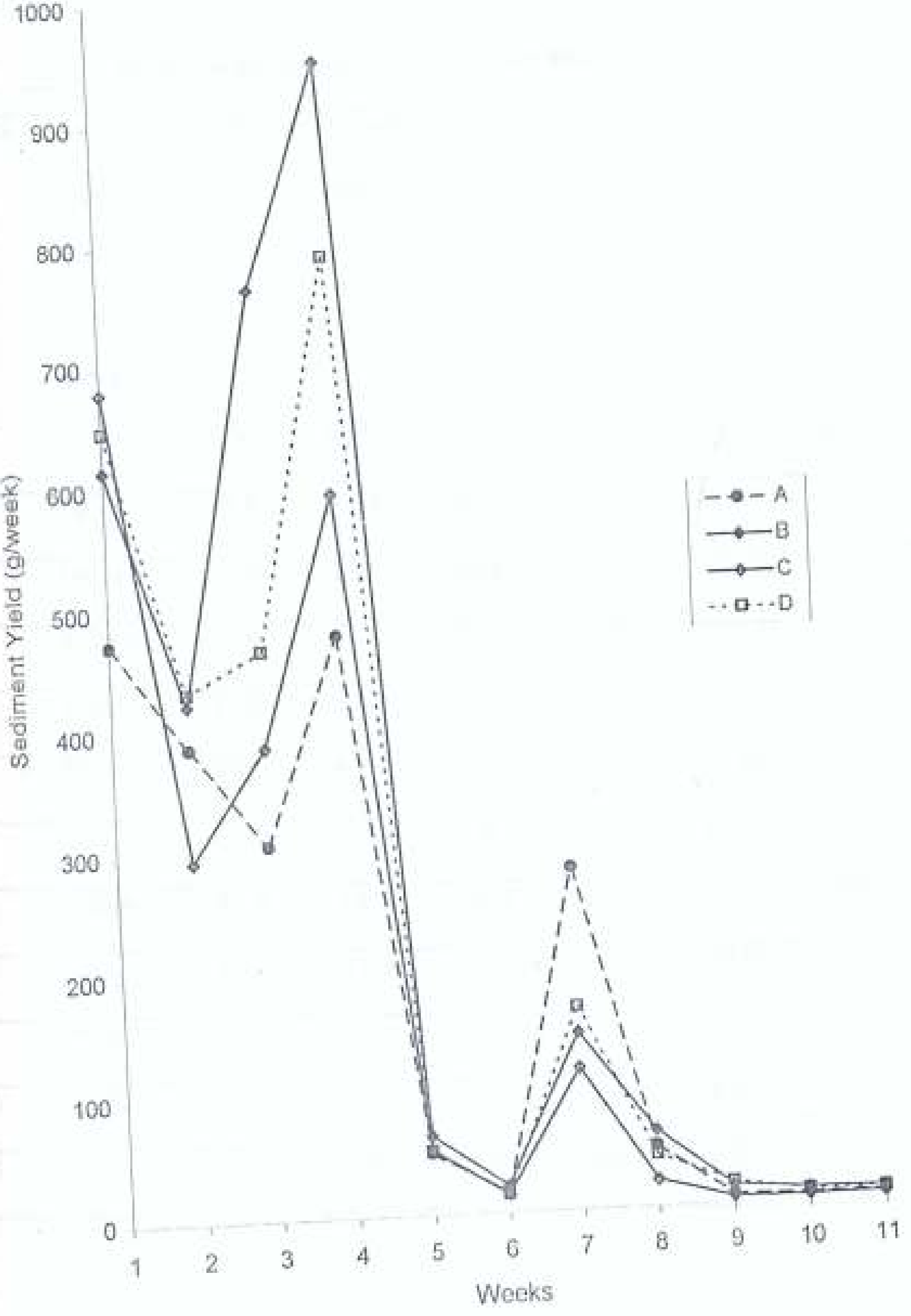

Fig.9. Sediment Yield for the 11 weeks.

Table 11. Total rainfall, total average runoff and the total sediment yield per week for each sampling period during the study period.

Week	Total Rainfall Amount (mm) per Week	Total Runoff (mm) per Week				Total sediment Weight (g) per Week			
		A($\bar{x}$)	B($\bar{x}$)	C($\bar{x}$)	D($\bar{x}$)	A($\bar{x}$)	B($\bar{x}$)	C($\bar{x}$)	D($\bar{x}$)
1	131.4	19.7	26.3	18.4	23.6	42.77	615.5	678.4	646.3
2	153.1	22.9	30.62	19.9	27.6	387.50	422.5	294.4	432.4
3	1125.4	18.9	25.1	16.3	22.5	305.50	761.7	386.4	465.4
4	110.4	15.6	22.0	14.4	19.9	475.93	949.0	592.1	787.7
5	33.4	5.0	6.7	4.3	6.0	51.35	65.3	53.4	53.0
6	56.8	8.5	11.4	7.4	10.2	16.70	22.5	15.3	16.0
7	145.4	21.2	29.0	18.9	26.1	279.47	146.1	117.0	166.1
8	62.4	9.4	11.9	8.14	11.2	50.07	62.6	21.9	43.4
9	11.8	1.7	2.4	1.5	2.1	8.13	15.6	5.6	18.2
10	11.0	1.6	2.2	1.4	2.0	6.4	10.8	4.8	9.4
11	12.0	1.8	2.4	1.6	2.2	6.8	9.6	5.4	8.9

Figure 10-11 shows average runoff, sediment yield and rainfall for the eleven weeks study period. Runoff depth and sediment yield was high during the first four weeks of the studied. There was a little dry spell within the fifth and sixth weeks as shown in Figure 10 and 11. At the seventh, week the rainfall was again very high. This then decreased until at the eleventh weeks when the dry season began to set in

Figure 12 show the average sediment yield and runoff depth for each treatment over the studies weeks. From Figure 12 it can be deduced that treatment A and C have the least sediment yield and runoff depth. While treatment B and D have the highest runoff and sediment yield.

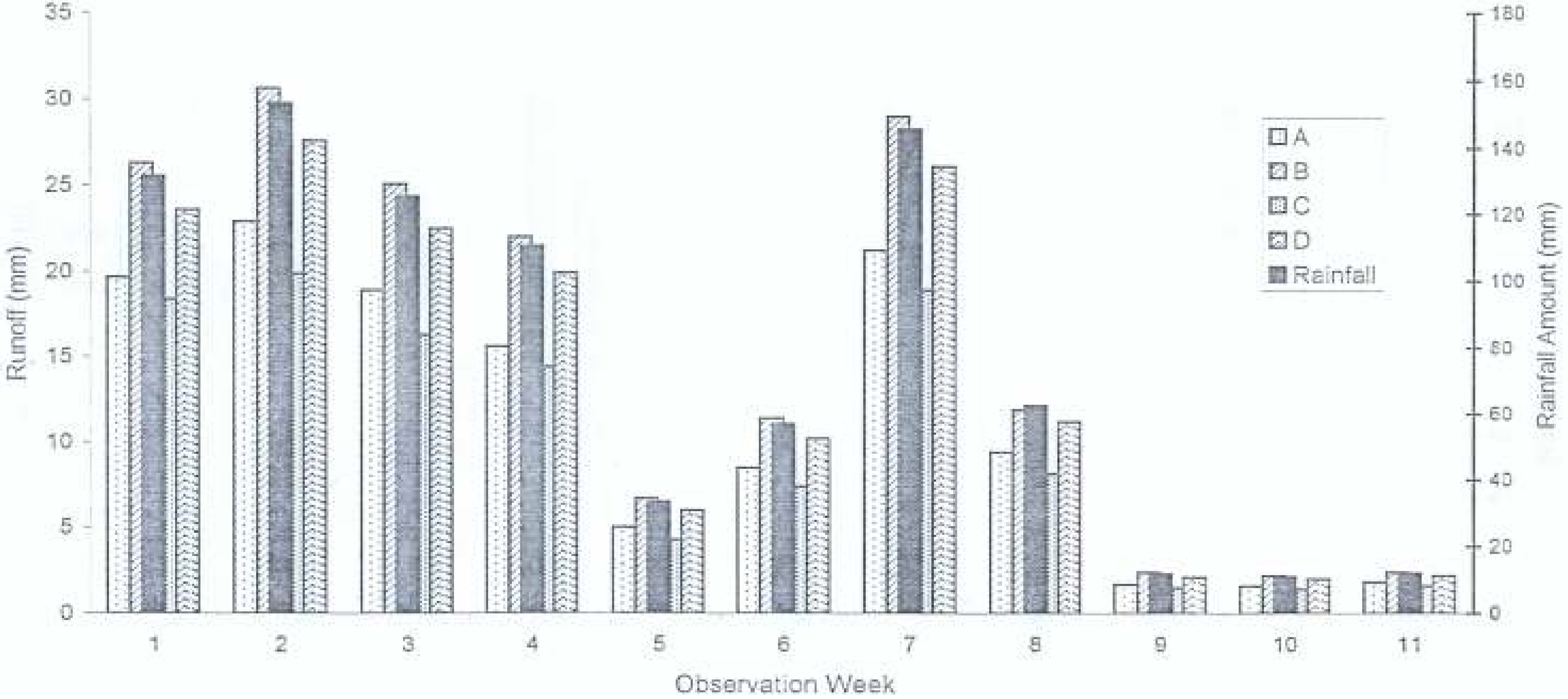

Fig.10 Observed Treatment Runoff for each sampling period during the study period.

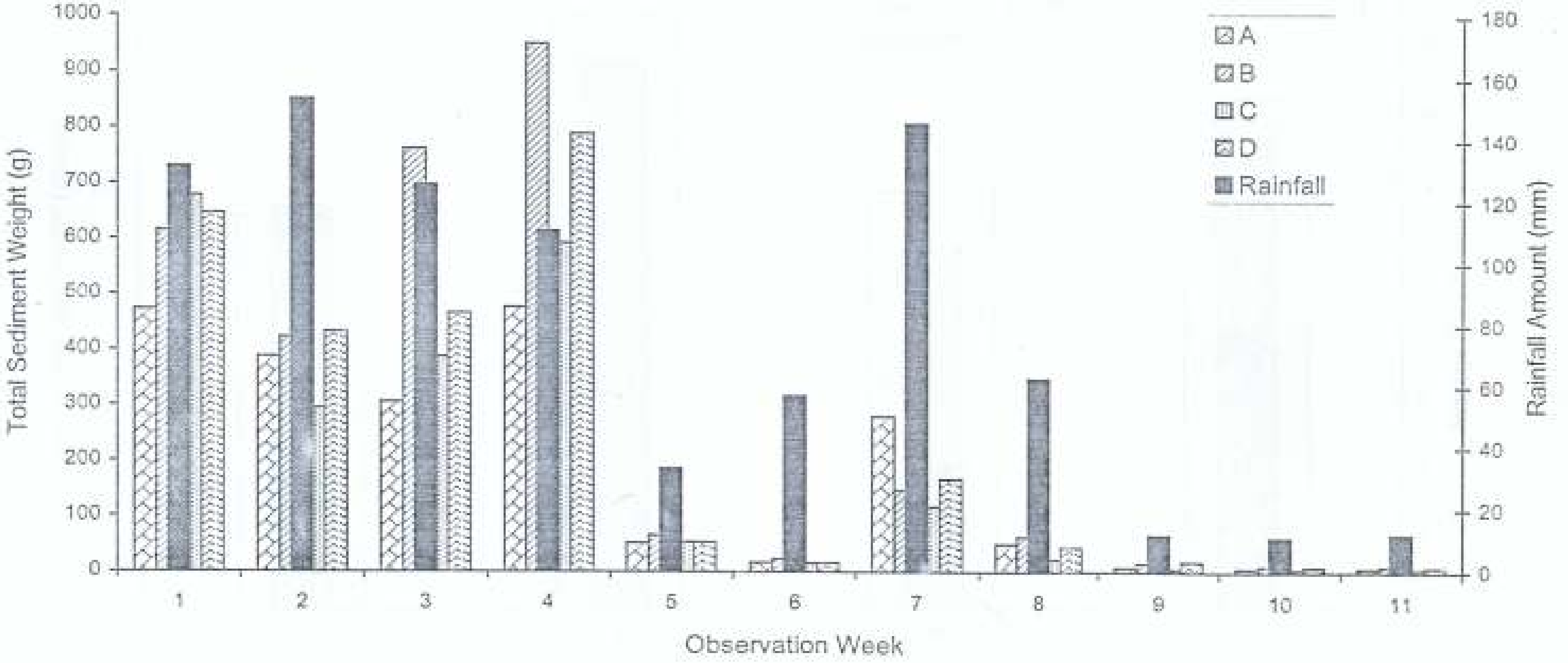

Fig.11: Observed Treatment Sediment Yield for each sampling period during the study period.

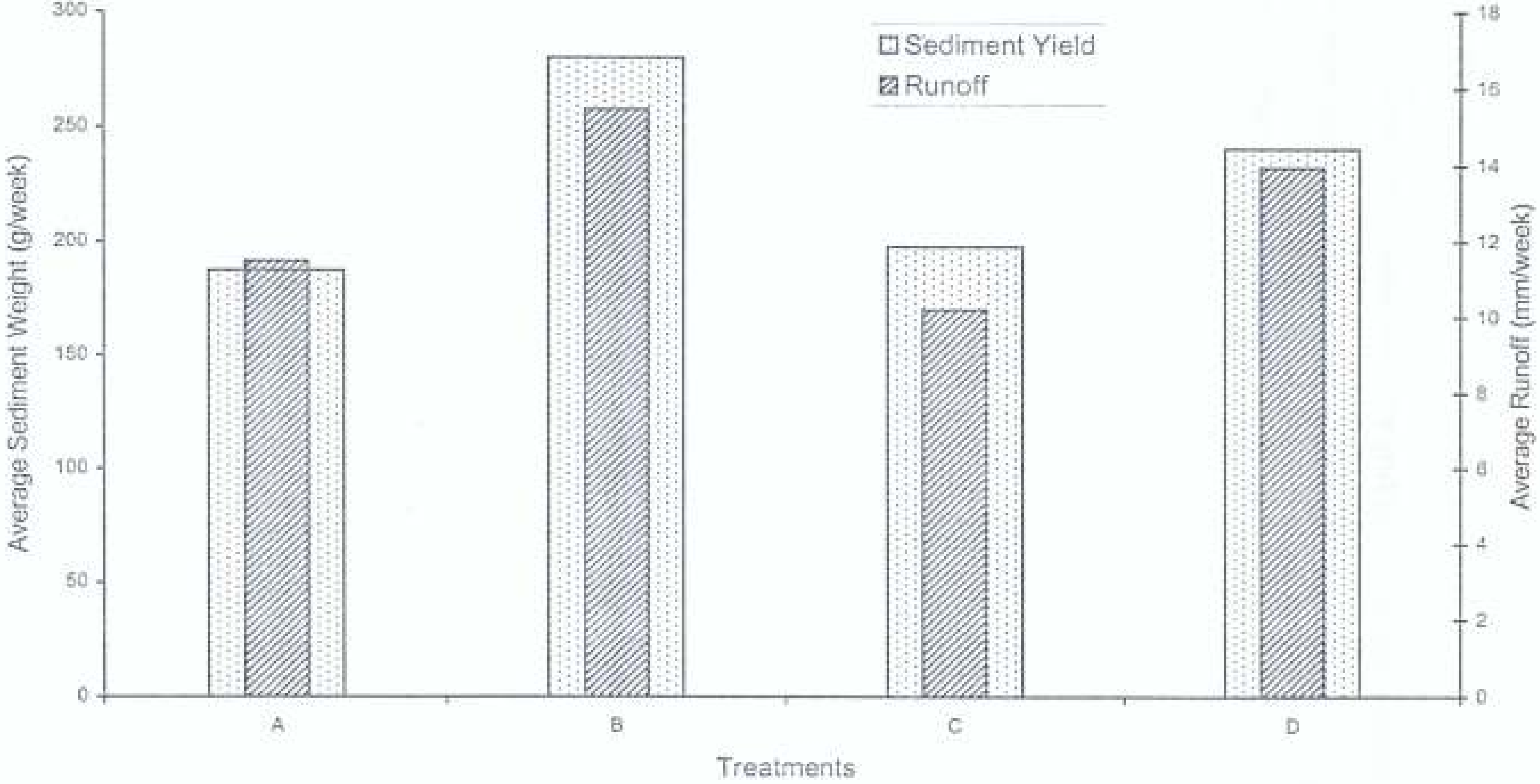

Fig. 12 Average Sediment Yield and Runoff Depth for each Treatment over the study period.

4.5 INFILTRATION

Figure 13 show the infiltration curve and the cumulative infiltration curve of the experimental soil. Initial infiltration was high, but decreased gradually with time to attain a steady state (Table 4).

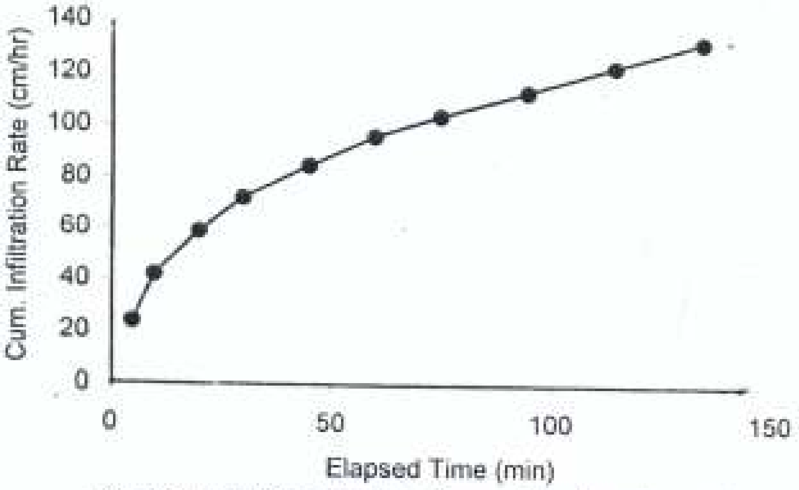

Fig.13 Cumulative Infltration Curve of the Experimental Soil

4.6 PLANT DATA

The result of the plant data is as presented in (Table 12). Statistical analysis indicated that there is no significant difference between plant densities and plant data (Table 13).

Table 12 PLANT DATA AFTER SIX WEEKS OFPLANTING

eatment	Plant height	Leaves Number	Leaves Area index (LAI)	Depth Rot Zone S	LEAVES		STEM		FRUIT	
					Fresh	Dry	Fresh	Dry	Fresh	Dry
					(g)	(g)	(g)	(g)	(g)	(g)
1	25	16	0.006	9.5	1.4	0.3	1.5	0.4	2.6	0.4
1	50	18	0.006	15	2.4	0.5	4.9	0.6	2.8	0.3
1	48	23	0.006	14.5	7.1	1.1	10.4	1.2	3.9	0.8
1	54	24	0.004	15.5	4.8	0.7	7.1	1.1	3.5	0.5
2	51	23	0.008	11.9	1.9	0.4	4.4	0.6	3.4	0.7
2	42	29	0.007	11.2	3.8	0.5	5.0	1.0	2.8	0.5
2	43	29	0.010	12.0	5.3	1.0	8.2	1.2	2.5	0.4
2	48	22	0.007	14.5	8.1	1.1	12.6	2.0	2.6	0.6
3	39	17	0.003	13.3	2.5	0.4	4.1	0.7	2.8	0.5
3	36	20	0.004	11.5	2.9	0.6	5.7	1.9	3.3	0.9
3	36	20	0.003	13.2	1.7	0.5	2.9	0.5	2.7	0.6
3	56	14	0.007	13.3	2.2	0.7	2.7	1.0	2.2	0.4

Table 13a Anova: Root zone depth

SUMMARY

Groups	Count	Sum	Average	Variance
A	3	34	11.3333	3.62333
B	3	39	13	4.75
C	3	40.1	13.3667	2.42333
D	3	42.3	14.1	0.48

ANOVA

E of Vari	SS	df	MS	F	P-value	F crit
Betweenr	12.3367	3	4.11222	1.45867	0.29692	4.06618
Within G	22.5533	8	2.81917			
Total	34.89	11				

Table 13b Anova: for plant Leaf Area Index

SUMMARY

Groups	Count	Sum	Average	Variance
A	3	0.02	0.00667	3.3E-07
B	3	0.018	0.006	1.2E-05
C	3	0.017	0.00567	6.3E-06
D	3	0.016	0.00533	4.3E-06

ANOVA

E of Vari	SS	df	MS	F	P-value	F crit
Between	2.9E-07	3	9.7E-07	0.16908	0.91428	4.06618
Within G	4.6E-05	8	5.7E-06			
Total	4.9E.05	11				

Table 13c Anova: For Fresh Biomass Yield

SUMMARY

Groups	Count	Sum	Average	Variance
A	3	28.6	9.5333	12.2033
B	3	43.3	14.4333	4.90333
C	3	27.1	9.03333	2.29333
D	3	54.1	18.0333	56.8033

ANOVA

E of Vari.	SS	df	MS	F	P-value	F crit
Between	164.723	3	54.9075	2.88216	0.10279	4.06618
Within G	152.407	8	19.0508			
Total	317.129	11				

4.7 RAINFALL - RUNOFF – MODELING

To model the effect of plant densities on runoff three assumption were made. These assumption are: depression Storage, Infiltration, and inflow were negligible. Parameters a and b of the model $Y = a_0 + b_1x$ were determined by linear regression analysis and were presented in (table 14 -17). The summary of the Runoff - Rainfall – model is as shown in (Table 18)

$$Y = a_0 + b_1 x \qquad \text{.........................(25)}$$

Where

Y = runoff depth (mm)

a_0 = intercept on runoff axis

b_1 = Slope of the best fit line

x = rainfall depth (mm)

a_0 and b_1 are best fit co-efficient. The model accounted for most of the variance in runoff under different plant densities. In all the treatment Co-efficient b values, the slope of the regression lines were significantly different ($p > 0.05$) among the treatments. Values of a_0 the intercept on the runoff axis also differ among the treatments. The results of the model are as shown in figure (14 – 17).

Table 14 RESULTS OF MODELLING FOR TREATMENT A

Regression Statistics	
Multiple R	0.99977685
R Square	0.99955375
Adjusted R Square	0.99953143
Standard Error	0.09894601
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	438.5822528	438.5823	44797.57	5.51955E-35
Residual	20	0.195806268	0.00979		
Total	21	438.7780591			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.02794397	0.034569677	-0.808338	0.428407
RAINFALL	0.14948396	0.000706264	211.6544	5.52E-35

Table 15 RESULTS OF MODELLING FOR TREATMENT B

Regression Statistics	
Multiple R	0.99978966
R Square	0.99957936
Adjusted R Square	0.99955833
Standard Error	0.12859848
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	785.9781941	785.9782	47526.83	3.05609E-35
Residual	20	0.330751384	0.016538		
Total	21	786.3089455			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	-0.03430427	0.044929632	-0.764846	0.453294	-0.128085793
RAINFALL	0.20011255	0.00091792	218.0065	3.06E-35	0.1981978

Table 16 RESULTS OF MODELLING FOR TREATMENT C

Regression Statistics	
Multiple R	0.99780961
R Square	0.99562402
Adjusted R Square	0.99540522
Standard Error	0.27391255
Observations	22

ANOVA

	df	SS	MS	F	Significance F
Regression	1	341.4084201	341.4084	4550.408	4.54584E-25
Residual	20	1.500561696	0.075028		
Total	21	342.9089818			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.01335848	0.095699344	-0.139588	0.890382
RAINFALL	0.13188827	0.001955154	67.45671	4.55E-25

Table 17 RESULTS OF MODELLING FOR TREATMENT D

Regression Statistics	
Multiple R	0.99092561
R Square	0.98193357
Adjusted R Square	0.98103024
Standard Error	0.76957135
Observations	22

ANOVA

	df	SS	MS	F	Significance F
Regression	1	643.779926	643.7799	1087.025	6.58142E-19
Residual	20	11.84480127	0.59224		
Total	21	655.6247273			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.21105858	0.268872212	-0.784977	0.441667
RAINFALL	0.18110806	0.005493106	32.97007	6.58E-19

Table 18 RESULTS OF THE RUNOFF - RAINFALL MODELLING

Treatment	a_0	b_1	R^2
A	-0.0279	0,1495	0.9996
B	-0.0343643	0,20011	0.9996
C	-0.0133585	0.13189	0.9956
D	-0.2110586	0.1811	0.9819

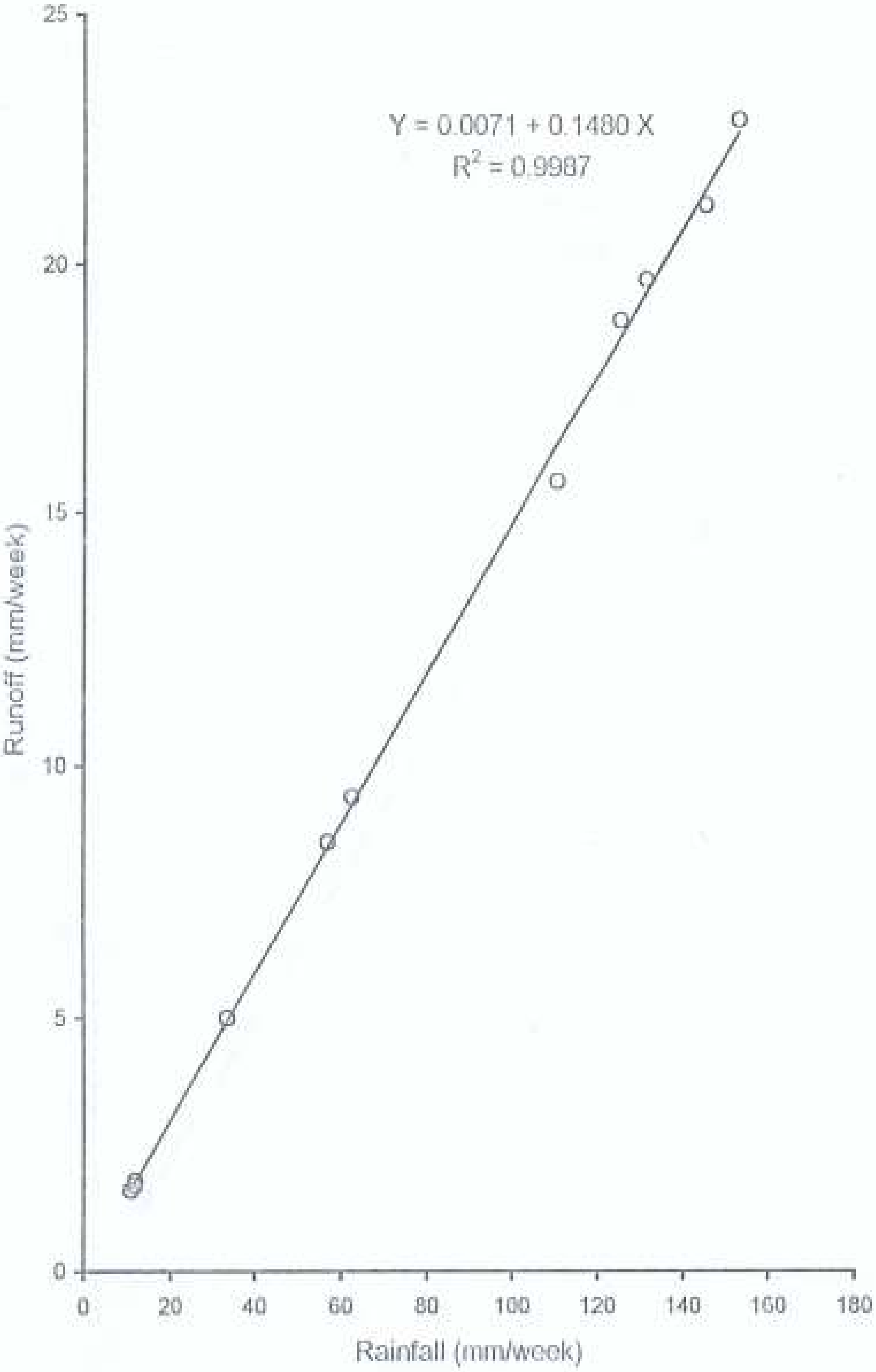

Fig.14 Linear Relationship between runoff and rainfall for Treatment A

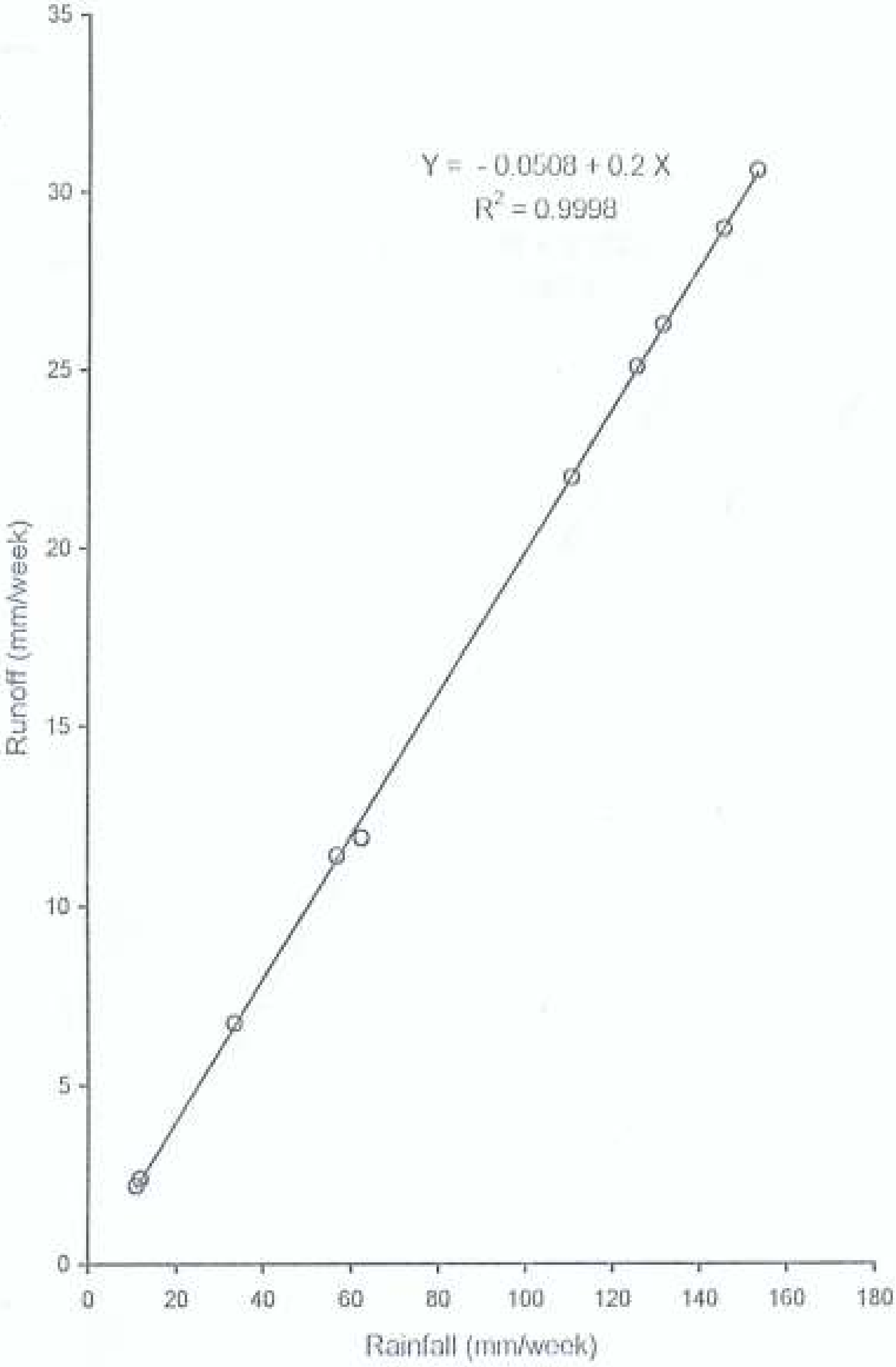

Fig.15 Linear Relationship between runoff and rainfall for Treatment B.

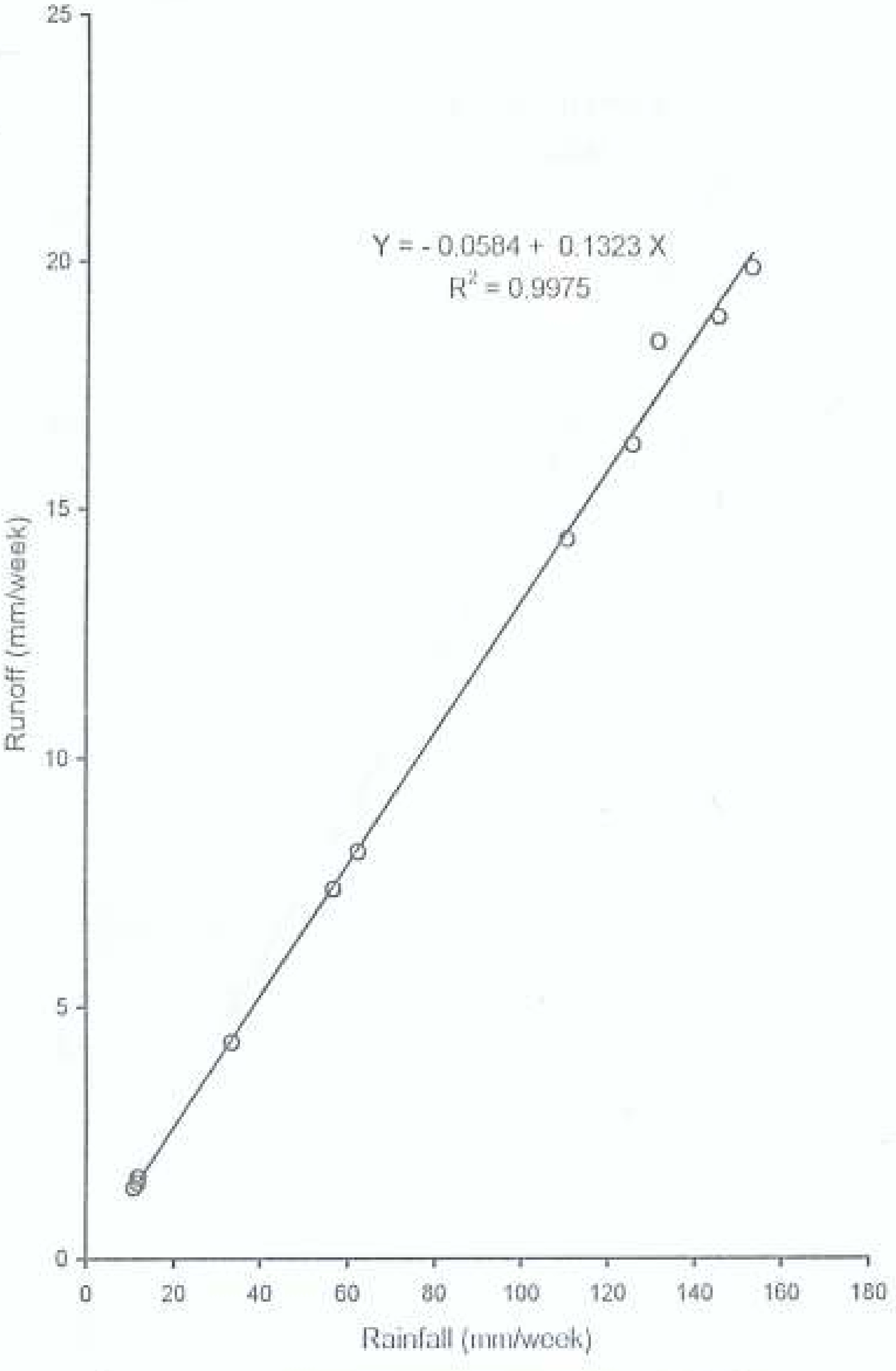

Fig.16 Linear Relationship between runoff and rainfall for Treatment C

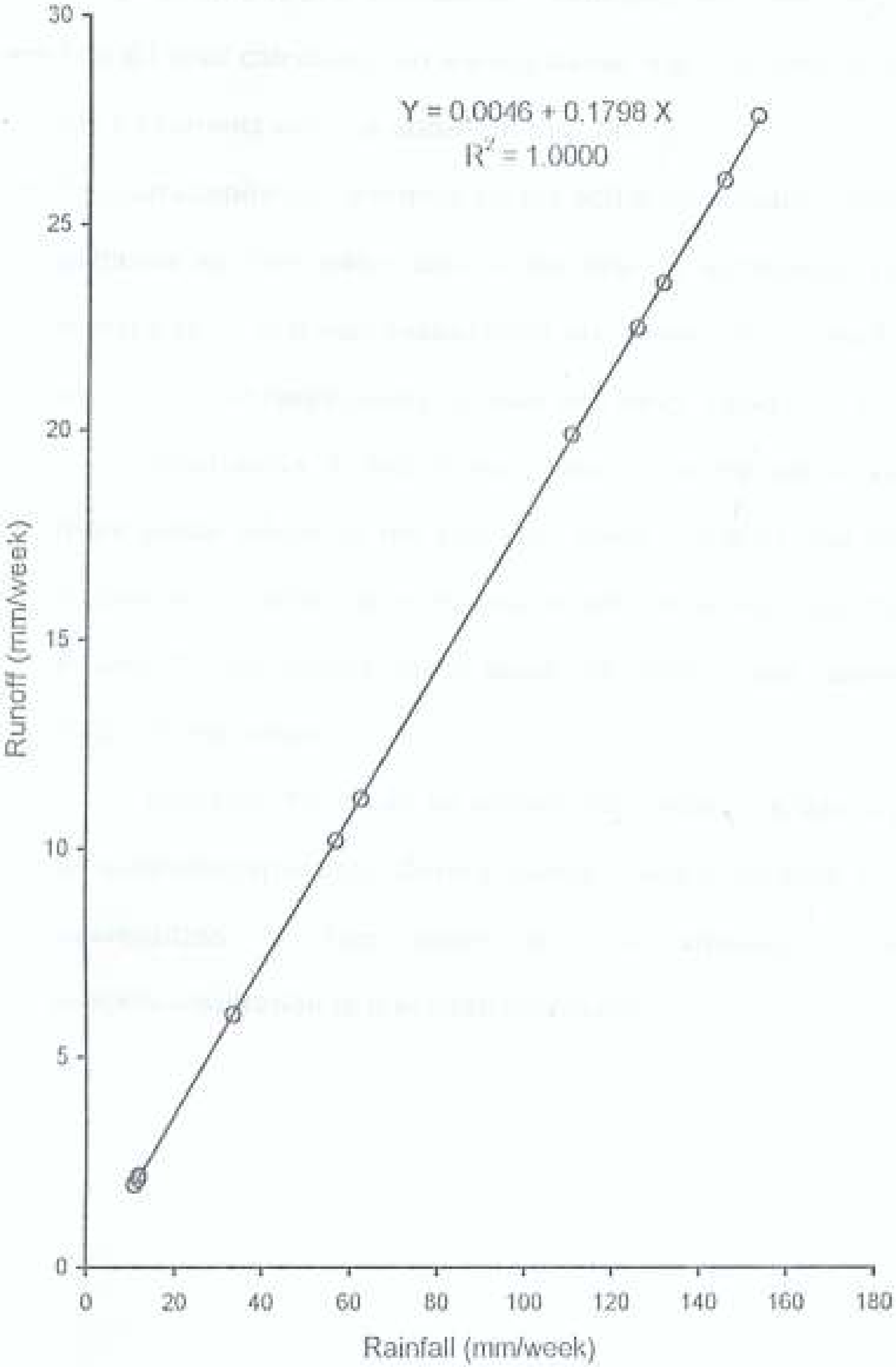

Fig.17 Linear Relationship between runoff and rainfall for Treatment D

4.8 WATER BALANCE

The components of water balance equation (3) for the eleven weeks for the four experimental treatments are presented in (Table 19). The ET was calculated on weekly basis, the relationship in the ET in all the treatments were as shown in (fig. 18).

Evapotranspiration is limited by the soil water content. Intercepted water behaves as free water and is the first to evaporate. However, plant transpiration and soil evaporation are limited by the leaf area and soil water content respectively (Savabi and Stott, 1994).

Treatments A and C had more plant densities, thereby having more water stored in the soil (soil water content) and invariably more evapotranspiration Table 19, and as shown in (Fig. 18). While treatment B and D had lesser plant densities, less water stored and lesser evapotranspiration.

From Fig.19, it can be shown that, rainfall is directly proportional to evapotranspiration. During rainfall, water content in the soil and interception of rain water by the amaranthus is increased, evapotranspiration is therefore increased.

Table 19: Evaporation for the Eleven weeks study period

Week	RAINFALL PER WEEK	RUNOFF PER WEEK				CHANGED IN DEPTH OF WATER STORED ΔS (mm)				EVAPORATION ET (mm/WK) $ET = PR + \Delta S$			
	P(mm)	A(mm)	B(mm)	C(mm)	D(mm)	A(mm)	B(mm)	C(mm)	D(mm)	A(mm/wk)	B(mm/wk)	C(mm/wk)	D(mm/wk)
1	131.4	19.7	26.3	18.4	23.6	4.1	3.5	4.3	3.7	115.8	108.6	117.3	111.5
2	153.1	22.9	330.62	19.9	27.6	0.6	0.3	0.6	0.5	130.8	122.8	133.8	126.0
3	125.4	18.9	25.1	16.3	22.5	-1.0	-0.2	-0.8	0.5	105.5	100.1	18.3	103.4
4	110.4	15.6	22.0	14.4	19.9	0.3	0.1	0.3	0.1	95.1	88.5	96.3	90.6
5	33.4	5.0	6.7	4.3	6.0	0	-0.4	0.2	0.6	28.4	26.3	29.3	28.0
6	56.3	8.5	11.4	7.4	10.2	-0.3	0.3	-0.8	-0.9	48.0	45.7	48.6	45.7
7	145.4	21.2	29.0	18.9	26.1	0.3	0.2	0.6	0.3	124.5	116.6	127.1	119.6
8	62.4	9.4	11.9	8.14	11.2	0.4	0.2	0.3	0.5	53.4	50.7	54.6	51.7
9	11.8	1.7	2.4	1.5	2.1	-0.3	-0.6	0.1	-0.6	9.8	8.8	10.4	9.1
10	11.0	1.6	2.2	1.4	2.0	0	0.2	-0.6	0.1	9.44	9.0	9..0	9.1
11	12.0	1.8	2.4	1.6	2.2	-0.1	-0.3	-0.4	-0.3	10.1	9.3	10.0	95

Statistical analysis of variance result (Table 20), indicated that plant densities had a significant effect on evapotranspiration. Further analysis using Fishers Least Significant Difference (LSD) also indicated that the average total evapotranspiration is significantly higher for treatment C been the most densely populated. This is followed by treatment A, D and B, in order of plant densities. Treatment B having the least plant density, and invariably the least evapotranspiration as shown in Table 20 and Figure 18.

RESULTS OF STATISTICAL ANALYSIS FOR EVAPOTRANSPIRATION

Table 20a SUMMARY

Treatment	Count	Sum	Average	Variance
A	3	2193.4	731.1333	2.333333
B	3	2056.8	685.67	
C	3	2234.1	744.7	1
D	3	2109	703	2.92

Table 20b ANOVA TABLE

Source of Variation	df	SS	MS	F	P-value	Ferit
Treatment	3	643.463	2145.821	647.632	6.95E-10	4.06618
Error	8	266.5066	3.313333			
Total	11	64463.969				

Table 20c Result of the Fisher's Least Significant Difference (LSD)

Treatment	Mean*
C	744.70a
A	731.13b
D	703.99c
B	685.60d

*Means followed by the same letter are significantly different (p>0.05)

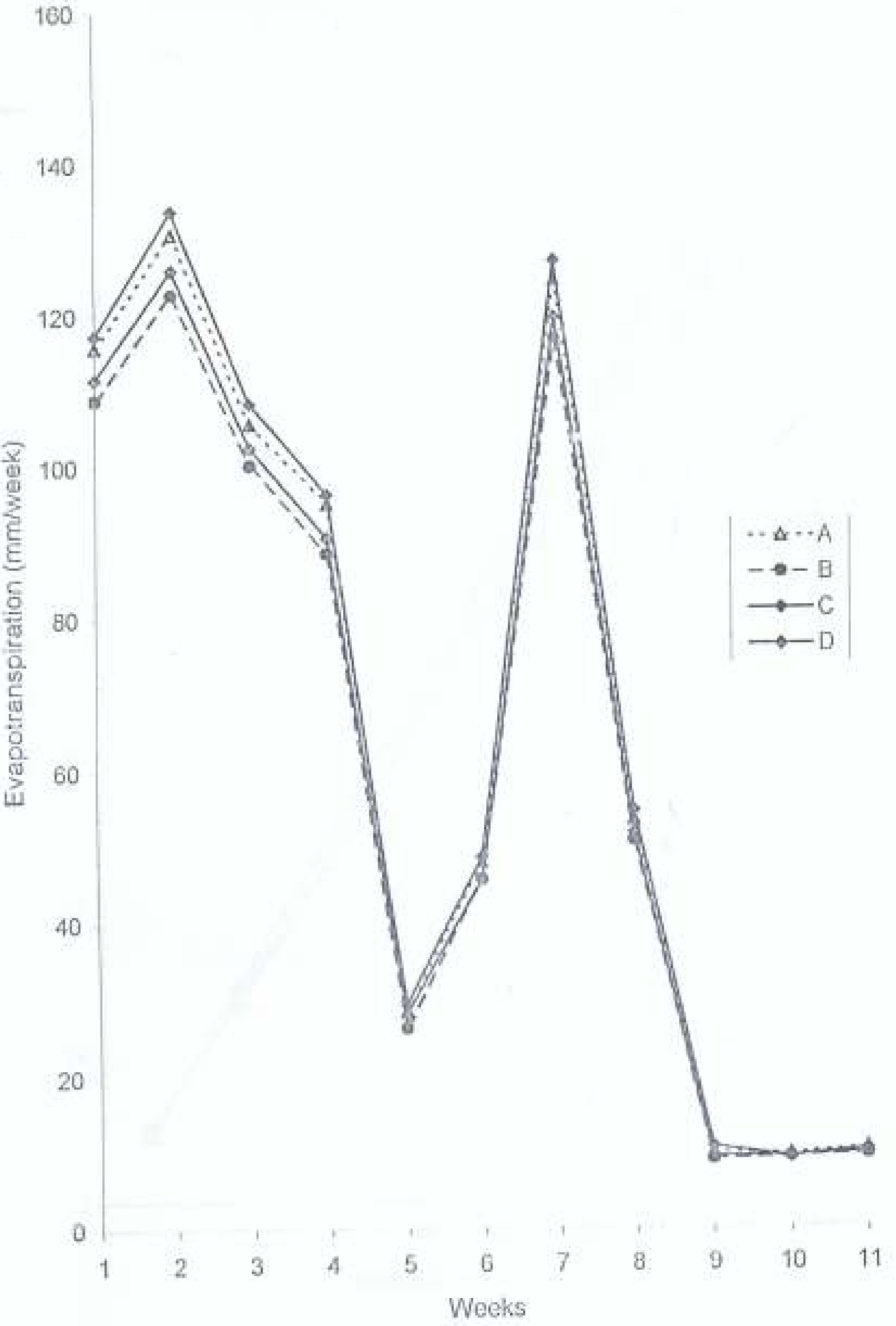

Fig.18 Evapotranspiration for the 11 weeks.

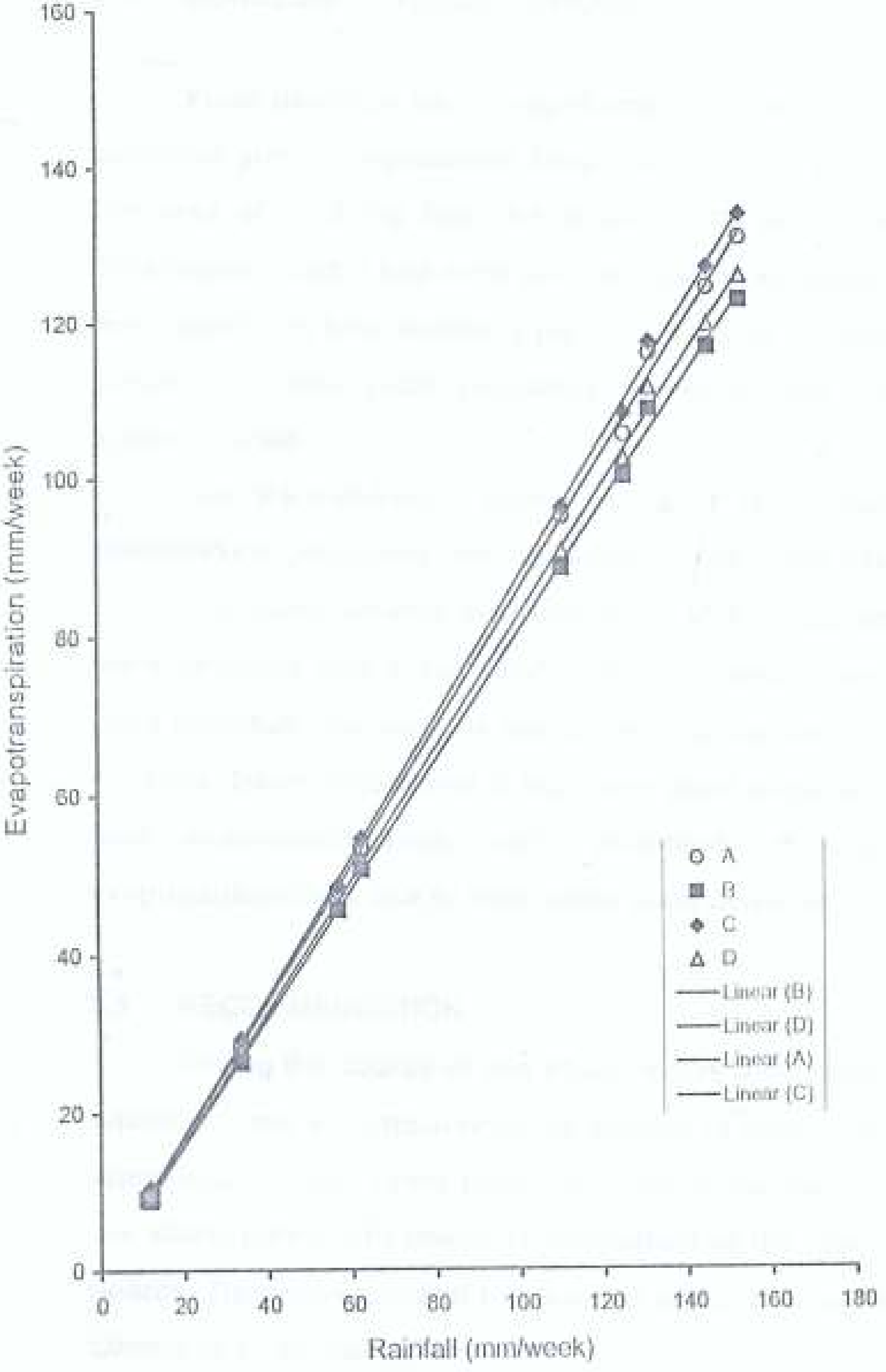

Fig 19 Linear Relationship between evapotranspiration and rainfall

CHAPTER FIVE

5.0 CONCLUSION ND RECOMMENDATION

Plant densities had a significant effect on reducing runoff and sediment yield on agricultural land. The more the population densities per area of land the less the erosion that will occur on the land. Treatments A and C had more plant population densities, thereby having less runoff and less sediment yield. Compared to treatments d and B which have less plant population densities and more runoff and sediment yield.

The Rainfall-Runoff model ($Y= a_0 + b_1x$), would be of great usefulness in predicting and calculating future runoff occurrnece.

The water balance equation ($ET = P-R \pm \Delta S$) also showed that plant densities had a significant effect on evaporation. The more the plant densities the more the evapotranspiration that would occurred on the land. Treatments A and C had more plant densities, thereby having high evapotranspiration, while treatments B and D has less evapotranspiration, due to their lesser plant densities.

5.1 RECOMMENDATION

During the course of this study, it was discovered that the runoff amount is less as compared to the amount of rainfall. During one of the storm event, I went to the field, I discovered that there were leakages at the sides, joints, and points of connection of the pipes to the wooden boards. Thus, gives one of the reasons while there are lesser runoff as compared to the rainfall amount.

My recommendation therefore, is that wooden board may not give an accurate measuring meter for runoff. Metal board will be more preferable.

CHAPTER SIX

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APPENDIX A

RECORD OF PLANT POPULATION IN EACH TREATMENT

Pd = P/A (cm^2)

Pd = Plant density of Amaranthus

P = Population of Amaranthus

A = Area of runoff plot.

Treatment	Population (p)	Plant density (P/m^2)
A-1	140	97
C-1	180	125
D-1	100	69
B-1	60	42
C-2	180	125
A-2	140	97
B-2	60	42
D-2	100	69
D-3	100	69
B-3	60	42
C-3	180	125
A-3	140	97

APPENDIX Bi Runoff Result.

A = Area of runoff plot Area = 1.2mx1.2m

H = V/A H = runoff depth = $1.44m^2$

V = runoff volume = $14400cm^2$

Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 64.0mm
A_1	13680	9.5	
A_2	13968	9.7	
A_3	13824	9.6	

B_1	1843.2	12.8	
B_2	1828.8	12.7	
B_3	1857.6	12.9	
C_1	13824	9.,6	
C_2	13680	9.5	
C_3	13968	9.7	
D_1	1627.2	11,3	
D_2	1684.8	11.7	
D_3	1656	11.5	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 67.4mm
A_1	1440	10.0	
A_2	1483.2	10.3	
A_3	1454.4	10.1	
B_1	1944	13.5	
B_2	1915.2	13.3	
B_3	1958.4	13.6	
C_1	12384	8.6	
C_2	12816	8.9	
C_3	12672	8.8	
D_1	1742..4	12.1	
D_2	1742.4	12.1	
D_3	1742.4	12.1	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 142.8mm
A_1	3081.6	21.4	
A_2	3110.4	21.6	
A_3	3067.2	21.3	
B_1	4118.4	28.6	

B_2	4089.6	28.4	
B_3	4147.2	28.8	
C_1	2664	18.5	
C_2	2692.8	18.7	
C_3	2678.4	18.6	
D_1	3686.4	25.6	
D_2	3715.2	25.8	
D_3	3700.8	25.7	
Treatment	Volume(v)(cm^3)	Depth(H) (mm)	RAINFALL 10.3mm
A_1	2016	1.4	
A_2	2304	1.6	
A_3	2160	1.5	
B_1	3024	2.1	
B_2	2880	2.0	
B_3	3312	2.3	
C_1	1872	1.3	
C_2	1872	1.3	
C_3	1872	1.3	
D_1	2736	1.9	
D_2	2592	1.8	
D_3	2880	2.0	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 37.4mm
A_1	8064	5.6	
A_2	7920	5.5	
A_3	8208	5.7	

B_1	10656	7.4	
B_2	10944	7.6	
B_3	10800	7.5	
C_1	7056	4.9	
C_2	7056	4.9	
C_3	7056	4.9	
D_1	9504	6.6	
D_2	9792	6.8	
D_3	9648	6.7	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 64.0mm
A_1	13680	9.5	
A_2	13968	9.7	
A_3	13968	9.7	
B_1	1857.6	12.9	
B_2	1828.8	12.7	
B_3	1857.6	12.9	
C_1	11952	8.3	
C_2	11808	8.2	
C_3	12096	8.4	
D_1	1641.6	11.4	
D_2	1656	11.5	
D_3	1670	11.6	
Treatment	Volume(v) (cm^3)	Depth (h) (mm)	RAINFALL 24mm
A_1	5184	3.6	
A_2	5472	3.8	
A_3	5328	3.7	

B_1	6624	4.6	
B_2	6912	4.8	
B_3	7056	4.9	
C_1	4464	3.1	
C_2	4320	3.0	
C_3	4608	3.2	
D_1	6192	4.3	
D_2	6192	4.3	
D_3	6192	4.3	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 32.8mm
A_1	6912	4.8	
A_2	7200	5.0	
A_3	7056	4.9	
B_1	9360	6.5	
B_2	9360	6.5	
B_3	9360	6.5	
C_1	6192	4.3	
C_2	6048	4.2	
C_3	6336	4.4	
D_1	8352	5.8	
D_2	8640	6.0	
D_3	8496	5.9	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 56.2mm
A_1	12095	8.4	
A_2	11952	8.3	
A_3	12240	8.5	

B_1	1612.8	11.2	
B_2	1612.8	11.2	
B_3	1612.8	11.2	
C_1	10656	7.4	
C_2	16512	7.3	
C_3	10512	7.3	
D_1	1440	10.0	
D_2	1468.8	10.2	
D_3	1468.8	10.2	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 21.4mm
A_1	4608	3.2	
A_2	4464	3.1	
A_3	4752	3.3	
B_1	14400	4.3	
B_2	14400	4.3	
B_3	14400	4.3	
C_1	5888	2.7	
C_2	4032	2.8	
C_3	4176	2.9	
D_1	5616	3.9	
D_2	5474	3.8	
D_3	5760	4.0	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 9.9mm
A_1	2161	1.5	
A_2	2016	1.4	
A_3	2304	1.6	

B_1	2880	2.0	
B_2	2736	1.9	
B_3	3024	2.1	
C_1	1872	1.3	
C_2	2016	1.4	
C_3	1728	1.2	
D_1	2592	1.8	
D_2	2592	1.8	
D_3	2592	1.8	
			RAINFALL: 23.5mm
A_1	5040	3.5	
A_2	4896	3.4	
A_3	5184	3.6	
B_1	6624	4.6	
B_2	6912	4.8	
B_3	6768	4.7	
C_1	4464	3.1	
C_2	4320	3.0	
C_3	4752	3.3	
D_1	6048	4.2	
D_2	6048	4.2	
D_3	6048	4.2	
Treatment	Volume (V) (cm^3	Depth (H) (mm)	RAINFALL 56.8 mm
A_1	11952	8.3	
A_2	11808	8.2	
A_3	12096	8.4	

B_1	1641.6	11.4	
B_2	1656	11.5	
B_3	1656	11.5	
C_1	10656	7.4	
C_2	10512	7.3	
C_3	10800	7.5	
D_1	1440	10.0	
D_2	1468.8	10.2	
D_3	1497.6	10.4	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 47.5mm
A_1	10080	7.0	
A_2	10224	7.1	
A_3	9936	6.9	
B_1	13680	9.5	
B_2	13536	9.4	
B_3	13824	9.6	
C_1	8928	6.2	
C_2	8784	6.1	
C_3	9072	6.3	
D_1	12384	8.6	
D_2	12528	8.7	
D_3	12240	8.5	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 49.4mm
A_1	10080	7.0	
A_2	10368	7.2	
A_3	10224	7.1	

B_1	13968	9.7	
B_2	14256	9.9	
B_3	14112	9.8	
C_1	9216	6.4	
C_2	9072	6.3	
C_3	8928	6.2	
D_1	12816	8.9	
D_2	12572	8.8	
D_3	12960	9.0	
Treatment	Volume (V) (Cm^3)	Depth (H) (mm)	RAINFALL 48.5mm
A_1	10224	7.1	
A_2	9936	6.9	
A_3	10080	7.0	
B_1	13824	9.6	
B_2	14256	9.9	
B_3	13824	9.6	
C_1	8938	6.2	
C_2	9216	6.4	
C_3	9072	6.3	
D_1	12384	8.6	
D_2	12672	8.8	
D_3	12528	8.7	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 13.0mm
A_1	2880	2.0	
A_2	2736	1.9	
A_3	3024	2.1	
B_1	3456	2.4	

B_2	3888	2.7	
B_3	3744	2.6	
C_1	2448	1.7	
C_2	2304	1.6	
C_3	2592	1.8	
D_1	3312	2.3	
D_2	3168	2.2	
D_3	3456	2.4	

Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 18.0mm
A_1	3744	2.6	
A_2	4032	2.8	
A_3	3888	2.7	
B_1	5184	3.6	
B_2	4896	3.4	
B_3	5472	3.8	
C_1	3168	2.2	
C_2	3456	2.4	
C_3	3313	2.3	
D_1	4464	3.1	
D_2	4752	3.3	
D_3	4608	3.2	

Treatment	Volume (V) (Cm^3)	Depth (H) (mm)	RAINFALL 31.4mm
A1	6768	4.7	
A2	6912	4.8	
A3	5760	4.0	
B1	8064	5.6	

B2	8208	5.7	
B3	8352	5.8	
C1	5904	4.1	
C2	5760	4.0	
C3	6048	4.2	
D1	8208	5.7	
D2	8352	5.8	
D3	8064	5.6	
Treatment	Volume (v) (cm^3)	Depth (H) (mm)	RAINFALL 11.8m
A1	2448	1.7	
A2	2304	1.6	
A3	2592	1.8	
B1	3312	2.3	
B2	3456	2.4	
B3	3600	2.5	
C1	2160	1.5	
C2	2304	1.6	
C3	2304	1.6	
D1	3024	2.1	
D2	2880	2.0	
D3	3312	2.3	
Treatment	Volume (V) (Cm^3)	Depth (H) (mm)	RAINFALL 11.0m
A_1	2160	1.5	
A_2	2304	1.6	
A_3	2160	1.5	
B_1	3168	2.2	
B_2	3024	2.1	

B_3	3312	2.3	
C_1	2016	1.4	
C_2	1872	1.3	
C_3	2160	1.5	
D_1	2880	2.0	
D_2	2736	1.9	
D_3	3024	2.1	

Treatment	Volume (V) (Cm^3)	Depth (H) (mm)	RAINFALL 12.0mm
A_1	2592	1.8	
A_2	2448	1.7	
A_3	2736	1.9	
B_1	3312	2.3	
B_2	3600	2.5	
B_3	3456	2.4	
C_1	2160	1.5	
C_2	2304	1.6	
C_3	2448	1.7	
D_1	3168	2.2	
D_2	3456	2.4	
D_3	3024	2.1	