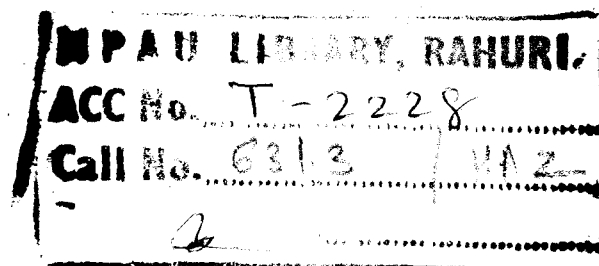


SOIL AND MOISTURE CONSERVATION THROUGH
TIED-RIDGES FOR PEARL MILLET
IN SCARCITY REGION

By

ASHOK KASHIRAMSINGH HAZARI



DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
FACULTY OF AGRICULTURAL ENGINEERING
MAHATMA PHULE AGRICULTURAL UNIVERSITY
RAHURI-413 722

1990

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**SOIL AND MOISTURE CONSERVATION THROUGH TIED-RIDGES
FOR PEARL MILLET IN SCARCITY REGION**

*A Thesis Submitted to the
MAHATMA PHULE AGRICULTURAL UNIVERSITY
Rahuri-413 722*

*in partial fulfillment of the
requirements for the
Degree*

of

MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)

in

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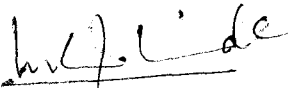
in

SOIL AND WATER CONSERVATION ENGINEERING


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RAHURI**

1990

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or other person to any other University or Institute for a Degree or Diploma.

Place : Rahuri
Dated : 28 Dec. 1990


ASHOK K. HAZARI

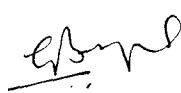
CERTIFICATE

This is to certify that the thesis entitled "SOIL AND MOISTURE CONSERVATION THROUGH TIED-RIDGES FOR PEARL MILLET IN SCARCITY REGION", submitted to the Faculty of Agricultural Engineering, Mahatma Phule Agricultural University, Rahuri, District Ahmednagar, (Maharashtra State) in partial fulfillment of the requirements for the award of the degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in SOIL AND WATER CONSERVATION ENGINEERING, embodies the results of a bonafide research work carried out by Shri. Ashok K. Hazari, under my guidance and supervision.

The results embodied in this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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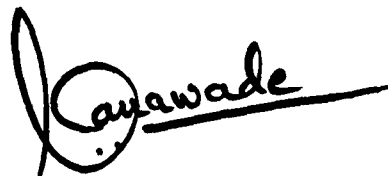

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CERTIFICATE

This is to certify that the thesis entitled "SOIL AND MOISTURE CONSERVATION THROUGH TIED-RIDGES FOR PEARL MILLET IN SCARCITY REGION", submitted to the Mahatma Phule Agricultural University, Rahuri, District Ahmednagar, (Maharashtra State) in partial fulfillment of the requirements for the award of the degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in SOIL AND WATER CONSERVATION ENGINEERING, embodies the results of a bonafide research work carried out by Shri A.K. Hazari, under the guidance and supervision of Professor G.B. Bangal, Professor and Head Department of Soil and Water Conservation Engineering, Mahatma Phule Agricultural University, Rahuri, District-Ahmednagar and that no part of the thesis has been submitted for any other Degree or Diploma.

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ACKNOWLEDGEMENTS

I am immensely grateful to Professor G.B. Bangal, Professor and Head Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, Rahuri and who was also my research guide. He was a good source of inspiration and encouragement. Right from the beginning of the experiment till the completion of the manuscript he was very constructively critical at every stage of writing, which helped me in presenting the dissertation to an acceptable degree.

I also thank the members of the advisory committee: Prof. A.A. Atre, Prof. M.G. Shinde, Prof. S.D. Gorantiwar, and Prof. S.V. Mahajan, for their help and guidance. I am thankful to Prof. B.M. Patil, Ex. Dean and Prof. L.R. Kanawade, Dean, Faculty of Agricultural Engineering, for the encouragement and providing the facilities for the study.

I thank Prof. B.F. Patil, for his help during the project work. I also thank the staff members of the Faculty of Agricultural Engineering and my colleagues, for their cooperation throughout the course of this study. Thanks are due to Shri. A.G. Karande, University Librarian and Shri. D.T. Dome, Agricultural Assistant, for their help in this work.

I am thankful to Mahatma Phule Agricultural University, Rahuri, for permitting me to avail the study leave and for providing the facilities for the work.

Special thanks are due to Mrs. Sheela M. Sawant of Om'ega Consultants, Pune, for the word processing and computer graphics.

Last, but not the least, I appreciatevely thank my wife, Vijaya, for her support, encouragements, and love.

Place : Rahuri
Date : 28 Dec. 1990


(A.K. HAZARI)

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LIST OF SYMBOLS

Symbol	Description
A	Soil loss
a	Constant
b	Exponent, constant
C	Crop management factor
C ₁	Conservation practice, tied-ridge of size 3.0 m x 6.0 m
C ₂	Conservation practice, tied-ridge of size 1.5 m x 3.0 m
C ₃	Control-cultivation across the slope
E	Kinetic energy, soil loss
EC	Electrical conductivity
EI	Erosion index
EI ₃₀	Rainfall erosivity index
I	Rainfall intensivity
K	Soil erodibility factor
K.E.	Kinetic energy
L	Slope length factor
l	Slope length
LS	Topographic factor
N	Nitrogen
P	Conservation practice factor, phosphate
Q	Runoff depth, discharge
R	Rainfall erosivity factor
r	Correlation coefficient
S	Slope steepness factor
s	Field slope
S ₁	0.5 per cent slope

LIST OF SYMBOLS (Continued)

Symbol	Description
S ₂	1.0 per cent slope
S ₃	3.0 per cent slope
T ₁	Tied-ridges of size 3.0 m x 6.0 m with across the slope cultivation on 0.5 per cent slope.
T ₂	Tied-ridges of size 1.5 m x 3.0 m with across the slope cultivation on 0.5 per cent slope.
T ₃	Plain plot with across the slope cultivation on 0.5 per cent slope (no tied-ridges).
T ₄	Tied-ridges of size 3.0 m x 6.0 m with across the slope cultivation on 1.0 per cent slope.
T ₅	Tied-ridges of size 1.5 m x 6.0 m with across the slope cultivation on 1.0 per cent slope.
T ₆	Plain plot with across the slope cultivation on 1.0 per cent slope (no tied-ridges).
T ₇	Tied-ridges of size 3.0 m x 6.0 m with across the slope cultivation on 3.0 per cent slope.
T ₈	Tied-ridges of size 1.5 m x 3.0 m with across the slope cultivation on 3.0 per cent slope.
T ₉	Plain plot with across the slope cultivation on 3.0 per cent slope (no tied-ridges).
USLE	Universal Soil Loss Equation
Var	Variety
x	Exponent in length factor equation
%	Per cent

LIST OF ABBREVIATIONS

Abbreviation	Description
cm	Centimetre
cm ³	Cubic centimetre
Fig.	Figure
g	Gram
gm	Gram
g cc ⁻¹	Gram per cubic centimetre
ha	Hectare
hrs day ⁻¹	Hours per day
kg	Kilograms
kg ha ⁻¹	Kilograms per hectare
Lit min ⁻¹	Litres per minute
M	Million
m	Metre
max.	Maximum
m ²	Square metre
m ³	Cubic metre
min.	Minute, minimum
m day ⁻¹	Metre per day
Mha	Million hectare
mm	Millimetre
mm hr ⁻¹	Millimetre per hour

LIST OF ABBREVIATION (Continued)

xv

Abbreviation	Description
mmhos	Millimhos
°C	Degree centigrade
q ha ⁻¹	Quintals per hectare
sq. m.	Square metre
t ha ⁻¹	Tonnes per hectare
t j ⁻¹	Tonnes per joule

ABSTRACT

SOIL AND MOISTURE CONSERVATION THROUGH TIED-RIDGES FOR PEARL MILLET IN SCARCITY REGION

by

Ashok K. HAZARI
Mahatma Phule Agricultural University
Rahuri-413 722 District Ahmednagar
1990

Research Guide : Prof. G.B. Bangal
Department : Soil and Water Conservation
Engineering

The objectives of this study were to determine the reduction in runoff and soil loss due to tied-ridges, to study the effect of tied-ridges on yield of Pearl Millet and to evaluate the effect of slopes on soil erosion and moisture retention by use of tied ridges.

The plots, each measuring 12 m x 24 m, were laid out on 0.5, 1.0 and 3.0 per cent land slopes. Tied ridges of size 1.5 m x 3.0 m and 3.0 m x 6.0 m along with plain plot as control were laid out on each slope. The crop, Pearl Millet (*Pennisetum typhoideum*) was sown across the slope in these nine treatments.

Five runoff producing storms with average intensities 38.76, 6.3, 52.66, 18.17 and 4.75 mm hr⁻¹ occurred during the crop growth period.

The runoff increased with slope in plain plots. No runoff was observed from plots with tied-ridges and hence there was no soil loss from these plots. The soil loss per unit of rain erosivity was maximum (1.93 kg ha⁻¹) from plain plot on 3.0 per cent slope. It decreased with decrease in slope.

ABSTRACT (Continued)

The conservation practice factor, P, was 0.032, 0.029 and 0.110 for 0.5, 1.0 and 3.0 per cent land slope, respectively in plain plots. As there was no soil loss, the conservation practice factor was zero for tied-ridges.

The average soil moisture was highest of all treatments at 15 cm and 30 cm depth in plots with tied-ridges of size 1.5 m x 3.0 m on all the slopes.

The grain yield was 32.44, 48.44 and 30.67 q ha⁻¹ in tied-ridges of size 3.0 m x 6.0 m on 0.5, 1.0 and 3.0 per cent land slope, respectively. This was the highest among the three treatments of conservation practices.

The tied ridges of size 3.0 m x 6.0 m were ^{found better} ~~best~~ in reducing runoff and soil loss and increasing the yield of pearl millet.

(64 pages)

Chapter Opener Page

1 . INTRODUCTION

Agriculture in most parts of India is still a gamble in annual rainfall. The rainfall in large region is inadequate and extremely uncertain with respect to its quantity and temporal and spatial distribution. As water is the most important single factor of crop production, the inadequacy and uncertainty of rainfall often cause partial or complete failure of crops and lead to periodic scarcities and famines. Such conditions naturally make the economic life of the cultivator in these regions extremely difficult and insecure.

Out of total cultivated area of 172.64 Mha. in our country, only 39.97 Mha. (23.15 per cent) have some access to irrigation water. The remaining 132.67 Mha (76.85 per cent) are rainfed agriculture lands (Epitome of Agriculture in Maharashtra, 1989). About 70 to 80 per cent of our annual precipitation is received during June to September and the coefficient of variation in annual rainfall varies from 15 to 80 per cent. About 1/3rd of the land gets less than 75 cm of rain and about another 1/3rd between 75 to 115 cm of rain. The remaining area receives rainfall of over 115 cm annually (Narayana, 1987). The age old land tillage, non-application of fertilizer, negligence of soil and water conservation measures give rise to erosion. The soil erosion hazards are high because of lack of sustained vegetative cover during the dry months and high erodibility of the soils. The monsoon season is also characterised by high rainfall intensities and erosivities. Combined with faulty cultural practices, which leads to both high soil and water losses and a loss of productivity. Soil erosion due to agricultural activities alone, is taking place at a rate of 5.3×10^3 M tonnes per year. About 500 M tonnes of soil is deposited in the surface reservoirs and about 1.6×10^3 M tonnes discharged in to the sea (Narayana and Ram Babu, 1983).

Out of a total geographical area of 30.76 Mha in Maharashtra 20.27 Mha is cultivated and only 1.91 Mha is irrigated (Epitome of Agriculture in Maharashtra, 1989). The rainfall is highly erratic, uncertain, and low in the scarcity zone,

which covers about 6.76 Mha of cultivable land. Major portion of the scarcity zone lies in the jurisdiction of Mahatma Phule Agricultural University, Rahuri, (5.75 Mha) (Patil and Kale, 1988). Agriculture in this region is highly dependent on aberrant rainfall, as the only source of water. Soil management practices are tailored to store and conserve as much rainfall as possible by reducing runoff and increasing the storage capacity of the soil profile. Therefore, a cultivation system for land in this region must first of all prevent soil from being washed away by rainfall which is badly distributed and fall in intense storms, and also maintain the soil in a state suitable for plant growth.

A reduction in the huge runoff losses from the land area will automatically mean that more water will become available for retention as soil moisture; while more soil moisture will support more permanent vegetation in the form of trees and grasses, and make rainfed agriculture more productive. Reduced runoff losses will also save a great deal of top soil from erosion and moderate the incidence as well as the severity of floods.

There are several soil and water conservation measures for reduction of the runoff and soil loss. In our country many soil conservationists had worked on the strip cropping, ~~contour~~ farming, contour/graded bunding, bench terracing, etc. in the past. All these methods even though they are effective, have certain disadvantages, like point rows and the cost of the land formation and maintenance. Furrow diking or tie-ridging not only controls the runoff more efficiently but it is also less expensive than other methods.

In India, per capita land holding is very low, and poor land holder cannot afford to go for costly mechanical soil protection work or land management. The method that not only will conserve the moisture but also retard erosion; will be suitable to such small farmer. So the method should be simple so that the farmer himself can adopt it easily with available implements and tools. Tied-ridges which are nothing but rectangular check basins with lower heights of ties, is one suitable work that may achieve this objective. However, very little work has

been done on the tie-ridging in our country. The practice of tie-ridging or furrow diking, where adjacent ridges are joined at regular intervals by barriers or ties of the same height, allow the water to infiltrate and prevent runoff and soil loss except during the intense storms and for steep slopes (Dagg and McCartney, 1968). The practice was found beneficial for many rainfed crops. The Pearl Millet, being one of the important rainfed cereal of the region, was cultivated using tie-ridging to harness various objectives of this method. The experiment was conducted to see the effect of tied-ridges on the conservation of soil and water on three slopes for medium deep, clay soil with the following specific objectives.

1. To determine the reduction in runoff and soil loss due to tied-ridges.
2. To study the effect of tied-ridges on yield of Pearl Millet.
3. To evaluate the effect of slopes on soil conservation and moisture retention by the use of tied-ridges.

Chapter Opener Page

2. REVIEW OF LITERATURE

Tie-ridging is the soil management practice for conservation of soil^{and} water. It consists of preparing main ridges across the slope and ties across the side slope. Thus, preparing small basins which will hold the rain-water at a place where it falls. This practice improves soil moisture status on flat lands in scarcity region. The work pertinent to tie-ridging has been reviewed and presented in this chapter.

2.1 EFFECT OF TIED-RIDGES

Wood (1933) studied the effect of construction of earth dams in the trench at intervals of 15 to 20 feet on level ground and 8 to 10 feet on slopes. He stated that there was no moisture lost by runoff. He also suggested that this technique can be applied to the furrows.

Sheed et al. (1935) studied the basin method of planting row crops and a basin lister planter, they observed the following advantages:

This method:

1. Reduces water erosion of the soil.
2. Lessens the danger of washing out seed and small plants.
3. Reduces the tendency for water to accumulate in ponds at low points in relatively flat fields.
4. Conserves the moisture.
 - a. In case of heavy dashing rain, the water is held in place until it soaks into the soil where it is available.
 - b. In case of ineffective showers of say $\frac{1}{4}$ inch rainfall it conserves some moisture.
5. The basin method of planting was effective in reducing wind erosion of the soil and protecting small plants from the

whipping and cutting action of heavy winds carrying small particles of soil.

Faulkner (1944) observed that ridging is more laborious than flat cultivation. However, there is extraordinarily large increase in yield of maize from ridging as compared with flat cultivation. He further noted that whenever the different sizes of ridges were compared, the higher yield was invariably obtained from the bigger ridges than smaller ones. This observation held good for maize and cotton. He also reported some surprising results that the yield of cotton on ridges in the wet year at Lubaga Station (Nigeria) was less than yield from the flat plots, even to the extent of 16 per cent.

Peat and Prentice (1949) have studied the maintenance of soil productivity in Sukumaland and adjacent areas of Tanganyika, and observed that there was an increase in yield of cotton and maize by 52 per cent and 34 per cent, respectively, in station type tied ridges, when native non-tied ridges compared with station type tied ridges. They also noted same observations in case of sorghum where increase of sorghum yield was 100 per cent in case of tie-ridging. They further observed that the yield of groundnut increased upto 59 per cent in case of tie-ridged cultivation when compared with the flat cultivation. They also observed that the crops react differently within limits to tie-ridging according to their different water requirements and possibly other characteristics.

Daniel (1950) studied the water conservation for wheat production in Oklahoma and observed that under continuous or annually recurring tillage of the same nature the highest average yield of wheat has been produced on plowed land (grain yield 18.5 bushels) and lowest on the stubble mulch plots (grain yield 14.8 bushels). The yield on the listed (17.9 bu.) and basin listed (17.8 bu.) land have been about the same. They were only slightly less than on the plowed.

Fisher and Burnett (1953) reported increased cotton lint yields i.e. 224 kg ha⁻¹ for unblocked furrows and 279 kg ha⁻¹ for block furrows. They further

reported that dry land cotton showed increased cotton lint yields 25 kg ha^{-1} for each additional 1 cm of water stored.

King (1960) in Northern Nigeria showed no significant increases in yield in a comparison between shallow and deep ploughing but, in a series of comparisons of flat and tied-ridges cultivation, the yield of seed cotton varied from 140 lb ac^{-1} for flat cultivation to 2275 lb ac^{-1} for tied ridges.

Peat and Brown (1960) observed the increase in crop yields in the Lake Province of Tanganyika. At Ukirigura, tie-ridging gave increased cotton and grain crop yields as well as it controlled erosion adequately. The mean increase in yield was 151 lb ac^{-1} in case of seed cotton and 95 lb ac^{-1} in case of millet grain. On the black loam and hard-pan soils large increases in yield from tie-ridging were resulted.

Lawes (1961) reported conservation of rainfall by ridging and cross-tieing and the yield of cotton in Northern Nigeria. The method designed to conserve the soil, also conserves rainfall. The results of experiment carried out at Samaru during the period 1956 to 58 comparing the cross-tied ridges with open furrows showed that there was increase in seed cotton yield by about 14 to 22 per cent in cross tied ridges. The figures of yield of seed cotton indicated that in seasons of below average rainfall cross-tieing is beneficial. But in seasons of more than average rainfall the benefit of moisture conservation is outweighed by the bad effect of standing water between the cross-tied during high rains. However, certain soil surface treatments can greatly improve the rate of infiltration by preventing the formation of surface 'seal' or 'cap'. Where runoff was prevented by tied-ridge cultivation the profile was saturated to a depth of 4 feet and with flat cultivation the soil 30 in. deep was not wet. He further reported that the infiltration of water depends not only on the treatment of soil surface but also on the time of land preparation. He observed that superiority of early preparation of land was attributed to three separate effects. First, the improved water infiltration into the stirred soil and the action of cross-ties in

preventing any runoff of early rains, build up soil moisture needed for rapid germination and good early growth. Secondly, early weed growth is substantially checked and the removal of water and nutrients by weeds is much reduced. Thirdly, the early opening up of soil and improved entry of water must affect the microbiological activity and nitrogen cycle. It is considered that on balance the changes so caused were likely to be favourable to the young cotton crop which was to follow. He further observed that maximum retention of rainfall was ensured by the technique of cross-tieing the ridges. By conserving the rainfall, improving the infiltration and aeration very large increase in seed cotton yield have been obtained.

Walton (1962) investigated moisture differences in the soil profile under tied-ridge and flat cultivation in Uganda and criticised tied ridges because in draught conditions after germination the ridges having a greater surface area, dried out more quickly than flat cultivation. He said that after the eighth week when the roots of cotton had reached a depth of 2 feet, tied-ridging should show significantly better results because by then additional water available under the ridges would in a dry spell at least equal the extra evaporation caused by ridging. He also correlated ridging and flat cultivation with rainfall, slope, and time of planting, and concluded that when planting is delayed under a bi-modal rainfall system tie-ridging will give increased yields.

Brown (1963) investigated the effects of the rainfall pattern and tied-ridge cultivation on the yield of cotton at Ukiriguru in Tanzania in the seasons 1947-1959 and found that when rainfall during the period December-March was optimum, variation in yield was less from tied-ridge plots (260 lb) than from those not tied-ridged (370 lb).

At Ousseltia in Tunisia in 1966 FAO staff reported no significant differences in yields of peas between flat, ridged and tie-ridged plots. The rainfall was, however, well distributed and they concluded that, because the only annual rainfed crops grown in the area were winter ones which did not lend

themselves to the sparse plant populations necessitated by ridge cultivation and summer crops could only be grown under irrigation, tie-ridge cultivation had no value in the area. They further reported that there were no significant differences in soil moisture in flat, ridged or tie-ridged plots, but the rainfall during the experiment was particularly well distributed and runoff was not a serious problem.

Lawes (1966) studied the rainfall conservation and the yields of sorghum and groundnuts in Northern Nigeria, and concluded that measures designed to conserve rainfall by preventing runoff and to improve the infiltration rate of the soil surface appear to have a less pronounced effect on sorghum and groundnuts than on cotton yield. As regard the soil moisture at 1 foot depth after early rains comparing open furrows with cross-tied land, he reported that the soil moisture (% over dry weight) in all furrows left open and all ridged tied was 12.5 and 17.7 per cent, respectively.

Dagg and Macartney (1968), during the study on agronomic efficiency of the N.I.A.E. mechanized tied-ridge system of cultivation on different types of soil, recorded the yield differences in case of maize crop under tied-ridged (2824 lb ac⁻¹), ridged (2465 lb ac⁻¹), and flat (2389 lb ac⁻¹) cultivation. Despite the variable performance of the variable soil types the average yield from the three cultivation methods showed an appreciable benefit from tied-ridging alone over cultivation on the flat.

Unger (1972) studied the dry land winter wheat grain sorghum cropping system in Northern High Plains of Texas and recorded the grain yields 2922, 2533 and 2470 kg ha⁻¹ for the blocked furrows, open furrows and flat planted areas respectively.

Clark and Hudspeth (1976) studied the runoff control for summer crop production in the Southern Plains of Texas and concluded that grain sorghum yields were increased 13 per cent and cotton lint increased 25 per cent when blocks were made in furrows to hold rainfall, prevent runoff and allow water to

infiltrate. They have also reported that furrow blocks have maximum benefits when a summer crop was growing instead of during fallow periods.

Bilbro and Hudspeth (1977) compared the yield, staple length, cotton lint and soil moisture from diked and undiked plots having 0.2% and 0.9% slopes, and reported the increase in lint yields from diking over undiked plots about 10.7 to 14.7 per cent under different tests. Diking had no significant effect on grade and staple length. The moisture reading about 36 hours after a 1.54 in. of rain showed that the top foot of soil in the diked plot had 19.2 per cent more total water (0.25 inches) than the undiked plots, which indicated that runoff was considerable in the undiked rows. He further observed that runoff from the diked plots was not visible. However, after some heavy rain considerable soil erosion was noticed in the undiked rows of the field with 0.9 per cent slope, while it was less in undiked plots with 0.2 per cent slope.

Haney (1978) reported that grain sorghum yield have been increased as much as 12 per cent and cotton as much as 25 per cent by basin tillage used in dry land farming in the Texas High Plains. Further he observed that a total of 3.9 inches of rain fell in 8 days; of this amount, 1.1 inches were added to soil profile in the conventional field, but 3.2 inches were added to the soil in the basin-tilled field.

Jones and Clark (1982) studied the effect of furrow dikes or basin tillage on runoff conservation, soil water content and crop yield at Bushland and Etter in Texas. They observed that, at Bushland, the furrow diking conserved an average of 4.0 cm per year runoff and increased average dry land grain sorghum yields 210 kg ha^{-1} (12%), and at Etter, furrow diking conserved 6.8 and 8.8 cm of runoff and increased sorghum yields 1660 and 1210 kg ha^{-1} in 1980 and 1981, respectively. They showed that the well constructed furrow dikes retained upto 5 cm of water surface storage thereby increasing infiltration and soil water storage while reducing soil and water losses. Further they observed that the over topping of dikes on a clay loam with slopes less than 1 per cent did not

result in noticeable erosion, however, on a 3 per cent slope significant erosion did occur. They concluded that the furrow diking was a conservation practice that can conserve water, reduce erosion and increase yields of summer crops grown at flat or gently sloping soils in the southern Great Plains of Texas.

Tompkins and Mahoney (1982) studied basin tillage for erosion control and showed that runoff from plots having dikes at 40 inch intervals between bedded rows was substantially less than from plots containing bedded rows with no dikes. Moreover, sediment concentration in the runoff water from the diked plots was less than in runoff from undiked plots.

Rawitz et al. (1983) studied tillage practices for soil and water conservation in the semi-arid zone and found that the traditional tillage system consisting of deep ploughing (30-45 cm) of dry soil in the fall followed by disking, smoothing and ridging is the worst choice as it could result in runoff losses as much as 60 per cent of the rainfall, accompanied by accelerated erosion. They further compared the traditional practice of tillage with deep ploughed land and left fallow during the entire rainy season, ridging after subsoiling instead of deep ploughing, subsoiling and ridging carried out in one minimum tillage operation, direct ridging without primary tillage, and basin tillage of ridges following either deep ploughing, subsoiling, or minimum tillage. This study showed that by far the most effective method for enhancing infiltration and eliminating runoff was the basin tillage system. The method is adaptable both to mechanized farming and to farming based on animal power or manual labour, and its application can ensure success where rainfall is limited.

Gerard et al. (1984) studied the effect of furrow diking and subsoiling on runoff and crop yields on gently sloping land in Rolling Plains of Texas and showed that the diking and subsoiling reduced runoff and significantly increased yields of sorghum and cotton. They observed the yields of diked sorghum and cotton were 108 and 32 per cent higher than the check, respectively. They further observed the effect of slope position on the crop

yields. They observed the yields of sorghum on the diked treatments on an Abilene loam soil averaged about 2550, 3300, and 1590 kg ha⁻¹ or about 302, 140, and 42 per cent more than check treatment on the upper, middle, and lower parts of the slope, respectively. In contrast, cotton yields on diked treatment on a Miles fine and loam soil averaged about 465, 515, and 475 kg ha⁻¹ or about 57, 37, and 11 per cent more than the check on the upper, middle, and lower parts of the slope, respectively. They further reported that the subsoiling effect varied with years and crops; and the results showed that a determinant crop such as sorghum is more critically affected by loss of water due to runoff than the less determinant cotton crop.

Morin et al. (1984) studied tillage practices for soil and water conservation in the semi-arid zone. They analysed the long-term rainfall record of the northern Negev of Israel and predicted the runoff. They showed that the basin tillage system decreased runoff by at least 50 per cent as compared with the conventional planting system. They also showed that the surface runoff was less in case of tied-ridges than the current soil preparation practices at 80 per cent probability by 80 per cent. Further they observed that the seasonal runoff from control plot was 17.7 mm with soil loss 293 kg ha⁻¹ and from basin tillage, with 0.6 m wide bed, the runoff was 7.4 mm with soil loss 72 kg ha⁻¹. Further they observed that the yield of wheat crop was significantly higher in wide bed (1.6 m) treatment (1403 kg ha⁻¹) than that of the narrow bed (964 kg ha⁻¹) and control treatment (975 kg ha⁻¹). They concluded that the yield increase in wide bed treatment was mainly due to more uniform local distribution of rain water in the soil; and the reason for low yield in the narrow bed (0.6 m) tied-ridges might be due to higher per cent of total area applied by basins and stunted growth due to water logged condition.

Wistrand (1984) studied furrow dike water conservation practices in Texas High Plain, and concluded that the furrow diking may substitute for other soil conservation structures but its ability to prevent erosion is limited. Furrow

diking is most successful in conserving soil when combined with other established conservation practices. He further reported that the average yield of the grain sorghum was 570 lb ac⁻¹ and 1776 lb ac⁻¹ from the undiked and diked plots, respectively, while the runoff retained in diked plots was 1.7 inches.

Estiri and Brown (1985) determined the optimum size and spacing of furrow dike based on runoff, which was calculated from a stochastic simulation model, and infiltration amounts, were calculated by using Green-Ampt equation. They also studied the influence of rainfall intensity, duration, slope and initial moisture content on the amount of runoff.

Krishna and Arkin (1985) had studied the two watersheds on black land, and runoff data for the period 1956 to 1981 and 1947 to 1966 at both the watersheds, and arrived at a conclusion that the dikes when build should not exceed the ridge height; and suggested that dikes in the black land preferably should be constructed in furrows with a slight grade (approximately 0.5% slope) and after stabilization and settling be not less than 7.6 cm (3 in.) high. They further reported that if large runoff events do occur excess water should be able to overtop the dike and drain down the furrows rather than across rows.

Baumhardt and Wendt (1987) studied the tillage and furrow diking effects on infiltration, soil water storage and yield of forage sorghum of Acuff loam soil. They observed that the infiltration of simulated rainfall was increased by chisel tillage, furrow diking and the absence of crusts. He showed that the runoff of natural rainfall was significantly less in furrow dikes, however, the soil water storage was slightly increased. No forage yield differences were measured among treatments.

Gerard (1987) studied the effect of furrow diking an subsoiling on the yields of sorghum and cotton in the rolling Plains of Texas. He showed that the diking significantly affected the yield of sorghum every year during 1979-1985. He observed that the yields of dike sorghum were 88, 48 and 30 per cent higher than yields of the check treatments on the upper, middle, and lower parts of the

slope, respectively. Diking increased the average yield of sorghum 50 per cent over the check for 1981-1985. Half diking increased sorghum yields an average of about 62 , 21 and 17 per cent on the upper, middle, and lower parts of the slope, respectively, and an overall average of 29 per cent higher than the average check yield. He also reported that, in 1979, the plants close to the dikes on the upper part of the slope were 36 per cent taller and appeared more productive than plants 25 to 50 ft. from the dikes, and this result indicated that the need for shorter intervals between dikes. He also observed the effect of diking on yields of cotton, and he showed that the diking treatments increased yields by an average of 22, 21 and 11 per cent on the upper, middle, and lower parts of the slope, respectively; and an average of 18 per cent during five years of investigation. Half diking increased yields over the check by 10 per cent from 1980 to 1985. He concluded that the factors such as year, per cent slope, and soils probably affect the response of cotton to diking. However, diking of the soils at this location with slopes of 0.1 to 0.2 per cent increased soil moisture storage and yields in three of the five years.

Jones and Clark (1987) studied the effects of furrow dikes on water conservation and dry land crop yields. They analysed the 28 years of runoff records and showed that the furrow diking retained 25 to 30 mm of runoff annually. They observed that the maximum annual runoff retention by diking during the 14 crop years of research was 111 mm. They showed that the maximum increase in sorghum yield was 2.46 Mg ha^{-1} in diking treatment. They also reported that the diking increased annual cropped sorghum yields on graded and contour furrow treatments by 49 and 14 per cent, respectively, whereas water use efficiencies were increased by 25 and 16 per cent, respectively. They also observed that the sunflower yields were increased significantly by diking during 1 year out of 3 years when sunflower was grown after 76 weeks of fallow, whereas sorghum yields were not affected by diking after fallow. They also showed that the 3 years average yields of sorghum 1.0

Mg ha⁻¹ and sunflower (0.14 Mg ha⁻¹) were significantly increased by decreasing the row spacing from 1.0 to 0.75 m.

2.2 UNIVERSAL SOIL LOSS EQUATION

Wischmeier and Smith (1965) developed the Universal Soil Loss Equation to estimate the soil loss. The equation proposed by them is :

$$A = R \times K \times LS \times C \times P$$

Where,

R = Rainfall and runoff erosivity index,

K = Soil erodibility factor, t j⁻¹

LS = Topography factor,

C = Cropping management factor,

P = Supporting conservation practice factor, and

A = Annual soil loss, t ha⁻¹

Foster et al. (1977) developed the runoff erosivity term for the Universal Soil Loss Equation, USLE, from analysis of an erosion equation derived from basic erosion principles. They further discussed how the slope-length-exponent of the USLE varied with runoff, soil erodibility, slope steepness and length erosion control practice.

McGregor (1978) determined the cropping and management factors for no-till and conventional-till soybeans from plot data. He divided the crop season into five growth periods and confirmed the conservation benefits of zero tillage

Das and Babu (1979) described the procedure for the computation of rainfall erosion indices, EI in metric units, and for conversion of existing EI values to metric units.

Dissmeyer and Foster (1981) tried new procedure for estimating the cover management factor, C, in the USLE for forest. Conditions, based on an evaluation of nine subfactors: 1. amount of bare soil, 2. canopy, 3. soil reconsolidation,

4. high organic content, 5. fine roots, 6. residual effect, 7. on-site, storage, 8. steps, 9. contour tillage. The procedure gave reasonable values of cover management factor, C, for forest conditions.

Mutchler et al. (1981) studied the sub-factor method for computing C factors for continuous cotton. They found that the subfactors are multipliers that represents the effects of land use residual, incorporated residue, tillage intensity and recency, macro roughness, canopy and cover. They showed the need for assessing the variation of soil erodibility.

Foster et al. (1982) worked on rainfall erosivity factor for individual storms. Several erosivity factors that could be used to estimate soil loss from individual storms were investigated. Rainfall erosivity factors that include both rainfall rate and amount terms, e.g. EI_{30} were found to be much better predictors of soil loss than a factor including rainfall amount alone. Lumped erosivity factors that include rainfall amount, rainfall intensity and runoff amount were even better predictors, while erosivity factors with separate terms for rainfall and runoff erosivity were best. They concluded that above listed factors did not greatly improve soil loss predictions as compared to EI_{30} .

Narain et al (1982) found values of C as 0.39 for green gram, 0.51 for maize, 0.62 for sorghum and 0.01 for *Dichanthium annulatum*, at Kota.

McGregor and Mutchler (1983) tried to determine crop management factor, C, for no-till and reduced till corn. They derived C value for the use in the USLE by crop stage. They obtained low C value as compared to those for conservationally tilled maize for silage and grain.

Verma (1984) suggested that the crop season can be divided in four stages for estimating cropping management factor, C, for Indian condition. He worked out the crop management factor, C, and developed the formula as:

$$C = \frac{\text{Per cent R} \times \text{Per cent soil loss}}{10000}$$

where,

R = Rainfall erosivity index

Castro and Zobeck (1986) studied the topographic factor in the USLE on irregular slopes. They found that the effect of slope shape can be added to estimates of LS based on uniform slopes by decreasing the LS for concave slopes and increasing the LS for complex and convex slopes by the correction ratios worked out by them. The difference in LS due to slope shape will vary with slope length and gradient.

Istock et al. (1986) conducted the study to determine weather erosion index. The index could be calculated using hourly rainfall data and suggested that the method could be used in other areas where hourly, but not break point, rainfall data available.

Chapter Opener Page

3 . MATERIAL AND METHODS

3.1 LOCATION AND EXPERIMENTAL DESIGN

3.1.1 LOCATION

The present study was conducted during *kharif* season of 1989 on the Instructional Farm of the Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, Mahatma Phule Agricultural University, Rahuri. It lies at 19° 24' latitude and 74° 39' longitude and 657 m above mean sea level.

3.1.2 SELECTION OF SITE AND LAND PREPARATION

Three plots of 42 m x 24 m each, available on the farm were selected for the study. The soil of all three plots was same in type and properties. These plots had slopes of 0.5, 1.0 and 3.0 per cent. These slopes were re-shaped to make them to exact degree without disturbing the soil profile. Each plot was then sub divided in to three sub plots, each measuring 12 m x 24 m. Thus there were nine plots for nine treatments.

3.2 EXPERIMENTAL SET UP

The variables involved in the experiment were slope, and conservation practices. Runoff, soil loss, soil moisture were recorded under natural storm conditions in the plots cultivated with Pearl Millet (variety: Eknath-301). The layout of the experiment is shown in Fig. 3.1.

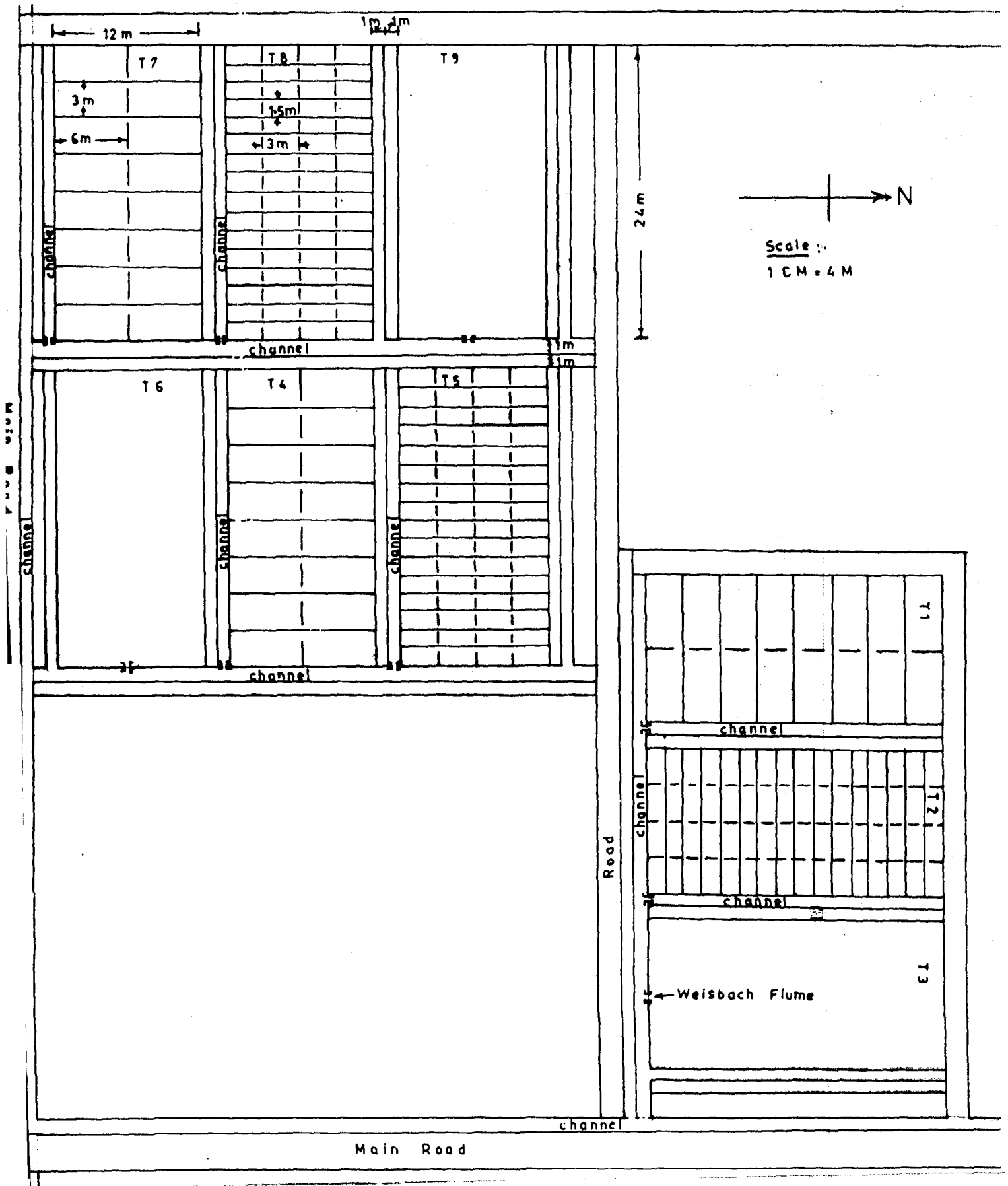


Fig. 3.1 Plan of the experimental plot.

3.2.1 EXPERIMENTAL LAYOUT

- a. Size of three main plots having different slopes : 42 m x 24 m.
- b. Number of sub-plots in each main plot : 3
- c. Size of each sub-plot : 12 m x 24 m.

3.2.2 TREATMENT DETAILS

There were nine treatment combinations formed by three conservation practices and three slopes.

Conservation practices :

1. C_1 : tied-ridges 3.0 m x 6.0 m
2. C_2 : tied-ridges 1.5 m x 3.0 m.
3. C_3 : Control, i.e. no tied ridges.

Land slope :

1. S_1 : 0.5 per cent
2. S_2 : 1.0 per cent
3. S_3 : 3.0 per cent

In all the treatment plots, cultivation was done across the slope.

Treatment combinations :

Slope	Conservation practice		
	C_1	C_2	C_3
S_1	$T_1 : S_1C_1$	$T_2 : S_1C_2$	$T_3 : S_1C_3$
S_2	$T_4 : S_2C_1$	$T_5 : S_2C_2$	$T_6 : S_2C_3$
S_3	$T_7 : S_3C_1$	$T_8 : S_3C_2$	$T_9 : S_3C_3$

Tied ridges are rectangular check basins, with lengths of basins across the slope. The height of a main ridge which was across the slope was 25 cm, and height of a tie ridge which was along the slope was 15 cm. These dimensions of main and tie-ridges were decided on the basis of one day maximum rainfall which was 129.6 mm recorded during last 14 years. The tied-ridges were formed manually. One sub plot in each main plot was control. The waterway was excavated at lower end of each experimental plot, where the runoff water from plots through flumes reached the waterway. Weisbach runoff measuring flumes of 120 lit min⁻¹ capacity were installed at outlet of each sub-plot to measure the runoff. Sediment sampling technique was used for determination of soil loss. Soil moisture and yield of the crop in each plot and rainfall were also recorded.

3.2.3 CROP DETAILS

- | | | | |
|----|------------------------------------|---|--|
| a. | Crop | : | Pearl Millet (<i>Pennisetum typhoideum</i>)
(Local name : Bajra Variety : Eknath - 301). |
| b. | Spacing | : | 30 cm x 15 cm |
| c. | Seed rate | : | 3 kg ha ⁻¹ |
| d. | Date of sowing | : | 30 th June 1989 and 1 st July 1989
Sowing was done by manual dibbling. |
| e. | Fertilizers applications | : | Out of the recommended dose of 60 kg N and 30 kg P per hectare; 30 kg N and 30 kg P per hectare were given at the time of sowing and remaining dose of 30 kg N per hectare was given one month after sowing. |
| f. | Date of harvesting: | : | 3 and 4 October 1989 |
| g. | Duration of crop | : | 95 days |
| h. | Rainfall during crop growth period | : | 535.9 mm |

3.3 OBSERVATIONS AND DATA ANALYSIS

3.3.1 RAINFALL MEASUREMENT

Due to prolonged dry spell after sowing of crop, one irrigation of 3.5 cm by sprinkler was applied for proper germination.

The automatic raingauge was fixed near the experimental plots for recording the rainfall data. During the crop growth period 535.9 mm rainfall was received, and during this period only five storms produced runoff, the details of which are given in Table 3.1.

Table 3.1 Storm duration and intensities.

Storm No.	Date	Duration hr.min.	Rainfall mm	Average Intensity mm hr ⁻¹
1.	18-8-1989	0.50	32.3	38.76
2	19-8-1989	1.40	10.5	6.30
3.	12-9-1989	0.50	43.8	52.66
4.	22-9-1989	2.55	53.0	18.17
5	29-9-1989	3.40	17.0	4.75

3.3.2 SOIL PROPERTIES

The soil of the experimental plots was medium deep, clay. Mechanical analysis of the soil was carried out and the following soil properties were known by soil analysis:

a.	Clay (less than 0.002 mm)	:	43.45 per cent
b.	Silt + very fine sand (0.002 to 0.100 mm)	:	14.14 per cent
c.	Sand (0.10 to 2.00 mm)	:	41.41 per cent

d.	Organic matter content	:	1.00 per cent
e.	Field capacity	:	39 per cent
f.	Wilting point	:	19 per cent
g.	Permeability	:	0.39 m day ⁻¹
f.	Bulk density	:	1.60 g cc ⁻¹
i.	Soil structure	:	Coarse granular
j.	Soil type	:	Clay
k.	pH	:	8.15
l.	EC	:	0.39 mmhos cm ⁻¹ at 20°C.

3.3.3 SOIL MOISTURE

The soil samples for determination of its moisture content were collected, once in a week on a particular day, from the experimental plots at 15 cm and 30 cm depths; and at three locations viz. upper, middle and lower parts of each plot along the slope. This schedule was changed when rainfall occurred on that day or previous day. In such cases moisture observations were taken after 48 hrs. of rainfall.

3.3.4 RUNOFF MEASUREMENT

Weisbach runoff measuring flumes were installed at outlet of each sub-plots to measure the runoff. The discharge through the flumes was manually recorded at an interval of 10 minutes during occurrence of runoff. The runoff volume was then computed.

3.3.5 SOIL LOSS MEASUREMENT

The soil loss was measured by collecting runoff samples at an interval of 10 minutes in half-litre capacity catch-cans. After allowing the particles to settle down at the bottom in the catch-cans, the water was decanted and slurry was dried in hot-air oven maintained at temperature 105°C for 24 hours. The total soil

loss for the total runoff for each time interval was calculated and expressed in tonnes per hectare for each experimental plots.

3.3.6 PARAMETERS IN USLE

Wischmeier and Smith (1965) proposed a USLE for estimating soil loss from cultivated fields. The equation is :

$$A = R \times K \times LS \times C \times P$$

Where,

R = Rainfall and runoff erosivity index;

K = Soil erodibility factor, tj^{-1}

LS = Topographic factor;

C = Cropping management factors;

P = Supporting conservation practice factor; and

A = Annual soil loss $t ha^{-1}$.

These parameters are described below:

Rainfall Erosion Index, R :

The rainfall erosion index, R is the sum of the EI_{30} products for all the major storms in the area. It is the product of Kinetic energy and 30 minutes maximum rain intensity. The units have been omitted from I_{30} and its numerical value alone used as a scale factor (Troch et al., 1980). The units of the soil erodibility factor, K are chosen so that the product of R and K is $t ha^{-1}$. Rainfall erosion index, R was obtained as 270.44 units for all five storms. Sample calculations are illustrated in Apendix-I.

Soil Erodibility Factor, K :

The soil erodibility factor, K converts units of R to amount of erosion. The original calculations were based on measurements made on standard plots with 9 per cent slope and 22.1 m long kept fallow by periodic tillage up-and-down the

slope. The units of K are $t j^{-1}$ to yield the product of R and K in $t ha^{-1}$. Wischmeier et al., (1958), studied the soil properties most intimately related to soil erodibility and developed a nomograph relating erodibility to easily measured or classified soil properties. With the help of nomograph (Fig. 3.2), the soil erodibility factor, K was selected by analysing the soil properties. The parameters such as per cent silt plus very fine sand, per cent fine to very coarse sand, organic matter content, soil structure and soil permeability were used to find the soil erodibility factor, K. The value of K as read from the nomograph (Figure 3.2) was $0.1083 t j^{-1}$ for all the land slopes.

Topographic Factor (LS) :

The topographic factor (LS) as given by Wischmeier and Smith (1978) adjusts the soil loss from the standard length of 22 m (73 ft.) and 9 per cent slope. These factors can be calculated from the equations :

$$L = (l/22)^x$$

$$S = \frac{(0.43 + 0.30 s + 0.043 s^2)}{6.574}$$

Where,

$$x = \begin{array}{l} \text{a constant,} \\ 0.5 \text{ for slopes } > 4 \text{ per cent,} \\ 0.4 \text{ for } 4 \text{ per cent, and} \\ 0.3 \text{ for } < 3 \text{ per cent.} \end{array}$$

$$l = \text{Slope length, m.}$$

$$s = \text{field slope per cent}$$

The slope length is measured from the point where surface flow originates, usually the top of the ridge, to the outlet channel or a point down the slope where deposition begins. Sample calculations are shown in Appendix-I.

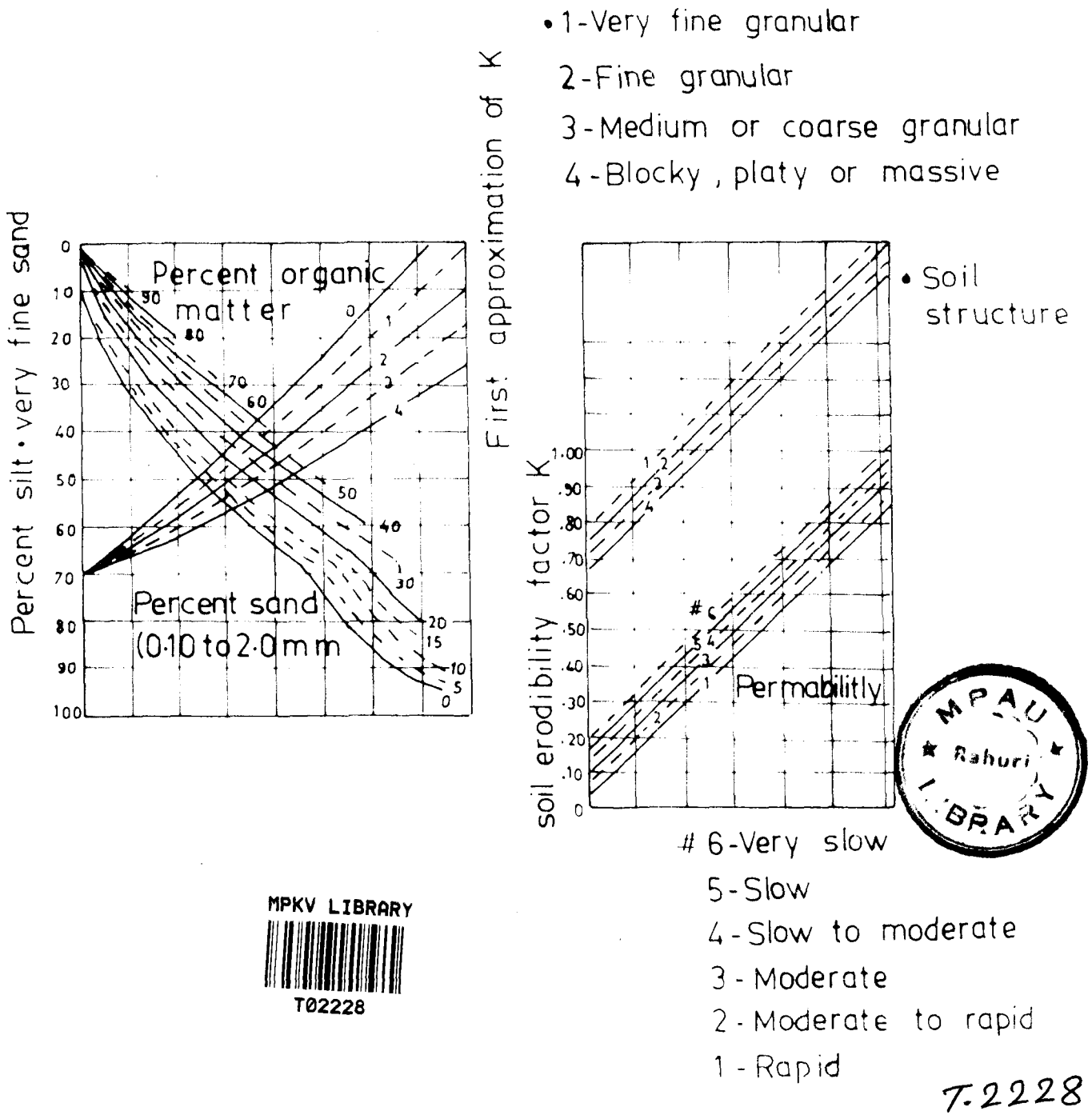


Fig. 3.2 A nomograph to determine the soil erodibility factor, K.
(Source: Troch, Hobbs, and Donahue, 1980)

Crop Management Factor, C :

This factor combines the effect of crop sequence and the other management practices. It is the ratio of soil loss from land having specified cropping management to soil loss from continuous cultivated fallow with identical soil, slope and rainfall. According to Roose (1975)¹ the C can be determined by considering different growth periods which will have different per cent of crop cover. The C values for these cover should then be multiplied by % R value and addition of these weighted C values give factor C for the crop. Narain et al. (1982) obtained C value for sorghum as 0.619. Sample calculations are shown in Appendix-I.

Conservation Practice Factor, P :

This factor is the ratio of soil loss with a specific supporting conservation practices like contouring, strip cropping, terracing etc., to the soil loss under cultivated fallow. The values of P vary according to the land slope and conservation practices. The values of P were calculated for different land slopes and treatments, using the observed quantities of factors A, R, K, LS and C in the equation, $A = R \times K \times LS \times C \times P$.

Procedure to determine factors in the equation is explained in Appendix-I.

3.3.7 GRAIN YIELD

The crop was harvested at maturity. Three sample plots of size 1.5 m x 3.0 m were selected randomly in upper, middle and lower zone of each plot to get average grain yield in the treatment.

¹ Original reference not seen.

4 . RESULTS AND DISCUSSION

The experiment was conducted to study the effect of tied-ridges and slope on runoff, soil loss, moisture retention in soil and yield of Pearl Millet. The runoff and soil loss data from runoff producing storms were recorded and analysed. Periodical observations on moisture retentions were taken from root zone in different treatments. The grain yield was also recorded for different treatments.

The soil losses measured during the experiment, were used to estimate the conservation practice factor (P) in Universal Soil Loss Equation, (USLE). Observations of runoff, soil loss and soil moisture were taken from 30.6.89 to 4.10.89. The data for five storms were recorded and analysed. These results are discussed in the following pages.

4.1 RUNOFF

The runoff was measured with Weisbach flumes installed at the end of each plot. The cumulative runoff for different storms is presented in Tables 4.1 to 4.5 along with the cumulative rainfall data during that storm. It is observed from table 4.1 to 4.5 that all the five storms produced runoff in T_9 i.e. plot with 3.0 per cent slope without any conservation practice. However, in T_3 storms 4 and 5 produced the runoff, and in T_6 storms 3, 4 and 5 produced the runoff.

4.1.1 EFFECT OF RAINFALL ON RUNOFF

In order to know the effect of rainfall on runoff a graph was plotted between cumulative rainfall and cumulative runoff, (Fig. 4.1). The relationship between cumulative rainfall and cumulative runoff is exponential. As there were only two and three points for treatments T_3 and T_6 , respectively, the nature of curve can not be explained very well. The relationship of the form:

Table 4.1 Cumulative rain, runoff and soil loss from the experimental plots*.

Storm No. 1 : Average rainfall intensity = 38.76 mm hr⁻¹.
Date : 18-8-1989

Time	Period	Rain mm	Cum- lative Rain mm	T ₉	
				Cum. runoff cm.	Cum. soil loss t ha ⁻¹
17.35	0	0	0	0	0
17.35 - 17.45	10	10.0	10.0	0	0
17.45 - 17.55	10	8.5	18.5	0	0
17.55 - 18.05	10	6.2	24.7	0	0
18.05 - 18.55	10	5.4	30.1	0.00139	0.00156
18.15 - 18.25	10	2.2	32.3	0.00208	0.00207

* In the treatments T₁ to T₈, no runoff was observed.

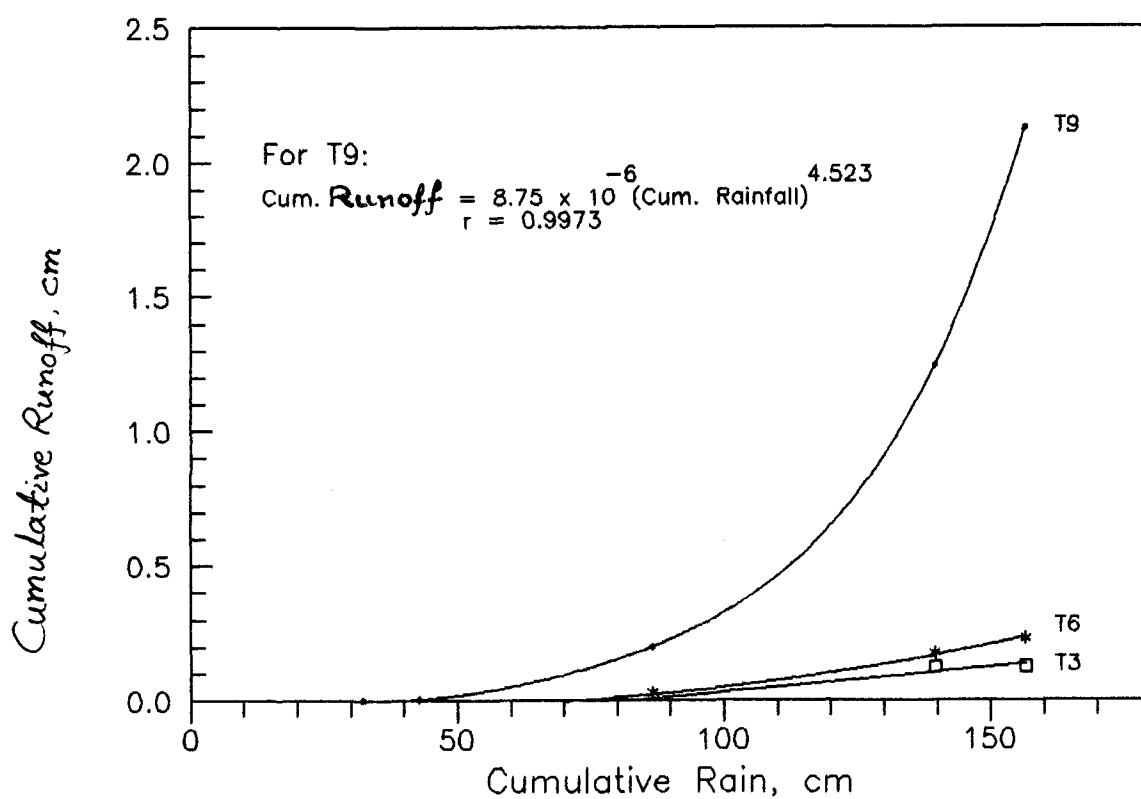


Fig. 4.1 Effect of rainfall on runoff.

Table 4.2 Cumulative rain, runoff and soil loss from the experimental plots*.

Storm No. 2 : Average rainfall intensity = 6.3 mm hr⁻¹.
Date : 19-8-1989

Time	Period min	Rain mm	Cum- lative Rain mm	T ₉	
				Cum. runoff cm.	Cum. soil loss t ha ⁻¹
12.30	0	0	0	0	0
12.30 - 12.40	10	0.3	0.3	0	0
12.40 - 12.50	10	0.2	0.5	0	0
12.50 - 13.00	10	0.2	0.7	0	0
13.00 - 13.10	10	0.1	0.8	0	0
13.10 - 13.20	10	0.1	0.9	0	0
13.20 - 13.30	10	0.3	1.2	0	0
13.30 - 13.40	10	5.3	6.5	0	0
13.40 - 13.50	10	2.5	9.0	0	0
13.50 - 14.00	10	0.5	9.5	0	0
14.00 - 14.10	10	1.0	10.5	0.0014	0.00074
14.10 - 14.20	10	-	-	0.0025	0.00084

* In the treatments T₁ to T₈, no runoff was observed.

Table 4.3 Cum. rain, runoff and soil loss from the experimental plots.*

Storm No. 3 : Average rain intensity = 52.56 mm hr⁻¹.
Date : 12-9-1989

Time	Period min	Rain mm	Cum. Rain mm	T ₆		T ₉	
				Cumulative runoff cm	Cumulative soil loss t ha ⁻¹	Cumulative runoff cm	Cumulative soil loss t ha ⁻¹
16.15	-	0	0	0	0	0	0
16.15 - 16.25	10	18.2	18.2	0	0	0	0
16.25 - 16.35	10	11.0	29.2	0	0	0.0069	0.00812
16.35 - 16.45	10	13.2	42.4	0.0017	0.00129	0.0208	0.02179
16.45 - 16.55	10	0.8	43.2	0.0122	0.00617	0.0764	0.05085
16.55 - 17.05	10	0.6	43.8	0.0260	0.00959	0.1389	0.07527
17.05 - 17.15	10	-	-	0.0288	0.01013	0.1736	0.08684
17.15 - 17.25	10	-	-	-	-	0.1840	0.0861
17.25 - 17.35	10	-	-	-	-	0.1910	0.09096
17.35 - 17.45	10	-	-	-	-	0.1937	0.09147
17.45 - 17.55	10	-	-	-	-	0.1945	0.09165

* In other treatments no runoff was observed.

Table 4.4 Cumulative rain, runoff and soil loss from the experimental plots.*

Storm No. 4 : Average rain intensity = 18.17 mm hr⁻¹.
Date : 22-9-1989

Time	Period	Rain-fall mm	Cumulative Rain-fall mm	T ₃		T ₆		T ₉	
				Cum. runoff cm	Cumulative soil loss q ha ⁻¹	Cum. runoff cm	Cumulative soil loss t ha ⁻¹	Cum. runoff cm	Cumulative soil loss t ha ⁻¹
22.50	0	0	0	0	0	0	0	0	0
22.50 - 23.00	10	0.5	0.5	0	0	0	0	0	0
23.00 - 23.10	10	5.2	5.7	0	0	0	0	0	0
23.10 - 23.20	10	14.6	20.3	0	0	0	0	0	0
23.20 - 23.30	10	20.0	40.3	0	0	0.00868	0.00289	0.01389	0.01481
23.30 - 23.40	10	5.8	46.1	0.02083	0.00560	0.36458	0.01106	0.06250	0.05045
23.40 - 23.50	10	0.6	46.7	0.06944	0.01561	0.85069	0.02194	0.40972	0.18364
23.50 - 00.00	10	0.5	47.2	0.09722	0.022046	0.11632	0.02771	0.67014	0.26407
00.00 - 00.10	10	0.4	47.6	0.11458	0.02245	0.13368	0.03004	0.84375	0.30623
00.10 - 00.20	10	0.6	48.2	0.12326	0.02288	0.14490	0.03116	0.93056	0.32120
00.20 - 00.30	10	0.7	48.9	-	-	0.14757	0.03133	0.99306	0.33024
00.30 - 00.40	10	0.6	49.5	-	-	-	-	1.02083	0.33381
00.40 - 00.50	10	0.7	50.2	-	-	-	-	1.03472	0.33550
00.50 - 01.00	10	0.9	51.1	-	-	-	-	1.03819	0.33601
01.00 - 01.10	10	0.5	51.6	-	-	-	-	1.04028	0.33626
01.10 - 01.20	10	0.4	52.0	-	-	-	-	1.04201	0.33643
01.20 - 01.30	10	0.3	52.3	-	-	-	-	1.04306	0.33651
01.30 - 01.40	10	0.2	52.5	-	-	-	-	1.04375	0.33654
01.40 - 01.50	10	0.5	53.0	-	-	-	-	1.04427	0.33658

* In other treatments no runoff was observed.

Table 4.5 Cum. rain, runoff and soil loss from the experimental plots.*
 Storm No. 5: Average rain intensity = 4.64 mm hr⁻¹.
 Date : 29-9-1989

Time	Period	Rain- fall mm	Cum. Rain- fall mm	T ₃		T ₆		T ₉	
				Cum. runoff cm	Cum. Soil loss q ha ⁻¹	Cum. runoff cm	Cum Soil loss t ha ⁻¹	Cum. runoff cm	Cum. Soil loss t ha ⁻¹
17.50	0	0	0	0	0	0	0	0	0
17.55 - 18.05	10	1.5	1.5	0	0	0	0	0	0
18.05 - 18.15	10	6.0	7.5	0	0	0	0	0.00608	0.00171
18.15 - 18.25	10	1.5	9.0	0.00261	0.00038	0.00521	0.00361	0.11719	0.03488
18.25 - 18.35	10	0.2	9.2	0.00261	0.00053	0.02951	0.00766	0.18316	0.05087
18.35 - 18.45	10	0.5	9.7	-	-	0.05035	0.00998	0.22483	0.05761
18.45 - 18.55	10	0.4	10.1	-	-	0.5382	0.010071	0.25955	0.06120
18.55 - 19.05	10	0.3	10.4	-	-	-	-	0.29253	0.06378
19.05 - 19.15	10	0.1	10.5	-	-	-	-	0.32031	0.06560
19.15 - 19.25	10	0.2	10.7	-	-	-	-	0.34983	0.06745
19.25 - 19.35	10	0.3	11.0	-	-	-	-	0.71441	0.06870
19.35 - 19.45	10	0.2	11.2	-	-	-	-	0.74566	0.06927
19.45 - 19.55	10	0.5	11.7	-	-	-	-	0.76996	0.07231
19.55 - 20.05	10	1.2	12.9	-	-	-	-	0.79601	0.07892
20.05 - 20.15	10	1.0	13.9	-	-	-	-	0.81510	0.08323
20.15 - 20.25	10	0.9	14.8	-	-	-	-	0.83073	0.08607
20.25 - 20.35	10	0.6	15.4	-	-	-	-	0.84462	0.08809
20.35 - 20.45	10	0.6	16.0	-	-	-	-	0.85781	0.089920
20.45 - 20.55	10	0.6	16.6	-	-	-	-	0.86996	0.08992
20.55 - 21.05	10	0.5	17.1	-	-	-	-	0.8764	0.09032
21.05 - 21.15	10	0.2	17.3	-	-	-	-	0.88212	0.09044
21.15 - 21.25	10	0.1	17.4	-	-	-	-	0.88316	0.09046
21.15 - 21.25	10	0.6	18.0	-	-	-	-	-	-

* In treatments T₁, T₂, T₄, T₅, T₇ and T₈ no runoff was observed.

$$Y = ax^b$$

was tried for T_9 and the equation developed with $r = 0.9973$ is as below :

$$\text{Cum. Runoff} = 8.75 \times 10^{-6} (\text{Cum. rainfall})^{4.523}$$

where, cumulative runoff and cumulative rainfall are in cm.

Tied-ridges on 0.5, 1.0 and 3.0 per cent slopes were effective in not producing the runoff and in holding all the rainfall water. Tied-ridges with 3.0 m x 6.0 m and 1.5 m x 3.0 m spacing were equally effective in retaining all the rainfall in all these three slopes. In T_3 runoff was only 1.8 per cent of rainfall, whereas it was 2.02 and 13.54 per cent of rainfall in T_6 and T_9 , respectively (Table 4.6). This indicated that even in plain plots runoff was very less in 0.5 and 1.0 per cent slopes. This seems to be the characteristics of the scarcity regions and soil with moderate and high permeability.

4.1.2 EFFECT OF LAND SLOPE ON RUNOFF

Total runoff from all the storms for different slopes and different treatments is shown in Table 4.7 along with the percentage increase in runoff due to the slope. Runoff occurred only from the plain plots and is compared in Table 4.7. It is revealed from this table that runoff increased with increase in land slope. Minimum runoff was obtained from plain plot with 0.5 per cent slope and maximum runoff was from similar plot with 3.0 per cent slope. The percentage increase in total runoff from plot with 3.0 per cent slope was 1587.30 and plot with 1.0 per cent slope was 82.54 with respect to the plot with 0.5 per cent slope.

Table 4.6 Runoff (cm) from different treatments.

Storm Number	Date	Rainfall mm	Rainfall Intensity mm hr ⁻¹	Runoff , cm		
				T ₃	T ₆	T ₉
Storm 1	18.8.89	32.3	38.76	-	-	0.0021
Storm 2	19.8.89	10.5	6.30	-	-	0.0024
Storm 3	12.9.89	43.8	52.66	-	0.0288	0.1944
Storm 4	22.9.89	53.0	18.17	0.1232	0.1475	1.0442
Storm 5	29.9.89	17.0	4.75	0.0026	0.0538	0.8831
Total Runoff cm				0.126	0.230	2.126
Rainfall, cm				7.0	11.38	15.66
Runoff as per cent of rainfall				1.80	2.02	13.57

Note : There was no runoff from other treatments.

Table 4.7 Effect of slope on total runoff.

Sr. No.	Treatments slope %	Total Runoff, cm			Percentage increase in runoff over 0.5 per cent
		Plain	Tied-ridges 1.5m x 3.0m	Tied-ridges 3.0m x 6.0m	
1.	0.5	0.126	-	-	-
2.	1.0	0.230	-	-	82.54
3.	3.0	2.126	-	-	1587.30

4.1.3 EFFECT OF TIED-RIDGES ON RUNOFF

In all the five runoff producing storms no runoff was recorded from plots with tied-ridges 1.5 m x 3.0 m and 3.0 m x 6.0 m as total rainfall from any of the runoff producing storms never exceeded the design rainfall (129.6 mm) described in Chapter 3. Therefore, it is seen that the design of tied-ridges for *fifteen* years return period helped in retaining rainfall due to all five storms.

4.2 SOIL LOSS

Soil loss was determined by sediment sampling. Cumulative soil loss for different treatments is shown in Table 4.1 to 4.5. As there was no runoff from treatments T₁, T₂, T₄, T₅, T₇ and T₈ there was no soil loss. The soil loss was observed from plain plots i.e. treatments T₃, T₆ and T₉. It was maximum for plot with 3.0 per cent slope (0.5216 t ha⁻¹) and minimum for plot with 0.5 per cent slope (0.0234 t ha⁻¹).

4.2.1 EFFECT OF RAINFALL ON SOIL LOSS

The relationship between cumulative rainfall and cumulative soil loss is shown in Fig. 4.2. This figure gives exponential relationship between cumulative rainfall and cumulative soil loss for T₉. However, for T₃ and T₆ there are only two and three points, respectively; and hence relationship cannot be explained very well. The relationship of the form $y = ax^b$ was tried for curve fitting for cumulative rainfall and cumulative soil loss.

The equation for T₉ obtained with $r = 0.9922$ is as follows:

$$\text{Cum. soil loss} = 1.93 \times 10^{-5} (\text{Cum. rainfall})^{3.776}$$

where, cumulative soil loss is in t ha⁻¹ and cumulative rainfall is in cm.

As the erosivity of rainfall is more associated with soil loss, the erosivities for different storms with corresponding soil loss are shown in Table 4.8. It is revealed from Table 4.8 that as erosivity increases soil erosion also increases.

Table 4.8 Soil loss (t ha⁻¹) from different treatments

Storm Number	Date	Rainfall erosivity R units	Soil loss, t ha ⁻¹		
			T ₃	T ₆	T ₉
1	18.8.89	41.65	-	-	0.0021
2	19.8.89	3.82	-	-	0.0008
3	12.9.89	105.57	-	0.0101	0.0917
4	22.9.89	113.06	0.0229	0.0313	0.3366
5	29.9.89	6.34	0.0005	0.0101	0.0904
Total Soil loss t ha ⁻¹			0.0234	0.0515	0.5216
Total runoff cm			0.126	0.230	2.126
Total rainfall cm			7.00	11.38	15.66
Rain erosivity, R units			119.41	224.98	270.44
Soil loss kg ha ⁻¹ per unit of rain erosivity			0.19	0.23	1.93

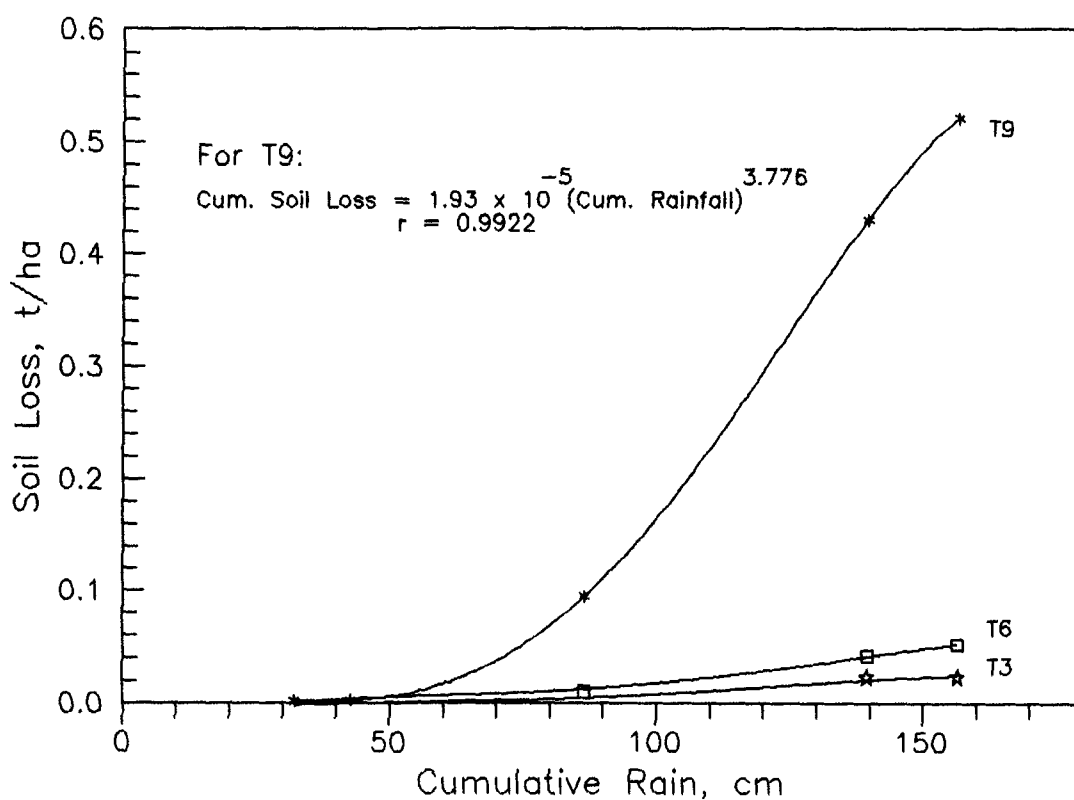


Fig. 4.2. Effect of rainfall on soil loss.

However, there was exception for storm 5. Here soil loss increased though the erosivity decreased. Probably due to more runoff and not due to erosivity. The soil losses were 0.19, 0.23 and 1.93 kg ha⁻¹ per unit of rain erosivity in T₃, T₆ and T₉, respectively. This indicated that the slope had interaction with rainfall erosivity and the slope has resulted in increasing the soil loss per unit of rainfall erosivity (Fig. 4.3). Rainfall erosivity up to 227 units was more or less ineffective in causing the erosion. Soil erosion increased very rapidly after this critical value.

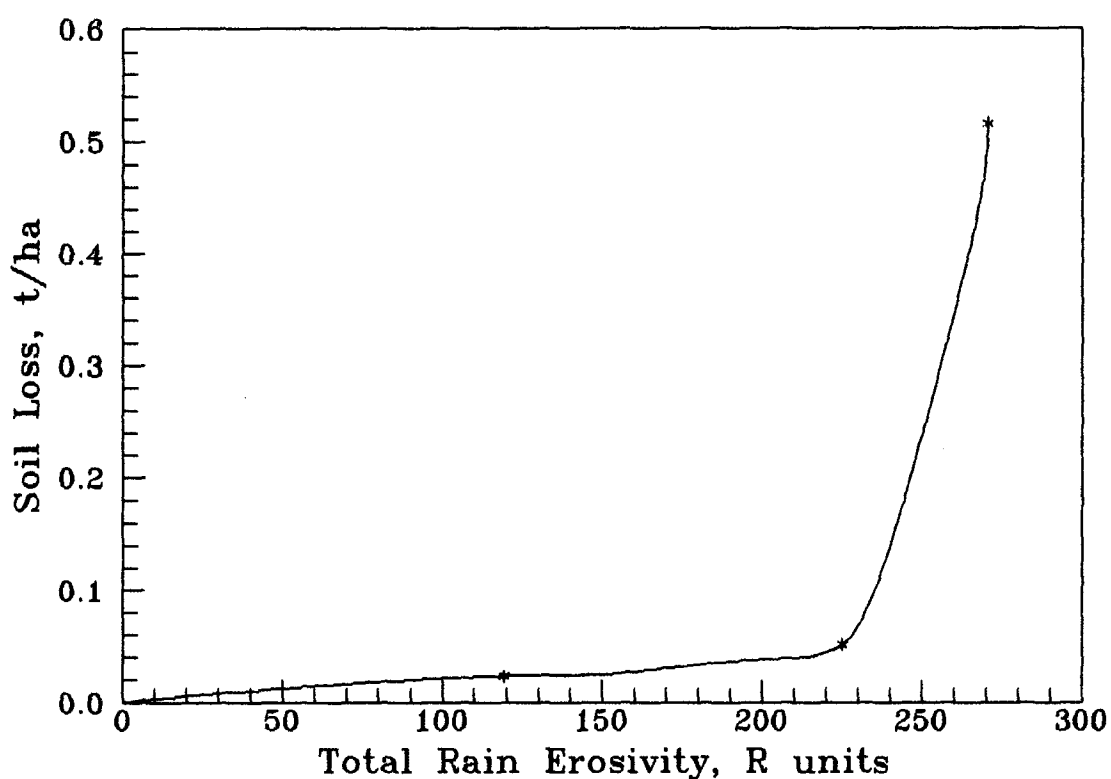


Fig. 4.3 Relation between total rain erosivity (R) causing erosion and soil loss.

4.2.2 EFFECT OF RUNOFF ON SOIL LOSS

The cumulative runoff and cumulative soil loss from all the five runoff producing storms are presented in Table 4.1 to 4.5. In order to evaluate the effect of runoff on soil loss, a graph of cumulative runoff and cumulative soil loss is plotted which is shown in Fig. 4.4. The relationship between the cumulative runoff and cumulative soil loss for treatment T₉ is:

$$\text{Cum. soil loss} = 0.324 (\text{Cum. runoff})^{0.838}$$

$$\text{With } r = 0.9983$$

where, cumulative soil loss is in t ha⁻¹ and cumulative runoff is in cm.

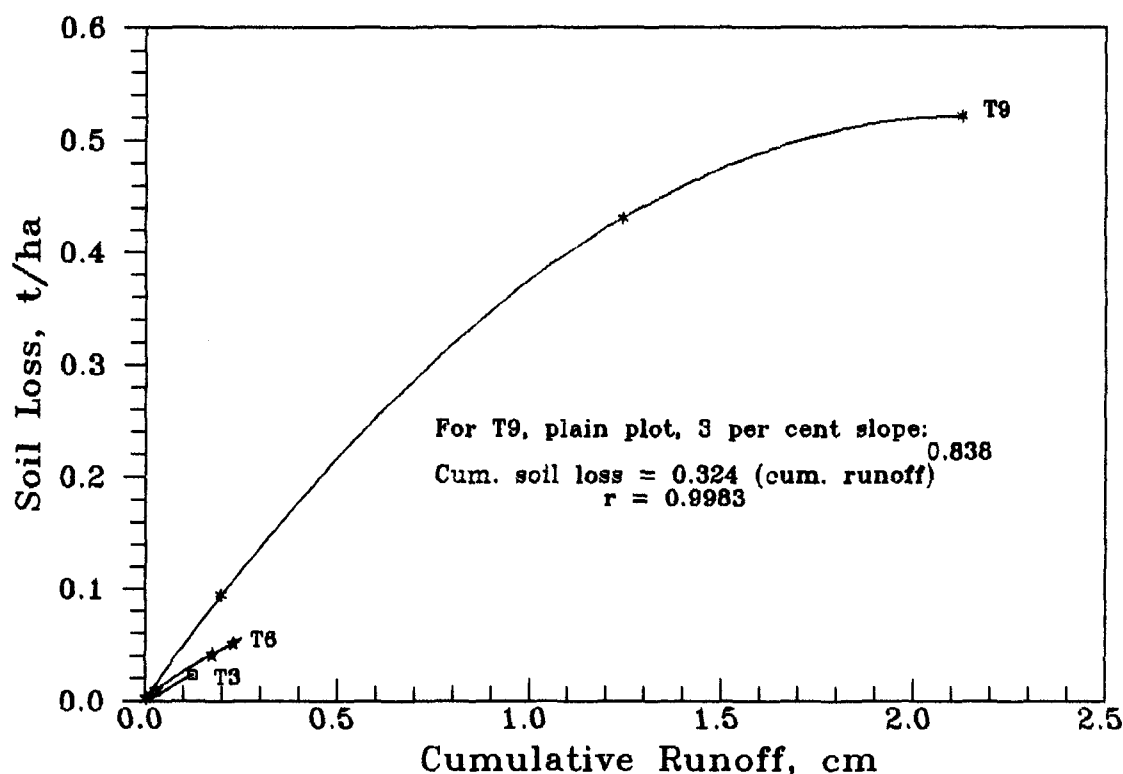


Fig. 4.4 Effect of runoff on soil loss.

The runoff is quite high during last storm which is due to more antecedent soil moisture and hence though the erosivity is less as reported in 4.2.1, soil loss is more. In T_3 , 0.126 cm runoff produced soil loss of 0.023 t ha^{-1} whereas in T_6 0.230 cm runoff produced soil loss of 0.05 t ha^{-1} and in T_9 , 2.13 cm runoff produced soil loss of 0.52 t ha^{-1} . This indicated that as the runoff increased the total soil loss also increased (Fig. 4.5 and Table 4.8).

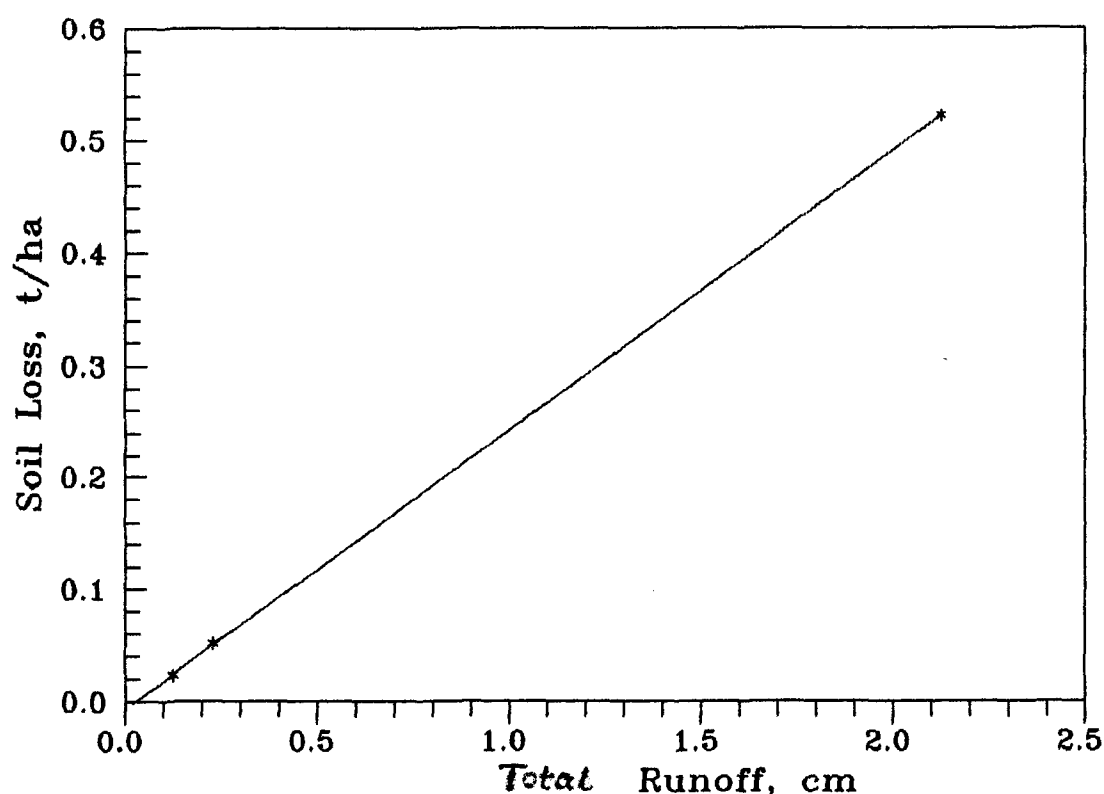


Fig. 4.5 Soil loss due to runoff in T_3 , T_6 , and T_9 .

4.2.3 EFFECT OF SLOPE ON SOIL LOSS

Total soil loss resulted from different treatments for all the runoff producing storms in Table 4.9. This table also gives percentage increase in soil loss due to slope. Maximum soil loss of 0.522 t ha^{-1} was observed from plain plot with 3.0 per cent slope, which was 2169.57 per cent more than the soil loss observed from similar plot with 0.5 per cent slope.

Table 4.9 Effect of slope on total soil loss.

Sr. No.	Treatments slope %	Total soil loss, t ha ⁻¹			Percentage increase in soil loss
		Plain	Tied-ridges 1.5m x 3.0 m	Tied-ridges 3.0 m x 6.0 m	
1.	0.5	0.023	0	0	0.00
2.	1.0	0.052	0	0	126.09
3.	3.0	0.522	0	0	2169.57

The topographic factor (LS) in USLE was evaluated for different slopes following the procedure given in 3.3.6. The LS factor for different slopes along with soil loss from those plots is shown in Table 4.10. The equation of the form $Y = ax^b$ was fitted to the curve obtained by plotting soil loss and LS factor, which is shown in Fig. 4.6. The equation is:

$$\text{Soil loss} = 24.999 (\text{LS})^{2.9145}$$

$$\text{with } r = 1.000$$

Where, soil loss is in t ha⁻¹. However, it may be mentioned here that the equation is based on only three points and therefore, the value of r and the constants in the equation will have to be confirmed from more number of observations.

Table 4.10 Effect of topographic factor (LS) on soil loss.

Sr. No	Land slope, s %	LS factor	Soil loss, t ha ⁻¹
1.	0.5	0.0915	0.0234
2.	1.0	0.1196	0.0515
3.	3.0	0.2653	0.5216

Note : Slope length was 24 m and value of m was 0.3 (3.3.6)

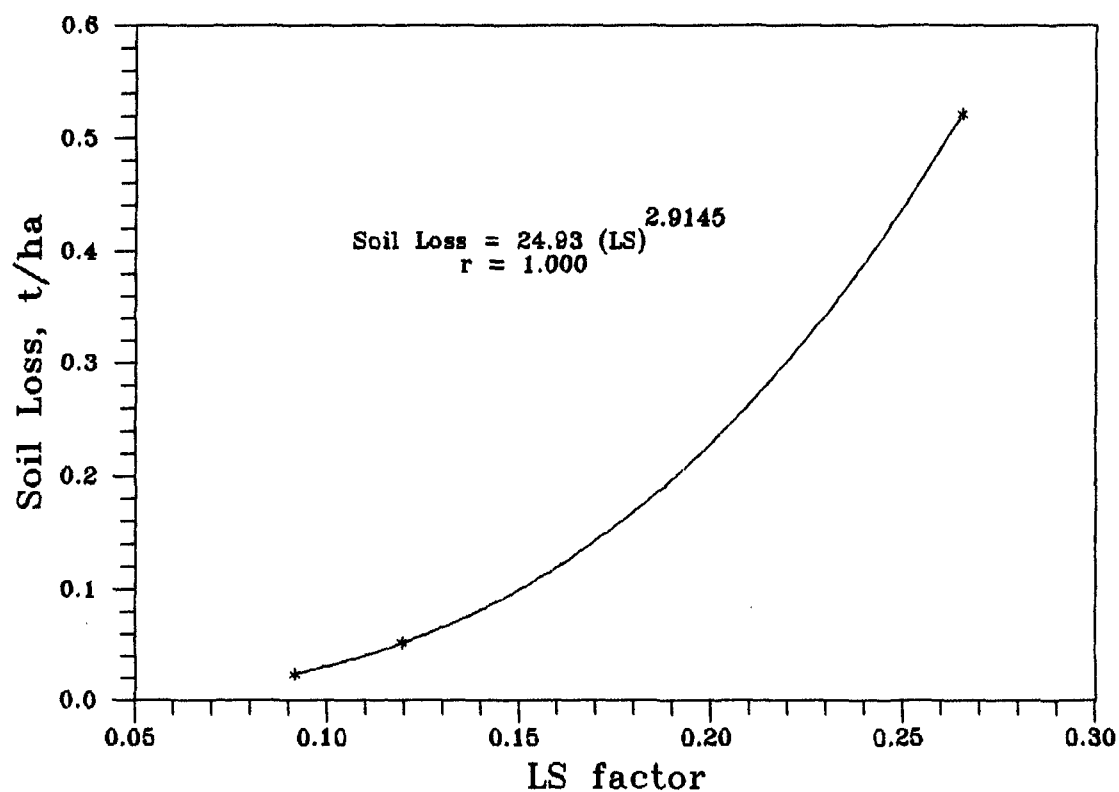


Fig.4.6 Effect of topographic factor on soil loss.

4.2.4 EFFECT OF TIED-RIDGES ON SOIL LOSS

There was no runoff from plots with tied-ridges as described in 4.1.3. This has resulted in no soil loss from these plots. The tied-ridges were designed on the basis of rainfall for 15 years return period (3.2.2). It is seen that both the spacing i.e. 3.0 m x 6.0 m and 1.5 m x 3.0 m were effective in retaining all the rainfall. Thus tied-ridges were effective in moisture conservation and erosion control, too.

4.2.5 CONSERVATION PRACTICE FACTOR (P)

The conservation practice factor P, was determined from known parameters: A, R, K, L, S and C in USLE. The parameters in the USLE along with soil loss for different treatments, are shown in Table 4.11. It is evident from Table 4.11 that the conservation factor P, is constant in 0.5 and 1.0 per cent slopes (i.e. 0.032 and

0.029 respectively). In 3.0 per cent slope this factor was 0.110. This factor should have been constant in all the three slopes; as there is no any conservation practice adopted in all these three slopes; and the slope has been taken care by the topographic factor. It seems that in 3.0 per cent slope, topographic factor does not contribute proportionately to the soil loss estimation and hence factor was high in 3.0 per cent slope. However, this needs confirmation by more number of experiments.

As there was no soil loss observed from the plots with tied-ridges, the conservation practice factor P, for tied-ridges was found to be 0, as shown in Table 4.11.

Table 4.11 USLE parameters in different treatments

Sr. No.	USLE parameters	T ₃	T ₆	T ₉
1.	R	119.41	224.98	270.44
2.	K	0.1083	0.1083	0.1083
3.	LS	0.0915	0.1196	0.2653
4.	C	0.6058	0.6058	0.6058
5.	P	0.0326	0.0292	0.1108
6.	A (t ha ⁻¹)	0.0234	0.0515	0.5216

Note : Conservation practice factor P, for ^{other} treatments is 0, because the runoff/^{and} soil loss were not observed from these treatments. Values of R are only for runoff producing storms, in respective treatments.

4.3 SOIL MOISTURE

The soil moisture at 15 cm and 30 cm depths was determined by gravimetric method. The soil moisture percentage in different treatments along with rainfall with respect to number of days after sowing is presented in Fig. 4.7 and Fig. 4.8. The moisture data was monitored once in a week at a regular interval. If there was rainfall on the day of observation then the observation day was postponed by two days.

4.3.1 EFFECT OF RAINFALL ON SOIL MOISTURE

The soil moisture pattern is cyclic and is a result of the antecedent rainfall in all the treatments, though the soil moisture levels are different in different treatments (Fig. 4.7 and Fig. 4.8). Treatments T₈, T₇ and T₉ showed higher moisture levels at 15 cm and 30 cm depth over other treatments. This was followed by T₅, T₄ and T₆ (Fig. 4.7 and 4.8).

4.3.2 EFFECT OF LAND SLOPE ON SOIL MOISTURE

The average soil moisture in different plots along with percentage increase due to land slope and tied-ridges at 15 cm and 30 cm depth is shown in Table 4.12 and Table 4.13, respectively. In plain plots the soil moisture decreased with increase in slope at both depths. However, this trend was not followed in plots with tied-ridges. The maximum average soil moisture was recorded in plot with 1.0 per cent slope with tied-ridges 1.5 m x 3.0 m at 15 cm and 30 cm depths (30.03 per cent and 30.56 per cent, respectively). The per cent increase in average soil^{moisture} was 11.02 and 10.19 for tied-ridges with size 1.5 m x 3.0 m and 3.0 m x 6.0 m, respectively. This was quite high as compared with increase in 0.5 per cent slope as seen in Table 4.12. Similar trend was observed at 30 cm depth. At 15 cm depth, 0.5 per cent slope and 1.0 per cent slope showed an increase of 10.43 and 10.22 per cent respectively over 3.0 per cent slope in plain plots. At 30 cm depth,

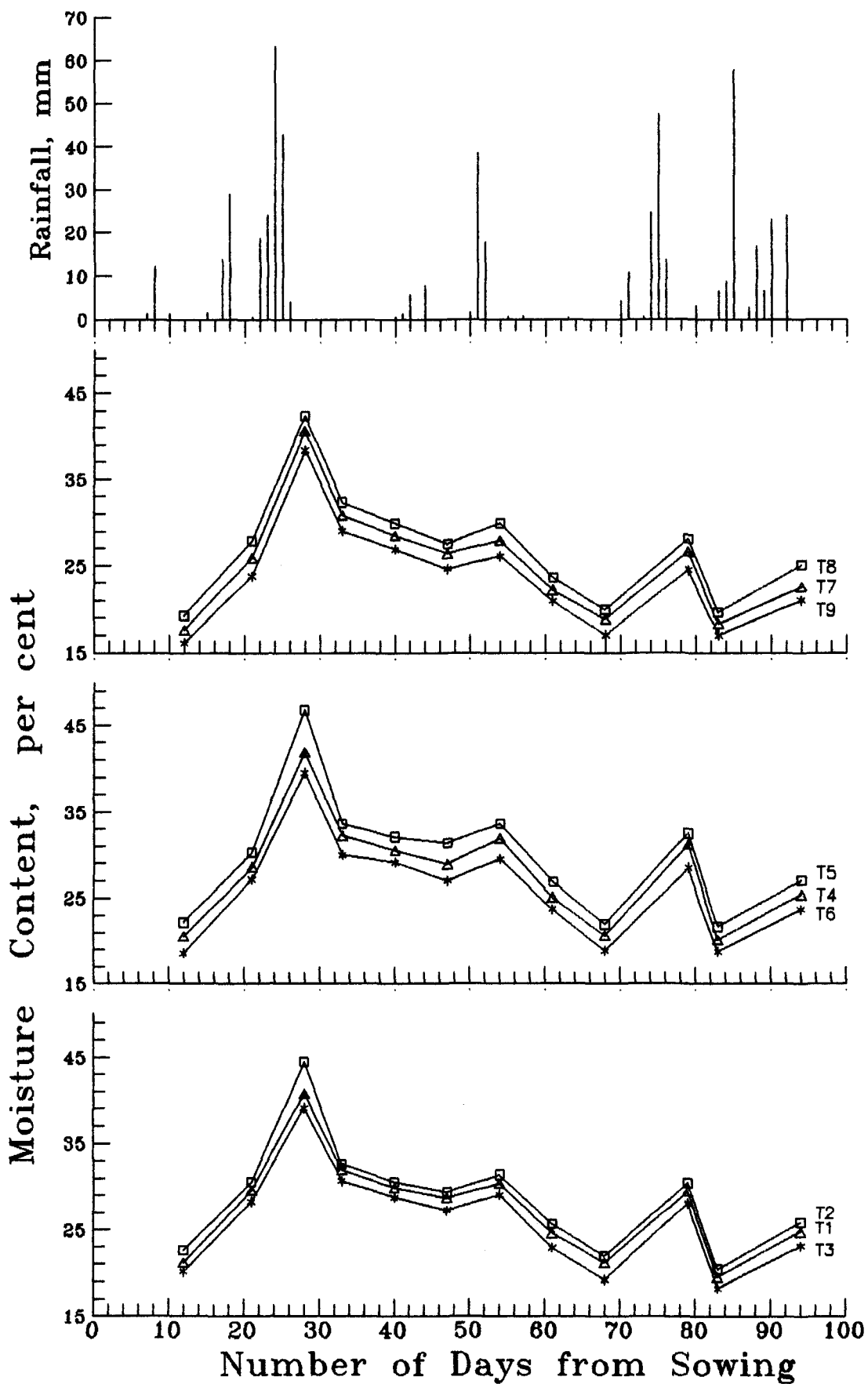


Fig. 4.7 Effect of rainfall, slope and conservation practice on soil moisture content at 15 cm depth.

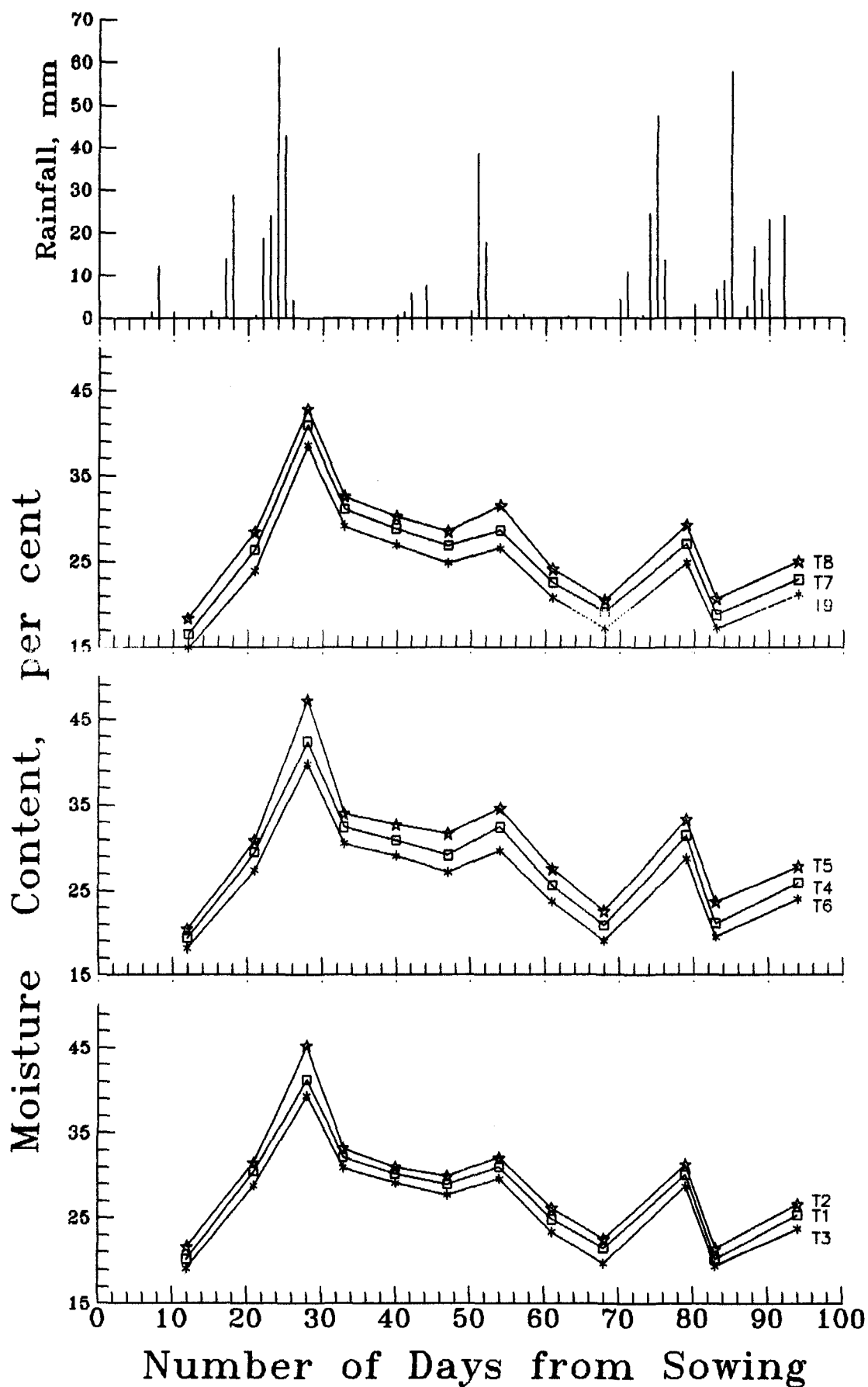


Fig. 4.8 Effect of rainfall, slope and conservation practice on soil moisture content at 30 cm depth.

Table 4.12 Effect of land slope and tied-ridges on soil moisture at 15 cm depth.

Slope %	Soil Moisture, %			Per cent increase in tied-ridges over plain plot	
	Tied-ridges 3.0 m x 6.0 m	Tied-ridges 1.5 m x 3.0 m	Plain Plot	Tied-ridge spacing 3.0 m x 6.0 m	Tied-ridge spacing 1.5 m x 3.0 m
0.5	27.65	28.84	26.26	5.29	9.82
1.0	28.11	30.03	26.21	7.25	14.57
3.0	25.51	27.05	23.78	7.28	13.75
Per cent increase against 3 % slope					
In 0.5%	8.39	6.62	10.43	-	-
In 1.0%	10.19	11.02	10.22	-	-

Table 4.13 Effect of land slope and tied-ridges on soil moisture at 30 cm depth.

Slope %	Soil Moisture, %			Per cent increase in soil moisture in	Percentage increase in soil moisture in
	Tied-ridges 3.0 m x 6.0 m	Tied-ridges 1.5 m x 3.0 m	Plain Plot	Tied-ridge spacing 3.0 m x 6.0 m	Tied-ridge spacing 1.5 m x 3.0 m
0.5	28.01	29.37	26.61	5.26	10.37
1.0	28.42	30.56	26.42	7.57	15.67
3.0	25.80	27.68	23.83	8.27	16.16
Percentage increase in soil moisture for 0.5 per cent land slope					
	8.57	6.11	11.67	-	-
Percentage increase in soil moisture for 1.0 per cent land slope					
	10.16	10.40	10.87	-	-

0.5 per cent slope and 1.0 per cent slope showed an increase of 11.67 and 10.87 per cent , respectively over 3.0 per cent slope in plain plots. It means that an increase of 10.8 per cent in soil moisture can be observed in 0.5 and 1.0 per cent slope over 3.0 per cent slope up to 30 cm depth. Thus in scarcity region reducing the slope may help in retaining soil moisture more by 10.8 per cent. This can be done by constructing the outwardly sloping very wide bench terraces and constructing the risers with flat slopes at the end of these benches.

4.3.3 EFFECT OF TIED-RIDGES ON SOIL MOISTURE

The practice of tied-ridges aims to soak rainfall where it falls. As there was no runoff from plots with tied-ridges, the increase in soil moisture in these plots with respect to plain plot was quite obvious. It is revealed from Table 4.12 and Table 4.13 that irrespective of land slope the average soil moisture was maximum in tied-ridges of size 1.5 m x 3.0 m followed by tied-ridges of size 3.0 m x 6.0 m and plain plot.

The maximum soil moisture was recorded in tied-ridges of size 1.5 m x 3.0 m irrespective of land slope. This might be due to even distribution of rainfall in narrow tied-ridges (1.5 m x 3.0 m). In case of broad tied-ridges (3.0 m x 6.0 m) the rain water accumulated towards downstream end due to land slope. Table 4.14 shows the percentage increase in soil moisture for narrow tied-ridges over broad tied-ridges at 15 cm and 30 cm depths.

The increase in average soil moisture due to tied-ridges was more at 30 cm depth than that at 15 cm depth, except for tied-ridges of size 3.0 m x 6.0 m on 0.5 per cent slope, where the increase in soil moisture at 15 cm and 30 cm depth was more or less same.

Table 4.14 Effect of size^{of} tied-ridges on soil moisture.

Sr. No.	Land slope %	Depth cm	Average soil moisture, %		Percentage increase in average soil moisture for tied-ridges 1.5 m x 3.0 m
			Tied-ridges 1.5 m x 3.0 m	Tied-ridges 3.0 m x 6.0 m	
1	0.5	15	28.84	27.65	4.30
		30	29.37	28.01	4.86
2	1.0	15	30.03	28.11	6.83
		30	30.50	28.42	7.53
3	3.0	15	27.05	25.51	6.04
		30	27.68	25.80	7.29

In tied-ridges the increase was 7.42 per cent in 0.5 per cent slope and 10.44 per cent in 1.0 per cent slope over 3.0 per cent slope, up to 30 cm depth. Tied-ridge spacing does not show any effect in 1.0 per cent slope but in 0.5 per cent slope the 3.0 m x 6.0 m spacing has been proved to be better than the closer spacing.

Irrespective of land management, soil moisture was 27.58, 28.40 and 25.45 per cents in 0.5, 1.0 and 3.0 per cent slopes, respectively. Thus in 3.0 per cent slope soil moisture status was lower than that in 0.5 and 1.0 per cent slopes, stressing the need of reducing the slope as discussed earlier.

4.4 GRAIN YIELD

The sowing of crop Pearl Millet was done on June 30, and July 1, 1989. Due to inadequate soil moisture one light irrigation of 3.5 cm was given by sprinkler on July 11, 89 for proper germination. The grain yield with soil moisture at 30 cm depth along with per cent increase in grain yield is presented in Tables 4.15 and 4.16.

Table 4.15 Effect of slope and soil moisture on grain yield.

Sr. No.	Slope %	Treatments	Soil moisture % at 30 cm depth	Grain Yield q ha ⁻¹	Percentage increase grain yield
1.	0.5	T ₁	28.01	32.44	41.72
		T ₂	29.37	25.40	10.97
		T ₃	26.61	22.89	-
2.	1.0	T ₄	28.42	48.44	91.24
		T ₅	30.56	38.22	50.89
		T ₆	26.42	25.33	-
3.	3.0	T ₇	25.80	30.67	40.88
		T ₈	27.68	27.11	24.53
		T ₉	23.83	21.77	-

Table 4.16 Effect of land slope on grain yield.

Land slope per cent	Soil moisture per cent	Grain yield (q ha ⁻¹)
0.5	27.99	26.91
1.0	28.47	37.33
3.0	25.77	26.52

4.4.1 EFFECT OF SOIL MOISTURE ON GRAIN YIELD

In tied-ridges with 3.0 m x 6.0 m size grain yields were higher than those in tied-ridges with 1.5 m x 3.0 m size though moisture level was higher in later size. The yield had negative correlation with soil moisture, in these two conservation practices. The yields were 32.44, 48.44 and 30.67 q ha⁻¹ with soil moisture levels of 28.01, 28.42 and 25.80 per cents in 0.5, 1.0 and 3.0 per cent slopes of land. However, in plain plots with no conservation practice, both yield and moisture levels were lower than those in tied-ridges. The per cent increments in 3.0 m x 6.0 m size tied-ridges were 41.72, 91.24 and 40.88 over the plain plots in 0.5, 1.0 and 3.0 per cent land slopes, respectively. (Table 4.15, Fig. 4.9).

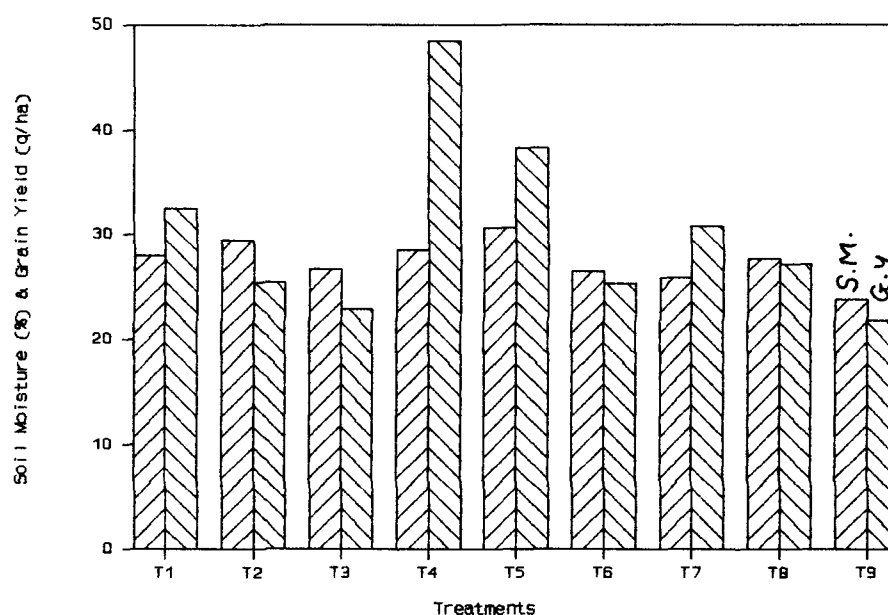


Fig. 4.9 Effect of slope and soil moisture at 30 cm depth on grain yield.

4.4.2 EFFECT OF SLOPE ON GRAIN YIELD

Both yield and soil moisture level were highest in 1.0 per cent land slope. The grain yield was 37.33 q ha⁻¹ and soil moisture was 28.47 per cent in 1.0 per cent land slopes. This was followed by 0.5 per cent land slope. In 3.0 per cent land slope, moisture level and yield were lowest due to more runoff. (Table 4.16). The increase in yield in 1.0 per cent land slope was 40.83 per cent over the yield in 3.0 per cent land slope.

4.4.3 EFFECT OF CONSERVATION PRACTICES ON GRAIN YIELD

The grain yields of Pearl Millet were 37.18, 30.24 and 23.33 q ha⁻¹ in 3.0 m x 6.0 m size tied-ridges, 1.5 m x 3.0 m size tied-ridges and plain plots, respectively, indicating that tied-ridges of 3.0 m x 6.0 m size were beneficial in more moisture retention and higher yield than that in other two treatments. Yield was lowest in plain plots (Table 4.17). The increase in yield in 3.0 m x 6.0 m size tied-ridges was 59.36 per cent over the yield from plain plots. Thus the effect of conservation practice was more than the effect of reduction in slope on yield.

Table 4.17 Effect of size of tied-ridge on grain yield.

Treatments	Soil Moisture, %	Grain yield, q ha ⁻¹
⁴ T ₁ , ⁷ T ₂ , T ₃	27.41	37.18
T ₂ , T ₅ , T ₈	29.20	30.24
T ₃ , T ₆ , T ₉	25.62	23.33

T.2228

In tied-ridges system some area can^{not} be brought under crop. This can be termed as area lost due to tied-ridging, which in turn may reduce plant population. The area lost due to tied-ridging of 3.0 m x 6.0 m and 1.5 m x 3.0 m is 1062.5 sq. m per hectare and 2083.33 sq. m per hectare respectively. The calculations are shown in Appendix II. Though there is loss of area in tied-ridging the yield is more, this might be due to proper distribution of rain water in tied-ridges.

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5 . SUMMARY AND CONCLUSIONS

The present experiment was conducted in order to study the effect of slope and tied-ridges on runoff, soil loss and crop yield. There were three slopes 0.5 per cent, 1.0 per cent and 3.0 per cent on which tied-ridges of two sizes 1.5 m x 3.0 m and 3.0 m x 6.0 m were prepared. One plain plot was kept as control on all the slopes. Pearl Millet was sown across the slope in all the treatments.

During the period of experiment five storms produced runoff. The rainfall, runoff, soil loss, soil moisture and grain yield data were recorded and analysed to evaluate the effect of slope and tied-ridges.

5.1 SUMMARY

The results obtained by analysing various data is summarised as below :

5.1.1 RUNOFF

The relationship between cumulative rainfall and cumulative runoff for plain plot on 3.0 per cent slope was:

$$\text{Cum. runoff} = 8.75 \times 10^{-6} (\text{cum Rainfall})^{4.523}$$

In plain plots on 0.5, 1.0 and 3.0 per cent the runoff was 1.8, 2.02 and 13.57 per cent of the rainfall.

There was no runoff from tied-ridges on all the slopes studied.

5.1.2 SOIL LOSS

The relationship between cumulative rainfall and cumulative soil loss for plain plot on 3.0 per cent slope was:

$$\text{Cum. soil loss} = 1.93 \times 10^{-5} (\text{cum. Rainfall})^{3.776}$$

The soil loss was 0.19, 0.23 and 1.93 kg ha⁻¹ per unit of rain erosivity for plain plots on 0.5, 1.0 and 3.0 per cent slopes, respectively. Rainfall erosivity upto 227 units was not effective in causing the erosion in plain plots

Cumulative soil loss and cumulative runoff were having a good correlation and the relationship can be expressed as:

$$\text{Cum. soil loss} = 0.324 (\text{cum. runoff})^{0.838}$$

The total soil loss from different treatments showed very good correlation with topographic factor LS. The relationship is as follows:

$$\text{Soil loss} = 24.999 (\text{LS})^{2.9145}$$

There was no soil loss from tied ridges on all the slopes, and hence the conservation practice factor P is zero. In plain plots the conservation practice factor P was found to be 0.032, 0.029 and 0.11 for 0.5, 1.0 and 3.0 per cent slopes, respectively.

5.1.3 SOIL MOISTURE

The average soil moisture at 15 cm and 30 cm depth was highest for tied-ridges of size 1.5 m x 3.0 m on 1.0 per cent slope (30.03 and 30.56 per cent, respectively).

At 15 cm depth the increase in soil moisture due to tied-ridges with respect to plain plot was from 5.29 per cent to 14.57 per cent irrespective of the size of tied-ridges and slope. This increase was from 5.26 per cent to 16.16 per cent at 30 cm depth.

5.1.4 GRAIN YIELD

The grain yield in each slope is maximum for tied-ridges of size 3.0 m x 6.0 m, which is 32.44, 48.44 and 30.67 q ha⁻¹. The per cent increase in grain yield due to tied-ridging was maximum in 1.0 per cent slope.

The percentage increase in grain yield for tied-ridges of 3.0 m x 6.0 m over tied-ridges of 1.5 m x 3.0 m was 27.72, 26.74 and 13.13 for 0.5, 1.0 and 3.0 per cent slope, respectively.

5.2 CONCLUSIONS

From the summary of the results following conclusions were deduced.

1. The tied-ridges were effective in reducing the runoff and soil loss on all the three slopes.
2. The cumulative runoff and cumulative soil loss from plain plot on 3.0 per cent slope showed the relationship of the form, $Y = ax^b$ with cumulative rainfall.
3. The relationship of total soil loss with topographic factor LS was found to be of the form $Y = ax^b$.
4. The conservation practice factor P was found to be zero for tied-ridges on all the slopes as there was no soil loss from tied-ridges.
5. The soil loss per unit of rain erosivity was maximum for plain plot on 3.0 per cent slope (1.93 kg ha^{-1}). The rainfall erosivity upto 227 units was not effective in causing the erosion in plain plots.
6. The cumulative soil loss showed good correlation with cumulative runoff with the equation of the form $y = ax^b$.
7. The soil moisture was highest in tied-ridges of size 1.5 m x 3.0 m in all the slopes.
8. The average soil moisture in tied-ridges of size 1.5 m x 3.0 m is more by 4.3 per cent to 7.53 per cent than in tied-ridges of size 3.0 m x 6.0 m.

9. The grain yield (48.44 q ha⁻¹) was highest in tied-ridges of size 3.0 m x 6.0 m on 1.0 per cent slope.
10. The grain yield was more in tied-ridges of size 3.0 m x 6.0 m on all the slopes than that from other conservation practices.

5.3 SUGGESTIONS FOR FUTURE WORK

1. The tied-ridges were prepared manually which increases the cost of tied-ridging system. A machine with cam-shaped wheels and scraper can be developed for preparation of tied-ridges.
2. The experiment can be conducted to determine the size of tied-ridges best suited for different slopes.
3. The experiment should be repeated for confirmation of the results.

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APPENDICES

APPENDIX-I

 Determination of parameters of USLE

1. Rainfall erosivity factor, R (for storm 1)

$$I_{30} = \frac{\Delta \text{ Rain}}{\Delta \text{ time}} = 2 \Delta \text{ Rain (from rainfall chart)}$$

$$E \text{ or KE} = 11.87 + 8.73 \log_{10} I$$

Where,

$$I = \text{Rainfall intensity (mm hr}^{-1}\text{)}$$

$$E \text{ or KE} = \text{Kinetic energy (J m}^{-2} \text{ mm}^{-1}\text{)}$$

$$EI = \frac{(\text{Total of Energy x Amount}) \times I_{30}}{1000} \text{ units}$$

$$\text{Therefore, (Energy x Amount)} = 843.158 \text{ J m}^{-2}$$

$$I_{30} = 49.4 \text{ mm hr}^{-1}$$

$$\text{Therefore, EI} = \frac{843.158 \times 49.4}{1000}$$

$$R \text{ or EI} = 41.652 \text{ units}$$

2. Length of slope factor, L.

$$L = \left(\frac{l}{22} \right)^x$$

$$\text{Therefore, } l = 24 \text{ m}$$

$$X = \text{a constant} \\ = 0.3$$

$$\text{Therefore, } L = \left(\frac{24}{22} \right)^{0.3} \\ = 1.02645$$

3. Gradient slope factor, S.

$$S = \frac{(0.43 + 0.30S + 0.043 \text{ s}^2)}{6.574}$$

Therefore, s = field slope in per cent

For $s = 1\%$,

$$S = \frac{0.43 + 0.30 + 0.043}{6.574} = 0.11758$$

4. Crop management factor, C.

Sr. No.	Stage	Days	Rainfall mm	C value	Adjustment Factor (% R value)	Weighted C value
1.	I	30	211.8	0.8	0.169	0.1352
2.	II	25	74.1	0.4	0.140	0.0560
3.	III	40	250.0	0.6	0.691	0.4146
Total					1.000	0.6058

Therefore, C factor for the crop period = 0.6058

5. Conservation practice factor, P.

$$A = R \times K \times LS \times C \times P$$

For treatment T_3 ,

$$A = 0.0234 \text{ t ha}^{-1}$$

$$R = 119.41 \text{ units}$$

$$K = 0.1083$$

$$LS = 0.0915$$

$$C = 0.6058$$

$$P = \frac{A}{R \times K \times LS \times C}$$

$$= \frac{0.0234}{119.41 \times 0.1083 \times 0.0915 \times 0.6058}$$

Therefore,

$$P = 0.0326$$

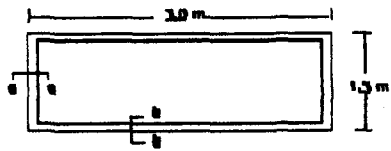
APPENDIX-II

Area lost per hectare in tied ridging

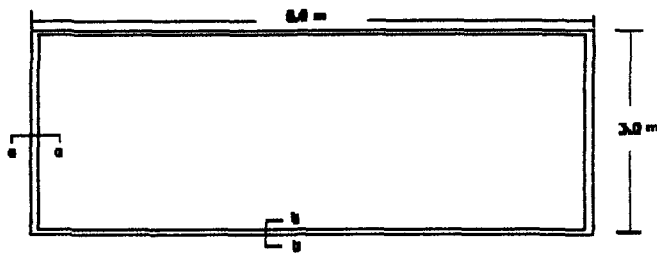
Height of main-ridge	=	25 cm	
Height of tied-ridge	=	15 cm	
Size of tied-ridges in all three slopes	=	i. 1.5 m x 3.0 m area	= 4.5 sq. m.
		Area lost per 4.5 sq. m.	= 0.9375 sq. m.
		Area lost per hectare	= 2083.33 sq. m.
		ii. 3.0 m x 6.0 m area	= 18.0 sq. m.
		Area lost per 18.0 sq. m.	= 1.9125 sq. m.
		Area lost per hectare	= 1062.5 sq. m.

Tie Ridging:

Size 1.5 m x 3.0 m



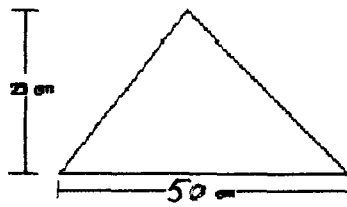
Size 6.0 m x 3.0 m



Section a-a:



Section b-b:



T. 2228

