CHARACTERIZATION OF RUNOFF GENERATED UNDER VARYING COWPEA (VIGNA UNGUICULATA) COVER

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CERTIFICATION

This is to certify that this work was carried out by AFUYE, Gabriel Gbenga (AGE/95/7016) in the Department of Agricultural Engineering, Federal University of Technology, Akure, in partial fulfilment of the requirements for the award of Master in 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 research work is dedicated to my late mother, Mrs. Ogunkeye Esther, who though bore the cross of bestowing on me an everlasting legacy of University education, but waited not to eat from the fruit therein.

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ABSTRACT

Erosion is one of the commonest environmental hazard that has rendered useless millions of hectares of arable soils in the tropics. This study was aimed at determining the runoff characteristics of soils planted with cowpea at different densities.

Treatments were based on three densities: A (Bare soil) which serves as the control, B (13 stands/m^2) and C (26 stands/m^2). Soil moisture content was monitored using gravimetric method. Precipitation, runoff, drainage depths and sediment yields were measured during the experiment which was replicated twice. Rainfall-sediment yield model was established for ease of prediction of runoff that could occur from different precipitations. The water balance equation was used to compute the evapotranspiration for each plot.

Results indicated that runoff depth was least in Treatment C (26 stands/m^2) and was highest on the bare soil. There were significant difference in the sediment yield between the bare soil and the soil planted with 26 stands/m^2 of cowpea with the bare soil having the highest value of sediment yield. Rainfall-sediment yield model show R^2 = 0.9665 in bare soil and 0.9085 in well covered soil in the second experiment respectively, an indication that plant density is a determinant of the sediment yield from rainfalls at any period or time.

The result of this research work is useful in the prediction of future runoffs based on the available storm data for a period.

CHAPTER ONE

Drought stress, poor and declining soil fertility accelerated by degradation of the natural vegetative cover and lack of efficient soil water management techniques have been identified as the major constraints to food production in the Sudano-Sahelian zone (Youdeowei, 1987). In particular, insufficient water supply is the most important single factor affecting agricultural production in the tropics.

FAO (1981) indicated that a bulk of the future crop production increases (60%) in the semi arid regions will have to come from higher yields per unit area of land. Under the rainfed agricultural systems in the Sudano Sahelian zone, where rainfall is low, variable and undependable, increases of crop yields per unit area will depend on making the most efficient use of this limited rainfall.

Water related problems in agriculture are not limited to rainfall alone and as Wadleigh et al., (1991) pointed out that there are 'many hydra-headed' problems emanating from the use and abuse of the soil moisture reservoir. Many research works in the Sudano-Sahelian zone indicated that rainfall in particular is not necessarily the crucial limiting factor to agricultural production, rather it is the proportion of rainfall which enters the soil moisture reservoir and its subsequent utilization by plants.

Understanding the magnitude and dynamics of different components of the crop water balance is crucial to the development of technological options for sustainable management of soil and water resources. In addition to rainfall and run off, a thorough knowledge is required of crop transpiration, soil water storage and losses such as seasonal values of evaporation, weed transpiration, deep drainage and run off.

Rainfall effectiveness in crop and livestock production can be enhanced by reducing these losses since the objectives of coil and crop management is to increase crop transpiration, plant biomass and harvest index.

In search of the following aforementioned, several research have been conducted in various places to ascertain different values of the term expressed in the water balance equation and their variability from place to place as dictated by the local environmental factors. For example, soil texture, structure and profile, relative humidity, wind speed and temperature, affect water loss to the atmosphere. Similarly the degree of cover is related to the amount of water loss through run off.

Efficient management of water resources particularly in the tropics must ensure high production and safeguard against occasional droughts. Drought being a natural phenomenon in this region and menace of erosion resulting from runoff in the rainforest/marine zone can be reduced through judicious management of soil crop and water.

In spite of obvious and remarkable advantage of irrigation over rainfed agriculture, availability of reliable data is a prerequisite to efficient design and operation of full or supplemental irrigation. Long term and even continuous records of scientifically credible data are therefore necessary to achieve sustainable development of water resources.

Accurate determination of farm runoff in particular and other components of water balance are some of the data which this project is aimed at determining using cowpea as case study.

1.1 Objectives of the Project

The objectives of this study are:

[i] to determine the amount of run off water and corresponding soil loss in the study area during rainfall under varying cowpea cover.

[ii] to evaluate the various components of soil water balance and establish mathematical relationships between runoff and sediment yield on field plots planted with cowpea at different densities.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Major Components of Water Balance

Hillel (1971) stated that, the water balance is simply a statement of the law of conservation of matter i.e. matter can neither be created nor destroyed but can only change from one state or location to another.

The water content of a given soil volume cannot increase without addition from outside nor can it diminish unless transported to the atmosphere by evaporation, transpiration or to deeper zone by drainage.

The production of any crop depend on the rate of evapotranspiration (ET). A crop at maximum ET in critical periods of its growth will produce high crop yield. It is therefore essential to be able to estimate accurately crop evapotranspiration in the field. Crop ET is estimated using water balance equation. The equation is generally written as:

$$ET = P + I \pm \Delta S \pm D \pm R \quad \text{[i]}$$

Where,

ET is evapotranspiration (mm)

P is precipitation (mm)

I is irrigation (mm)

ΔS is change in soil water storage (mm)

D is deep drainage (mm), and

R is run off (mm)

Each of the terms is briefly discussed below.

2.1.1 Precipitation (Rainfall)

Dugdale et al. (1991) stated that no calculation of the soil water balance can be contemplated without the knowledge of the precipitation as the prime input. If this requirement is needed for a large area, we shall need to know the characteristics of its variability as well as the average over the area. They asserted that in the case of the Sahel, there is considerable spatial variability in rainfall together with the surface features which govern infiltration and local run off. This leads to great heterogeneity in the water balance on scales from tens of meters upwards, hence to similar variability in evaporation (Filtrocroft et al., 1991).

On the other hand, Shen and Li (1973) as cited by Gilet et al. (1995) examined the effects of the raindrop impact on flow resistance over a smooth surface. A set of regression equations was presented for relating Darcy - Weisbach roughness coefficients to rainfall intensity and Reynolds number. They affirmed that for most upland agricultural area the effects of raindrop impact on flow resistance are expected to be minimal.

Agnew (1982) reported that Sahelian rainfall has been the low long term mean for the last 20 years. Meanwhile, Farmer (1989) demonstrated the effect of low long term rainfall mean upon identifying abnormally low rainfall of changing the base period for calculations. In addition to this, Tickell (1986) and Flohn (1987) had earlier held the view that significantly low rainfall has led to widespread and persistent drought in the Sahel since the late 1960s. Their views or observation have been based upon meteorological definitions of drought.

Beran and Rodier (1985) argued that a reduction in precipitation is the primary characteristic of drought but Gregory (1986) and Wihite and Glantz (1985) asserted that there are numerous alternatives which use soil water availability. In the light of this, they maintained that drought is as a result of the impact of water shortages rather than just rainfall.

In their submission, Schmidt et al. (1997) stated that long variability of monthly total precipitation is required in many areas of water resource management and engineering design such as long range planning for municipal water supply, permitting agricultural water use, planning for waste water reuse, flood routing, levee design, reservoir design and irrigation system design and management. They argued further that both the distributions of monthly precipitation totals and the possibility of changes in these distributions are fundamental to all of these activities.

In their research, Kanemasu et al. (1988) reported that growing season duration, rainfall and crop yield depend significantly on the onset data of the assured rains. They stated that information of this nature derived from climatic data is a powerful planning tool and must be used toward planning for sustainable development of land and water resources.

Furtherance to this, Dugdale et al. (1991) noted that measurements of precipitation (P) and irrigation (I) are usually easy and simple and are normally done with the aid of rain guage(s). But, they stated that in an area so large and sparsely inhabited as the Sahel that it is clearly not practicable to operate a network of rainguages dense enough to give the information which is needed on a daily or even more frequent basis. One naturally turns to observations from satellites which can observe the whole of the Africa continent impartially and regularly which also provide immediate communication of the result to any number of receivers.

Monteith (1991) stated that shortage of water in the semi arid tropics is not a consequence of poor annual rainfall, rather that the problem for human settlement and particularly for agriculture is the seasonal distribution of rainfall and the rate at which it is lost by evaporation.

2.1.2 Water Storage (ΔS)

In principle, assessment of soil water storage appears simple. In practice, however scientifically credible estimates of soil water storage on the field scale may be cumbersome and subject to error because of large spatial and temporal variations. Most methods have their specific advantages and disadvantages for instance, instruments used for measuring soil water content are usually accurate only for changes longer than a week or so unless a large amount of water has been added by rainfall or irrigation.

Non-destructive techniques (e.g. Neutron Moderation) are usually expensive and require careful calibration for all soils and major horizons. The neutron probe samples a large volume but the maintenance of equipment is a problem to be considered for operations in the tropics.

Smith and Harris (1981) as quoted by Gregory (1991) stated that depth and texture of the soil are the major problems affecting the storage of soil water and have a direct effect on the potential length of the growing season in rainfed environments. On deep soils the additional rain in wet years can be stored at depth and used to extend the period of grain fill whereas on shallow soils, there is little benefit from wetter years.

2.1.3 Drainage (D)

Lysimeter was derived from two Greek words, lysis and metron meaning to dissolve and measure respectively. Lysimeter can therefore be described as any device used to study the rate, amount and composition of percolation water through a soil profile. It can also be properly defined as a container filled with soil or enclosing a soil mass located in the field to represent the field environment with bare or vegetated surface (crop or grass) for determining the evapotranspiration of a growing crop or reference vegetative cover or determining evaporation from the bare soil.

The five principal determinations in settling up a lysimeter are: the soil, plant, water, soil block or container and the weighing accessories (in case of the weighing type). There are two basic types of lysimeters, they are the weighing and non-weighing lysimeter.

The weighing lysimeter is used for high precision research works where high accuracy is needed and the time interval for reading is short. The weighing lysimeter had been sub grouped according to the weighing device employed to record changes.

The different types of weighing lysimeters are:

[i] mechanical weighing lysimeter

[ii] electronic weighing lysimeter

[iii] hydraulic lysimeter

[iv] floating lysimeter

The general principle involved in all weighing lysimeters is that changes in the weight of the lysimeter indicate either incoming or removal of water as the case may be. An increase in weight indicate addition of water while a decrease shows the loss of water as evapotranspiration over short intervals. But the complexity in the installation and cost of construction limit the use. The following lysimeters are the available weighing type.

[i] <u>Mechanical Weighing Lysimeter</u>

In this instrument, mechanical balances are installed to assure direct changes in the weight of the container and soil mass. These changes are due to precipitation, irrigation (increase) or to evapotranspiration or drainage (Abuoukhaled, 1982), in case of decrease.

Different provisions are made so that the inner container of the tank can be removed and weighed periodically. The principle of counter weighing mechanical balance has been applied to large lysimeters and had given successful and accurate results of evapotranspiration in short interval of time. The lysimeter is sensitive but its cost limit its use to specialized institutions.

[ii] Electronic Weighing Lysimeter

The principle employed here is that the changes in weight of inner container and the soil mass are recorded using the strain gauges of electronic load cell. The electronic lysimeter is very sensitive and its use is limited to the research station.

[iii] Hydraulic Weighing Lysimeter

The changes in weight of the lysimeter cause a change in the height of the fluid in the manometer. This could be readily used for daily measurements of evapotranspiration but the limitation to its use is the rubber bolsters, which may expand if they are made of elastic materials.

[iv] Floating Lysimeter

The floating lysimeter is based on the principle of Archimedes or the buoyancy law. The container for the lysimeter and the soil plant on top of the fluid usually water or zinc chloride solutions are increased due to the addition of water leads to rise in the level of the fluid and vice versa.

The hydrostatic lysimeters are relatively less costly and highly sensitive. However, heavy liquids are required in order to achieve the maximum upthrust. The major limitations to the use of this lysimeter is that changes in temperature affect the thermal expansion, evaporation and the effects of wind also reduced the accuracy.

Non-weighing lysimeter is used to determine the evapotranspiration from the crop and/or the uncovered soil by removing and subtracting volumetrically the quantity that collect at the bottom from the total water input through precipitation or irrigation. Example of the non-weighing lysimeter is the drainage lysimeter.

There are various models of drainage lysimeter. The most popular design is that by Thornthwaite, 1948. The instrument is connected using oil drums and pipe as seen in Fig. 1.

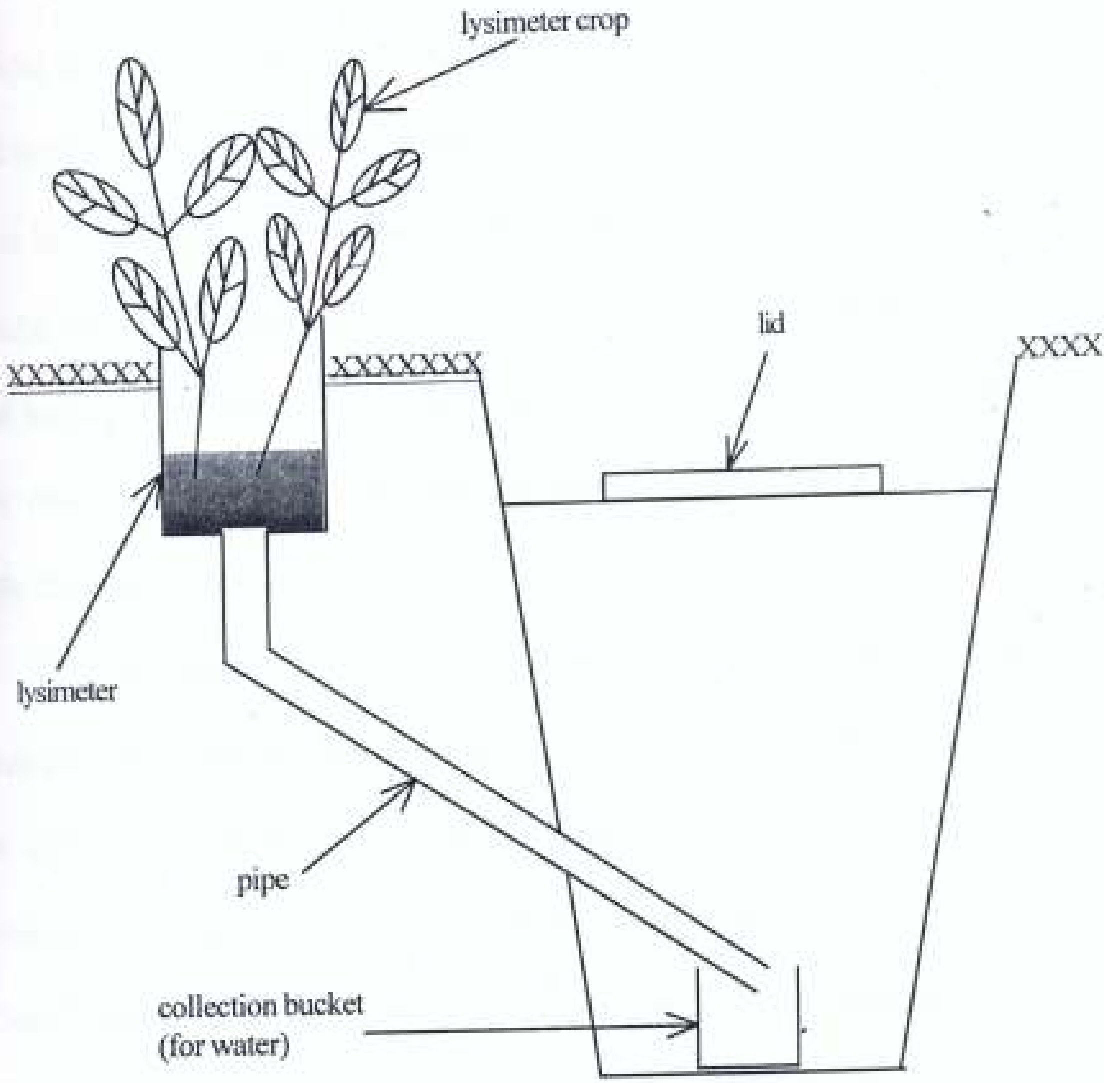

Fig. 1: Drainage lysimeter

Drainage lysimeters have a number of limitations which one should guard against. They are difficult and may be costly to install and leakage can also be a problem. The instrument should be dug out once in a while and inspected for any leakage. For this reason, there should be at least two drainages at a given site to ensure that there is at least one functioning all the time. For credible result to be obtained, it is necessary that six drainage lysimeters be installed at a given site while the result obtained averaged.

During installation the soil structure is usually disturbed, therefore measurement should not commence until particles have settled and the soil structure is similar to the one surrounding the lysimeter. Although drainage lysimeters are usually read daily, results for periods of less than 5 to 7 days are not reliable because of storage water in the soil. Not withstanding, this adverse effect has been found to be minimal in sandy soils in Nigeria.

Drainage lysimeters are also subject to both oasis and clothesline effect due to the vertical energy transfer from the air above an irrigated plot and horizontal heat transfer which occurs when warm air blows through a small irrigated plot with little or no guard area respectively.

To Combat these effects Thornnthwaite and Matter (1955) have suggested that drainage lysimeters should have buffer zone of at least 400 meters in very dry area and 300 meters elsewhere to obtain reliable values.

These guard areas should be kept permanently moist through artificial irrigation since the dryness of the area around the drainage lysimeter is an actual feature of the local climate. Although excessive irrigation might modify this climate and result in unduly low readings of potential evapotranspiration especially in relatively arid environments.

Hoogmoed et. al. (1991) stated that lysimeter can contain several cubic meters of soil but may be as simple as 20 or 30 cm diameter tubes sunk 10 to 50 cm into the ground. They can be lifted out regularly for weighing or left with a solid plate at the bottom to induce (artificial) saturation and lateral flow into a collection pit (Angew, 1982; Shawcroft and Gardner, 1983; Kmocke et al., 1985). Preferably but not necessarily, lysimeters contain undisturbed soil. This is done by removing layers of soil on the same spot, keeping it in separate containers until you get to the equivalent depth of the lysimeters. This is followed by laying the layers into the lysimeter with the deepest layer at the bottom and the top soil also at the top of the lysimeter.

2.1.4 Infiltration

Bourwer (1986) used two ring cylinder infiltrometer which made use of ponded water by measuring the rate of fall of the water level in the inner ring, while water infiltration into the soil between the two rings ensures one dimensional flow. He discovered that the method is not suitable for soils with macro pores where flow is not one dimensional or of soil with fragile surface crusts which will break when the rings are pushed into the ground.

In their research, Falayi and Bouma (1975) handled the crust by carefully cutting it with razor blade a few millimeter inside the infiltrometer ring before the ring is pushed into the soil. The gap between the ring and the undisturbed crust is sealed with a gypsum paste or preferably with quick drying hydraulic cement. Water was applied from a burette with a mariote device to control suction. Sub-crust matric potential is measured with a small tensiometer. This they found to be suitably accurate and quick for crusts without too many rocks in them. Rainfall hitting the soil surface may have a considerable effect on its condition. This is especially true for the climatic conditions in the tropical zone where rainfall is aggressive. But Williams et al. (1995) reported that undisturbed microphytic crusts enhanced infiltrability at some sites in the United States. This enhancement was attributed to the ability of microphytes to reduce development of physico-chemico rain crusts in loessal - silt soils. Furthermore, they asserted that infiltration into sandy soils increased three fold after lichen crusts had been removed from plots in Western New South Wales Australia.

In addition to this, Yair (1990) reported that in the Negev Israel, preliminary results indicated that removal of a thin microphitic crust increased infiltration capacity and reduced erosion of clays and silts. Although, he added that not all microphytic crusts reduce erosion potentials.

In another research, Williams et. al. (1995) reported that removing microphytes from a sandy site in Australia increased infiltration to such an extent that run off and interrill erosion were negligible. To explain this, they attributed their results to exposure of macropores with the removal of the microphytic crust.

2.1.5 Evapotranspiration (ET)

Evapotranspiration (ET) could be measured directly from the lysimeter already discussed by weighing the lysimeter at least two times a day (e.g. early in the morning and at evening when sun is setting). Since the deep drainage/drained water would have been trapped by water proof pan, it follows that the difference between the early morning weight and the evening weight constitute the water loss for that day into the atmosphere.

Based on experimental results, theoretical considerations and review of literature Idso (1981) discovered that evaporation from an extensive body of water does not increase measurably by the introduction of any type of vegetation upon its surface. However Anderson and Idso (1987) suggested that the increase in evapotranspiration (ET) of such water plant as water hyacinth in experimental studies was due to the increased peripheral exposure to advective energy. They reported that the ratio of wet land plant evapotranspiration (ET) to open water evaporation is linearly related to the ratio of vegetation area to open surface area.

Wallace et al. (1988) in another research measured components of evapotranspiration (ET), soil evaporation (E) and crop transpiration (CT) for millet using small lysimeters and eddy correlation technique. They observed that the ratio of actual to potential evaporation ranged from 0.3 to 0.6 while the crop was present and was below 0.3 after harvest. These authors also computed the crop factor for millet as defined by Doorebos and Pruit (1977). The crop factor averaged 0.38 for the ten days before harvest and 0.15 for a similar period after harvest.

Long and Pesand (1988) in Niamey assessed the influence of neem (Azadirachia Indica) wind break on water use efficiency (WUE) of millet. The result indicated WUE by 27.3 and 67.7% for grain and dry matters production respectively. In another research, Relchandt et al. (1990) measured water use by maize along a transect of 120 m and found that ET varied from 1.6 to 3.2 mm/day during one sampling period. These data suggest that soil spatial variability does have effect on calculations of evapotranspiration (ET). However, Owonubi et al. (1991) stressed that transpiration by plants and evaporation from soil and water surfaces involves an input of energy from the phase transformation of water from liquid to vapour and the transportation of the vapour away from the surface. Furthermore, they maintained that the potential magnitude of evapotranspiration (ET) in any environment is therefore dependent on solar radiation, temperature, humidity and wind speed. Out of these, radiation and temperature in general tend to have the most influence on evapotranspiration (ET), they argued.

2.1.6 Run Off (R_{off})

Hoogmoed et al. (1991) defined run off as a process involving a flow of water over the soil surface. It could be expressed in form of equation thus:

$$R_{off} = P\ (+ Irr) - SSD - I \quad \text{......................} \quad (2)$$

Where,

SSD is the surface storage and detention

I is the infiltration

Three parameters are involved

- rainfall reaching the soil surface
- infiltration of water into the soil profile; and
- the static and dynamic storage capacity of the soil surface depending on the slope and roughness/configuration of the surface.

These three parameters are dynamic and not independent from each other, for example; surface roughness and infiltration capacity may both decrease under rainfall.

Run off collecting areas in agricultural research may range from areas of less than 1 m^2 up to a complete water shed. Basically there are three classes of plot size namely, the small plots, USLE (Wiscmeier) plots and water shed type plots which are hereunder discussed:

The small plots ranging from 1 - 2 m^2 are used commonly in combination with rainfall simulations, but can also be used under natural rainfall. The plot can be easily installed; it is cheap and all runoff water and sediment can be collected.

The Wischmeier of USLE plots are large enough to permit study of the combined processes of rainfall, runoff and erosion. Standard plots are 1.8 m wide and 22 m long. Though the construction of such plots is not all that expensive, their operation can be rather time consuming. Wischmeier and Smith came out with the Universal Soil Loss Equation (U.S.L.E) when they work on such plot like this (Hoogmoed et al., 1991).

The watershed-sized plots may comprise agricultural fields plus natural drainage ways. The field area may consist of cropped areas or natural vegetation, or a combination of both. Preferably, the area should be under only one type of cover or treatment.

The size and shape of a watershed permits the evaluation of conservation measures on a larger-than-field scale (terraces 'digues filtrantes' etc.). The major disadvantage is that the results obtained from these plots cannot easily be reproduced.

Many studies have been conducted to examine erosion and sedimentation resulting from forest management. Hoover (1952) in his research conducted to examine erosion and sedimentation resulting from forest management in North Carolina as cited by Grace III et al. (1998), measured 5238 m^3 of soil loss in four years from 3.7 km of road; up to 90% of the sediment following the felling of timber operations, came from temporary and permanent roads used by lorries. He therefore stressed that effective methods to control erosion from forest roads would directly influence water quality in the forest ecosystem. But Lawes (1964) at the Institute of Agricultural Research (IRA) Zaria used small catchment gauges to asses runoff losses from bare and mulched plots. He obtained figures as high as 45% of annual rainfall from frequently cultivated bare fallow while run off on the mulched plots was negligible. On the other hand, Kowal (1970) used data of over five years period which included cropped land, from which he showed that run off varied with management practice, being greatest on cropped plots ridged along the falling coutour and in bare falow land and least in cropped land with alternatively tied ridges. Besides early in the season, all rainstorms of more than 20 mm in 24 hour resulted in some run off.

In their research, Meyer et al. (1972) found an inverse correlation between rock cover and erosion rates. Coverage of 34 t/ha of stone showed ineffective erosion control, where as 303 t/ha of stone was an effective erosion control treatment.

Dyrness (1975) in the mounts of Western Oregon made use of five different seeding mixtures on a five-year old 1:1 cut slope to assess the effectiveness of grass legumes mixtures and mulch, application in controlling soil erosion. It was found that effective erosion control depends on fast initial vegetation growth and cover.

Treatment with mulch applied at a rate of 4.5 t/ha were found to be more effective than treatments without mulch. The study showed the importance of mulching to minimize soil losses during the first few months after construction.

Berglund (1976) in his own study, discovered that establishment of plant and liter cover was found to be most important deterrent to surface erosion. Erosion from undisturbed forest land is less than 0.27 t/ha/year which is less than the normal rate of geological erosion estimated at 0.49 to 0.8227 t/ha/year (Smith and Starney, 1965; Partic, 1976; Beasley, 1979; Yoho, 1980). However, they stated that higher level of soil erosion can occur when the forest cover and forest floor are disturbed by forest operations. But forest road construction has been cited as the dominant source of erosion in the forest of the eastern United States (Patric, 1976; Swift, 1984).

Laflen and Molderhauer (1979) in their research studies conducted to evaluate cropping effects on erosion under natural rainfall conditions, found that annual soil loss from corn following soybean was bigher than that from corn following corn. Furthermore they discovered that most of the annual difference occurred during the rough fallow and rapid growth periods.

Laflen and Colving (1981) studied soil loss from three types of tillage (conventional, reduced and no-till) from which they found that soil loss, sediment concentration and residue cover were significantly different for no-till compared with both conventional and reduced tillage systems. Specifically Yoo et al. (1987) documented more than 50% reduction in soil for a first year no-till system when compared with a conventional tilled system.

Brenneman and Laflen (1982) together with Cogo et al. (1984) concluded that residue cover reduces erosion in one of the following four ways:

(i) dissipation of the energy from raindrop impact.

(ii) slowing run off and increasing flow depth which in turn reduces the impact of rain drops.

(iii) absorption of some of the forces from run-off that are usually applied to the soil surface.

(iv) creation of small reservoirs of pounded run off causing deposition.

Alberts et al. (1985) on the other hand did not find any difference in soil during the seed bed period between continuous soybean and continuous corn that were conventionally tilled.

Field-scale rainfall simulation has also been used to evaluate the effect of prior cropping effect on soil loss. Results have ranged from those that have found a prior cropping effect (Oschwald and Siemens, 1976) to those that have not found an effect (Laflen and Colving, 1981).

Norton et al. (1985) reported the role which residue plays in controlling erosion. They analysed four management systems and reported that residue cover and roughness index were correlated to soil loss ($r^2 = 0.76$) with most of the variance in erosion being explained by the residue cover factor.

Zhu et al. (1989) studied the effect of no till soybeans with a winter cover crop on run off and soil loss using natural rainfall plots. They reported run off and soil loss reduction of approximately 90 and 50% respectively. The lower soil losses were attributed to increase in soil cover during the critical erosion period. Flows that do not inundate the vegetation, buffer strips of forage species planted in 5 to 15 m wide, strips separating cropped areas can slow run off and trap sediment (Neibling and Alberts, 1979; Hayes et al. 1984; Magette et al., 1989; Line, 1991).

However, if flow concentrate and force the vegetation into a prone state, the flow-retarding and filtering effectiveness of buffer strips is greatly reduced (Kouwen et al., 1981; Dillaha et al., 1989; Flanagan et al., 1989). Dabney et al. (1993) reported from their finding that narrow hedges promoted sediment deposition primarily by slowing run off in the pounded back water. The retarded flow allows for the settling of transported sediment. In these pounded area, in field situations, this flow is spread along the barrier and reduces the potential for ephemeral gully erosion. The design of vegetative barriers for concentrated flow zones depend on anticipated run off rates, sediment, load, topography and density of the vegetation being established.

McGregor and Dabney (1993) in their research using stiff-grass hedges that were transplanted across the lower end of standard erosion plots showed the hedges to be quite effective in reducing soil losses for uniform - flow condition. However, much greater flow rates occur in many field situation where run off concentrates. Therefore, the research was conducted to evaluate the effectiveness of stiff grass hedges for retarding run off and trapping transported sediment in major upland channels. Then, they defined vegetative barriers as narrow strips of stiff erect, dense, perennial vegetation established along the general contour of slopes, but crossing concentrated flow areas at convenient angles for farming.

Kemper et al. (1993) argued that stiff grass hedges are a subset of vegetative barriers which has great potential for reducing sheet, rill and ephemeral gully erosion on crop land. Carter (1985); Finkel (1986); Heede (1991) and Teamah (1993) agreed that hedges or other porous barriers crossing paths of concentrated flow channels, slow run off, cause temporary pounding upslope of the barrier, and allow time for the settling of suspended sediments.

Flanagan et al. (1989); Dilaha et al. (1989) and Magette et al (1989) concluded that stiff erect extend the range conditions where grass strips can control run off and sediment yield by withstanding higher flow rates and allowing deeper sediment deposits than grasses normally used. They argued that conventional grass buffer strips and filter strips can fall where run off flows concentrate because the grass becomes submerged at discrete location which allows increased water velocities or because vegetation fails to grow fast enough to avoid being inundated with sediment.

Benkobi et al. (1993) also studied the effect of surface cover types, their combinations and percent ground coverage on soil loss using a rotating boom rainfall simulator. They found that a combination of rock cover and vegetation liter may offer effective erosion control.

Gantzer et al. (1987) likewise studied the effects of soybean and corn residues on soil strength and splash detachment. However, very limited information is available on the effect of dead roots on soil erodibility, splash detachment and aggregate stability.

Edwards et al. (1994) indicate that run off concentration and mass transport of various poultry liter components depend on variable such as rainfall intensity, poultry liter, application rate, cover, number of rainfall events following application and amount of time between litter application and rainfall.

Chidey and Alberts (1997) stated that the effect of root parameters was not observed on splash detachment as they were on soil strength, aggregate stability, dispersion ratio and their rill erodibility. They maintained that soil splash is mainly due to the forces of falling raindrops breaking down aggregates. They cited from the work of Hudson (1981) which stated that the kinetic energy of raindrops falling at terminal velocity is from one to two order magnitude greater than the kinetic energy associated with gently flowing water. They concluded that dead roots had no effect on run off but significantly influenced ($P<0.05$) soil loss and sediment concentration. Furthermore they maintained that soil loss and sediment concentrations from annual row crops were significantly higher than those from perennial crop; however the differences in soil loss among the crops were small relative to the differences in root mass and root length. More also that dead roots had no effect on the soil bulk density which significantly influence soil shear strength.

Grace III et al. (1998) studies the effect of erosion on mat native grass and exotic grass with a bare control in the controlling of erosion on both cut slope and fill slope. They discovered that erosion control treatment had a significant effect on reducing sediment yield from newly constructed road side slopes. On fill slopes, the erosion mat exotic grass and native grass stabilization treatments were equally effective, reducing sediment yield by about 85% compared with the bare soil control treatment. On cut slopes, the efficacy increased from native grass to exotic grass to erosion mat. In addition the erosion mat reduced cut slope sediment production by a factor of four compared with the exotic grass treatments. On the more erodible conditions of the fill slope the extra cost of the erosion mat treatments was not justified.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site

The study site is situated on the five acre farmland of the Department of Agricultural Engineering Federal University of Technology Akure, Ondo State of Nigeria. Akure is situated between latitude 7°N and 8°N and longitude 5°E and 6°E. The annual precipitation ranges between 1000 mm and 1500 mm. The average monthly temperature during the raining and dry seasons are 27°C and 30°C respectively. The maximum relative humidity during the wet and dry seasons are 75% and 50% respectively.

The soil in the experimental farm site is sandy-clay loam which lies over a red clay loam subsoil (Fasinmirin, 2001). The average infiltration rate of soil in the site is 9.89 cm/hr and the slope of the land on average is 7.6% (Malumi, 2001).

3.2 Agronomic practice

Field experiments were carried out at the farm site during the raining seasons of 1998 between June and August and was repeated between August and October. The field was cleared and seed bed prepared manually with hoe. Cowpea was planted at the spacing of 40.0 cm by 60.0 cm for the scarcely covered plots while the densely covered plot was planted at 15.0 cm and 60.0 cm. A 3 m strip was allowed in-between plots to prevent interference of crops. Cowpea (Vigna Unguiculata) was manually sown in the plots on 10th June, 1998. The runoff meters were driven approximately 30 cm into the slope surface to ensure that rainfall and surface runoff within each plot were isolated from adjacent plot A. 100 mm diameter PVC was inserted into the hole created midway at the bottom of the runoff metre (Figs 2 & 3 and Plates 1 & 2). The PVC pipe leads to an excavated ditch in which was placed 25 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 and as well prevent direct evaporation.

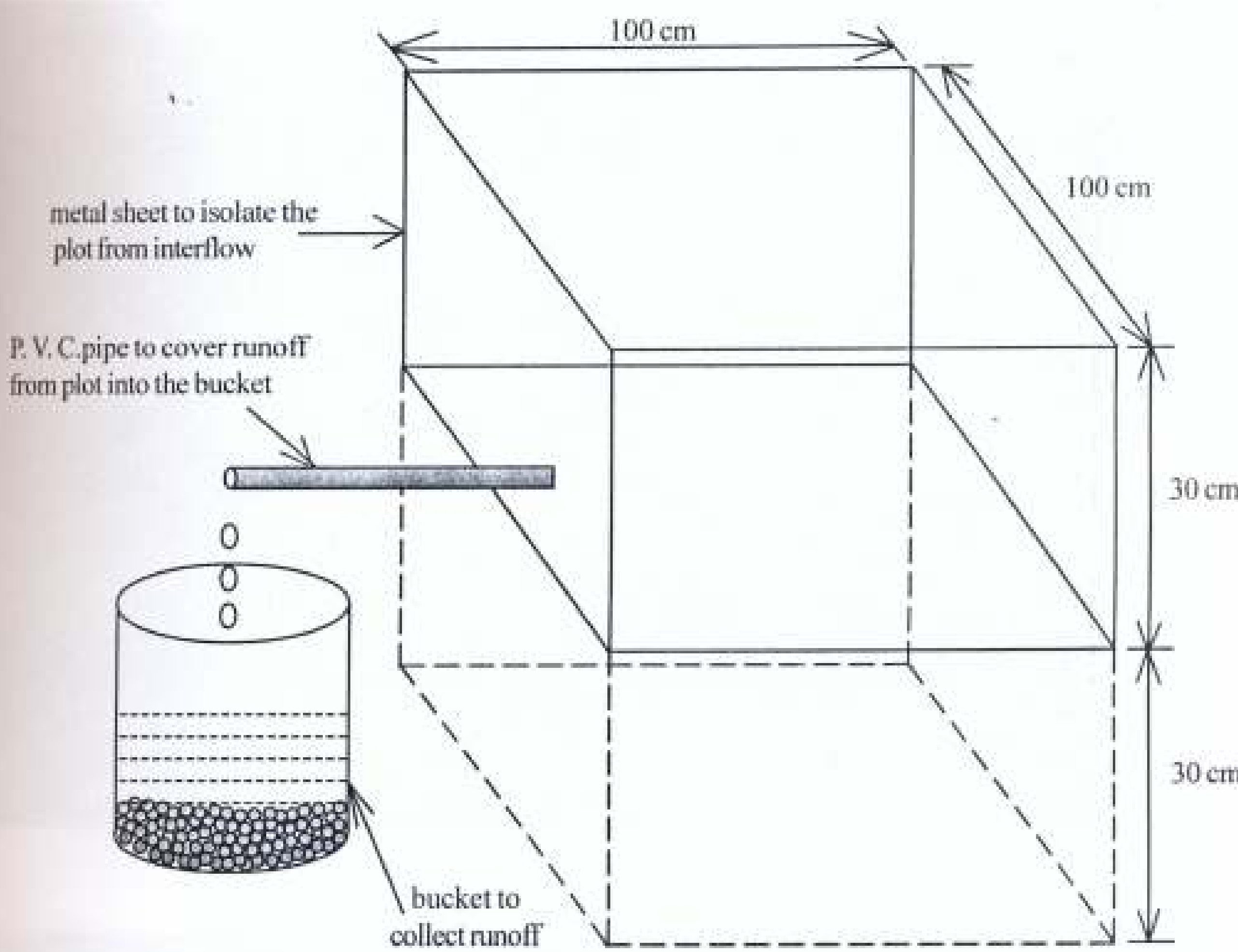

Fig. 2: A runoff meter used in the field.

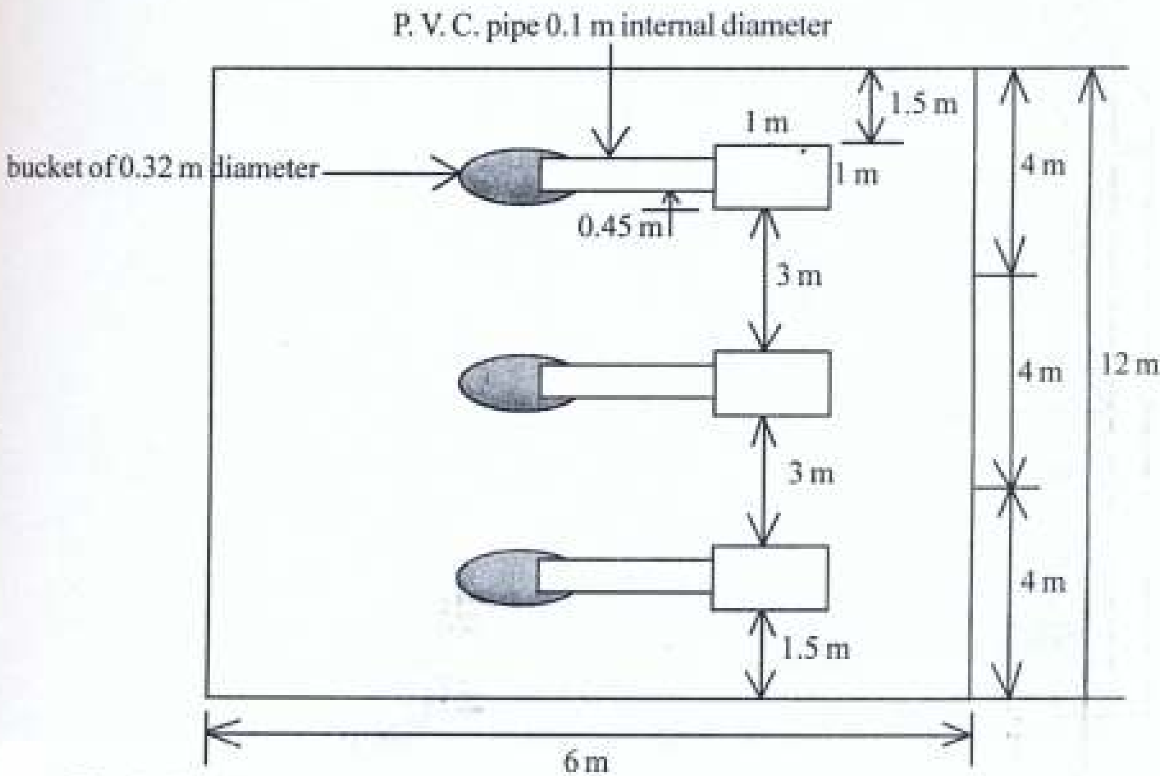

Fig. 3: Field layout of runoff meter

Plate 1 A view of the experimental plot showing lysimeter and Rainguage

Plate 2A A view of the experimental plot showing soil sampling with soil auger.

Plate 2B A view of the Runoff metre Installation on field

3.3 TREATMENT AND EXPERIMENTAL PROCEDURES

There were treatments based on the degree of vegetation cover (Plant densities) as shown in Table 1. The plant densities were 26 plants/m^2 for the well covered soil 13 plants/m^2 for the partially covered soil and zero plants/m^2 for the bare soil.

Table 1: Different plant densities in treatments

Treatment code	Definition
A	Bare soil
B	Sparsely covered soil with 13 stands/m^2
C	Densely covered soil with 26 stands/m^2

3.4 MEASUREMENTS

3.4.1 Estimation of Evaporation

The crop water use were determined from the principle of inflow-outflow (water balance method) as shown by Equation 3

$$E_T = P + I - R \pm \Delta S - D \quad \text{..............................} \quad (3)$$

Where

E_T = Evapotranspiration (mm)

P = Precipitation (mm)

I = Irrigation (mm)

R = Runoff (mm)

ΔS = Change in groundwater storage (mm)

D = Drainage (mm)

3.4.2 Rainfall

The major variable influencing sediment yield and runoff volume measured in this study was rainfall amount. Rainfalls were measured by a single rainguage located on the site. Readings were taken immediately after each rainfall and their values are compared with values obtained from a standard meteorological station situated $1^1/_2$ km away from the site of experiment. While the values were sometimes closely similar, there were times when they were not. The disparity was due to localized rainfalls.

3.4.3 Runoff

Runoff water was measured after each rainfall. The runoff collected at each recipient was carefully measured using a measuring cylinder. Three samples were collected from each of the plot A, B and C to estimate the sediment yield. The volume of each sample was $^1/_2$ litre. The samples were analysed to determine the sediment yield by oven drying it and weighing, following the procedure recommended by Greenberg et al. (1992) and Dabney et al. (1995). The sediment yield was taken as the average value of the three samples. Total sediment yield was determined by adding deposited and suspended sediment fractions in the containers.

The runoff values were determined using the relationship:

$$R_o = \frac{V_w}{A_c} \qquad \text{.. (4)}$$

Where,

V_w = Volume of water collected (m^3)

A_c = Area of catchment (m^2)

R_o = Runoff (m)

3.4.4 Soil Moisture Content

The soil moisture content at depths, 0 cm, 20 cm, 40 cm and 50 cm from each plot were determined once per week using the gravimetric method. The change in soil water storage was calculated from the difference in water content of the root zone before irrigation and the water content after irrigation (see appendix).

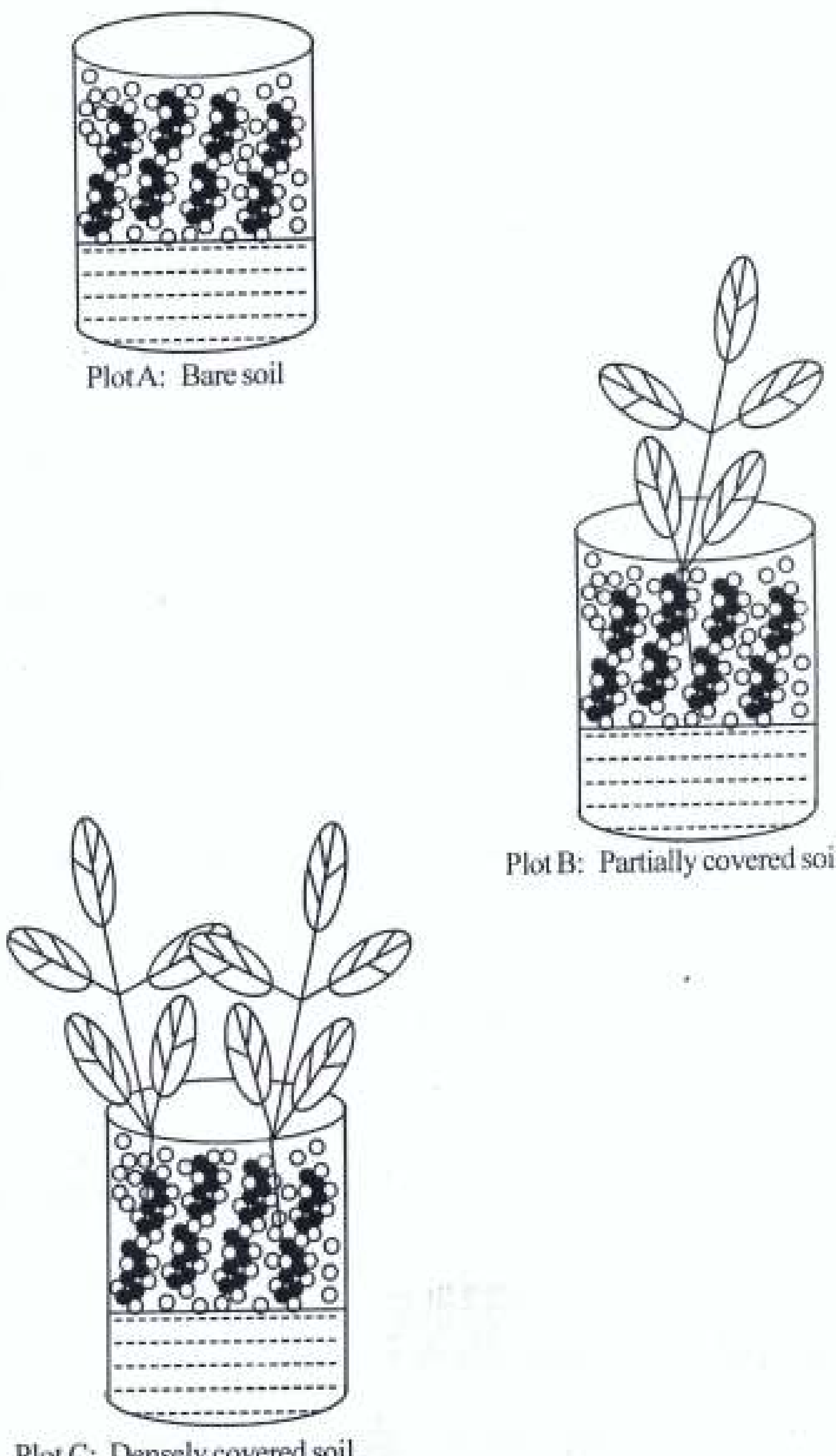

Fig. 4: Mini lysimeter

3.4.5 Soil Bulk Density

Soil sample were taken from the three plots for the determination of bulk densities. The bulk density was calculated using the formula below:

$$\text{Bulk density} = \frac{\text{Mass of oven dried soil}}{\text{Volume of soil}} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

$$\text{Dry density} = \frac{\text{Bulk density}}{1 + \text{Moisture content (\%)}} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

3.4.6 Drainage

The drains from each plot were collected by means of three mini lysimeters which were installed one in each of the plots. Fig. 5 shows a section of the drainage lysimeter on the field. The drainage lysimeters were inserted directly beside each of the three Runoff meters and were subjected to same treatment as carried out in the runoff meters.

3.5 Statistical Analysis

Results obtained were subjected to statistical test such as means and analysis of variance (ANOVA) at 5% level to test whether there is or no significant difference among treatments.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Rainfall

Rainfall data during the first and the second experiments are presented in Tables 2-7. There were rainfalls during the 7th to the 42nd days after planting but were not enough to cause runoff in any of the plots during the first experiment. This may be due to porous and loose structure of the soil influenced by tillage operation carried out on the soil. Hence, the greater proportion of rain water infiltrated into the soil. This agrees with the observation of Jarvis et al. (1985) which stated that infiltration into the soil and rate of wetting from irrigation were consistently faster on tilled soil than untilled soil.

However, there were few but heavy rainfalls during the second experiment which falls in the second peak of the raining season. Storm event of 116.20 mm during the 28th DAP produced the highest runoff and sediment yield of 35.2 mm and 737.6 g respectively on the bare soil. In contrast to this is the reduced runoff (19.9 mm) and sediment yield (52.0 g) observed in the well covered soil under the same storm event as in 116.2 mm of the 28th DAP. Zero runoffs were recorded from 42nd to the 70th DAP during the second experiment due to the onset of the dry season that was characterized by few or no rainfall.

Table 2: Total rainfall, total average runoff and total sediment yield per week for each Sampling period during 1st experiment (Bare soil).

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	2.00	0.00	0.00
14	5.20	0.00	0.00
21	3.65	0.00	0.00
28	2.50	0.00	0.00
35	6.32	0.00	0.00
42	7.00	0.00	0.00
49	29.4	18.44	105.56
56	18.1	1.26	10.50
63	41.6	22.16	135.60
70	21.4	9.26	40.70
77	25.2	12.66	80.75
84	15.1	1.67	22.20
91	49.6	36.34	168.20

Table 3: Total rainfall, total average runoff and total sediment yield on partially densed soil for each Sampling period during 1st experiment.

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	2.00	0.00	0.00
14	5.20	0.00	0.00
21	3.65	0.00	0.00
28	2.50	0.00	0.00
35	6.32	0.00	0.00
42	7.00	0.00	0.00
49	29.40	13.32	70.20
56	18.10	2.02	11.05
63	41.60	17.80	87.75
70	21.40	8.24	50.22
77	25.20	8.26	59.69
84	15.10	5.50	18.24
91	49.60	31.30	150.50

Table 4: Total rainfall, total average runoff and total sediment yield on well covered soil per week for each Sampling period during 1st experiment.

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	2.00	0.00	0.00
14	5.20	0.00	0.00
21	3.65	0.00	0.00
28	2.50	0.00	0.00
35	6.32	0.00	0.00
42	7.00	0.00	0.00
49	29.4	15.40	32.62
56	18.10	0.76	1.00
63	41.60	15.26	45.67
70	21.40	7.22	45.67
77	25.20	7.78	48.36
84	15.10	3.05	16.72
91	49.60	25.20	140.66

Table 5: Total rainfall, total average runoff and total sediment yield on bare soil for each Sampling period during 2nd experiment.

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	71.9	16.22	220.20
14	71.3	20.12	246.70
21	56.4	24.32	263.67
28	116.2	35.20	737.60
35	75.6	25.20	268.63
42	11.8	0.50	0
49	10.0	0.20	0
56	5.2	0	0
63	1.00	0	0
70	1.04	0	0

Table 6: Total rainfall, total average runoff and total sediment yield on partially densed soil for each Sampling period during the 2nd experiment.

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	71.9	14.02	130.08
14	71.3	16.02	138.0
21	56.4	20.02	156.60
28	116.2	25.60	365.70
35	75.6	19.20	180.90
42	11.8	0.02	0.00
49	10.0	0.00	0.00
56	5.2	0.00	0.00
63	1.00	0.00	0.00
70	1.04	0.00	0.00

Table 7: Total rainfal, total average and total sediment yield on a well covered soil for each Sampling period during the 2nd experiment.

DAP	Total rainfall amount (mm)	Total runoff (mm) per week	Total sediment weight (g/m^2) per week
7	71.9	11.20	093.30
14	71.3	13.60	103.60
21	56.4	15.50	106.60
28	116.2	19.90	052.02
35	75.6	16.60	115.36
42	11.8	0.00	0.00
49	10.0	0.00	0.00
56	5.2	0.00	0.00
63	1.00	0.00	0.00
70	1.04	0.00	0.00

4.2 Runoff

The runoffs from each storm event are depicted in Figs 6-11. In general, runoff and sediment yield from bare soil are highest when compared with the partially and well covered soils. The vegetation cover in the well covered plot must have brought about greater interception, decreased raindrop energy and decreased runoff. Similar observations were made by Grace III et al. (1988). Interception is increased as leaf foliage develop in the partially covered and well covered soil. This resulted into decreased runoff in the two treatments. This agrees with the observations of Chandler and Water (1998).

4.3 Rainfall Runoff Relationship

Rainfall-Runoff Relationships were developed for each plot (Figs. 6-11). The amount of rainfall that produced surface runoff differed among plots. The rainfall needed to initiate runoff is always greater in well covered soil than the partially covered and bare soils. It was observed that rainfalls from 7th to the 42nd DAP during the first experiment for three runoff meters and rainfalls from the 42nd to the 70th DAP resulted in no runoff during the second experiment for the same set of meters. This was as a result of the set-in of dry season.

4.4 Rainfall - Sediment Yield

The results of rainfall and sediment yield are shown in Figs. 12-17 and Tables 2-7. Zero sediment yield were observed from the precipitations that occurred in the first 42nd DAP during the first experiment on bare

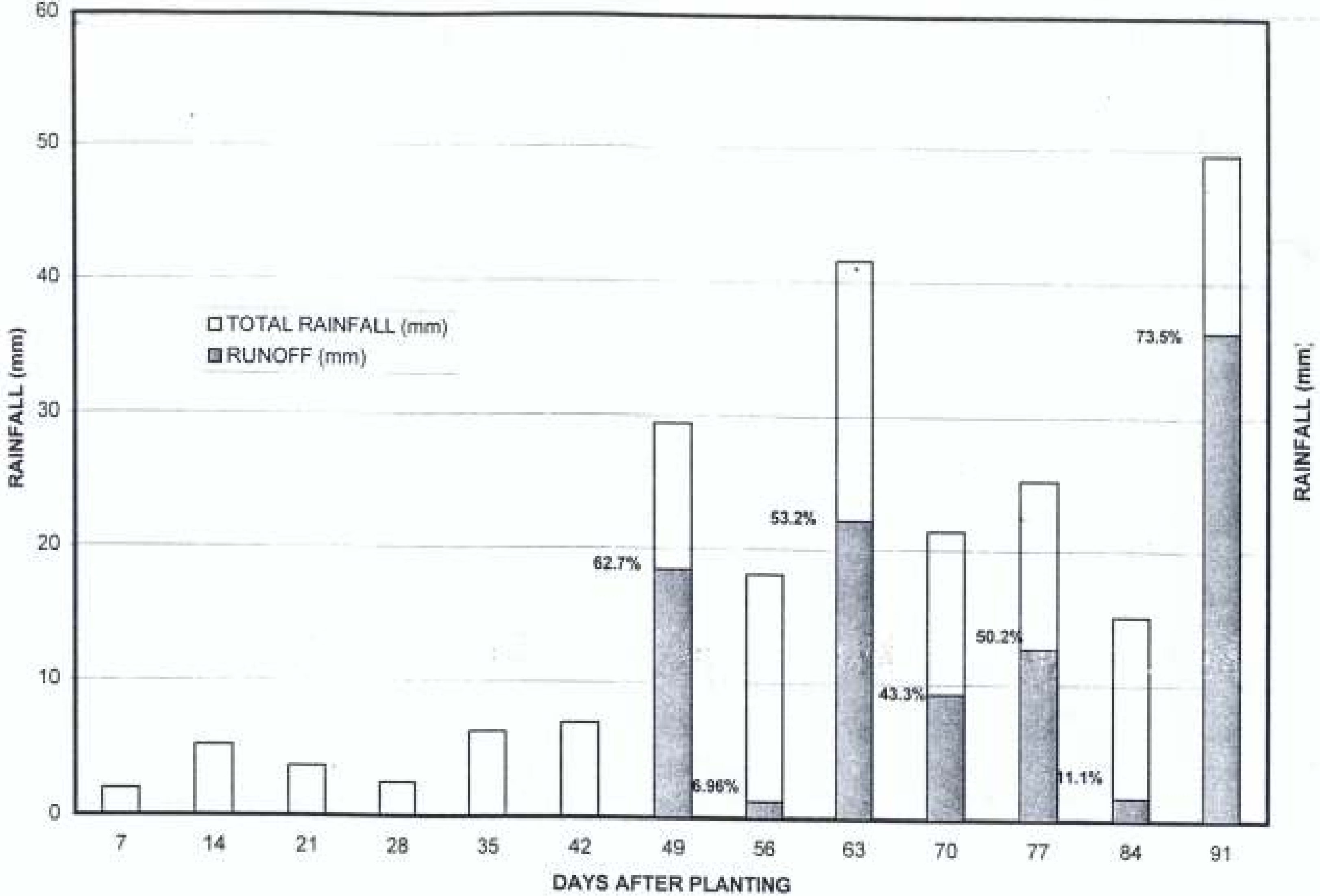

FIG. 5: RAINFALL AND RUNOFF AGAINST DAYS AFTER PLATING (DAP) FOR BARE SOIL DURING THE 1ST EXPERIMENT

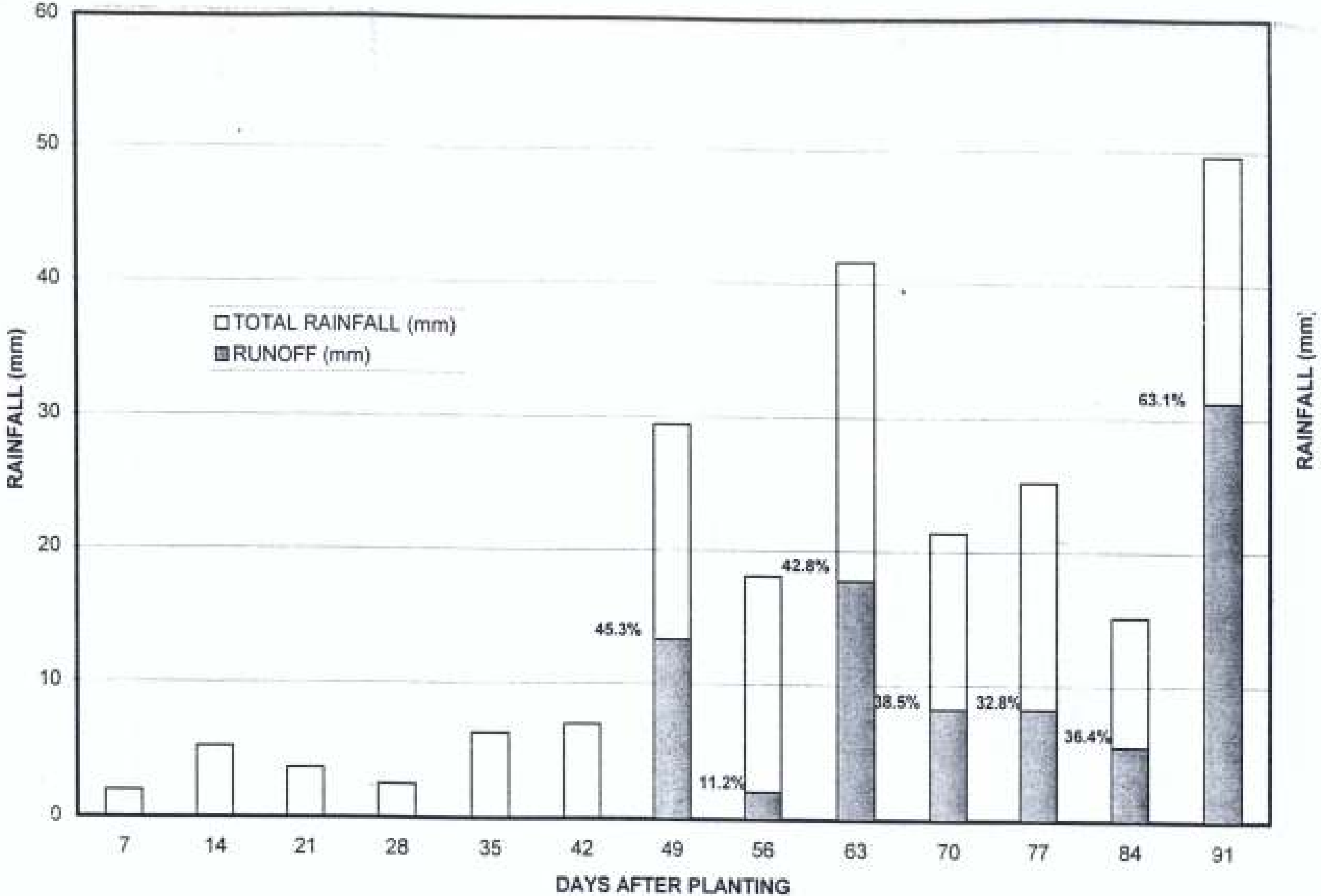

FIG. 6: RAINFALL AND RUNOFF AGAINST DAYS AFTER PLANTING FOR PARTIALLY DENSED SOIL DURING THE 1ST EXPERIMENT

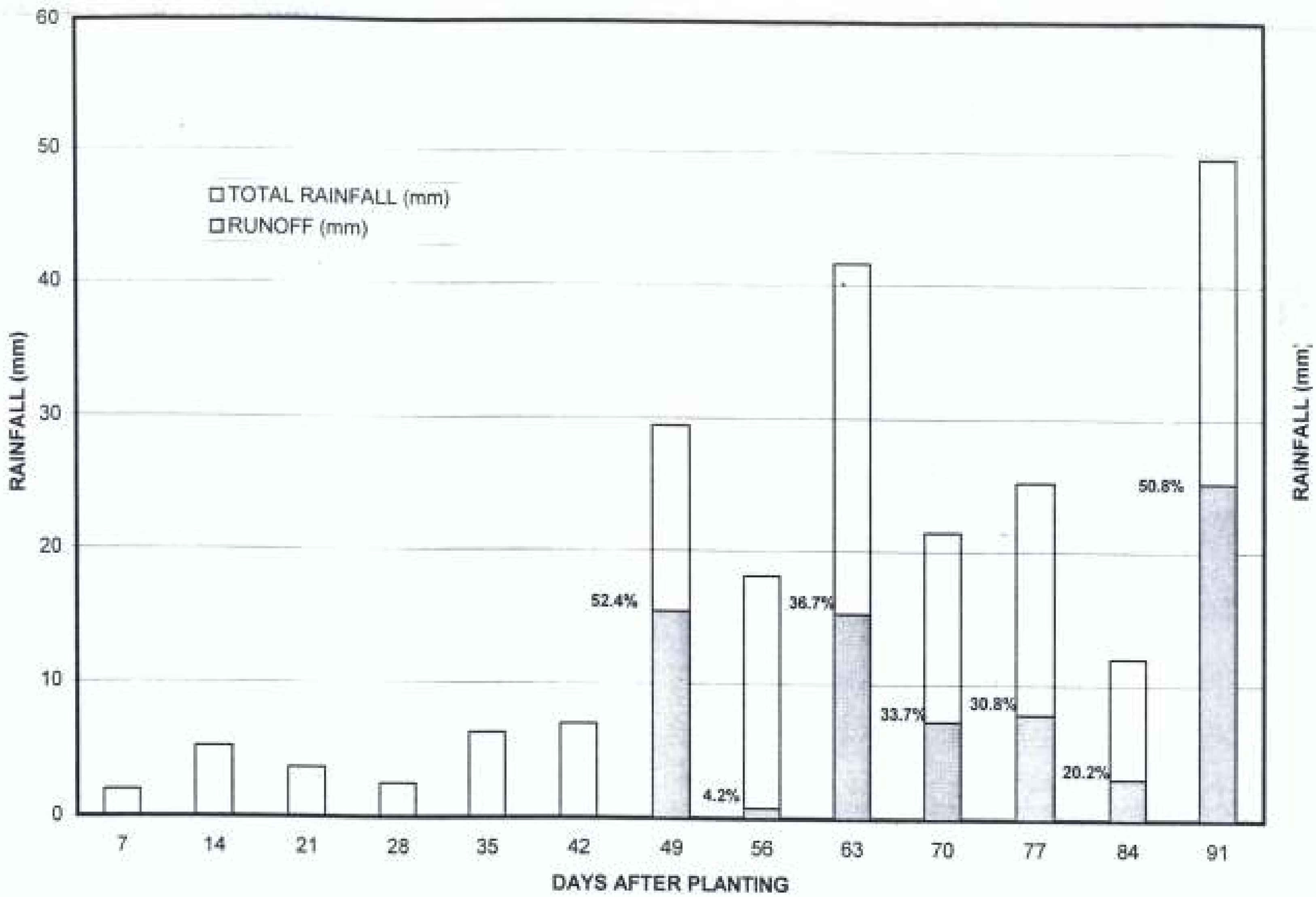

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FIG. 7: RAINFALL AND RUNOFF AGAINST DAYS AFTER PLANTING FOR WELL COVERED SOIL DURING 1ST EXPERIMENT

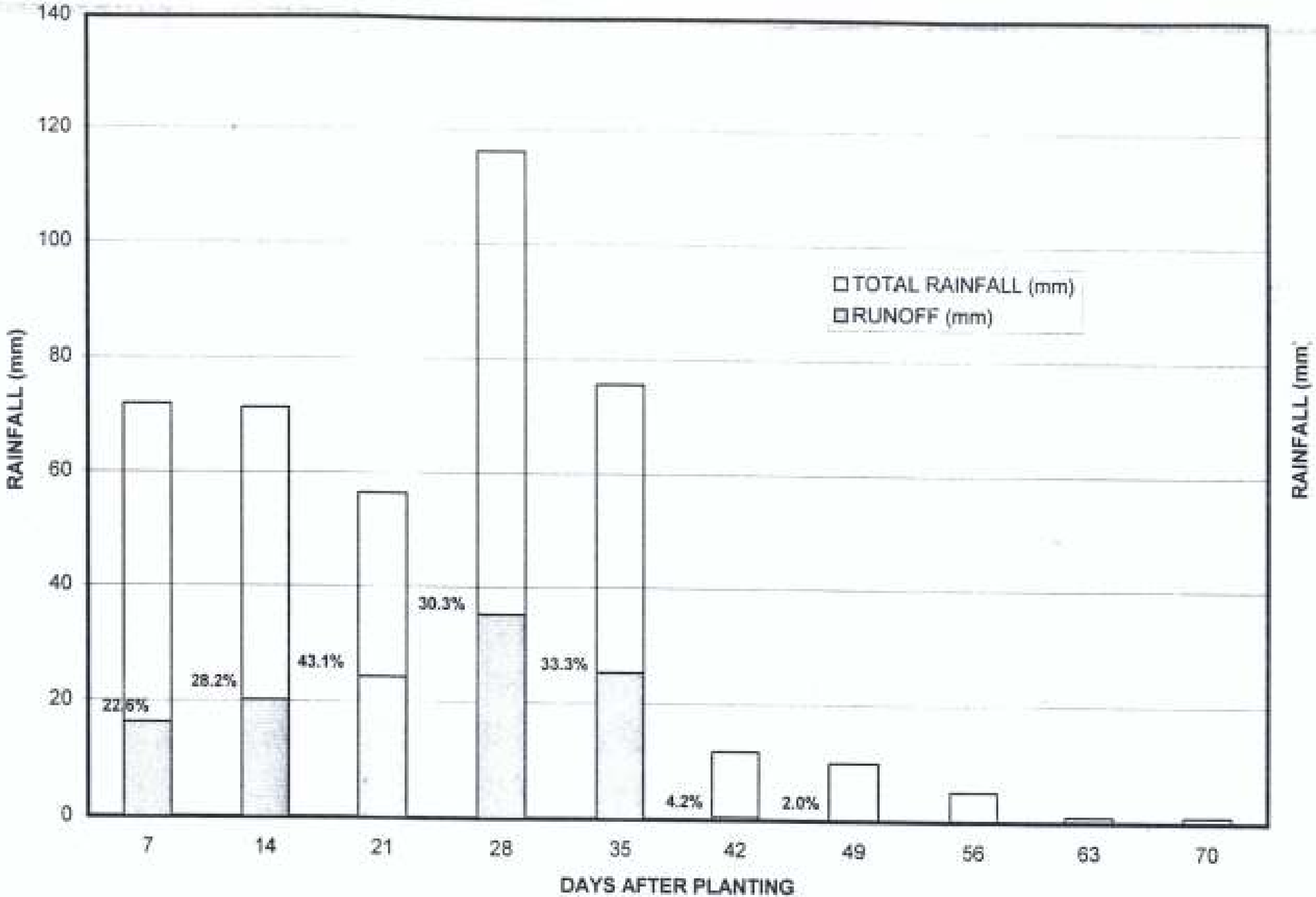

FIG. 8: **RAINFALL AND RUNOFF AGAINST DAYS AFTER PLANTING FOR BARE SOIL DURING 2ND EXPERIMENT**

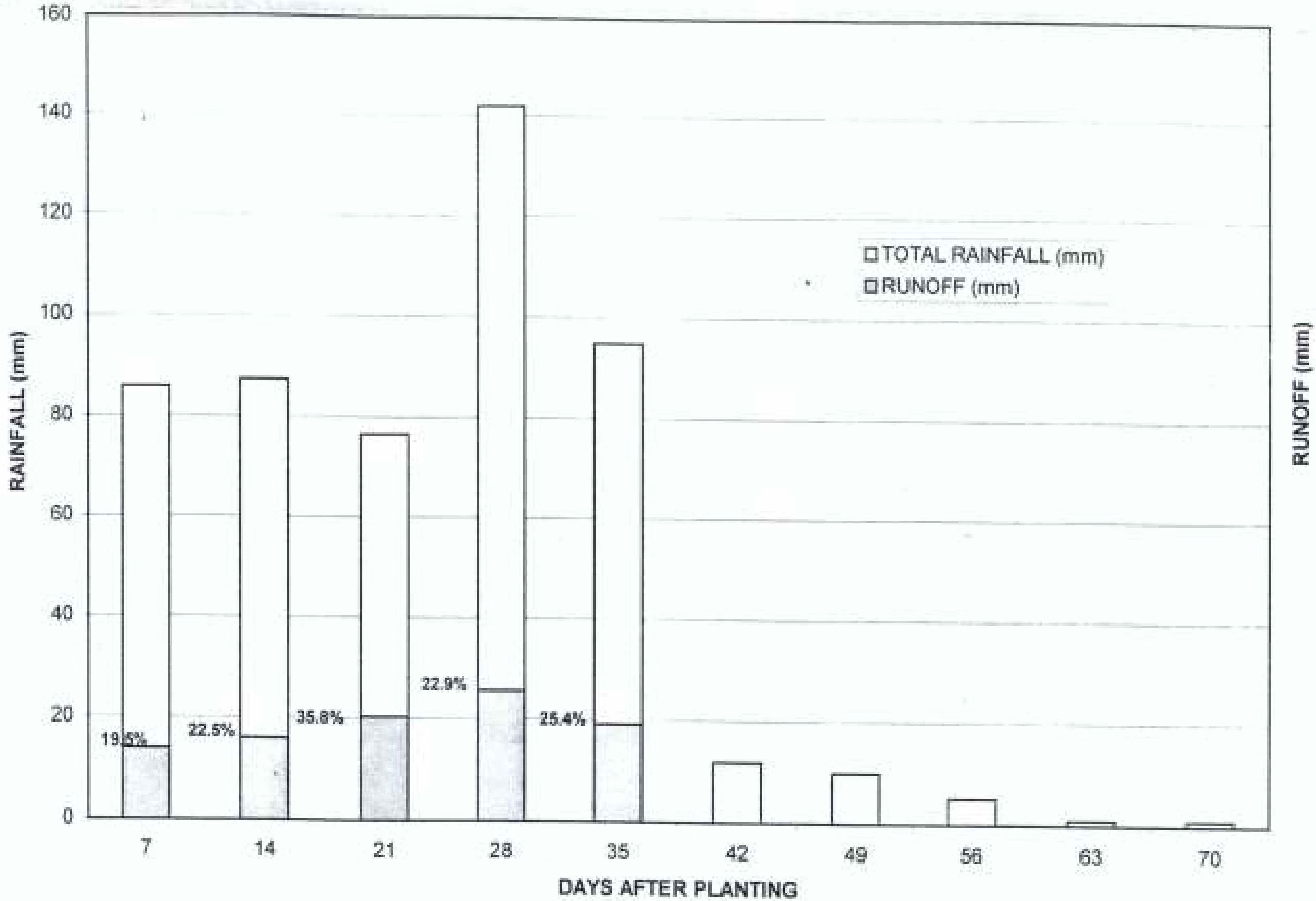

FIG. 9: RAINFALL AND RUNOFF AGAINST DAYS AFTER PLANTING FOR PARTIALLY DENSED SOIL DURING 2ND EXPERIMENT

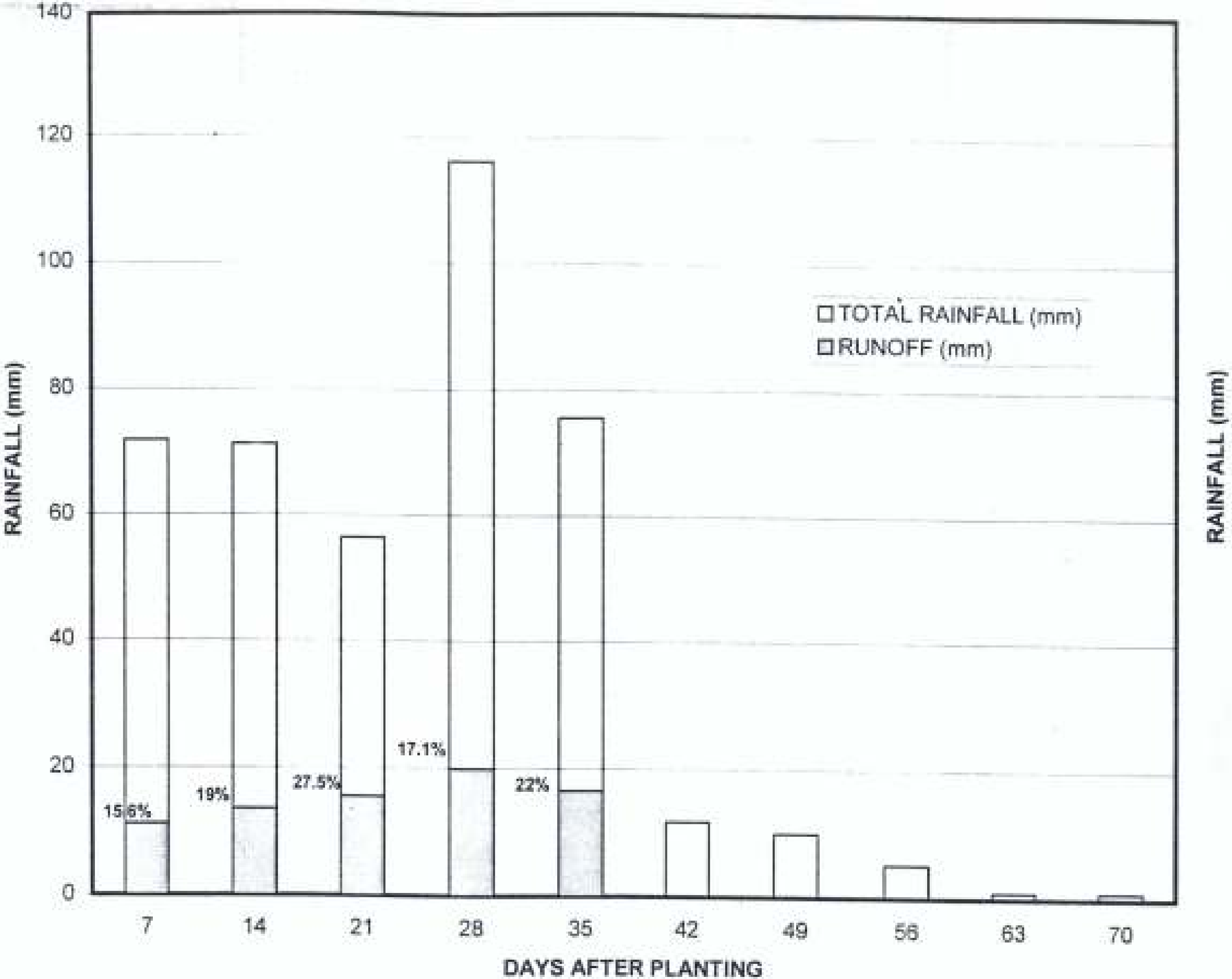

FIG. 10: RAINFALL AND RUNOFF AGAINST DAYS AFTER PLANTING FOR WELL COVERED SOIL DURING 2ND EXPERIMENT

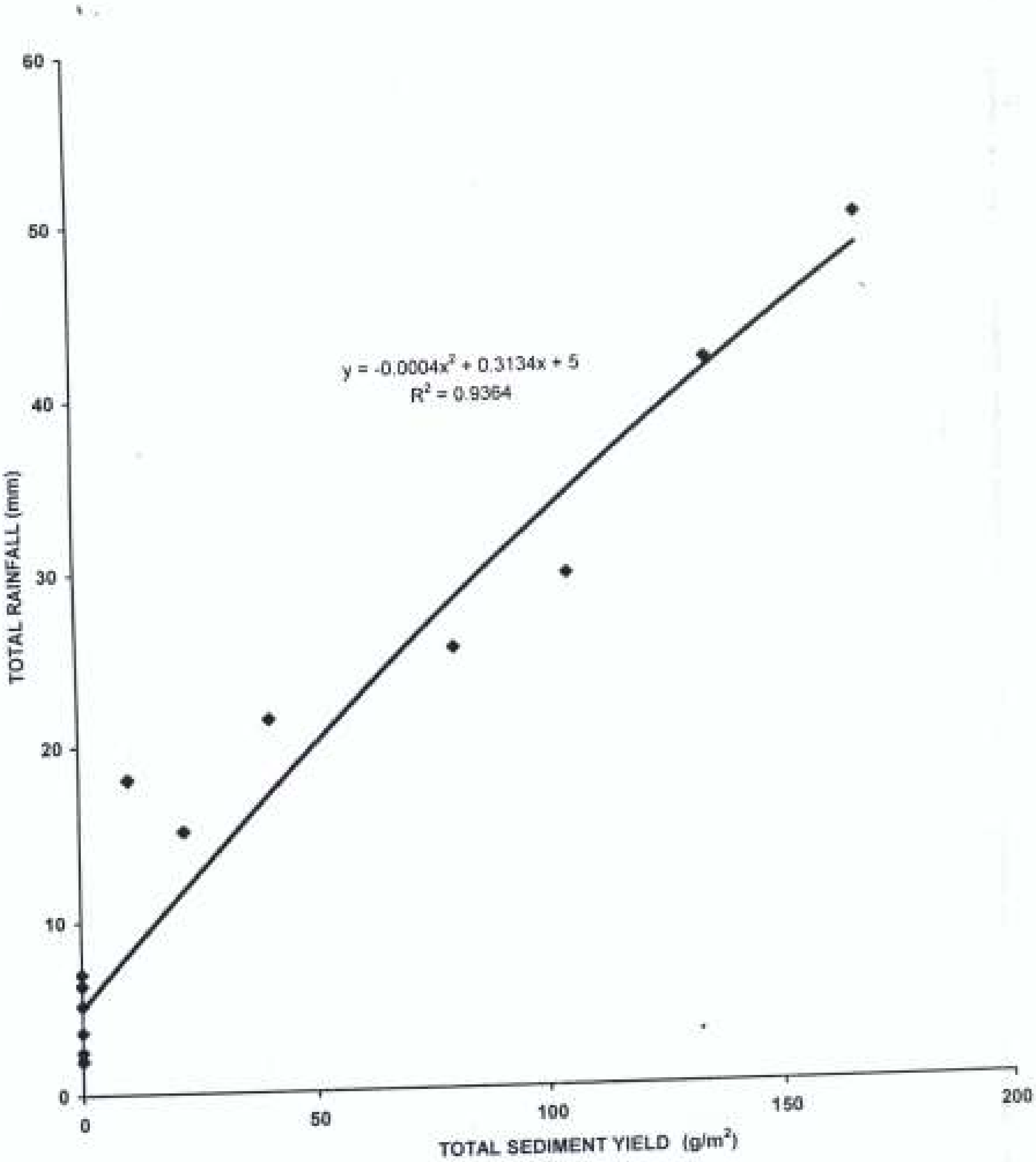

FIG. 11: REGRESSION OF TOTAL RAINFALL(mm) ON TOTAL SEDIMENT YIELD (g) (BARED SOIL 1ST EXPERIMENT)

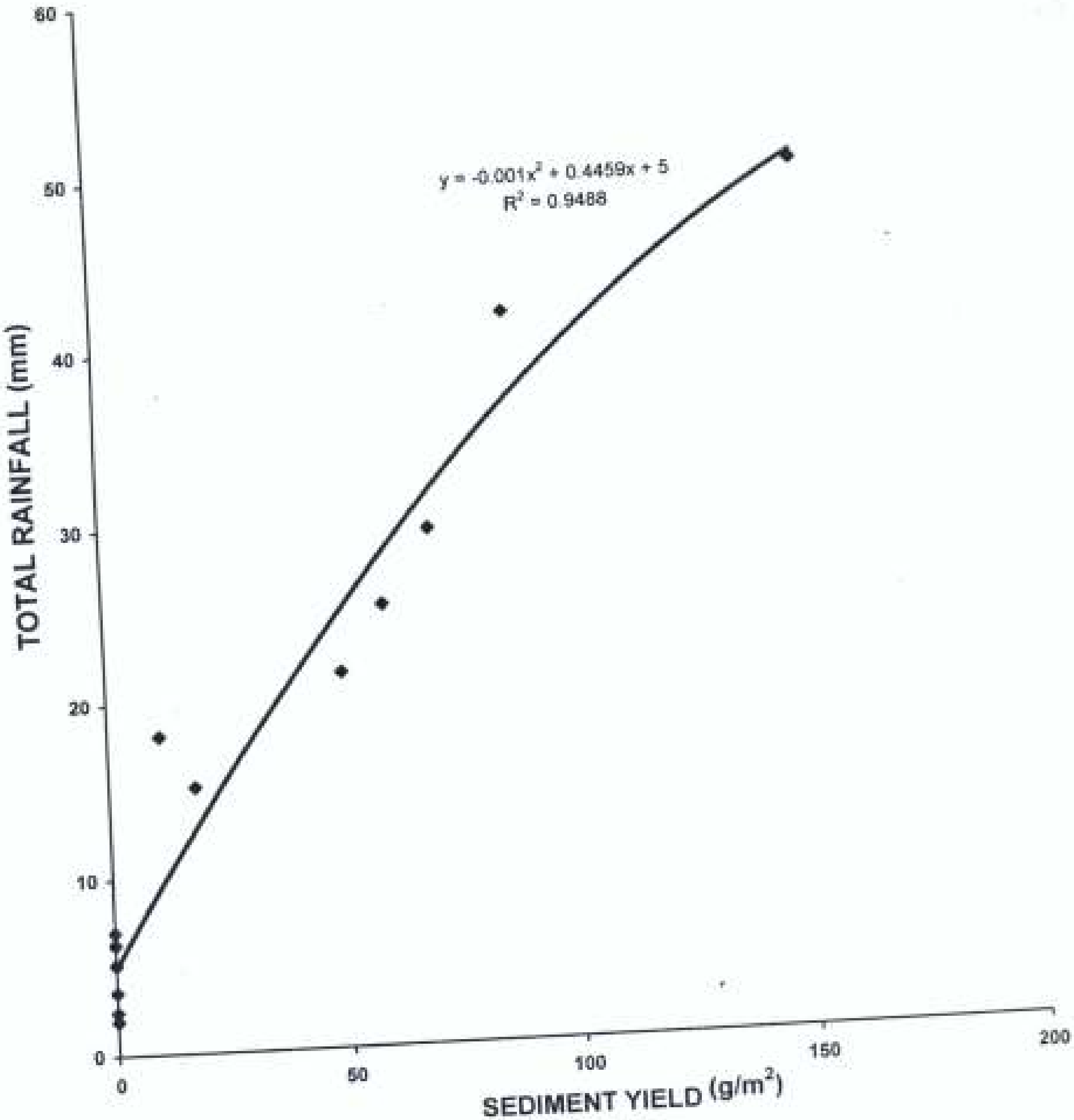

FIG. 12: REGRESSION OF TOTAL RAINFALL (mm) ON TOTAL SEDIMENT YIELD (g) FOR PARTIALLY DENSED SOIL DURING THE 1ST EXPERIMENT

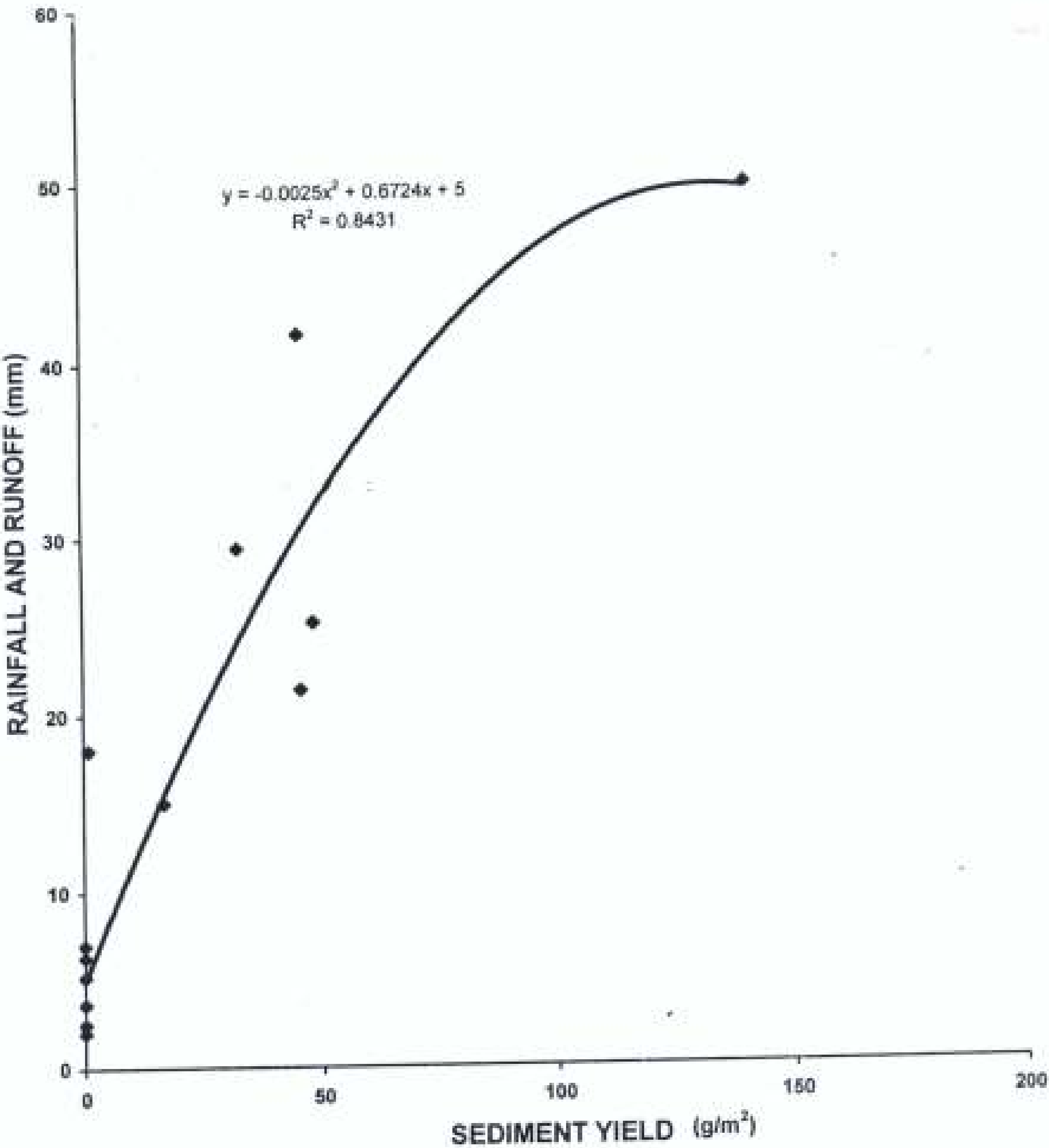

FIG. 13: REGRESSION OF RAINFALL AND RUNOFF (mm) AGAINST SEDIMENT YIELD (g) FOR WELL COVERED SOIL DURING THE 1ST EXPERIMENT

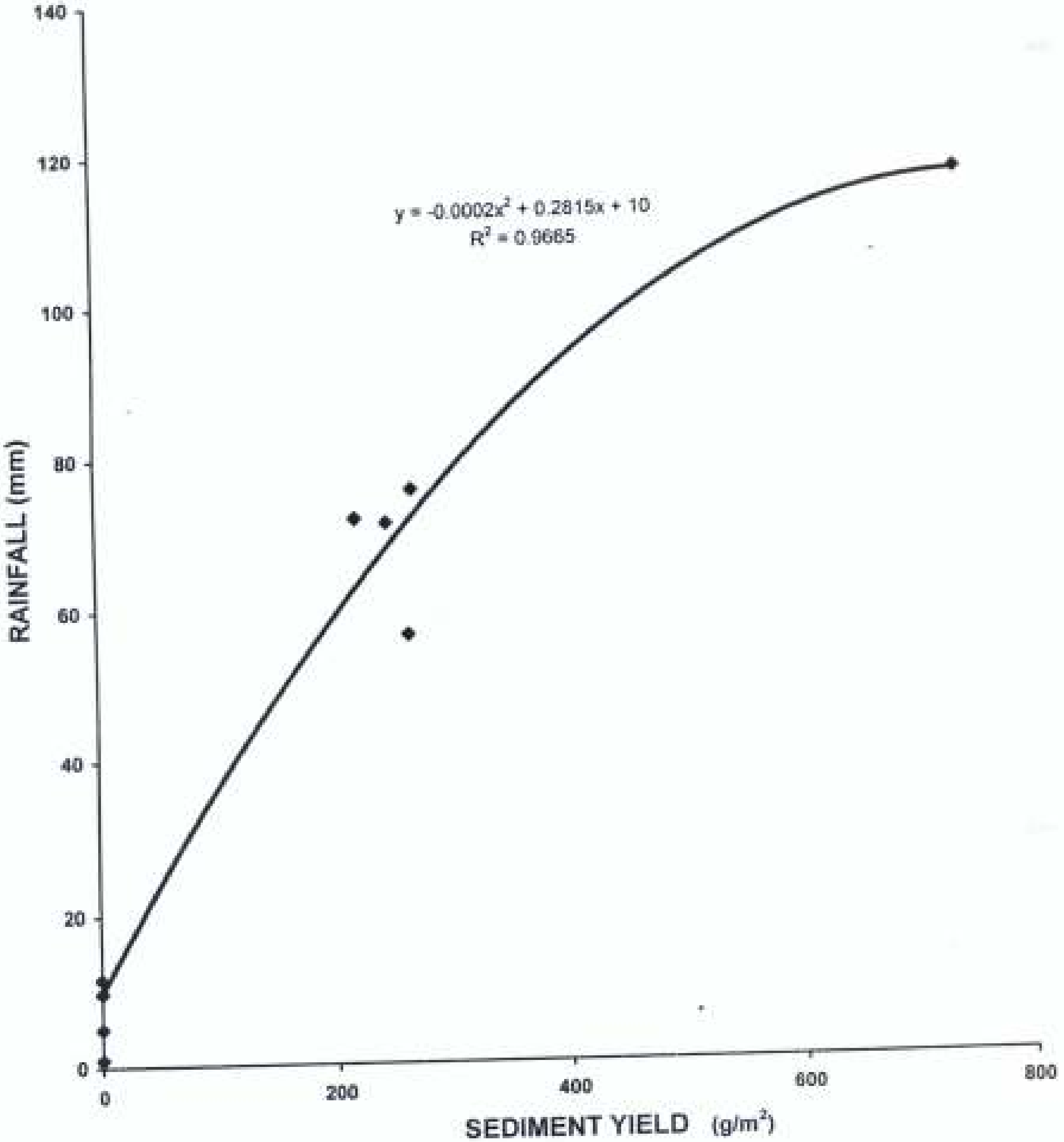

FIG. 14: REGRESSION OF RAINFALL (mm) ON SEDIMENT YIELD (g) FOR BARED SOIL DURING THE 2ND EXPERIMENT

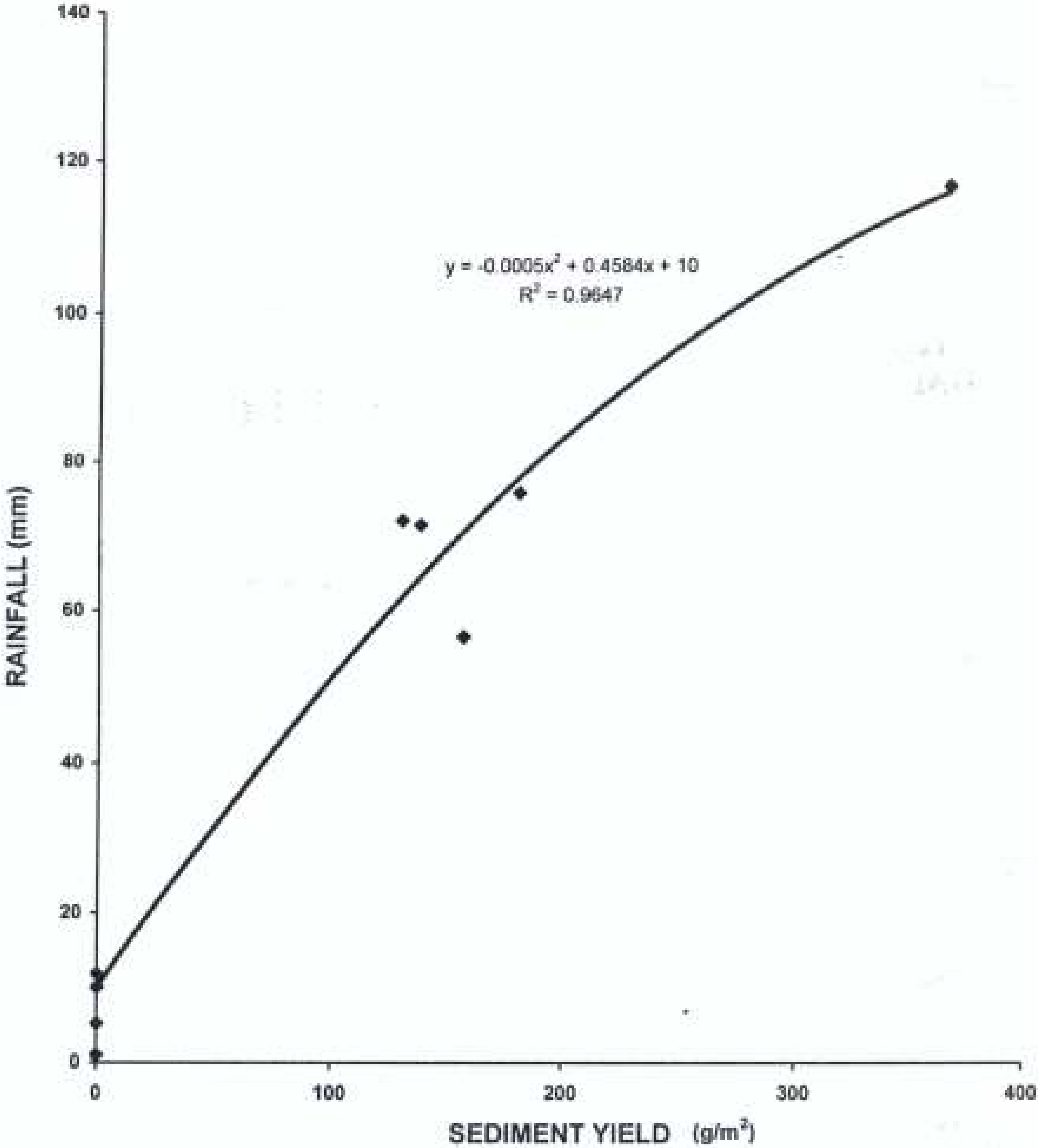

FIG. 15: **REGRESSION OF RAINFALL (mm) ON SEDIMENT YIELD (g) FOR PARTIALLY DENSED SOIL DURING 2ND EXPERIMENT**

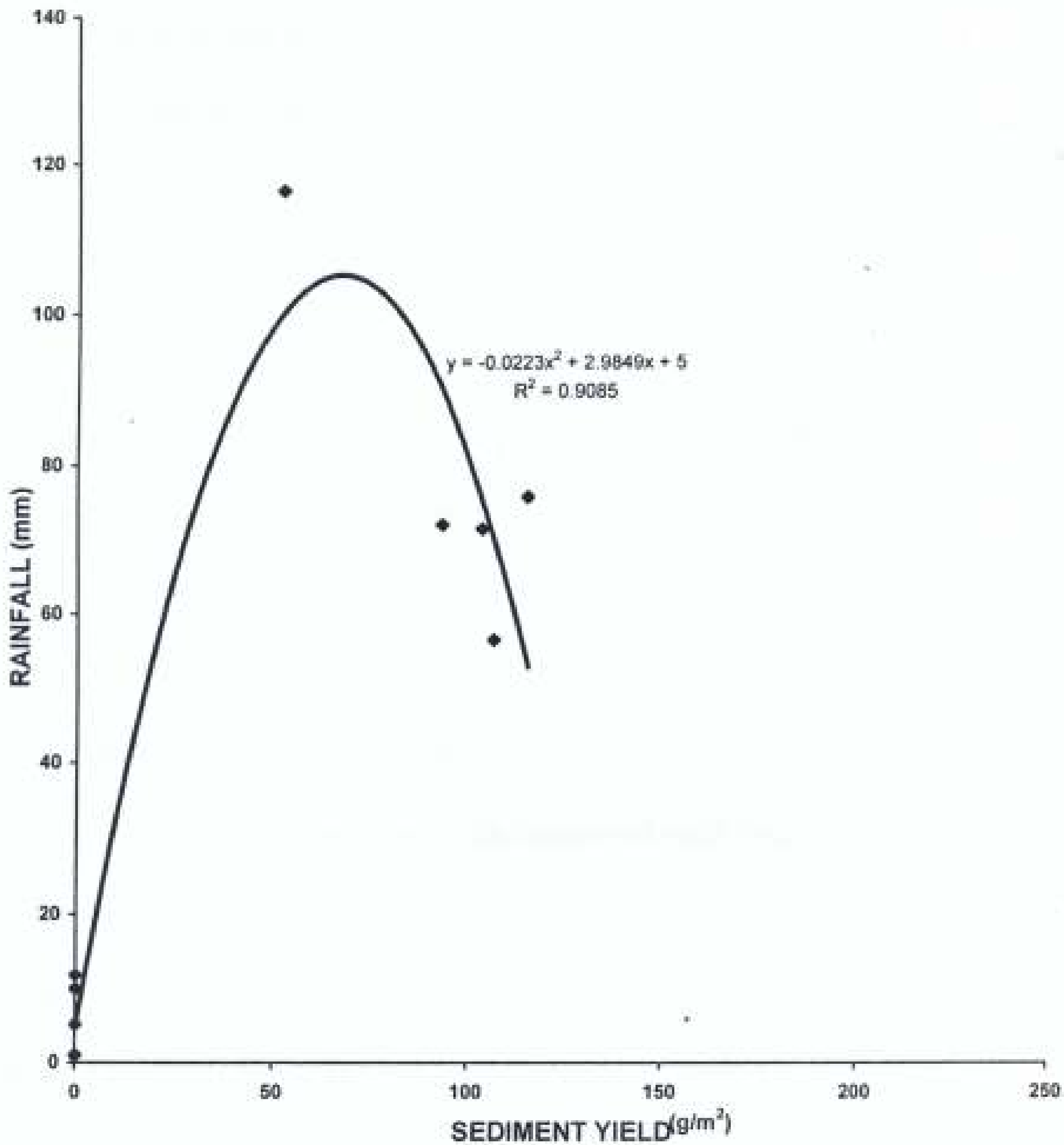

FIG. 16: REGRESSION OF RAINFALL (mm) ON SEDIMENT YIELD (g) FOR WELL COVERED SOIL DURING 2ND EXPERIMENT

soil. Thereafter, it rose to 135.6 which occurred at the 63rd DAP. However, the highest sediment yield of 168.2 was caused by a storm of 496 mm during the 91st DAP.

In general, the sediment yield in the partially and well covered plots were lower than that observed on the bare soil.

Regression analysis carried out between the rainfall and sediment yield during the 1st trial showed a polynomial relationship with the highest correlation coefficient R = 0.9741 in the partially covered soil (Figure 13) and a regression equation of

$$y = -0.001x^2 + 0.4459x + 5$$

Correlation R between rainfall and sediment yield became lowered to a value 0.9182 in the well covered soil. This can be adduced to the cover provided by leaves of the plants on the densely covered soil thus reducing sharply the sediment yield even at high rainfall. During storm events, water which was suppose to fall directly on soil and cause runoff and sediment yield were intercepted by the canopy of the cowpea. This enhanced the water retention capacity of the soil and as well increased evapotranspiration.

Also, during the second experiment, very high storm were observed to be responsible for the high sediment yields recorded, most especially on the bare soil (Table 5). The highest sediment yield was 737.6 caused by a storm event of 116.2 mm during the 28th DAP of the 42nd experiment. It was generally observed that soil loss of the event attained its peak immediately after the establishment of plots and then decreased when crop began to grow to maturity with all leaves fully developed. Similar observation was made by Grace III et al. (1998).

4.5 EVAPOTRANSPIRATION

The result of evapotranspiration in the three treatment during the 1st and 2nd experiment are shown in Figs. 18-23 and Tables 8-13. Evapotranspiration values of 13.08 and 83.30 mm/week were observed to occur in the well covered soils respectively. This may be as a result of more water stored in the plots.

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 areas and soil water content respectively, Savabi and Scott (1994).

It was observed that evapotranspiration is a function of rainfall. During rainfall, water content in the soil and interception of rain water by leaves of cowpea increased and therefore evapotranspiration increased.

Table 8: Evapotranspiration values on function of days after planting in plot A (bare soil) during the 1st trial.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.00	0.00	0.00	0.00	0.00
7	2.00	1.27	0.00	0.00	0.73
14	5.20	1.30	0.00	0.00	3.90
21	3.65	0.61	0.00	0.00	3.00
28	2.50	-0.47	0.00	0.00	2.03
35	6.32	0.74	0.00	0.00	5.58
42	7.00	-0.92	0.00	0.00	7.92
49	29.4	-0.12	18.44	0.00	8.08
56	18.1	2.33	1.26	0.00	6.18
63	41.6	0.52	22.96	0.00	6.57
70	21.4	-0.87	9.26	0.00	3.34
77	25.2	-0.14	12.66	0.00	2.80
84	15.1	0.00	1.67	10.76	2.67
91	49.6	-0.27	36.34	12.65	0.34

Table 9: Evapotranspiration values on function of days after planting in plot B (Partially covered soil) during the 1st trial.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.00	0.00	0.00	0.00	0.00
7	2.00	-0.82	0.00	0.00	1.18
14	5.20	-0.01	0.00	0.00	5.19
21	3.65	1.88	0.00	0.00	5.53
28	2.50	-1.00	0.00	0.00	2.40
35	6.32	0.49	0.00	0.00	7.70
42	7.00	1.69	0.00	0.00	7.79
49	29.4	-1.61	13.32	0.00	8.77
56	18.1	0.78	2.02	0.00	9.76
63	41.6	1.28	17.80	0.00	11.58
70	21.4	-0.21	8.24	0.00	4.90
77	25.2	0.17	8.26	0.00	6.26
84	15.1	0.31	5.50	5.49	4.42
91	49.6	-0.54	31.30	14.36	3.40

Table 10: Evapotranspiration values on function of days after planting in plot C (well covered soil) during the 1st trial.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.00	0.00	0.00	0.00	0.00
7	2.00	0.40	0.00	0.00	1.60
14	5.20	1.58	0.00	0.00	3.62
21	3.65	1.51	0.00	0.00	2.14
28	2.50	-0.42	0.00	0.00	2.92
35	6.32	0.30	0.00	0.00	6.02
42	7.00	0.94	0.00	0.00	6.06
49	29.4	0.35	15.40	0.00	8.13
56	18.1	0.23	0.76	0.00	8.09
63	41.6	-0.54	15.26	0.00	13.08
70	21.4	-0.09	7.22	0.00	8.25
77	25.2	0.21	7.78	0.00	9.49
84	15.1	-0.39	3.05	5.72	5.94
91	49.6	-0.41	25.20	17.58	6.41

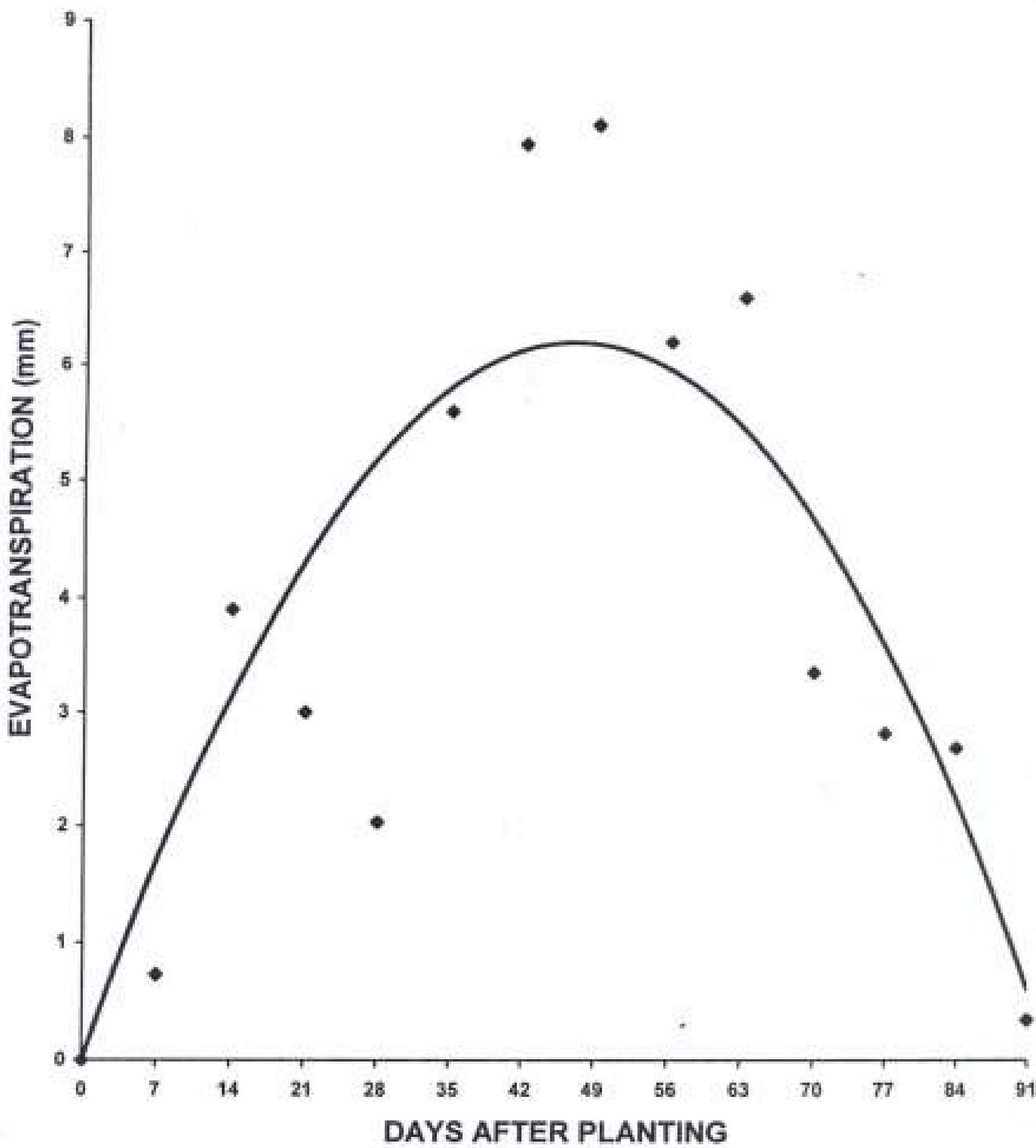

FIG. 17: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (BARED SOIL) 1ST EXPERIMENT

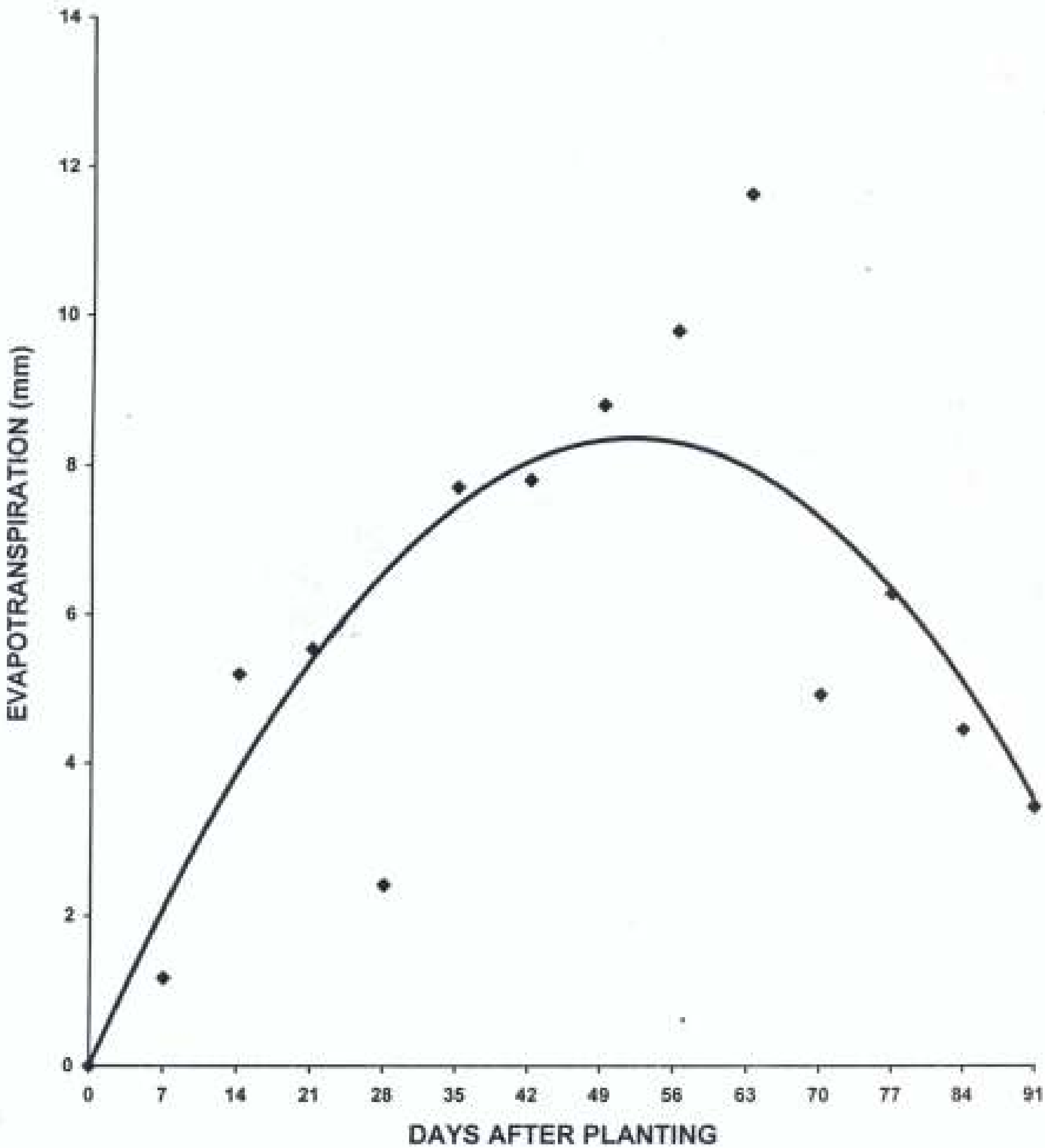

FIG. 18: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (PARTIALLY DENSED SOIL) 1ST EXPERIMENT

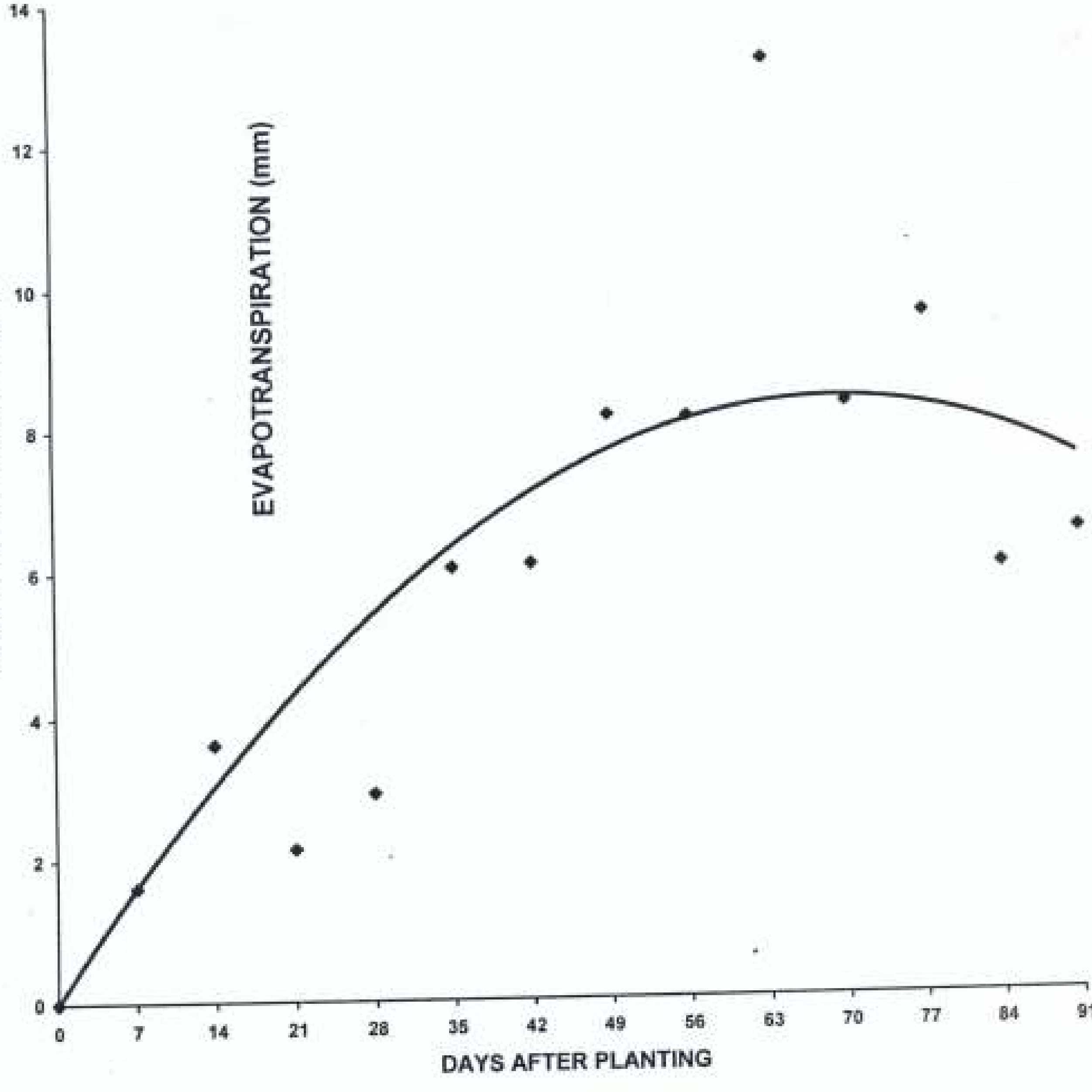

FIG. 19: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (WELL DENSED SOIL) 1ST EXPERIMENT

Table 11: Evapotranspiration values on function of days after planting in Plot A (bare soil) during the 2nd trial.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.0	0.00	0.00	0.00	0.00
7	71.9	-0.83	16.22	6.30	48.15
14	71.3	1.08	20.12	10.32	42.54
21	56.4	2.64	24.32	5.34	29.38
28	116.2	0.61	35.20	15.67	65.94
35	75.6	-5.23	25.20	13.62	31.55
42	11.8	-0.90	0.50	2.60	7.80
49	10.0	0.05	0.20	4.20	5.65
56	5.2	-0.48	0.00	0.00	4.72
63	1.00	-0.04	0.00	0.00	0.96
70	1.04	-0.14	0.00	0.00	0.90

Table 12: Evapotranspiration values on function of days after planting in Plot B (partially densed soil) during the 2nd experiment.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.0	0.00	0.00	0.00	0.00
7	71.9	-0.40	14.02	6.00	51.48
14	71.3	-0.47	16.02	8.94	45.87
21	56.4	1.11	20.20	4.22	33.09
28	116.2	3.24	25.60	16.34	77.50
35	75.6	0.48	19.20	10.62	46.26
42	11.8	-3.26	0.02	0.07	7.75
49	10.0	-1.25	0.00	1.02	7.73
56	5.2	-0.54	0.00	0.00	4.66
63	1.00	-0.03	0.00	0.00	0.97
70	1.04	-0.27	0.00	0.00	0.77

Table 13: Evapotranspiration values on function of days after planting in Plot C (well densed soil) during the 2nd experiment.

DAP	Rainfall (mm)	ΔS (mm)	Runoff (mm)	Drainage (mm)	ET (mm)/week
0	0.0	0.00	0.00	0.00	0.00
7	71.9	-0.55	11.20	6.50	53.65
14	71.3	-0.50	13.60	9.02	48.18
21	56.4	-0.24	15.50	3.60	37.06
28	116.2	1.70	18.90	15.70	83.30
35	75.6	-1.15	16.60	11.30	46.55
42	11.8	-2.00	0.00	0.02	9.78
49	10.0	-0.26	0.00	0.00	9.74
56	5.2	-0.77	0.00	0.00	4.43
63	1.00	-0.37	0.00	0.00	0.63
70	1.04	-0.18	0.00	0.00	0.86

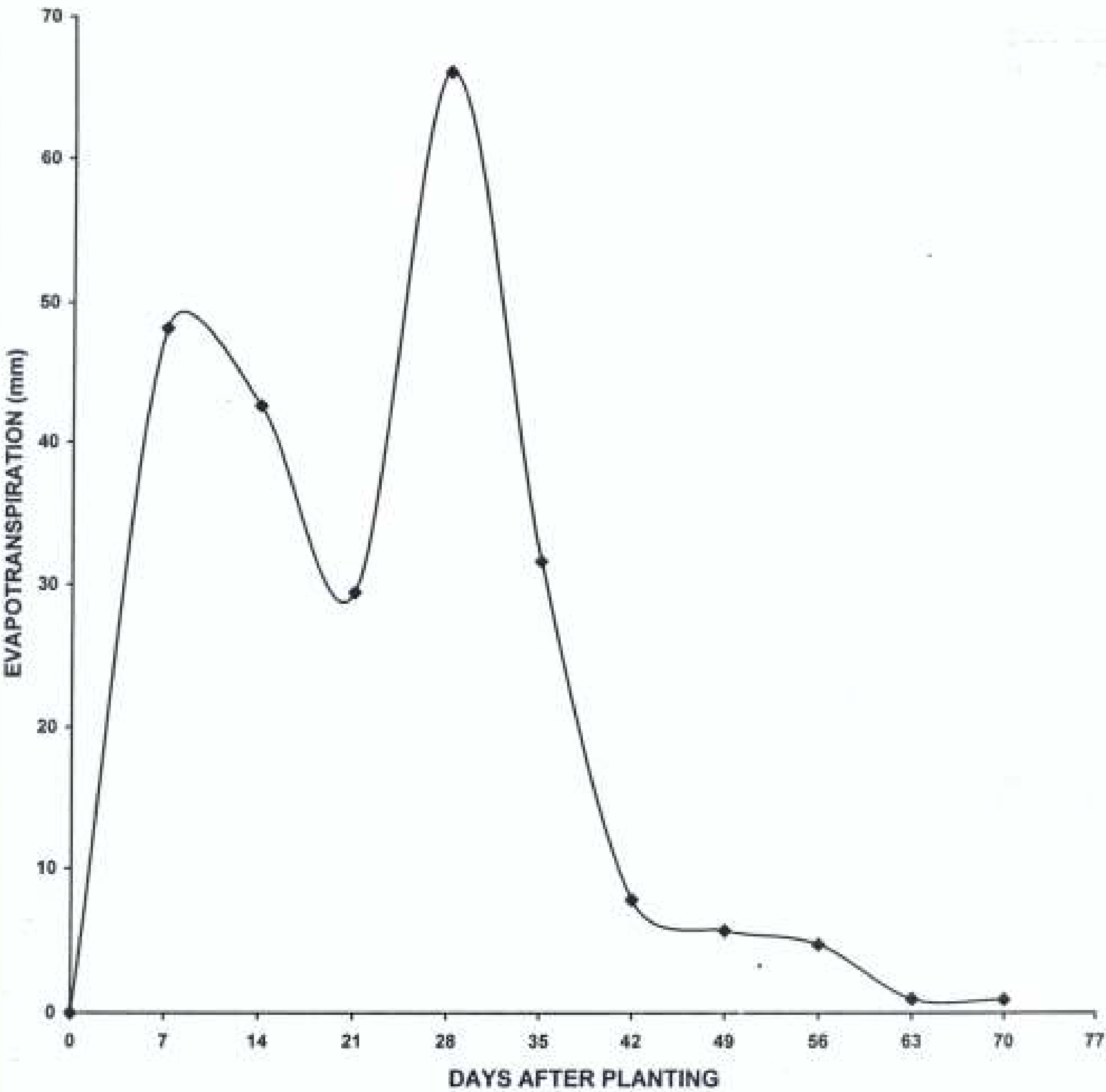

FIG. 20: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (BARED SOIL) 2ND EXPERIMENT

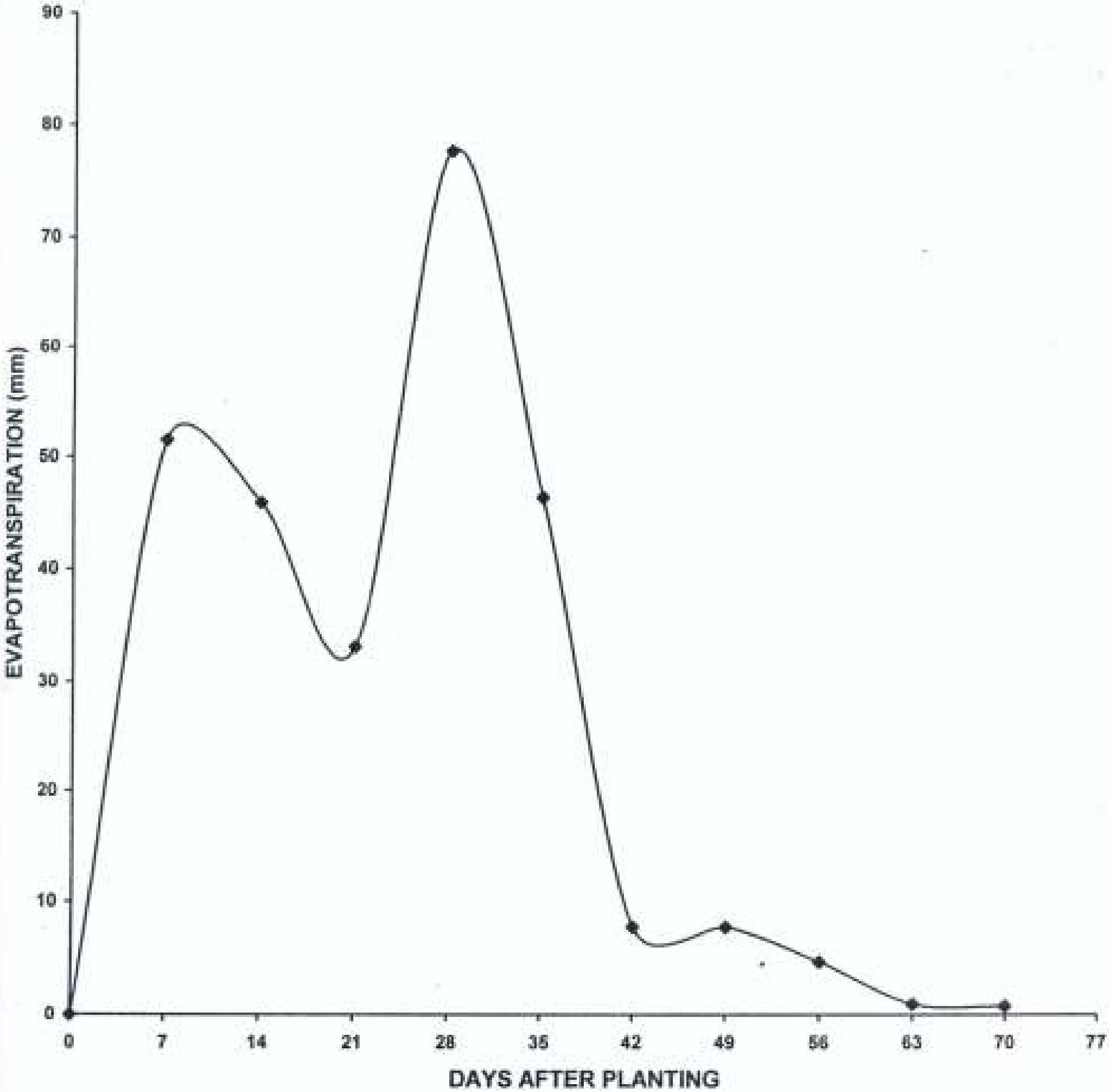

FIG. 21: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (PARTIALLY DENSED SOIL) 2ND EXPERIMENT

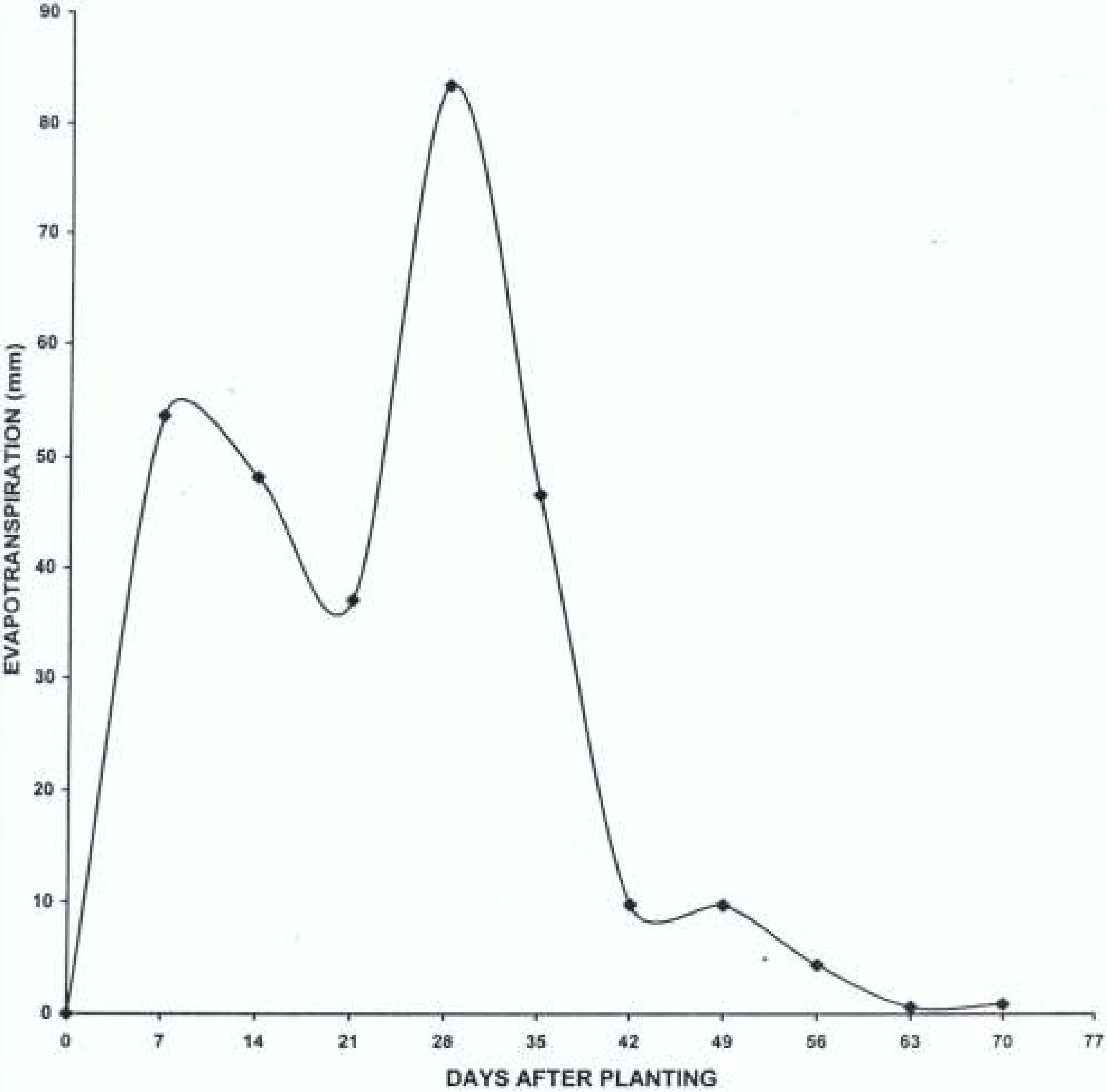

FIG. 22: EVAPOTRANSPIRATION VERSUS DAYS AFTER PLANTING (WELL DENSED SOIL) 2ND EXPERIMENT

Statistical analysis (Tables 14-15) indicated that there were no significant differences in evapotranspiration among treatments during the 1st experiment at 5% level. Same observation was made among treatment during the second experiment. However, the difference in evapotranspiration become significant at 5% level when the well covered soil is compared between the 1st and 2nd experiments.

This observation must have been as a result of heavy rainfalls that occurred during the 2nd experiment.

A look at the data on Tables 11-13 at 21 DAP during the 2nd experiment, the rainfall was 56.4 mm compared with 71.3 mm of the previous week and 116.2 mm of the week after, which resulted to low evapotranspiration when compared with aforementioned weeks.

Evapotranspiration being a function of rainfall. The more rainfall received, the more evapotranspiration produced which eventually gave rise to the sinusoidal nature of the graph on fig. 21, 22 and 23 respectively.

Table 14: Analysis of variance of evapotranspiration during the 1st experiment.

Summary

Groups	Count	Sum	Average	Variance
Bare soil	13	53.14	4.087692	6.532536
Partially densed soil	13	78.88	6.067692	8.882069
Well covered soil	13	81.75	6.288462	10.3982

ANOVA

Source of variation	SS	df	MS	F	P-value	F-crit
Between groups	38.1876051	2	19.0938	2.219108	0.123364	3.25944
Within groups	309.753631	36	8.604268			
Total	347.941236	38				

Calculated F is less than F-critical hence the values are not significantly different at 0.05 level.

Table 15: Analysis of Variance of Evapotranspiration during the 2nd experiment.

Summary

Groups	Count	Sum	Average	Variance
Bare soil	10	237.59	237.59	534.0685
Partially densed soil	10	276.08	276.08	724.0535
Well covered soil	10	294.18	294.18	803.9957

ANOVA

Source of variance	SS	df	MS	F	P-value	F-crit
Between groups	167.0506	2	83.5253	0.121514	0.88606	3.354131
Within groups	18559.06	27	687.3725			
Total	18726.11	29				

Calculated F is less than F-critical hence the values are not significantly different at 0.05 level.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study evaluated the rainfall run-off characteristics of soil cropped with cowpea (Vigna unguiculata) under three different plant populations. The aim was to investigate the runoff potentials of the soil on the field and the sediment moved by runoff waters during and after rainfall.

The soil moisture content was closely monitored to show the effect of rainfall on soil regime and the change in soil moisture storage.

[1] Results indicated that runoff and sediment from the field is a function of the amount of rainfall and plant densities on the field.

[2] Storm event of 116.2 mm at 28th DAP during the 2nd experiment produced the highest runoff and sediment yield of 35.2 mm and 137.60 g respectively on the bare soil. The situation is vice-versa on well covered soil which shows that plant densities had a significant effect on reducing runoff and sediment yield on agricultural land.

[3] The more the plant population per area of land, the less the erosion that occur on the land. Partially covered soil and well covered soil produced a reasonably high level of interception of rainfall and consequently reduced runoff and sediment yield from field.

[4] Rainfall sediment yield model ($y = -0.0025x^2 + 0.6724x + 5$) and correlation coefficient R = 0.9182 were observed in the well covered soil during the 1st experiment while a higher correlation coefficient R = 0.9677 was observed on bare soil. This is an indication that the sediment yield is higher where there is less soil cover.

[5] Evapotranspiration (83.30 mm/week) was highest on the well covered plot in the 28th DAP during the second experiment and a corresponding lowest value of 65.94 mm/week was observed on the bare soil. The water balance showed that plant densities had a significant effect on evapotranspiration. The more the plant densities, the more the evapotranspiration that would occur on the land.

5.2 RECOMMENDATION

The experiment spanned just a year. Though the results provide background data and shows the trend to be expected from rainfall-runoff-sediment yield relationship under varying crop cover, more research of the order of five consecutive years would be able to predict accurately the runoff and sediment yield that may be obtained from various storm events.

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APPDENDIX

APPENDIX A: Result of Soil Moisture Content and Depth of Water durin

1st trial in plot A between June - September.

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stor
0	1.63	9.73	1.49	0.145	0 - 20	2.80
	1.63	10.22	1.47	0.150	20 - 40	3.00
	1.64	11.30	1.47	0.166	40 - 50	1.66
						7.56
7	1.63	10.74	1.47	0.158	0 - 20	3.16
	1.65	13.01	1.43	0.186	20 - 40	3.72
	1.65	13.47	1.45	0.195	40 - 50	3.95
						8.83
14	1.68	13.20	1.484	0.196	0 - 20	3.92
	1.69	13.80	1.485	0.205	20 - 40	4.10
	1.68	14.30	1.478	0.211	40 - 50	2.11
						10.13

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
21	1.66	14.20	1.45	0.206	0 - 20	4.12
	1.68	15.10	1.46	0.220	20 - 40	4.40
	1.70	15.14	1.47	0.222	40 - 50	2.22
						10.74
28	1.64	13.30	1.45	0.193	0 - 20	3.86
	1.67	14.50	1.46	0.212	20 - 40	4.24
	1.71	14.56	1.49	0.217	40 - 50	2.17
						10.27
35	1.70	14.00	1.49	0.208	0 - 20	4.16
	1.68	15.20	1.46	0.222	20 - 40	4.44
	1.72	16.30	1.48	0.241	40 - 50	2.41
						11.01
42	1.65	13.40	1.45	0.194	0 - 20	3.88
	1.68	13.75	1.47	0.202	20 - 40	4.04
	1.67	15.00	1.45	0.217	40 - 50	2.17
						10.09
49	1.65	12.50	1.47	0.184	0 - 20	3.68
	1.68	13.32	1.48	0.210	20 - 40	4.20
	1.68	14.22	1.47	0.209	40 - 50	2.09
						9.97

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
56	1.67	17.00	1.43	0.243	0 - 20	4.86
	1.67	17.00	1.43	0.243	20 - 40	4.86
	1.70	17.92	1.44	0.258	40 - 50	2.58
						12.30
63	1.68	17.22	1.43	0.246	0 - 20	4.92
	1.67	18.84	1.40	0.264	20 - 40	5.28
	1.69	18.35	1.43	0.262	40 - 50	2.62
						12.82
70	1.68	15.67	1.45	0.227	0 - 20	4.54
	1.68	16.80	1.44	0.242	20 - 40	4.84
	1.70	17.82	1.44	0.257	40 - 50	2.57
						11.95
77	1.67	16.40	1.43	0.234	0 - 20	4.68
	1.68	16.35	1.44	0.235	20 - 40	4.70
	1.69	17.00	1.44	0.245	40 - 50	2.45
						11.81
84	1.66	16.30	1.43	0.233	0 - 20	4.66
	1.67	16.55	1.43	0.237	20 - 40	4.74
	1.69	16.65	1.45	0.241	40 - 50	2.41
						11.81
91	1.68	15.58	1.45	0.226	0 - 20	4.52
	1.70	16.05	1.46	0.234	20 - 40	4.68
	1.70	16.05	1.46	0.234	40 - 50	2.34
						11.54

APPENDIX'B: Result of Soil Moisture Content and Depth of Water during

1st trial in plot B between June - September

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
0	1.63	10.43	1.47	0.153	0 - 20	3.06
	1.64	12.50	1.46	0.182	20 - 40	3.64
	1.64	12.75	1.45	0.185	40 - 50	1.85
						8.55
7	1.63	9.64	1.48	0.143	0 - 20	2.86
	1.64	10.36	1.48	0.153	20 - 40	3.06
	1.65	12.33	1.47	0.181	40 - 50	1.81
						7.73
14	1.65	9.50	1.51	0.143	0 - 20	2.86
	1.64	9.83	1.49	0.146	20 - 40	2.92
	1.66	13.30	1.46	0.194	40 - 50	1.94
						7.72
21	1.66	12.50	1.47	0.184	0 - 20	3.68
	1.66	13.50	1.46	0.197	20 - 40	3.94
	1.67	13.46	1.47	0.198	40 - 50	1.98
						9.60

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
28	1.69	10.36	1.53	0.158	0 - 20	3.16
	1.69	11.20	1.52	0.170	20 - 40	3.40
	1.70	13.70	1.49	0.204	40 - 50	2.04
						8.60
35	1.69	12.75	1.49	0.189	0 - 20	3.78
	1.68	13.76	1.48	0.204	20 - 40	4.08
	1.69	14.30	1.49	0.213	40 - 50	2.13
						9.09
42	1.67	13.60	1.47	0.199	0 - 20	3.98
	1.67	15.70	1.44	0.226	20 - 40	4.52
	1.69	15.60	1.46	0.228	40 - 50	2. 28
						10.78
49	1.68	10.00	1.53	0.153	0 - 20	3.88
	1.64	11.23	1.47	0.165	20 - 40	3.30
	1.68	13.45	1.48	0.199	40 - 50	1.99
						9.17
56	1.62	13.60	1.43	0.194	0 - 20	3.88
	1.67	14.01	1.46	0.204	20 - 40	4.08
	1.67	14.20	1.46	0.207	40 - 50	2.07
						9.95

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
63	1.67	14.56	1.46	0.213	0 - 20	4.26
	1.69	15.60	1.46	0.228	20 - 40	4.56
	1.69	16.60	1.45	0.241	40 - 50	2.41
						11.23
70	1.68	14.00	1.47	0.206	0 - 20	4.12
	1.70	15.20	1.47	0.223	20 - 40	4.46
	1.70	16.80	1.45	0.244	40 - 50	2.44
						11.02
77	1.66	15.20	1.44	0.219	0 - 20	4.38
	1.67	14.80	1.45	0.215	20 - 40	4.30
	1.70	17.30	1.45	0.251	40 - 50	2.51
						11.19
84	1.70	14.00	1.49	0.209	0 - 20	4.18
	1.71	16.70	1.46	0.244	20 - 40	4.88
	1.71	16.70	1.46	0.244	40 - 50	2.44
						11.50
91	1.67	14.66	1.46	0.214	0 - 20	4.28
	1.68	15.36	1.46	0.224	20 - 40	4.48
	1.70	15.00	1.48	0.220	40 - 50	2.20
						10.96

APPENDIX C: Result of Soil Moisture Content and Depth of Water during 1st trial in plot C between June - September.

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
0	1.69	8.80	1.56	0.137	0 - 20	2.74
	1.69	9.20	1.55	0.143	20 - 40	2.86
	1.70	10.22	1.51	0.184	40 - 50	1.84
						7.44
7	1.66	9.80	1.51	0.148	0 - 20	2.96
	1.67	10.56	1.51	0.159	20 - 40	3.18
	1.67	11.32	1.50	0.170	40 - 50	1.70
						7.84
14	1.67	11.00	1.50	0.165	0 - 20	3.30
	1.69	13.32	1.49	0.198	20 - 40	3.96
	1.69	14.68	1.47	0.216	40 - 50	2.16
						9. 42
21	1.70	13.46	1.50	0.202	0 - 20	4.04
	1.70	15.66	1.47	0.230	20 - 40	4.60
	1.69	15.68	1.46	0.229	40 - 50	2.29
						10.93

DAP	Db	'Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
28	1.65	12.76	1.46	0.186	0 - 20	3.72
	1.65	15.82	1.42	0.225	20 - 40	4.50
	1.68	15.84	1.45	0.229	40 - 50	2.29
						10.51
35	1.66	13.31	1.46	0.194	0 - 20	3.88
	1.67	15.80	1.44	0.227	20 - 40	4.54
	1.67	16.70	1.43	0.239	40 - 50	2.39
						10.81
42	1.65	15.20	1.43	0.217	0 - 20	4.34
	1.66	15.20	1.42	0.245	20 - 40	4.90
	1.66	17.80	1.41	0.251	40 - 50	2.51
						11.75
49	1.69	75.50	1.46	0.226	0 - 20	4.52
	1.68	17.57	1.43	0.251	20 - 40	5.02
	1.70	17.80	1.44	0.256	40 - 50	2.56
						12.1
56	1.66	16.60	1.42	0.236	0 - 20	4.72
	1.67	17.50	1.42	0.253	20 - 40	5.06
	1.67	18.00	1.41	0.255	40 - 50	2.55
						12.33

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
63	1.66	15.38	1.44	0.221	0 - 20	4.42
	1.68	16.76	1.44	0.241	20 - 40	4.82
	1.68	18.00	1.42	0.255	40 - 50	2.55
						11.79
70	1.69	14.00	1.48	0.207	0 - 20	4.14
	1.70	17.30	1.45	0.251	20 - 40	5.02
	1.70	17.65	1.49	0.254	40 - 50	2.54
						11.70
77	1.68	15.63	1.45	0.227	0 - 20	4.54
	1.68	16.77	1.44	0.241	20 - 40	4.82
	1.69	17.70	1.44	0.255	40 - 50	2.55
						11.91
84	1.66	15.20	1.44	0.219	0 - 20	4.38
	1.67	16.24	1.44	0.234	20 - 40	4.68
	1.67	17.36	1.42	0.246	40 - 50	2.46
						11.52
91	1.68	14.36	1.46	0.209	0 - 20	4.18
	1.67	15.40	1.45	0.223	20 - 40	4.46
	1.68	17.30	1.43	0.247	40 - 50	2.47
						11.11

APPENDIX D: Result of Soil Moisture Content and Depth of Water during

2nd trial in plot A between September - November

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
0	1.63	12.73	1.45	0.184	0 - 20	3.68
	1.63	12.82	1.44	0.185	20 - 40	3.70
	1.64	13.01	1.45	0.188	40 - 50	1.88
						9.26
7	1.63	10.92	1.46	0.159	0 - 20	3.18
	1.65	11.90	1.47	0.175	20 - 40	3.50
	1.65	11.92	1.47	0.175	40 - 50	1.75
						8.43
14	1.68	12.70	1.49	0.189	0 - 20	3.78
	1.69	12.72	1.50	0.191	20 - 40	3.82
	1.69	12.75	1.50	0.191	40 - 50	1.91
						9.51
21	1.66	16.26	1.43	0.235	0 - 20	4.70
	1.68	17.22	1.43	0.245	20 - 40	4.90
	1.70	17.71	1.44	0.255	40 - 50	2.55
						12.15

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
28	1.64	18.17	1.39	0.252	0 - 20	4.70
	1.67	18.63	1.40	0.261	20 - 40	4.90
	1.71	17.02	1.46	0.25	40 - 50	2.55
						12.15
35	1.70	9.02	1.56	0.141	0 - 20	2.82
	1.68	10.20	1.52	0.155	20 - 40	3.10
	1.72	10.31	1.56	0.161	40 - 50	1.61
						7.53
42	1.65	8.65	1.52	0.131	0 - 20	2.62
	1.68	9.23	1.54	0.129	20 - 40	2.58
	1.67	9.36	1.53	0.143	40 - 50	1.43
						6.63
49	1.65	8.32	1.52	0.126	0 - 20	2.52
	1.68	8.92	1.54	0.137	20 - 40	2.74
	1.68	9.21	1.54	0.142	40 - 50	1.42
						6.68
56	1.67	7.70	1.55	0.119	0 - 20	2.38
	1.67	8.12	1.54	0.125	20 - 40	2.50
	1.70	8.39	1.57	0.132	40 - 50	1.32
						6.20

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
63	1.68	7.62	1.56	0.119	0 - 20	2.38
	1.67	8.05	1.55	0.125	20 - 40	2.50
	1.69	8.21	1.56	0.128	40 - 50	1.28
						6.16
70	1.68	7.56	1.56	0.117	0 - 20	2.34
	1.68	7.79	1.56	0.121	20 - 40	2.42
	1.70	8.06	1.57	0.126	40 - 50	1.26
						6.02

APPENDIX E: Result of Soil Moisture Content and Depth of Water during

2nd trial in plot B between September - November

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
0	1.63	14.36	1.42	0.204	0 - 20	4.08
	1.63	14.50	1.43	0.207	20 - 40	4.14
	1.64	14.92	1.43	0.213	40 - 50	2.13
						10.35
7	1.63	13.63	1.43	0.195	0 - 20	3.90
	1.64	13.90	1.44	0.200	20 - 40	4.00
	1.65	14.21	1.44	0.205	40 - 50	2.05
						9.95
14	1.65	12.22	1.47	0.179	0 - 20	3.58
	1.64	13.56	1.44	0.195	20 - 40	3.90
	1.66	13.69	1.46	0.200	40 - 50	2.00
						9.48
21	1.66	10.68	1.50	0.160	0 - 20	3.20
	1.66	11.10	1.49	0.165	20 - 40	3.30
	1.67	12.63	1.48	0.187	40 - 50	1.87
						8.37

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
28	1.69	15.36	1.46	0.224	0 - 20	4.48
	1.69	15.80	1.46	0.231	20 - 40	4.62
	1.70	17.35	1.45	0.251	40 - 50	2.51
						11.61
35	1.69	16.34	1.45	0.237	0 - 20	4.74
	1.68	16.82	1.47	0.242	20 - 40	4.84
	1.69	17.42	1.47	0.251	40 - 50	2.51
						12.02
42	1.67	10.63	1.50	0.159	0 - 20	3.18
	1.67	10.92	1.50	0.164	20 - 40	3.28
	1.69	11.00	1.52	0.167	40 - 50	1.67
						8.13
49	1.68	8.36	1.55	0.129	0 - 20	2.58
	1.64	9.20	1.50	0.138	20 - 40	2.76
	1.66	10.21	1.51	0.154	40 - 50	1.54
						6.68
56	1.62	8.01	1.49	0.119	0 - 20	2.38
	1.67	8.37	1.54	0.129	20 - 40	2.58
	1.67	9.02	1.53	0.138	40 - 50	1.38
						6.34

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
63	1.67	7.68	1.55	0.119	0 - 20	2.38
	1.69	8.22	1.56	0.125	20 - 40	2.56
	1.69	8.22	1.55	0.137	40 - 50	1.37
						6.37
70	1.68	7.30	1.56	0.114	0 - 20	2.28
	1.70	8.00	1.57	0.125	20 - 40	2.50
	1.70	8.03	1.57	0.126	40 - 50	1.26
						6.02

APPENDIX F: Result of Soil Moisture Content and Depth of Wtare stored during 2nd trial in plot C between September - November

$$Ds = \frac{Db}{1 + Mc}$$

Ds - Dry density
Db - Bulk density
Mc - Moisture content

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
0	1.69	14.86	1.47	0.218	0 - 20	4.36
	1.69	14.92	1.47	0.213	20 - 40	4.26
	1.70	15.36	1.47	0.226	40 - 50	2.26
						10.88
7	1.66	13.36	1.46	0.195	0 - 20	3.90
	1.67	14.67	1.45	0.213	20 - 40	4.26
	1.67	15.01	1.45	0.217	40 - 50	2.17
						10.33
14	1.67	12.42	1.48	0.184	0 - 20	3.68
	1.69	13.35	1.49	0.199	20 - 40	3.98
	1.69	14.75	1.47	0.217	40 - 50	2.17
						9.83
21	1.70	12.00	1.52	0.182	0 - 20	3.64
	1.70	13.05	1.50	0.196	20 - 40	3.92
	1.69	13.62	1.49	0.203	40 - 50	2.03
						9.59

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
28	1.65	15.00	1.43	0.214	0 - 20	4.28
	1.65	16.26	1.42	0.231	20 - 40	4.62
	1.68	16.60	1.44	0.239	40 - 50	2.39
						11.29
35	1.66	13.45	1.46	0.196	0 - 20	3.92
	1.67	14.22	1.46	0.207	20 - 40	4.14
	1.67	14.26	1.46	0.208	40 - 50	2.08
						10.14
42	1.65	10.33	1.49	0.154	0 - 20	3.08
	1.66	11.01	1.49	0.164	20 - 40	3.28
	1.66	12.02	1.48	0.178	40 - 50	1.78
						8.14
49	1.69	9.79	1.54	0.151	0 - 20	3.02
	1.68	10.35	1.52	0.157	20 - 40	3.14
	1.70	11.22	1.53	0.172	40 - 50	1.72
						7.88
56	1.662	9.00	1.52	0.137	0 - 20	2.74
	1.67	9.45	1.52	0.144	20 - 40	2.88
	1.67	9.86	1.52	0.149	40 - 50	1.49
						7.11

DAP	Db	Mc (%)	Ds	Mc (vol basis Ds x Mc)	Depth of soil	Depth of water stored
63	1.66	8.46	1.53	0.129	0 - 20	2.58
	1.68	8.90	1.54	0.137	20 - 40	2.74
	1.68	9.20	1.54	0.142	40 - 50	1.42
						6.74
70	1.69	7.90	1.57	0.124	0 - 20	2.48
	1.70	8.60	1.56	0.134	20 - 40	2.68
	1.70	9.00	1.56	0.140	40 - 50	1.40
						6.56