THE EFFECT OF RIDGED Vs FLAT CULTIVATION AT TWO SLOPES UPON RUNOFF, EROSION, CROP GROWTH AND YIELD

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BY

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CERTIFICATE

This is to certify that this thesis entitled "The effect of ridged Vs flat cultivation at two slopes upon runoff, soil erosion, crop growth and yield" submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in Agriculture in the major subject of Agronomy of the Andhra Pradesh Agricultural University is the result of bonafide research work carried out by Syed/Khalid Abdulla Shams under our guidance and supervision. No part of this thesis has been submitted for any degree or diploma or published in any other form.

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

(B. A. KRANTZ)

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KHALID ABDULLA SHAMS

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INTRODUCTION

INTRODUCTION

Soil and water are the basic factors in crop production and it is a fact that with conservation farming maximum food production is expected and at the same time the soil is also conserved for the benefit of future generations.

Soil and water issues are becoming major problems all over the world in the developed as well as the developing countries, where millions of hectares are declining in productivity. In India, an estimated 167 out of 328 million hectares of land needs protective treatment to stop further soil depletion as an estimated 6,000 million tons of soil material is lost annually containing 2.5, 3.8 and 2.6 million tons of N, P and K_2O respectively (Kanwar, 1973).

The problem is also severe in developed countries including USA where erosion has ruined and seriously damaged 130 million hectares, 350 million hectares has lost the greater portion of its top soil, while in the land under crop production about 20 million hectares have been rendered useless for crop production and a like amount is approaching that condition. Another 40 million hectares now under the plow have lost more than half of the top soil (Miller et al, 1965).

To avoid soil and water losses, traditional measures like fallowing, traditional bunding and conventional irrigation methods must be replaced or supplemented by economically viable farming systems capable of increased and stabilized agricultural production (Krantz et al, 1976). Effective

soil and water management systems should aim at reduced soil erosion, surface runoff and simultaneously increase the infiltration of rainfall and avoid problems of drainage.

Preliminary observations at ICRISAT showed that systems that involve broad ridges separated by furrows offered greater efficiency for moisture conservation as compared to flat planting and contour-budning, due to the fact that contour bunding resulted in inundation of parts of the land, reducing the crop yield. Ridges or beds functioned as mini-bunds at a grade lower than the maximum slope of the land; velocity of runoff was thus reduced and the infiltration increased (Krantz, 1976).

Slope (which is a non-monetary input) is also an important factor with which one can manipulate soil and water losses. According to the law of falling bodies, velocity varies as the square root of vertical drop. This implies that if the land slope is increased by four times, the velocity of water flowing on its surface is gaining four fold increase in erosive power since the latter varies as square of velocity. Consequently the quantity of material of a given size eroded is increased by 32 times and the size of the particle that can be transported by pushing or rolling is increased by 64 times (Michael & Ojha, 1966).

Along with mechanical measures, the crop factor is also important in reducing soil and water losses. An efficient plant type is essential for best utilization of land and environment. Intercropping is a device

for risk-covering in rainfed agriculture of the semi-arid tropics, as well as for getting greater efficiency in utilizing moisture and making maximum use of the environment.

Keeping the above aspects in view, the present research study was designed to determine optimum slope and cultivation methods to minimise erosion and runoff using intercropping of sorghum and pigeonpea as test crop.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The research work done since 1927 on the effect of slope, methods of cultivation, vegetative cover, and rainfall intensity on runoff and soil erosion are reviewed below.

A. Effect of Slopes:

The degree of slope plays an important role in runoff and erosion which ultimately influence crop production. The greater the slope, the greater will be the soil and water loss. Runoff increases on steeper slopes, but not as rapidly as the loss of soil (Anonymous (d) 1974).

Gadkary (1954) stated that a 0.5 percent slope is optimum for light and medium soils. The runoff coefficient varies with slope. In sandy loam soil having slopes of 0-5%, 5-10%, and 10-30%, the runoff coefficient was 0.5, 0.6 and 0.72 respectively. The rate of peak runoff with slopes of 8% is almost 3 times as much as slopes of that of slopes at 1.5% (Ramser 1927).

According to Gurmel Singh et al (1967), a sorghum crop gave maximum soil and water loss while groundnut gave minimum soil loss. In all cases, the soil loss was within permissible limits; Erosion and runoff were greater on a 1.0 percent slope than a 0.5 percent slope. Using different slopes with ridge and furrow systems, the percentage of runoff was 11.5 and 18.4 with 0.4 and 1% slopes, respectively (Krantz and Kampen 1976).

The runoff and erosion increased with increase in percentage of slope.. In Texas (USA) on cotton soils with slopes of 0.00, 1.0 and 2.0 percent, erosion was 5.5, 13.0 and 17.5 tons/hectares, and runoff was 6.4, 15.1 and 15.5 percent of rainfall respectively (Anonymous (b) 1974). Millar et al (1965) stated that erosion varies with percentage of slope and kind of vegetative cover. They found that soil with 3.7 percent slope under corn, red clover and continuous blue grass was 20, 3, 0.5 tons/hectare respectively, while under 8.0 percent slopes it was 52, 10 and 0.5 tons/ hectare respectively. This shows that under continuous blue grass, slope had no effect. Balvir Verma et al 1968) stated that runoff with 2 percent slope under natural fallow, perennial grass and mung-sorghum was 2.1, 0.1 and 17.8 percent of rainfall, respectively and erosion was 2.04, 1.5 and 3.4 tons/hectare, respectively. Erosion from 0.84 percent and 0.35 percent slope were 0.3 and 0.15 tons/hectare, whereas runoff percentage of rainfall showed little variation.

B. Studies on Methods of Cultivation:

Soil and water management by mechanical means also plays an important role. Some of the conventional methods of land preparation were proved to be less beneficial for soil and water conservation and crop yield as well. Systems involving broad ridges, and narrow ridges are effective in reducing erosion and runoff because each furrow acts as temporary storage and the ridge immediately below as a dam; thus the excess runoff is held in these furrows and absorbed slowly by the soil. Broad ridges resulted in enough soil between furrows to prevent water from breaking across to

the neighbouring furrow and negate the need for hilling (Dave Howe 1971). Erosion of soil on a monsoon-fallowed watershed amounted to about 7 tons/hectare, which was approximately five times the quantity measured from a watershed cultivated to a ridge and furrow system (Krantz and Kampen 1973).

Howard et al (1955) stated that contour cultivation has reduced the runoff from rains of low and meidum intensity by as much as 80 percent when compared to surface runoff from similar fields ploughed up and down the slope. There was a yield increase of corn and soybean when sown on narrow rows compared to broad ridges, but at the same time for narrow ridges fertility cost, machinery depreciation, seed and crop expenses increased (Anonymous 1971). Millar (1965) found that erosion and runoff from up and down cultivation were greater than from contour cultivation. Estimated soil loss was 67.5 and 12.5 tons/hectare whereas runoff percentage of total precipitation was 20.0 percent and 2.0 percent respectively. Similarly, in Dehra Dun, soil and water loss from up and down cultivation were almost double as compared to contour cultivation (Anonymous (a) 1975). There was significant increase in yield of sorghum, sesamum and groundnut under contour ridge cultivation as compared to a flat planting system. Average yields of 544, 84, 237 kg/hectare under contour ridge and 303, 57 and 49 kg/hectare under flat planting system, respectively, were recorded in Sudan (Greenfield and Shams 1972). The cultivation of a potato crop on steep slopes at Ootacmund resulted in a soil loss of 37.7 tons/hectare, but it was reduced to 12.9 tons/hectare by growing potato only on contour

furrows. By mixing potato and lupin, the soil loss was reduced to a minimum of 1.1 tons/hectare (Anonymous 1974 (b)). Krantz and Kampen (1976) recorded that runoff was reduced from 181 mm to 166 mm by using a 150 cm bed compared to the flat system.

At Ootacmund contour farming as compared to up and down the slope cultivation of potato reduced the runoff by 50.0 percent and erosion by 60.0 percent (Raghunath et al 1967; and Patnaik 1976).

Krantz and Kampen (1976) observed that runoff from a narrow ridge system (75 cm apart) was 235 mm, from a flat bed system it was 181 mm, whereas it was only 166 mm from broad ridges 150 cm apart. They also found that soil erosion from fallow was five times the loss from cropped watersheds in ridge and furrow system. Contour cultivation increased the yield by 10.0 percent at Bellary and by 22.0 percent at Chandigarh over the control treatment (Anonymous (c) 1974).

Research work carried out by ICRISAT workers indicated that by following ridge and furrow system runoff and soil erosion can be manipulated. It was reported that sorghum grain yield on narrow ridge was 3.68 tons/hectare compared to 2.68 tons/hectare under flat cultivation, while pigeonpea yield was 2.26 tons/hectare under narrow ridge compared to 2.36 under flat cultivation (Krantz et al 1974/75).

C. Effect of Amount and Intensity of Rainfall:

Rainfall has 256 times more kinetic energy than the surface runoff, if we assume 25.0 percent runoff with surface flow of 1 meter/second and a rain terminal velocity of 8 meter/second. The energy output of a rain of 2"/hour on one hectare of land is equal to that of fifteen tractors with 40 horse power (Norman Hudson 1973). By artificially applying rainfall through nozzles which produce small size or mist type of rain drop, higher intake rates were observed compared to those from larger rain drop size (Musgrave 1955).

Wasiullah and Ram Babu (1970) reported from the compilation of rainfall-runoff data in the year 1964 that a rainfall of 1202 mm produced 5.1 percent runoff whereas in 1965, 9 percent runoff was recorded with only 785.2 mm rainfall; this inconsistency must have been due to intensity of rainfall. Basu and Patnaik (1954) observed that soil erosion and runoff under field conditions were entirely dependent on the few intense showers of the rainy season. The percentage of runoff and soil erosion increased with intensity of rainfall. The cumulative runoff percentage, with rainfall of 1.11, 2.22, 3.33 and 4.44 inches was 8.63, 36.99, 51.44, and 62.28 percent, respectively. Similarly, cumulative soil loss was 0.23, 1.31, 2.30 and 4.22 tons/hectare, respectively. Wischmeier (1959) stated that at low intensity there is little or no erosion because rain falls as small drops with low intensity and hence low energy. The critical limit of intensity of erosive rainfall for East Africa was estimated at 25 mm/hr; in the tropics at 60 mm/hour and for temperate regions at 35 mm/hr. He also stated

that in the temperate regions only 5.0 percent of the rains are erosive, while in tropical areas 40.0 percent of the rains are erosive. The soil loss from a clean cultivated fallow system was increased with the increase in the rainfall intensities (Ellison 1944).

Tejwani et al (1966) stated that in Gujarat for fields under sunhemp the rainfall with an intensity of 33.8 mm/hour caused runoff. On the other hand the lower limit of intensity of rainfall to cause runoff in a loamy soil in Vasad was 35 mm/hour, where the percentage runoff was 17.5 to 18.7%. The interception of rainfall was high in case of light showers; interception was 37.3% when the shower amount was 4.2 mm, but it was only 4.1 percent when the showers were 140.3 (Anonymous (c) 1975).

According to Tamhane (1968) and Wischmeier (1969) the erosion potential of a storm is determined by the intensity, antecedent climatic and surface conditions, and interaction effects. The product of storm energy in ton/hectare and its maximum 30 minutes intensity (E 30) in cm/hour provided a measure of the specific manner in which prolonged intensity is combined in the storm. By suspending two layers of mosquito gauze, which allowed the rain to pass through, it was observed that the soil loss from the gauze plot, where splash erosion was elimintaed, was reduced to one percent of the soil loss from the unprotected plot (Hudson 1957). Ellison (1959) observed that more splash erosion was transported down the slope than up the slope and that sandy soils suffer fertility erosion with heavy sand grains remaining. Rainfall patterns are non-uniform and high

intensities result in surface erosion losses in the Semi-Arid Tropics. It is advisable to use more scientific and stable forms of soil conservation and land use (Krantz and Kampen 1976).

In normal rainfall, soil is commonly thrown to a height of 2-3 feet and to a horizontal distance of 5 feet. As much as 15 tons of soil were recorded in over-grazed pastures. Cover that is dense enough to prevent rain drops from striking the earth in the first place efficiently prevents soil transportation (Musgrave 1955). Ben Osborn (1955) stated that the total energy of rain drop at 2"/hour equals roughly 250 HP which is sufficient to lift the 7" top soil layer to a height of 3 feet 86 times during an hour's rain. The effective rainfall that reached the ground water was 51 percent when the rainfall intensity was less than 18 mm/hour while only 6 percent of the rainfall reached the ground water level when the intensity was 48 mm/hour (Dakshinamurthi 1962).

D. Erosion and runoff:

In many developing countries increased pressure on the land in low rainfall areas has resulted in expansion of cultivated agriculture into marginal areas and intensification of agricultural activities on unsuitable lands. Increased exposure of land resources to the hazards of wind and water erosion is the result (FAO Report 1974). Kanwar (1972) reported that soil loss due to erosion is 6000 million tons/annum in India alone, leading to barrenness of the land. In Iowa (USA) a farmer with a 13 ton/hectare corn yield is losing 2 bushels of soil for every bushel of corn he produces. The soil loss of 13 ton/hectare every year (260 bushels) is more

than twice the average corn yield. In trials with 4 levels of erosion, the size and number of ears in wheat and maize and pods of peas decreased with increasing erosion and the average number of grains or seeds produced per plant decreased by 62, 77, and 41 percent respectively. High levels of erosion decreased the yield of wheat by 2.1 tons/hectare, maize yield by 3.5 tons/hectare and pea yield by 1.55 tons/hectare (John Maddy 1972).

Vander Sypen (1972) estimated that under conditions of about 800 mm annual rainfall, between 100 and 300 mm are lost annually as runoff. Virmani (1976) estimated average runoff from red and black soils on the basis of water balance studies using 70 years data at Hyderabad. Runoff (surface runoff and groundwater) from fallow red soil was calculated at 134 mm and from the medium to deep black soil it was only 39 mm; these figures do not take into account rainfall intensity. Thus there is greater possibility of runoff in farming the red soils.

The runoff percentage of rainfall increases with percentage of slope also. Krantz and Kampen (1974-75) found that percentage runoff was increased from 12.5% to 16.1% when the percentage slope was increased from 0.4 to 0.8 percent.

All rainfall exceeding 2" in a day caused runoff at Sholapur; rainfall varying from 1 to 2 inches caused runoff in more than 80% of the occasions, and the rainfall varying from ½ to 1 inch caused runoff in more than 35.0 percent of the occasions, while below ½" only infrequently caused runoff (Anonymous 1974). Runoff and soil loss studies on caly

soil of 0.5 and 1.0 percent slopes under natural cover, cultivated fallow, cowpea, Phaseolus aureus, Cyamopsis tetragonloba and maize showed that runoff and soil loss were considerably reduced under natural cover. Among different crops they were highest under maize and lowest under Cyamopsis tetragonloba; accordingly it is suggested that maize on slopes should be intercropped with a legume (Bhola et al 1975). From experiments conducted during 1958-66 at a slope of 2.0 per cent, yields were negatively correlated with runoff and soil loss. Only Bajra crop (Pennisetum typhoides) has given a small positive value, probably because the crop is suited to low rainfall on poor soils (Balvir et al 1968).

E. Effect of Vegetative Cover on Erosion and Runoff:

Michael and Ojha (1965)(c) stated that a good vegetative cover such as a thick growth of grass or a dense forest, may negate completely the effects of climate, topography and soil on erosion. The effect of vegetative cover is due to the effect of the interception of rainfall, decreasing runoff velocity, in addition to the effects of the roots, its biological influence and the transpirational effects. Mirchandani (1953) reported that the degree to which the plant cover can reduce the soil and water losses depends upon the species and life form. Annual plants are less effective than perennials; bunch type plants are inferior to sod-forming ones. Plants possessing fibrous root systems are superior to those having tap roots.

Krantz et al (1975-76) recorded 24% of runoff in a monsoon-fallowed watershed. In the ridged and cropped watersheds the runoff varied with type of soil. The runoff in deep black soil, shallow black soils and red soils was 10-15 percent, 10 percent and 25-30 percent, respectively. They also found that soil loss of 2.51 tons/hectare in monsoon-fallowed black soil watersheds was ten times more than from cropped watersheds with ridges and furrows at slopes of 0.4 to 0.8 percent. Ben Osborn (1955) stated that splash from bare crop land has a detaching capacity of 33.2 to 222.6 tons of soil per hectare. On bare range and pasture land soil splash under similar raindrop impact varied from 8.8 to 160.4 tons/hectare. Millar et al (1965) observed that land planted to cotton year after year suffered an annual loss of 13.8 tons/hectare, whereas under natural condition it was 0.005 tons/hectare by geological erosion.

The water losses as percentage of rainfall for grass (Cynodon dactylon), bare fallow, bare-and-ploughed and natural grasses were 27.1, 71.1, 59.6 and 21.2 percent respectively, while the soil losses were 2.1, 42.4, 155.95, and 1.02 tons/hectare respectively (Anonymous 1975). The average runoff and soil loss for three years under various cropping systems at Agra showed that the soil water loss was less in case of a legume when compared to natural fallow and sorghum crop. Millar (1946) reported that cultivation caused an increase in rainfall penetration and curtailment of soil erosion. The uncultivated soil lost, through runoff, 47.9 percent of the total rainfall of 11.69 inches, while the runoff from cultivated soil was only 15.4 percent. The soil losses were 77.5 and 14.6 tons/hectare respectively.

Adams et al (1976) observed that sorghum planted in closer rows used more water efficiently than when planted in conventional rows, because the leaf canopy intercepted more sunlight, broke the force of falling raindrops and increased water intake by the soil. Similarly Raghunath et al (1963) found that the bare and bare-and-ploughed plots had 3-4 times the total runoff and 600 to 4000 times the soil loss as compared to the grass-covered plots in certain storms. Studies at Pullman, Washington indicated that a plot that loses soil at the rate of 220 tons/ha under fallow might lose only 22 tons if it is planted to small grains, 5 tons if it is in good pasture, and less than two tons if it is in good forest cover (Gottschalk & Jones 1969).

F. Effect of Intercropping:

The objective of intercropping is to utilize all the space efficiently to ensure best use of land, labour, fertilizers and rainfall while monitoring the constancy of the population of the principal crop. To achieve these objectives, paired-rows techniques with a wider interspace to include an intercrop is sometimes used.

Sorghum and pigeonpea mixture are mainly cultivated to use the environment more fully throughout the season. Pigeonpea, being tap-rooted, draws upon the subsoil phosphate. Sorghum pigeonpea intercropping is advisable because the proportion, the qualities and stages at which the two intercrops take the nutrients are different (Anonymous (c) 1974).

At Coimbatore the work on sorghum and pigeonpea showed that the protein content of the grain was increased by 26 percent as a result of intercropping (Anonymous (c) 1974). Under mixed cropping of sorghum and pigeonpea, the incidence of wilt was much reduced due to the deeper root system of pigeonpea which escapes the fungus-infecting zone of the topsoil (Anonymous (c) 1974).

Mirchandani (1953) found that intercropping can minimize the soil and water loss when compared to sole crop planted continuously. It was reported that pearl millet-pigeonpea intercropping at Sholapur reduced the soil losses to 28.58 tons/hectare compared to 43.9 tons/hectare in case of sole sorghum. Under continuous cover sod, the soil loss was only 1.4 tons/hectare. The total annual runoff from Vigna radiata - sorghum, Pennisetum typhoides and perennial grass cover (Dicanthium annulatum) were 140.74, 166.66 and 1.0 mm respectively, whereas the soil loss was 2327.78, 3415.22 and 1.49 kg/hectare respectively (Balvir Verma et al 1968).

Raghunath et al (1967) reported that by introducing cover into the rotation, the soil loss could be reduced by 67 percent compared to a continuous monoculture of corn or wheat. Patnaik (1976) recorded a heavy loss of soil (42 tons/hectare) from bare fallow land having 9 percent slope, while a grass-legume mixture made the annual soil losses negligible (only 1.0 ton/hectare). Water loss on an 8.0 percent slope, under different cropping systems, such as up-and-down cultivation of maize and wheat, contour cultivation of maize-cowpeas-wheat, giant star grass and cultivated fallow were 54.1, 41.2, 32.7 and 35.9 percent respectively, and soil

losses were 28.5, 19.3, 28.3 and 44.0 tons/hectare respectively (Anonymous 1960-1963). Runoff and soil loss measurements on 8.0 percent sloping land have shown that up-and-down cultivation of maize alone resulted in a soil loss of 28.5 ton/hectare; this was reduced by 30 percent when maize and cowpeas were grown together across the slope. Soil loss was reduced to only 1.0 ton/hectare under grass cover (Anonymous (c) 1974).

MATERIALS AND METHODS.

MATERIAL AND METHODS

Site:

An investigation entitled "The effect of ridged Vs flat cultivation at two slopes upon runoff and soil erosion" was conducted at ICRISAT, Patancheru, Hyderabad, A.P., India during the rainy season of 1976. Patancheru is situated at an altitude of 545 meters above mean sea level, with a longitude of 78°-16° E and a latitude of 17°-32° N.

Climate:

Rainfall during the experimental period was 616.2 mm spread over 52 rainy days (with over 2.5 mm rain/day). The maximum temperature ranged from 27.2 to 33.3°C, minimum temperature from 12.8 to 22.4°C, humidity from 21% to 93% while the sunshine hours ranged from 1.3 to 10.7 hrs/day (Appendix-1) (Fig.1).

The rainfall was regular up to the second week of September and this was beneficial to the sorghum crop but not to pigeonpea because there was a long dry spell from mid-September to the first week of November.

Soil:

The experiment was laid out in the field No.RA-19 of the ICRISAT site at Patancheru. The soil was sandy loam with light reddish brown colour locally known as "Chalka Soil".

Six soil samples were taken at random from each replication to a depth of 60 cm to make a composite soil sample which was analysed for mechanical and chemical properties. The data are given below:

FIG.1a METEOROLOGICAL DATA AT WEEKLY INTERVAL (JUL 2 - DEC. 30, 1976)

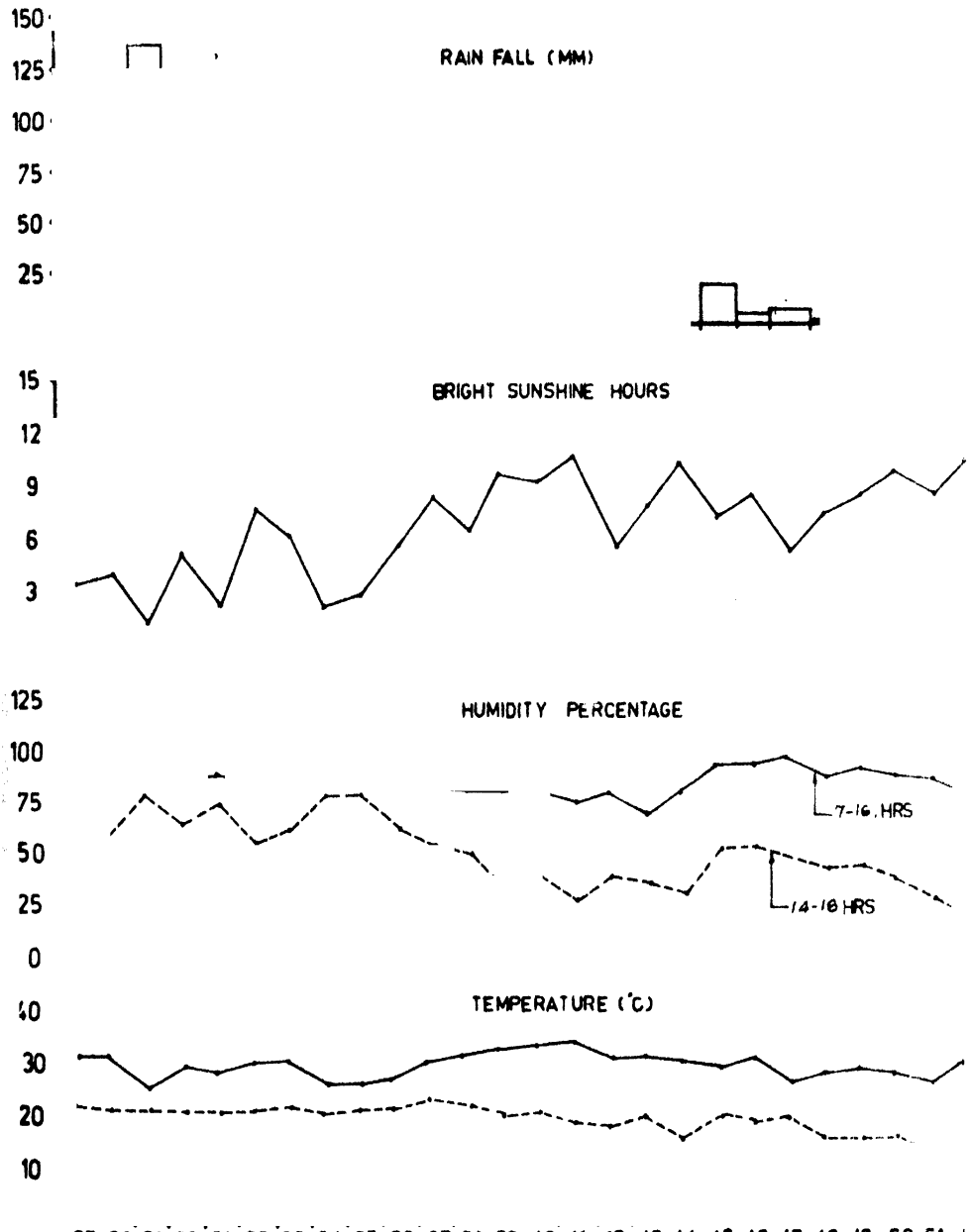
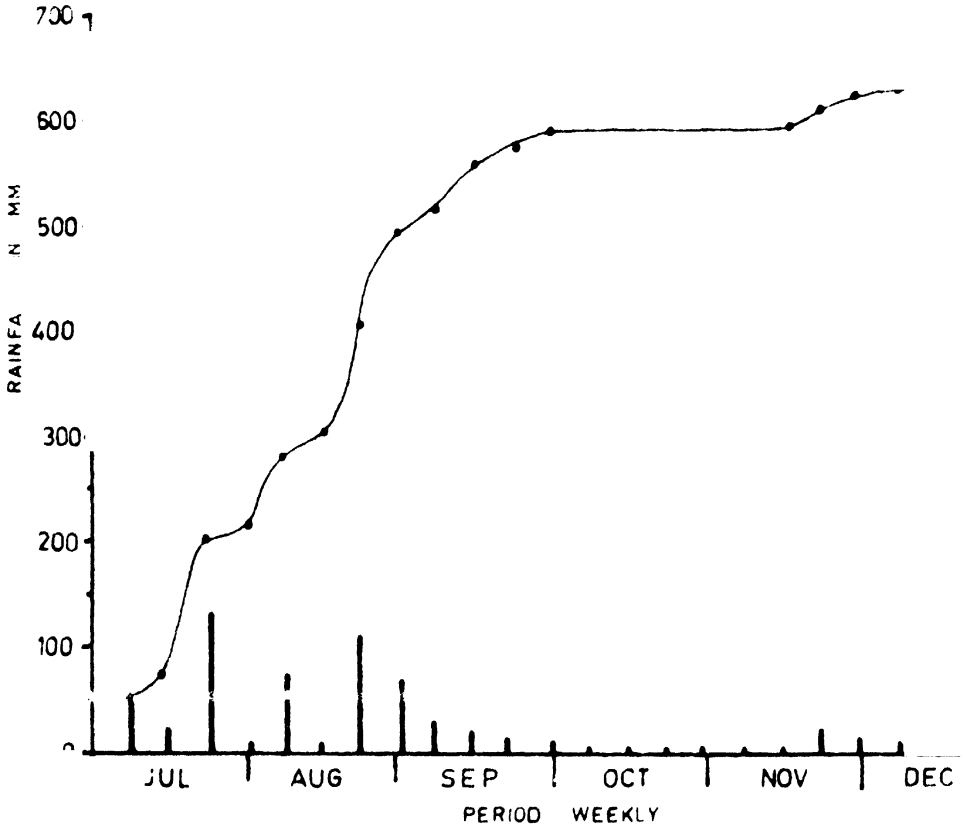


FIG 1b: CUMULATIVE RAINFALL DURING CROP GROWING PERIOD (WEEKLY BASIS)



(a) Mechanical analysis:

Coarse sand	-	63.1%
Fine sand	-	16.6%
Silt	-	5.2%
Clay	-	15.1%
Soil bulk density	-	1.527
Field capacity	-	10.5%
Wilting point	-	3.5%
Infiltration rate	-	30 mm/hr (at 5.5% soil moisture)

Chemical analysis of soil:

pH	-	8.15
EC (millimhos/cm^2)	-	0.145
Available N kg/ha	-	274.25
Available P_2O_5 kg/ha	-	45.02
Available K_2O kg/ha	-	260.00

The soil was fertile and suitable for sorghum and pigeonpea.

Previous history of the field:

The field has been kept fallow since 1973.

Experimental details:

Design of experiment: The experiment was laid out in split plot design (Fig.2) and replicated three times. Slope of the land was taken as the main treatment, while the method of cultivation was adopted as subtreatment.

Plot size: Gross plot size was 52 M x 7.5 (390 sq.m.) whereas net plot size was 50 M x 6 M (300 sq.m.).

Treatments:

Main treatments were 2 slopes (0.4% and 1.0%). The sub-treatments were 2 surface layout treatments (flat, and broad ridges of 150 cm).

Treatment	Levels	Symbol used in layout plan
Main treatments:		
Slope of the land	i. 0.4%	S_1
	ii. 1.0%	S_2
Sub-treatment:		
Method of cultivation	i. Flat	C_1
	ii. Broad ridge (150 cm)	C_2
Replications:	Three	

Variety:

Hybrid sorghum CSH-6	Sorghum vulgare
Pigeonpea type HY-3A	Cajanus Cajan

The above two crop varieties are recommended for intercropping because hybrid CSH6 is short duration (90-95 days) and gives less grain deterioration if caught in rains at harvest. Type HY-3A has deep roots and the habit of limited branching at the first stage of its growth but more branching at the upper portions which carry the pods. With such intercropping, the space and subsoil moisture are used efficiently and

there is continuous soil cover during kharif and rabi seasons, reducing the weed menace and splash erosion. Pigeonpea was drilled at 150 cm between the rows and 15 cm within the rows. Two rows of sorghum were drilled 60 cm between the pair rows and 10 cm within the row. The spacing between sorghum and pigeonpea rows was 45 cm.(photo 2).

Details of cultural operations:

A detailed statement of the different cultural operations is given in appendix-2.

Preparatory tillage and survey:

The experimental area was first plowed with a heavy double-offset-disc-harrow followed by wide-level-blade with the purpose of grading the land but not levelling it.

The whole area was then surveyed at 20 metre grids and the contour map was prepared at reduced level. Survey was started from a nearby permanent bench mark and from that our temporary bench mark was fixed.

Referring to the contour map, an area which gave the required slopes (0.4% & 1.0%) was selected. No levelling being needed for the experiment because only by reorientation, the plots could be adjusted to the required slopes. The area was first laid out into 6 main plots as per layout plan (3 with 0.4% and 3 with 1% slope) surrounded by big bunds for the purpose of collecting the rainfall which fell on the plots. Each main plot was then divided into two subplots (50 m x 6 m) which were alloted randomly to flat cultivation or broad ridges separated by furrows at 1.50 m.

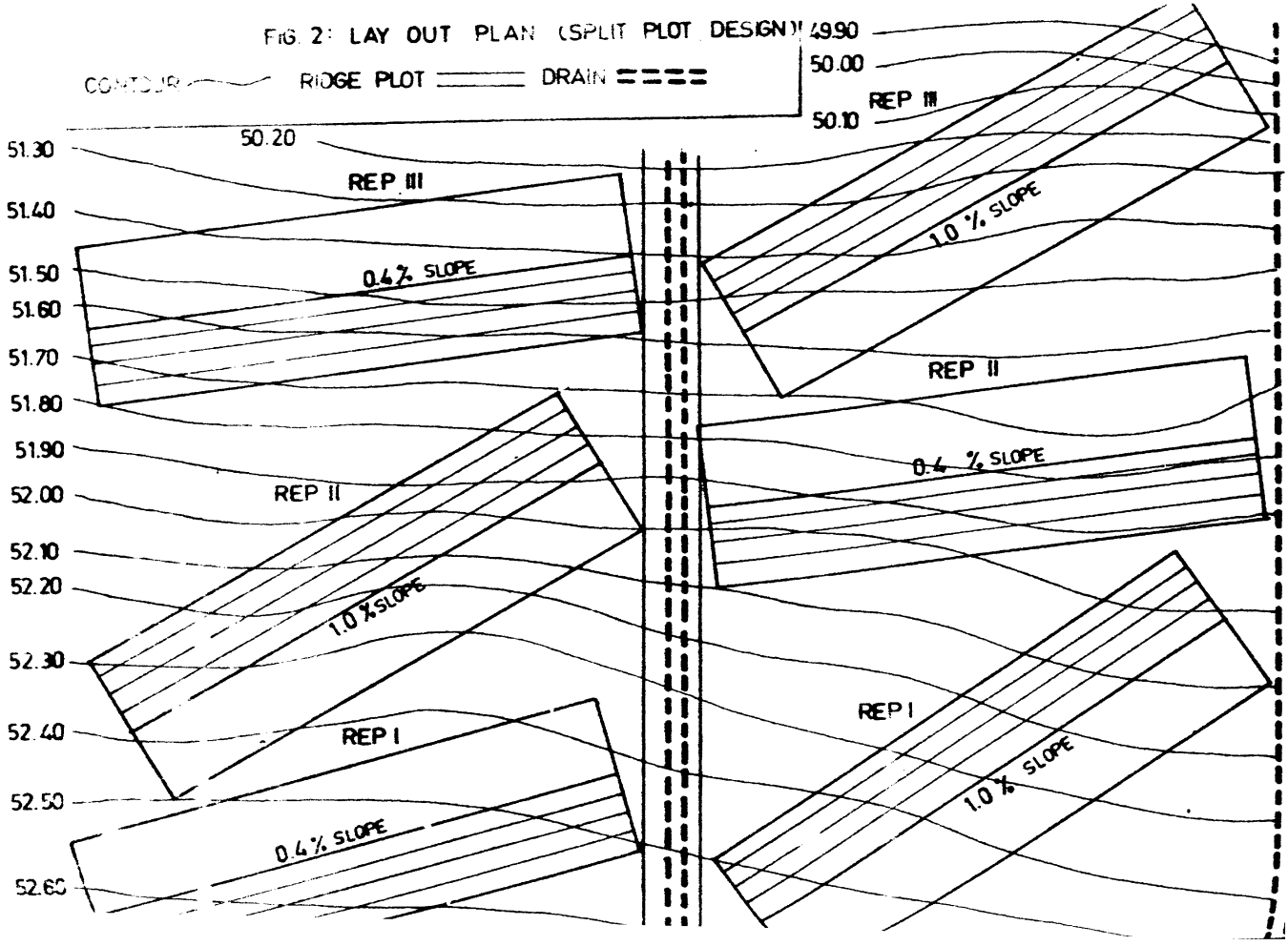


FIG. 2: LAY OUT PLAN (SPLIT PLOT DESIGN)
CONTOUR
RIDGE PLOT
DRAIN
49.90
50.00
50.10
50.20
51.30
51.40
51.50
51.60
51.70
51.80
51.90
52.00
52.10
52.20
52.30
52.40
52.50
52.60
REP III
REP III
1.0 % SLOPE
0.4 % SLOPE
REP II
REP II
0.4 % SLOPE
1.0 % SLOPE
REP I
REP I
0.4 % SLOPE
1.0 % SLOPE

Seed and sowing:

For sowing, a bullock-drawn planter-cum-fertilizer was used. This was arranged to drill two rows of sorghum and one row of pigeonpea. The spacing between pigeonpea rows was 1.5 m. The sorghum was sown 15 cm on either side from the pigeonpea rows so that 60 cm spacing was available between two sorghum rows.

The seed rate was 10 kg/ha for sorghum and 5 kg/ha in case of pigeonpea. Sowing was completed on 2nd July 1976 and the seedlings were thinned within two weeks, finally keeping one seedling every 10 cm in case of sorghum and every 15 cm for pigeonpea.

Application of fertilizer:

Zinc sulphate (22% Zn) was broadcasted at 60 kg/ha according to the laboratory advice. Basal dose of diammonium phosphate (18:46) was applied at 125 kg/ha to provide 22.5 kg/ha nitrogen and 25 kg/ha phosphorus (57.5 P_2O_5).

One month after sowing top dressing of 77.5 kg/ha nitrogen was made with urea fertilizer (46% N) which was manually drilled in band to the side of sorghum crop. The total application was 100 kg N/ha for sorghum and 22.5 kg N/ha for pigeonpea, while 57.5 kg P_2O_5/ha was common to both the crops.

The diammonium phosphate was broadcasted on the soil surface and then sowing was done with the planter which mixed the fertilizer in the soil during the process of ridging and sowing.

Cultivation and weeding:

The first weeding was arranged one month after sowing. The flat plots were intercultivated with sweeper hoes which were mounted to the bullock-drawn toolbar. In case of broad ridges, ridger bottoms were adjusted at 150 m to run in the furrows while the hoe sweepers were adjusted to remove the weeds on the beds. Within row cultivation for all plots was done by manual labour.

A second hand weeding was arranged 50 days after sowing for all the plots because the height of the crops was more than the ground clearance of the toolbar.

Plant Protection Measures:

Clean and healthy seeds of sorghum and pigeonpea were used. To control shootfly, 2-3 endrin granules were applied to the leaf whorls of the sorghum seedlings two weeks after sowing.

To control shootfly and stemborer in sorghum, endrin granules 2% at 20 kg/ha were applied when the age of the crop was five weeks.

For pigeonpea, Endosulphan 35% was sprayed at the age of eight weeks to control leaf webbers. A similar dose was applied four months after sowing to control pod borrer.

In general, incidence of pest and diseases on the two crops was negligible, which might be due to the prompt plant protection measures taken.

Harvesting:

Harvesting of sorghum started at the crop physiological maturity (95 days after sowing). This was done purposely to save moisture for the pigeonpea crop which was in the flowering stage.

First harvest of p.pea was completed on December 31st (180 days after sowing) by which time the pods were almost dry but had not started opening or shattering. A second picking was arranged two weeks later, but the pods this time were few compared to the first picking.

Collection of data:

(A) Surface runoff and erosion:

For studying the quantity of surface runoff, multi-slot drums of a 400 litres capacity were partially buried at the lowest corner of each plot where the runoff could be collected. This corner was surrounded with two walls of brick with cement plastering extending to both sides. At the base two tiles of 'Shahabad' were arranged; this system allowed the runoff to concentrate at the bottom of the plot (photo 1).

Each plot was a separate drainage area and from each plot the runoff was collected through 4" pipes which connected the collection basin to the bottom of the multi-slot drum.

Twelve tubes of diameter 2" were welded to the drum at its upper two-third's portion and adjusted by using a carpenter's level to give equal discharge. Only one of these tubes was connected to discharge

PHOTO (1)
Set of Single and Multi - Slot Drums
for Collection of Runoff & Erosion

PHOTO (2)
Sorghum - Pigeonpea Intercropping
Before Harvest of Sorghum Crop

in the single-slot drum (photograph 1). The size of the drum and the number of slots had been constructed to function for a single storm amounting up to 100 mm with 5% runoff.

The volume of surface runoff was calculated by recording the depth of runoff in the multi-slot drum and the single-slot drum and then referring to a caliberated graph to find the volume of water in each drum. Total surface runoff from each plot equals the volume of water in the single slot barrel multiplied by 12 plus the volume of water in the multi-slot barrel. Runoff was calculated as percentage of rainfall (1.0 mm/ha = 10 cubic meter water).

$$\text{Surface runoff (percentage)} = \frac{\text{Depth of surface runoff (mm)}}{\text{Depth of rainfall (mm)}} \times 100$$

Soil Erosion:

For studying the amount of erosion, a sample of one litre was taken from the centre of each drum after thoroughly stirring the water in the drum. This sample was taken to the laboratory where it was stirred again and a sample of 200 ml was taken in a beaker of known weight. The beaker was put on a hot plate to allow the water to evaporate and was again weighed, The quantity of soil loss in one litre of runoff was then calculated and multiplied by the volume of the surface runoff. The value obtained was multiplied by the factor (33.33) to get the quantity of erosion from one hectare under that treatment (the area of plot = 300 msq 1/33.3 hectare). After taking the readings and samples, the contents of the drums were drained and the drum cleaned before the next shower.

Soil samples were taken regularly down to 60 cm depth to calculate the antecedent soil moisture content and to study its effect on surface runoff and erosion.

(B) Plant characters:

For studying different plant characters, 10 sorghum plants and 6 pigeonpea plants were fixed by bamboo pegs and the plants were labelled and numbered for recording the observations.

Pre-harvest data:

The height of the labelled plants was recorded at 15 day intervals starting one month after sowing; the plant height was taken from ground level to the top of the growing point.

Number of leaves per plant:

Total number of leaves on each observation plant was counted at 15 days interval starting from one month after sowing.

Leaf area index:

From each plot, two plants from each crop were pulled out and their leaves were fed to the leaf area measurement apparatus. The total leaf area was divided by the area under the plant to obtain the leaf area index.

Shoot drymatter production:

In each treatment, the plants from half linear metre were harvested at ground level and thoroughly dried in an oven adjusted to $60^{o}C$. The dry weight was recorded after 24 hours.

Post-harvest data:

From the two central rows in each plot, four rectangles 8.0 x 1.5 m were located at random and the average of the four was taken for the post-harvest data.

(A) Sorghum:

(1) Number of earheads in 12 square meters:

In each rectangle, the number of sorghum heads was counted and the average of the four blocks recorded.

(2) Number of spikes per earhead:

For five heads from each rectangle, the number of spikes/earhead was counted and the average recorded.

(3) Number of spikelets/spike:

For the same five heads, the number of spikelets/spike was counted and the average was recorded.

(4) Number of grains/spikelet:

The average number of grains per spikelet was recorded for 5 spikelets taken at random from the above.

(5) Earhead length and girth:

The average head length and girth was taken for the labelled plant for every sorghum head, the average for the girth was also taken at the center and the two tapering ends.

(6) Test weight of seeds:

From the threshed and cleaned grains of each treatment, the weight of one thousand seeds was recorded for 3 samples taken at random and average test weight was worked out.

(7) Grain yield per plot:

This was recorded after the grains from each plot were thresher and properly dried.

(8) Straw yield per plot:

Dried straw weight was recorded from each plot.

(9) Moisture efficiency:

This can be calculated by the following formula:

$$\frac{\text{Yield (kg/ha)}}{\text{Effective rainfall}}$$

where effective rainfall = total rainfall - runoff.

B. Pigeonpea:

(1) Number of pods per plant:

For 6 plants in each treatment the average number of pods per plant was recorded.

(2) Number of grains per pod:

Grain number/pod was recorded on 10 pods and the average was worked out.

(3) Test weight of seed:

From the cleaned grains of pigeonpea from each plot, the average weight of one thousand grains taken at random was recorded.

(4) Grain yield per plot:

This was recorded after the grains from each plot were cleaned and air-dried.

(5) Straw yield per plot:

Dried straw weight was recorded from each plot.

(C) Utilisation of saved runoff:

This may be defined as a measure of the increase in grain yield as a result of unit saved (mm) from surface runoff. It was calculated by the equation:

$$\frac{Yt - Yo}{Ro - Rt} = \frac{\Delta Y}{\Delta R}$$

Where Yt = grain yield under slopes 0.4% with broad ridge method of cultivation.

Yo = grain yield under slopes 1.0% with broad ridges; from 0.4% with flat cultivation or 1.0% slope with flat cultivation.

Rt = Total runoff from 0.4% slope with flat cultivation.

Ro = Total runoff from 1.0% slope under broad ridge method of cultivation; from 0.4% with flat cultivation or 1.0% with flat cultivation.

(D) Statistical Analysis:

The data were analysed as per the split plot design by using Fisher's method of "Analysis of Variance". The treatment mean sum of square was divided by the error mean sum of square and the 5.0 percent levels of 'F' test were compared to test the significance of the findings. Where the findings were significant, C.D. at 5% level was calculated and in case non-significant results, only S.E. was calculated.

Methods of regression analysis were utilised in order to study the effects of slope, methods of soil cultivation and the intensity and the amount of rainfall on surface runoff and soil erosion.

(E) Correlation studies:

Correlations were done in order to evaluate the contribution of various factors of surface runoff, soil erosion and crop characters.

RESULTS

RESULTS

I. Surface runoff and soil erosion:

There was a total rainfall of 616.2 mm spread over 50 rainy days during the crop period. Of these, eleven showers with total depth 399.1 mm were erosive in nature. The cumulative pattern of rainfall during the season is shown in Fig. 1(b).

The relationship between rainfall, its intensity, crop L.A.I., antecedent soil moisture deficit, surface runoff and soil erosion at each erosive shower, are shown in Fig.27.

The detailed characteristics of each erosive showers is discussed below.

(1) First rainfall recorded:

The total rainfall was 90.0 mm with maximum 30 minutes intensity (E30) of 8.0 mm/hour. The antecedent soil moisture deficit down to the 60 cm layer was14.3 mm and the leaf area index (L.A.I.) was 0.3.

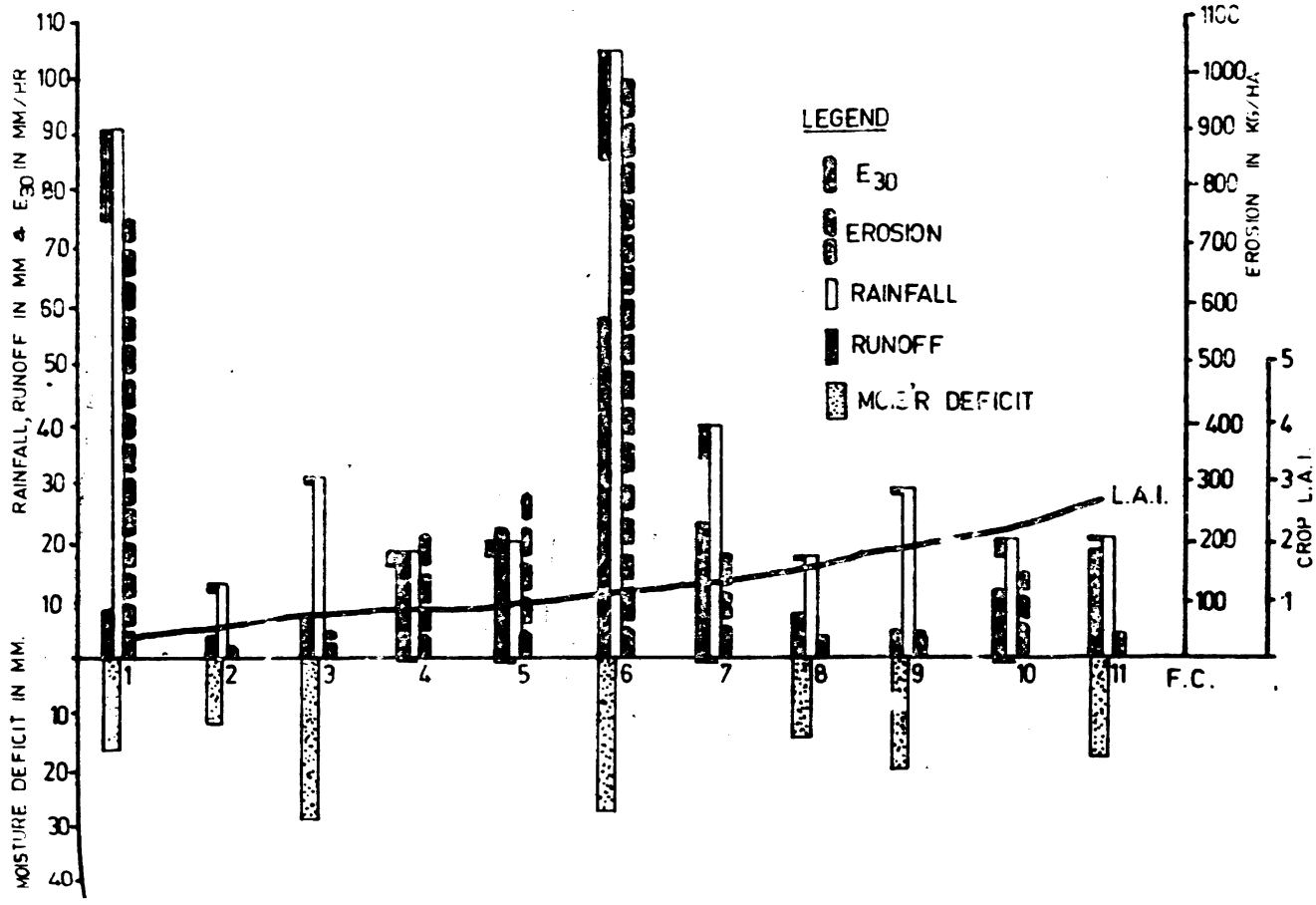
The trend of the shower is shown in Fig..3.

(a) Surface runoff:

The runoff from the above rain is presented in Table 1(a).

The surface runoff recorded had shown no significant difference between the main treatments. However, the percentage of surface runoff was more with 1.0 percent slope (16.6%) as compared to 15.3 from 0.4 percent slope.

FIG 27. RAINFALL , L.A.I. AND MOISTURE DEFICIT RELATIONSHIP.



There was no significant difference between the subtreatments. The flat system of cultivation resulted in runoff of 17.1% of the rainfall whereas ridges of 150 cm between the furrows resulted in 14.8% surface runoff.

The interaction effects were not significant. However, 0.4% slope with ridges had given the minimum runoff (14.5%) while 1.0% slope on the flat had shown the highest runoff (18.0%).

(b) Soil erosion:

Soil erosion from the first recorded shower is presented in Table 1(b).

The soil loss recorded showed no significant difference between the main treatments. The quantity of soil loss was more under 1.0% slope (889.5 kg/ha) as compared to that from 0.4% slope (589.5 kg/ha).

There was significant difference between the sub-treatments. Flat systems of cultivation resulted in soil erosion of 1080.5 kg/ha whereas bed system resulted in 398.5 kg/ha.

Interaction effects were not significant.

(2) Second rainfall recorded:

The total rainfall was 12.9 mm and the maximum E30 was 3.5 mm/hr.

The antecedent soil moisture deficit in the top 60 cm was 11.1 mm and the LAI was 0.50.

The trend of the shower is shown in Fig.4 .

3 RAINFALL PATTERN IRS E IVE SI RS

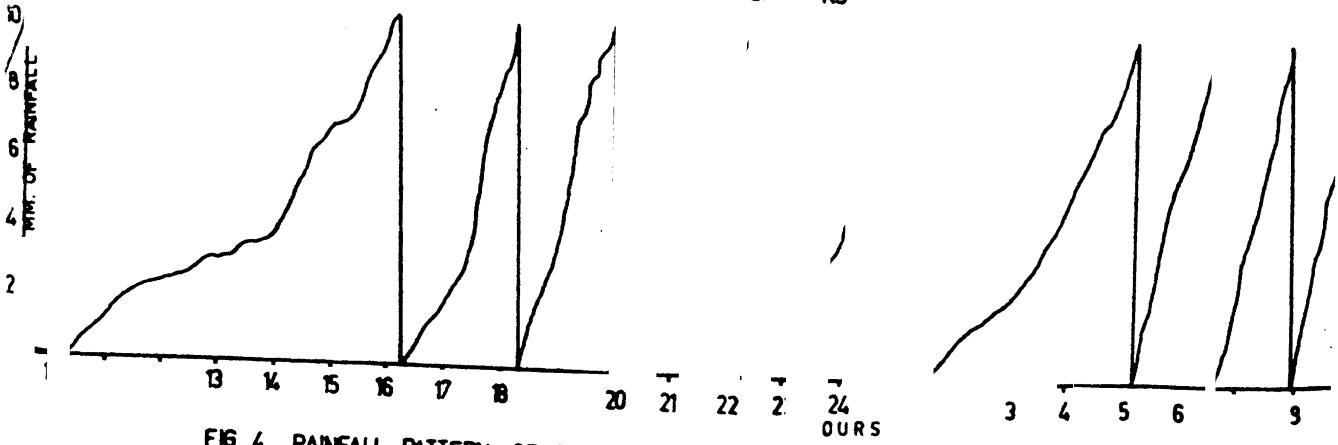
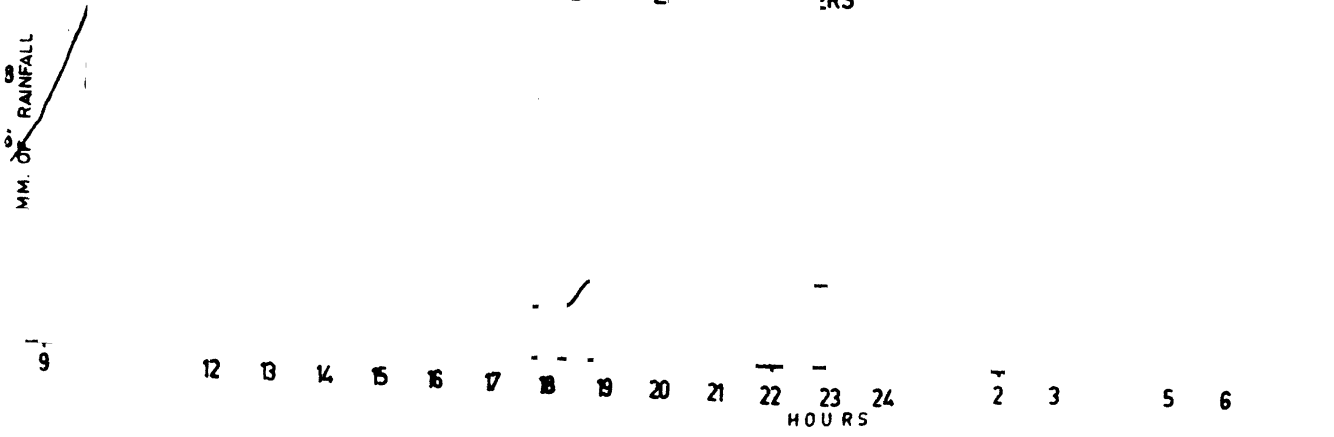


FIG. 4 RAINFALL PATTERN OF SE E :RS



Date of rainfall : 21.7.76
Amount of rainfall : 90.0 mm
Max. intensity E_{30} : 8.0 mm/hr
Antecedent soil moisture deficit : 14.8 mm
Crop L.A.I. : 0.3

Table 1 (a)

Surface runoff from the first erosive showers

mm

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	16.2	18.0	17.1	14.6	16.2	15.4
Ridge	14.5	15.2	14.8	13.0	13.7	13.4
Mean	15.3	16.6	15.95	13.8	14.9	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.23	-
Cultivation	N.S.	0.20	-
Interaction	N.S.	0.31	-

Table 1 (b)

Soil erosion from the first erosive showers

Cultivation	Percent slope 0.4	1.0	Mean
Flat	852	1309	1080.5
Ridge	327	470	398.5
Mean	589.5	889.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	128.0	-
Cultivation	Sig.	131.3	364.6
Interaction	N.S.	183.4	-

(a) Surface runoff:

The surface runoff from the second erosive shower is presented in Table 2(a).

There was no significant difference between the main treatments. However, the percentage runoff was greater with 1.0% slope (1.8) as compared to 0.4 percent slope (1.3).

There was no significant difference between the subtreatments. Flat system of cultivation resulted in runoff of 1.9% compared to 1.3% from cultivation of broad ridges.

Interaction effect was also not significant.

(b) Soil erosion:

Soil losses from the second erosive shower are presented in Table 2(b).

The soil losses recorded showed no significant difference between the two slopes. However the soil loss was more with 1.0% slope (14.3 kg/ha) as compared to 0.4% slope (10.8 kg/ha).

Subtreatments also had shown no significant difference. Fla systems of cultivation resulted in soil loss of 13.8 kg/ha whereas bed systems resulted in 11.3 kg/ha as soil losses.

Interaction effects were also not significant.

Table 2 (a)

Date of rainfall : 28.7.76
Amount of rainfall : 12.9 mm
Max. intensity E_{30} : 3.5 mm/hr
Antecedent soil moisture deficit : 11.1 mm
Crop L.A.I. : 0.5

Surface runoff from the second erosive showers

mm

Slope	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	1.6	2.2	1.9	0.2	0.3	0.25
Ridge	1.1	1.5	1.3	0.1	0.2	0.15
Mean	1.3	1.8		1.15	0.25	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.05	-
Cultivation	N.S.	0.76	-
Interaction	N.S.	0.91	-

Table 2 (b)

Soil erosion from the second erosive showers

Cultivation	Percent slope 0.4	1.0	Mean
Flat	11.3	16.3	13.8
Ridge	10.3	12.3	11.3
Mean	10.8	14.3	

Results of Statistical Analysis

Source	"f" test	S.E.	C.D. (0.05)
Slope	N.S.	0.86	-
Cultivation	N.S.	0.35	-
Interaction	N.S.	.036	-

(3) Third rainfall recorded:

The total rainfall was 31.3 mm and the maximum E30 was 7.0 mm/hr. The antecedent soil moisture deficit down to 60 mm was 27.6 mm and the crop LAI was 0.70.

The trend of the shower is shown in Fig. 5 .

(a) Surface runoff:

The surface runoff from this shower is presented in Table 3(a).

Surface runoff showed no significant difference between the main treatments. However the percentage of runoff from 1.0 percent slope was more (2.8%) as compared to (2.1%) from 0.4% slope.

There was significant difference between the two methods of cultivation. Flat systems of cultivation resulted in runoff of 3.0% whereas ridges of 150 cm resulted in only 1.9% of the rainfall.

(b) Soil erosion:

Soil erosion from the third shower is presented in Table 3(b).

The soil loss from the third erosive shower showed no significant difference between the main treatments. However the soil loss was more with 1.0 percent slope (51.9 kg/ha) as compared to 0.4 percent slope (37.5 kg/ha).

There was significant difference between the sub-treatments; cultivation on the flat resulted in soil loss of 52.3 kg/ha whereas the broad ridges resulted in 37.2 kg/ha.

Interaction effect was not significant.

FIG. 5 : RAINFALL PATTERN OF THIRD EROSIVE SHOWERS.

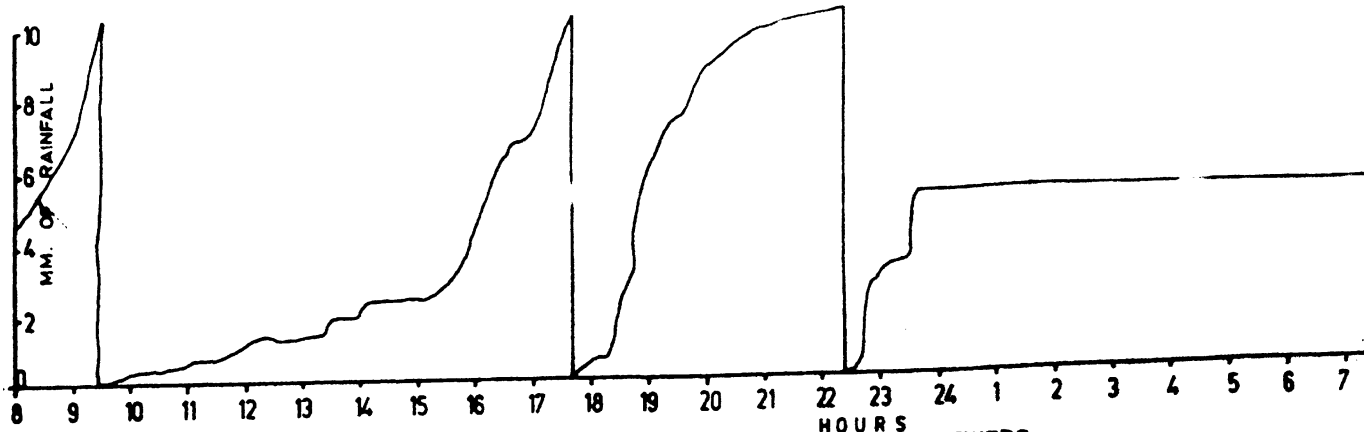
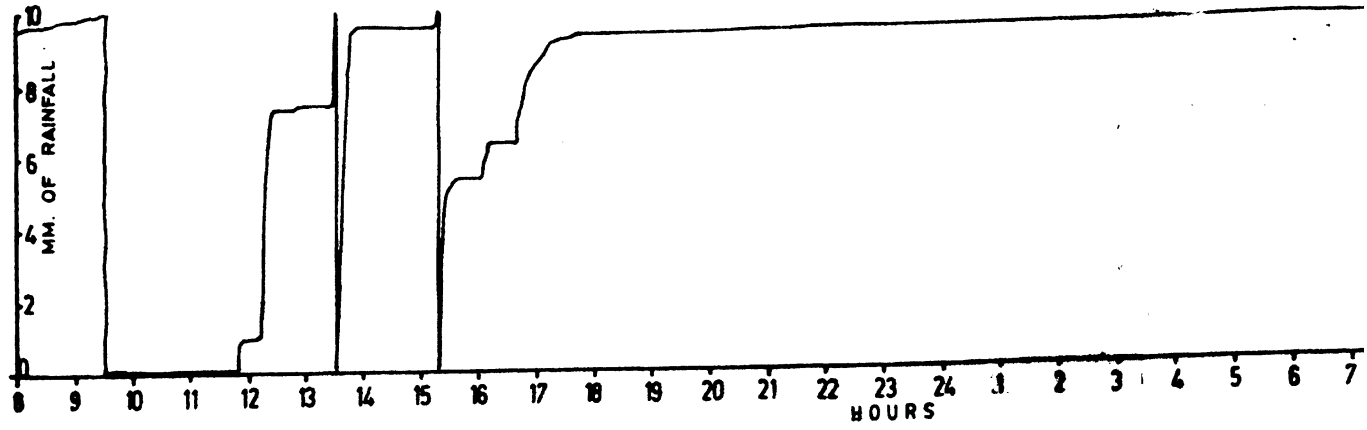


FIG. 6 : RAINFALL PATTERN OF FOURTH EROSIVE SHOWERS



Date of rainfall : 3.8.76
Amount of rainfall : 31.3 mm
Max. intensity E_{30} : 7.0
Antecedent soil moisture deficit : 27.6 mm
Crop L.A.I. : 0.7

Table 3 (a)

Surface runoff from the third erosive showers

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	2.4	3.6	3.0	0.8	1.1	1.0
Ridge	1.7	2.10	1.9	0.5	0.7	0.6
Mean	2.1	2.8	0	0.7	0.9	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.89	-
Cultivation	Sig.	0.59	1.16
Interaction	N.S.	0.11	-

Table 3 (b)

Erosion from the third erosive showers

Cultivation	Percent slope 0.4	1.0	Mean
Flat	39.0	65.6	52.3
Ridge	36.0	35.3	37.2
Mean	37.5	51.9	

Results of Statistical Analysis

Source	'F' Test	S.E.	C.D. (0.05)
Slope	N.S.	1.12	-
Cultivation	Sig.	0.59	1.65
Interaction	N.S.	1.27	-

(4) Fourth erosive rainfall recorded:

The total rainfall was 38.8 mm and the maximum 30 minutes intensity (E30) was 19.0 mm/hr. The antecedent soil moisture deficit before this shower was 38.00 mm down to 60 cm soil layer and the crop LAI was 0.7.

The trend of this shower is shown in fig. 6 .

(a) Surface runoff:

The surface runoff from the fourth recorded rainfall is presented in Table 4(a).

There was significant difference between the main treatments. The percentage of runoff was higher from 1.0 percent slope (16.2%) as compared to 0.4 percent slope (12.7%).

There was also significant difference between the two methods of cultivation. Flat system of cultivation resulted in 16.1% runoff as compared to 12.8% from broad ridges.

There was significant difference between the interactions. 1.0% slope on the flat system resulted in 17.9% runoff as compared to only 11.2% from 0.4% slope with broad ridges.

(b) Soil erosion:

Soil losses from the fourth erosive shower are presented in Table 4(b).

The soil losses showed significant difference between the two slopes. Soil losses form 1% slope was more(281.5 kg/ha) as compared to 243.5kg/ha from 0.4% slope.

Date of rainfall :4.8.76.
Amount of rainfall :18.8 mm
Max. intensity E_{30} :19 mm/hr
Antecedent soil moisture deficit :Zero
Crop L.A.I. :0.7

Table 4 (a)

Surface runoff from the fourth erosive showers

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	14.3	17.9	16.1	2.7	3.4	3.1
Ridge	12.2	14.5	12.8	2.1	2.7	2.4
Mean	12.7	16.2		2.4	3.1	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig.	0.06	0.27
Cultivation	Sig.	0.55	1.5
Interaction	Sig.	0.08	0.23

Table 4 (b)

Soil erosion from the fourth erosive showers (Kg/ha)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	253.7	309.3	281.5
Ridge	233.3	255.7	244.5
Mean	243.5	282.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig.	3.06	13.17
cultivation	Sig.	0.75	2.08
Interaction	Sig.	3.15	8.75

There was significant difference between the sub-treatments. Flat system of cultivation resulted in 281.5 kg/ha whereas broad ridges systems recorded 244.5 kg/ha.

The interaction effect was also significant. 1.0% slope on the flat recorded 309.3 kg/ha as compared to 233.3 kg/ha from 0.4% slope with broad ridges.

(5) Fifth erosive rainfall:

The total rainfall was 19.6 mm and the maximum 30 minutes intensity was 22.0 mm/hr. The field on the previous day was at field capacity. The crop LAI was 0.70.

The trend of the shower is shown in Fig. 7 '.

(a) Surface runoff:

The surface runoff from this rainfall is presented in Table 5(a).

There was significant difference between the main treatments. 1.0% slope recorded more runoff (18.2%) as compared to 13.2% from 0.4%. There was also significant difference between the two methods of cultivation. Flat system of cultivation resulted in 19.4% runoff as compared to 12% runoff from broad ridges. The interaction showed significant difference. 1.0% slope on the flat recorded 21.0% runoff as compared to 8.5% from 0.4% slope with broad ridges.

Date of rainfall : 9.8.76
Amount of rainfall : 19.6 mm
Max. intensity E_{30} : 22.0 mm/hr
Antecedent soil moisture deficit : F.C.
Crop L.A.I. : 0.8

Table 5 (a

Surface runoff from the fifth erosive showers

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	17.8	21.0	19.4	3.5	4.1	3.8
Ridge	8.5	15.5	12.0	1.6	3.0	2.3
Mean	13.2	18.2		2.6	3.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig.	1.10	4.72
Cultivation	Sig.	1.00	2.81
Interaction	Sig.	1.50	4.15

Table 5 (b)

Soil erosion from the fifth showers

Cultivation	Percent slope 0.4	1.0	Mean
Flat	262.0	453.0	357.5
Ridge	142.0	259.0	200.5
Mean	202.0	256.0	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig.	9.52	40.99
Cultivation	Sig.	6.58	18.29
Interaction	Sig.	11.58	32.20

(b) Soil erosion:

Soil losses recorded from the fifth erosive rainfall is presented in Table 5(b).

The soil erosion showed significant difference between the slopes The soil losses were higher from 1.0% slope (256 kg/ha) as compared to 0.40% slope (202 kg/ha).

There was significant difference between the sub-treatments. Flat system of cultivation resulted in higher soil losses (357.5 kg/ha) compared to 200.5 kg/ha) from broad ridge system.

The interaction between land slope and cultivation methods was significant. By resorting to broad ridge cultivation runoff reduced to nearly half compared to flat method of cultivation and the difference was significant. Under each method of cultivation 0.4% slope resulted only about half the erosion compared to 1% slope. Thus a combination of 0.4% slope andbroad ridge cultivation resulted in a soil loss of 142 kg/ha compared to 453 kg/ha under flat cultivation with 1% slope.

FIG. 7 : RAINFALL PATTERN OF FIFTH EROSIVE SHOWERS

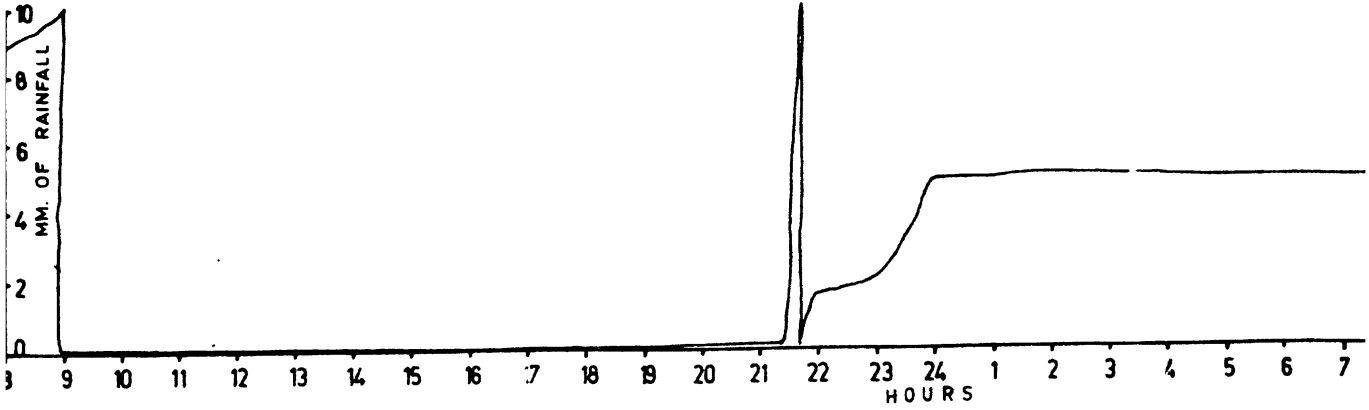
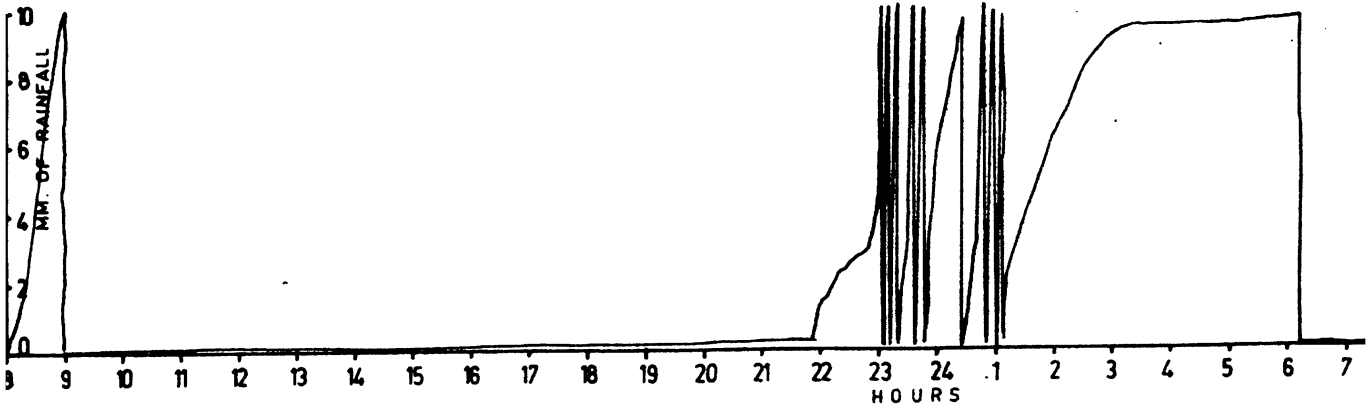


FIG. 8 : RAINFALL PATTERN OF SIXTH EROSIVE SHOWERS



(6) Sixth rainfall recorded:

Total rainfall was 102.3 mm and the maximum 30 minutes intensity was 57.0 mm/hr. The antecedent soil moisture deficit down to 60 cm layer was 26.2 mm. The crop LAI was 1.2.

The trend of the above shower is shown in fig. 9.

(a) Surface runoff:

Surface runoff is presented in table 6(a).

The surface runoff recorded showed no significant difference between the main treatments from rainfall with such high intensity showers. However the runoff was same from 1% slope (18.1%) as compared to 17.8% from 0.4% slope (18%).

There was no significant difference between these two methods of cultivation. Flat system of cultivation resulted in 18.3% runoff while broad ridges resulted in 17.7% runoff.

Interactions effect was also not significant.

(b) Soil erosion:

Soil erosion from the sixth shower is presented in Table 6(b).

There was no significant difference between the main treatments. 1% slope recorded 1015.5 kg/ha as compared to 954 kg/ha from 0.4% slope.

The difference between the methods of cultivation was significant. Flat system of cultivation resulted in 1127 kg/ha as compared to 842.5 kg/ha from broad ridges.

The interaction effect was also not significant.

Date of rainfall : 19.8.76.
Amount of rainfall : 102.3 mm
Max. intensity E_{30} : 57.0 mm/hr
Antecedent soil moisture deficit : 26.2 mm
Crop .L.A.I. : 1.2

Table 6 (a)

Surface runoff from the sixth showers
(Percent)

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	18.2	18.6	18.3	18.6	18.9	18.8
Ridge	17.8	17.6	17.7	18.1	17.9	18.0
Mean	18.0	18.1		18.4	18.4	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.09	-
Cultivation	N.S.	0.12	-
Interaction	N.S.	0.12	-

Table 6 (b)

Erosion from the Sixth showers
(Kg/ha)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	1117	1137	1127
Ridge	791	894	842.5
Mean	954	1015.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	51.10	-
Cultivation	Sig.	36.40	101.0
Interaction	N.S.	62.70	-

(7) Seventh rainfall recorded:

Total rainfall was 39 mm and the maximum 30 minutes intensity was 23 mm/hr.. The soil on the previous day was at field capacity and the crop LAI was 1.20.

The trend of the shower is shown in fig. 9 .

(a) Surface runoff:

The surface runoff from the above shower is presented in Table 7(a).

The surface runoff recorded showed no significant difference between the main treatments. However 1% slope resulted in 16.55% surface runoff as compared to 14.95% from 0.4% slope.

There was significant difference between the sub-treatments. Flat systems of cultivation recorded 18.5% surface runoff as compared to 13% from broad ridges.

The difference between the interactions was not significant.

(b) Soil erosion:

Soil erosion from the seventh erosive shower is presented in table 7(b)

There was significant difference between the two slopes 1% slope recorded 234.5 kg/ha as compared to 140.5 kg/ha from 0.4% slope.

There was significant difference between the methods of cultivation. Flat method resulted in 232.5 kg/ha as compared to 142.5 kg/ha from 0.4% slope.

The interaction effects were not significant.

Date of rainfall : 20.8.76.
Amount of rainfall: 39.0 mm
Max. intensity E_{30} 23.0 mm/hr
Antecedent soil moisture deficit : F.C.
Crop L.A.I. : 1.2

Table 7 (a)

Surface runoff from the seventh erosive showers

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	18.4	18.6	18.5	7.1	7.2	7.2
Ridge	11.5	14.5	13.0	4.5	5.6	5.0
Mean	14.95	16.55		5.8	6.4	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	1.67	-
Cultivation	Sig.	0.38	1.07
Interaction	N.S.	1.72	-

Table 7 (b)

Soil erosion from the seventh erosive rainfall

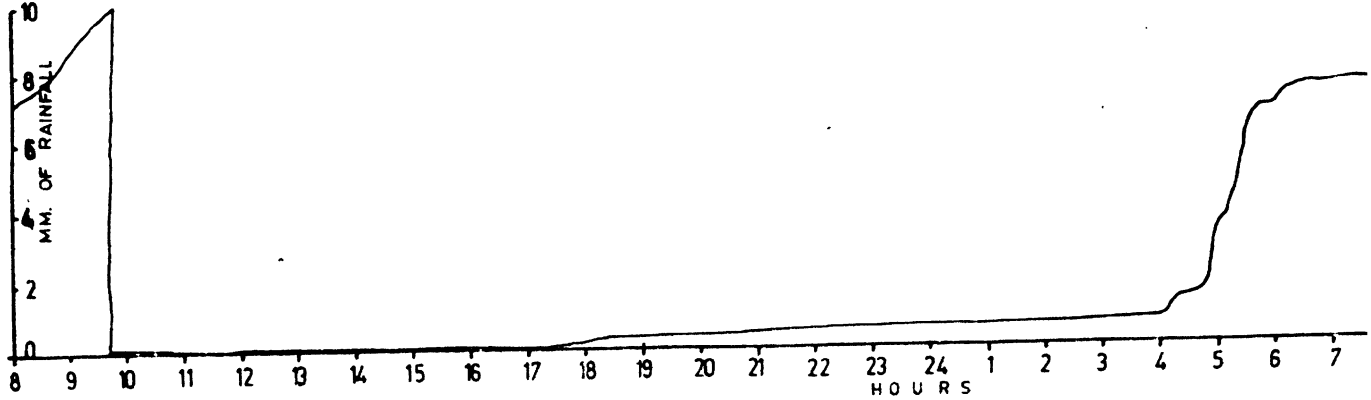
Cultivation	Percent slope 0.4	1.0	Mean
Flat	179.0	286.0	232.5
Ridge	102.0	183.0	142.5
Mean	140.5	234.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig.	7.5	32.3
Cultivation	Sig.	10.2	28.3
Interaction	N.S.	12.6	-

FIG. 9 : RAINFALL PATTERN OF SEVENTH EROSIVE SHOWERS

FIG. 10 : RAINFALL PATTERN OF EIGTH EROSIVE SHOWERS



(8) Eighth rainfall recorded:

The amount of rainfall was 17.2 mm and the maximum 30 minutes intensity was 7.2 mm/hr; the antecedent soil moisture deficit before this shower was 12.8 mm down to 60 cm soil layer. The crop LAI was 1.30.

The trend of the shower is shown in fig. 10.

(b) Surface runoff:

The surface runoff from the above shower is presented in table 8(a)

The surface runoff recorded showed no significant difference between the two slopes. However, very slight difference was observed between the main treatments. 4.1% of the rainfall was collected as surface runoff from 0.4% slope, as compared to 4.4% from 1% slope.

There was no significant difference between the subtreatments. Flat cultivation resulted in 5.1% runoff as compared to 3.4% from broad ridges method of cultivation.

Interactions showed no significant difference.

(b) Soil erosion:

Soil erosion from the eighth shower is presented in table 8(b).

There was no significant difference between the main treatments. However, 1% slope recorded more soil losses (37.0 kg/ha) than 0.4% slope (26.5 kg/ha). Subtreatments also showed no significant difference. Cultivation on the flat resulted in 37.0 kg/ha compared to 26.5 kg/ha from broad ridge cultivation.

There was no significant difference between the interactions.

Date of rainfall : 24.8.76.
Amount of rainfall : 17.2 mm
Rainfall intensity : 7.0 mm/hr
Antecedent soil moisture deficit : 12.8 mm
Crop L.A.I. : 1.5

Table 8 (a)

Surface runoff from eighth erosive showers
(Percent)

Cultivation	Percent slope			Percent slope		
	0.4	1.0	Mean	0.4	1.0	Mean
Flat	4.8	5.4	5.1	0.8	0.9	0.9
Ridge	3.4	3.4	3.4	0.6	0.6	0.6
Mean	4.1	4.4		0.7	0.8	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.28	-
Cultivation	N.S.	0.10	-
Interaction	N.S.	0.11	-

Table 8 (b)

Soil a erosion from the eighth erosive showers

Cultivation	Percent slope		Mean
	0.4	1.0	
Flat	32.0	42.0	37.0
Ridge	21.0	32.0	26.5
Mean	26.5	37.0	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.86	-
Cultivation	N.S.	1.93	-
Interaction	N.S.	2.12	-

(9) Ninth rainfall recorded:

The total rainfall was 18.5 mm and the maximum 30 minutes intensity (E30) was 3.5 mm/hr. The antecedent soil moisture deficit down to 60 cm layer was 19.2 mm and the crop LAI was 2.0.

The trend of the shower is shown in Fig.11.

(a) Surface runoff:

The surface runoff from the above shower is presented in Table 9(a)

There was no significant difference between the main treatments. 1% slope lost 4.75% of the rainfall as runoff while the losses were 3.25% from 1.0% slope.

There was no significant difference between the two methods of cultivation. Runoff from cultivation on the flat was 4.15% compared to 3.55 from broad ridges.

The difference between the interaction was not significatn.

(b) Soil erosion:

Soil erosion from the ninth erosive shower is presented in Table 9(b).

There was no significant difference between the main treatments. However, 1% slope recorded more soil losses (30.4 kg/ha) compared to 27.4 kg/ha from 0.4% slope.

There was no significant difference between the subtreatments. From cultivation on the flat, the soil erosion was 31 kg/ha whereas from broad ridges the soil erosion was 26.8 kg/ha.

Interaction showed no significant difference.

Date of rainfall : 30.8.76
Amount of rainfall : 28.5 mm
Max. intensity E_{30} : 3.5 mm/hr
Antecedent soil moisture deficit : 19.2 mm
Crop L.A.I. : 2.0

Table 9 (a)

Surface runoff from the ninth showers (percent)

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	3.4	5.5	4.45	1.0	1.5	1.3
Ridge	3.1	4.0	3.55	0.8	1.1	0.9
Mean	3.25	4.75		0.9	1.3	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slopw	N.S.	0.29	-
Cultivation	N.S.	0.20	-
Interaction	N.S.	0.20	-

Table 9 (b)

Soil erosion from ninth showers (Kg/ha)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	29.5	32.5	31.0
Ridge	25.3	28.3	26.8
Mean	27.4	30.4	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.34	-
Cultivation	N.S.	0.86	-
Interaction	N.S.	0.93	-

FIG 11 : RAINFALL PATTERN OF NINTH EROSIVE SHOWERS

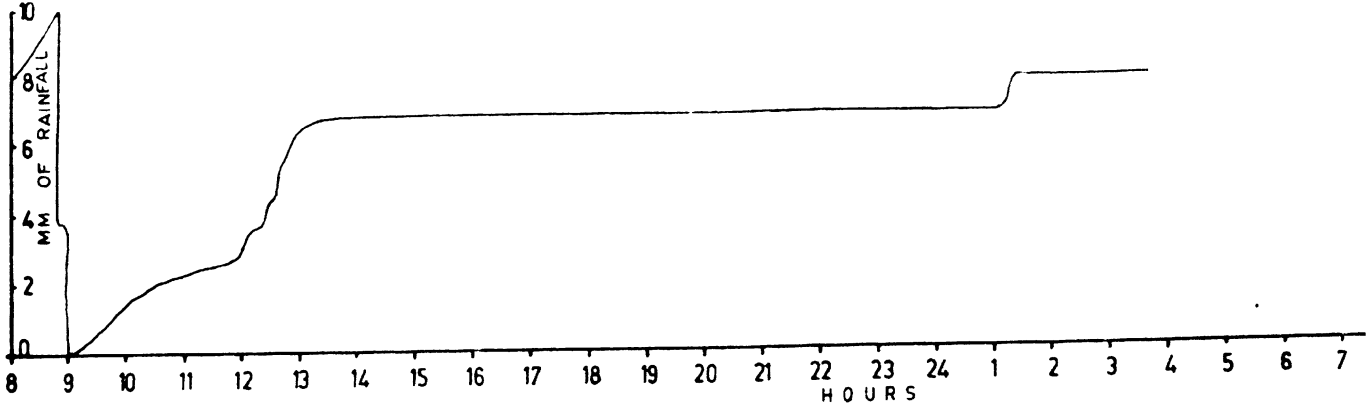
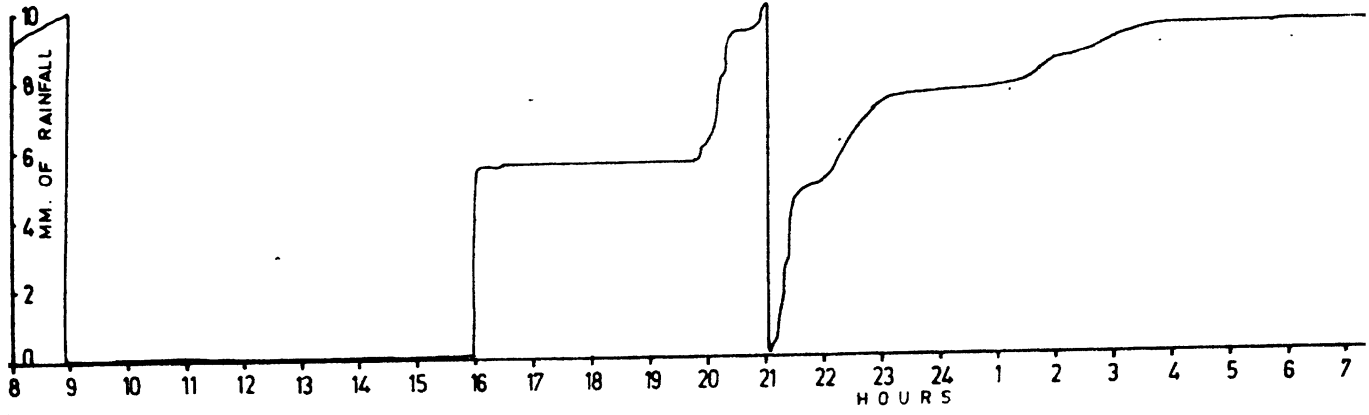


FIG. 12 : RAINFALL PATTERN OF TENTH EROSIVE SHOWERS



(10) Tenth rainfall recorded:

The amount of rainfall received was 19.5 mm with maximum 30 minutes intensity of 11 mm/hr and the soil before this shower was at field capacity. The crop LAI was 2.2.

The trends of this shower are shown in Fig.12.

(a) Surface runoff:

Surface runoff from this shower is presented in Table 10(a).

The surface runoff recorded showed no significant difference between the main treatments but 1% resulted in more runoff (15.35%) while from 0.4% slope 12.2% of the rainfall was collected as runoff.

There was no significant difference between the sub-treatments. Cultivation on broad ridges recorded 12.2% runoff as compared to 15.8% from flat system of cultivation.

There was no significant difference between the interactions.

(b) Soil erosion:

Soil erosion from the 10th erosive shower is presented in Table 10(b)

There was no significant difference between the main treatments. More soil loss was recorded from 1% slope (442 kg/ha) compared to135 kg/ha from 0.4% slope.

The difference between the subtreatments was significant. The soil loss from the flat plots was 151.3 kg/ha as compared to 125.7 kg/ha from broad ridge system.

There was no significant difference between the interactions.

Date of rainfall : 4.9.76
Amount of rainfall : 19.5 mm
Max. intensity E_{30} : 11.0 mm/hr
Antecedent soil moisture : F.C.
Crop L.A.I. : 2.2

Table 10 (a)

Surface runoff from the tenth erosive showers

Cultivation	Percent slope 0.4	1.0	Mean	Percent slope 0.4	1.0	Mean
Flat	14.4	17.3	15.8	2.9	3.5	3.2
Ridge	11.0	13.4	12.2	2.2	2.7	2.5
Mean	12.7	15.3		2.6	3.1	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.10	0.10
Cultivation	N.S.	0.11	0.11
Interaction	N.S.	0.13	0.13

Table 10 (b)

Soil erosion from tenth showers

Cultivation	Percent slope 0.4	1.0	Mean
Flat	145.3	157.3	151.3
Ridge	124.7	126.7	125.7
Mean	135.0	142.0	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	1.06	-
Cultivation	Sig.	1.21	3.4
Interaction	N.S.	1.61	-

(11) Last rainfall recorded:

The total precipitation received from this last erosive shower was 20.0 mm with maximum 30 minutes intensity of 18.0 mm/hr. The antecedent soil moisture deficit down to 60 cm layer was 16.8 mmand the crop LAI was 2.70.

The trends of this shower are presented in fig.13 .

(a) Surface runoff:

Surface runoff from this shower is presented in table 11(a).

There was no significant difference between the maintreatments. However, 1% slope recorded more runoff (3.9%) as compared to 2.2% runoff from 0.4% slope.

The difference between the two methods of cultivation was also not significant. 3.8% of the total rainfall was collected as runoff from flat system of cultivation as compared to 2.8% runoff from broad ridge system of cultivation.

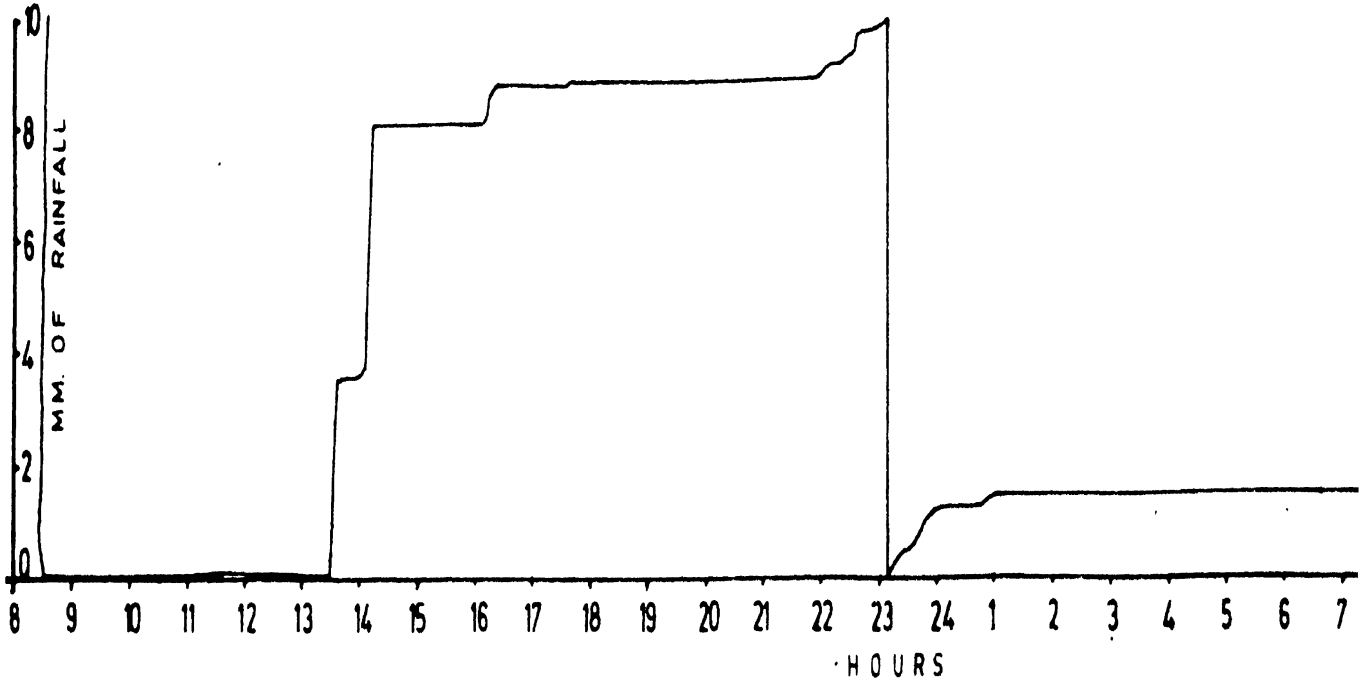
There was no significant difference between the interactions.

(b) Soil erosion:

Soil erosion from the last erosive shower is presented in table 11(b).

There was no significant difference between the main treatments. However, more erosion was recorded from 1% slope (41.45 kg/ha) as compared to 34.85 kg/ha from 0.4% slope.

FIG. 13 : RAINFALL PATTERN OF ELEVENTH EROSIVE SHOWERS



Date of rainfall : 11.9.76
Amount of rainfall : 20.0 mm
Max. intensity E_{30} : 18 mm/hr
Antecedent soil moisture deficit : 16.8 mm
Crop L.A.I. : 2.7

Table 11 (a)

Surface runoff from eleventh showers (%)

	Percent slope			Percent slope		
	(percent)					
Cultivation	0.4	1.0	Mean	0.4	1.0	Mean
Flat	3.5	4.1	3.8	0.7	0.8	0.8
Ridge	1.9	3.7	2.8	0.4	0.7	0.5
Mean	2.2	3.9		0.5	0.8	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.86	-
Cultivation	N.S.	0.14	-
Interaction	N.S.	0.16	-

Table 11 (b)

Soil erosion from the eleventh showers

	Percent slope		
Cultivation	0.4	1.0	Mean
Flat	44.0	43.6	43.8
Ridge	25.7	39.3	32.5
Mean	43.8	41.5	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.33	-
Cultivation	N.S.	0.80	-
Interaction	N.S.	0.87	-

The difference between the subtreatment was not significant. 43.8 kg/ha was recorded from flat system of cultivation as compared to 32.5 kg/ha from broad ridge system of cultivation.

There was also no significant difference between the interactions.

(12) Total runoff from all erosive showers:

The total erosive showers received during the crop growth period (July 3rd to end of December) was 399.1 mm.

Average of runoff as compared to total erosive rainfall is presented in Table 12(a).

There was no significant difference between the main treatments. However, 1% slope recorded more runoff (12.9%) as compared to 0.1% slope (11.7%).

The difference between the two methods of cultivation was also not significant. Flat method of cultivation recorded 13.1% runoff as compared to 11.2% from broad ridges system.

There was no significant difference between the interactions.

(13) Total soil erosion from all showers:

The total rainfall which resulted into erosion during the crop growth period was 399.1 mm.

Total soil erosion from the different treatments is presented in Table 12(b).

Total erosive showers
during crop season :399.1 mm

Table 12 (a)

Surface runoff from all erosive showers

Cultivation	Percent slope			Percent slope		
	0.4	1.0	Mean	0.4	1.0	Mean
Flat	12.7	14.0	13.45	50.6	55.8	53.2
Ridge	10.7	11.7	11.2	42.7	46.7	44.7
Mean	11.7	12.9		46.7	51.2	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.27	-
Cultivation	N.S.	0.25	-
Interaction	N.S.	0.37	-

Table 12 (b)

Soil erosion from all showers (Kg/ha)

Cultivation	Percent slope		
	0.4	1.0	Mean
Flat	2620	3592	3106
Ridge	1538	2000.3	1769
Mean	2079	2796	

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	Sig .	4.61	19.87
Cultivation	Sig .	11.60	32.41
Interaction	Sig .	12.49	34.67

There was significant difference between the main treatments. Slope of 1% recorded 2796 kg/ha as compared to 2079 kg/ha from 0.4% slope i.e. 34.5%more erosion was recorded from 1% slope.

There was significant difference between subtreatmnets. Flat method of cultivation resulted in more soil erosion (3106 kg/ha) as compared to 1769 kg/ha from ridge system of cultivation i.e. an increase of 75.6%.

The interaction effect was also significant. 1% slope on the flat resulted in 3592 kg/ha.s Soil loss as compared to 1539 kg/ha from 0.4% slope with ridge system of cultivation. On the other hand, 0.4% slope on the flat recorded more soil loss (2620 kg/ha) as compared to 2000.3 kg/ha from 1% slope with ridge system of cultivation.

(14) Total erosion within the field:

The total rainfall which had resulted into erosion during the crop growth period was 399.1 mm.

Total within field erosion which was collected outside the multi-slot drum comprising of coarse sand and small gravel is presented in Table 13.

There was a significant difference between the main treatments. Slope of 1% resulted in significantly higher erosion (561.8 kg/ha) as compared to 0.4% slope (295.4 kg/ha).

There was a significant difference between the subtreatment. Flat method of cultivation resulted in significantly higher erosion (627.2 kg/ha) as compared to 229.9 kg/ha from broad ridge system.

Interaction effects were significant. Comparing the cultivation method under each slope, broad ridge method of cultivation reduced the soil erosion compared to flat method by 307% and 18% under 0.4% and 1% slopes respectively. These differences were highly significant.

Similarly, comparing the slopes under each method of cultivation, 0.4% slope reduced the erosion compared to 1% slope by 264% and 90% under flat and broad ridge methods of cultivation respectively.

By optimum combination of broad ridge method and 0.4% slope, soil erosion reduced by 431% compared to flat method and cultivation under 1% slope.

Table 13

Within field erosion (kg/ha

Cultivation	Percent slope		Mean
	0.4	1.0	
Flat	436.7	817.8	627.2
Ridge	154.0	305.8	229.9
Mean	295.35	561.8	428.5

Results of statistical analysis

Source	'F test	S.E.	C.D.
Slope	Significant	0.65	2.81
Cultivation	Significant	0.24	0.67
Interaction	Significant	0.69	1.93

Conserved runoff utilization efficiency:

The conservation in runoff and differences in grain yield of sorghum and pigeonpea were worked out between the treatments with differing slopes and cultivation method. The data are shown in Table 14 (a & b).

TABLE 14 (a) Sorghum

Treatments	ΔYield kg/ha	ΔRunoff (mm/ha)	M.U.E. (kg/ha mm)
1. 1.0% flat Vs 1% bed	190	8.9	21.3
2. 0.4% flat Vs 0.4% bed	80	8.0	10.0
3. 1.0% flat Vs 0.4% flat	170	5.0	34.0
4. 1.0% bed Vs 0.4% bed	60	4.1	14.6
5. 1.0% flat Vs 0.4% bed	250	13.0	19.2

TABLE 14 (b) Pigeonpea

Treatments	ΔYield kg/ha	ΔRunoff (mm/ha)	M.U.E. (kg/ha mm)
1. 1.0% flat vs 1.0% bed	60	8.9	6.7
2. 0.4% flat vs 0.4% bed	20	8.0	2.5
3. 1.0% flat vs 0.4% flat	50	5.0	10.0
4. 1.0% bed vs 0.4% bed	10	4.1	2.4
5. 1.0% flat vs 0.4% bed	70	13.0	5.4

Maximum advantage of yield was (250 kg/ha) sorghum and 70 kg/ha pigeonpea was observed by changing the system from 1% slope with flat cultivation to 0.4% slope with broad ridges cultivation. Taking any one factor, higher advantage of yield and conservation of runoff was observed by adapting broad ridge cultivation in 1% slope compared to flat cultivation under this slope. However, the moisture use efficiency was highest between 1% and 0.4% slope treatments with flat cultivation. This was due to minimum differences in runoff (7 mm/ha) with substantial differences in yield (170 kg/ha). This trend can be due to better conservation of moisture even under non-erosion showers with 0.4% slope.

II. Crop Characters

(a) Plant height:

The cumulative growth of the plants is presented in Fig. 15(a) & 15(b). Data on plant height at different stages of crop growth are presented in Appendix-3, and that at harvest in table 15 (a) and 15 (b).

All treatments recorded the peak growth of sorghum at 60 days and for pigeonpea at 120 days after sowing, irrespective of percent runoff and erosion losses.

The plant height difference at harvest were not significant due to soil slopes and cultivation methods and their interactions. However the plant height in 0.4% slope was more than in 1% slope, and similarly in broad ridges plant height was more than flat method of cultivation.

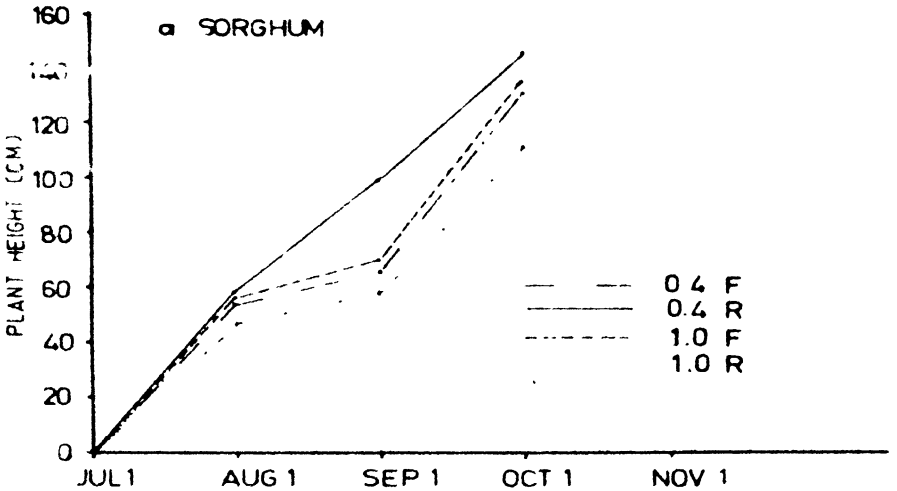
More plant height was observed in 0.4% slope with broad ridges method of cultivation and lowest in 1% slope with flat cultivation. Interaction between slopes and methods of cultivation was not significant.

This trend was similar in both crops.

(b) Number of leaves per plant:

Data on mean number of leaves per plant of sorghum and pigeonpea at 15 days interval are presented in Appendix-4 and trends are shown in Figs. 17 and 20. The number of leaves per plant at final stage are given in Table 16 (a) and 16(b).

FIG 15 PLANT HEIGHT (CM) OF SORGHUM & P.PEA



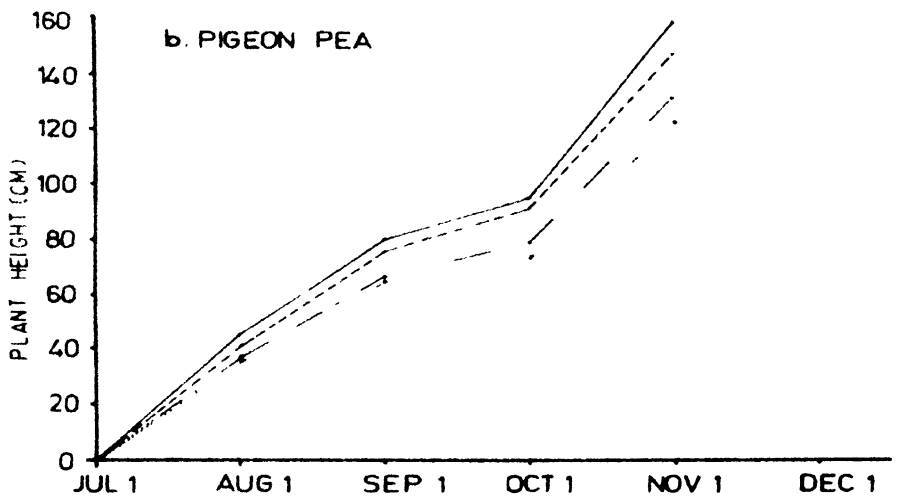


FIG. 16 : NO. OF LEAVES PER PLANT OF

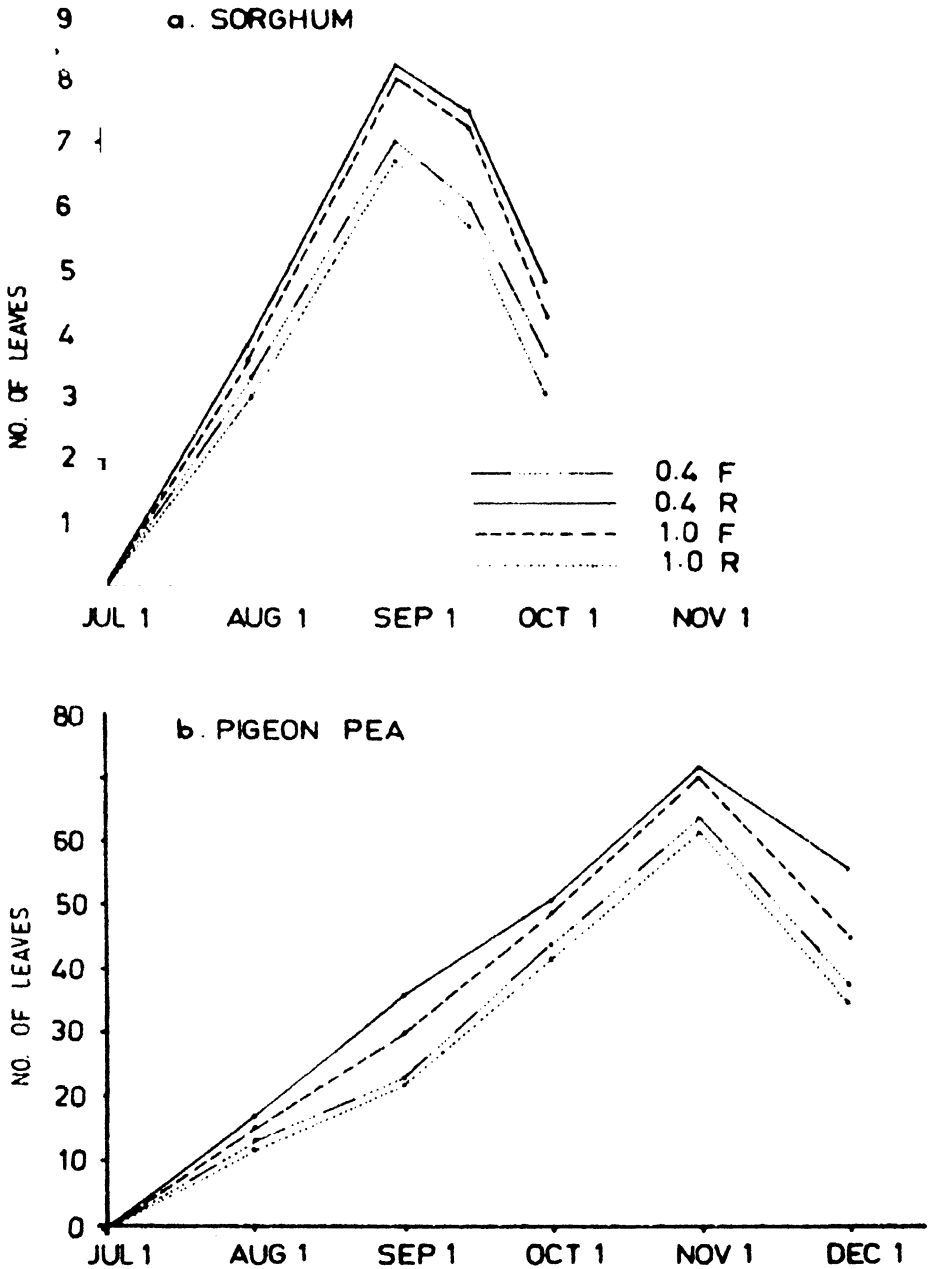


Table 15 (a)

Plant height (in cm) at harvest (a) sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	143	137	140
Ridge	152	146	149
Mean	147.5	141.5	

Results of Statistical Analysis

Source	F	S.E.	C.D. (0.05)
Slope	N.S.	0.57	-
Cultivation	N.S.	1.52	-
Interaction	N.S.	1.83	-
			-

Table 15 (b)

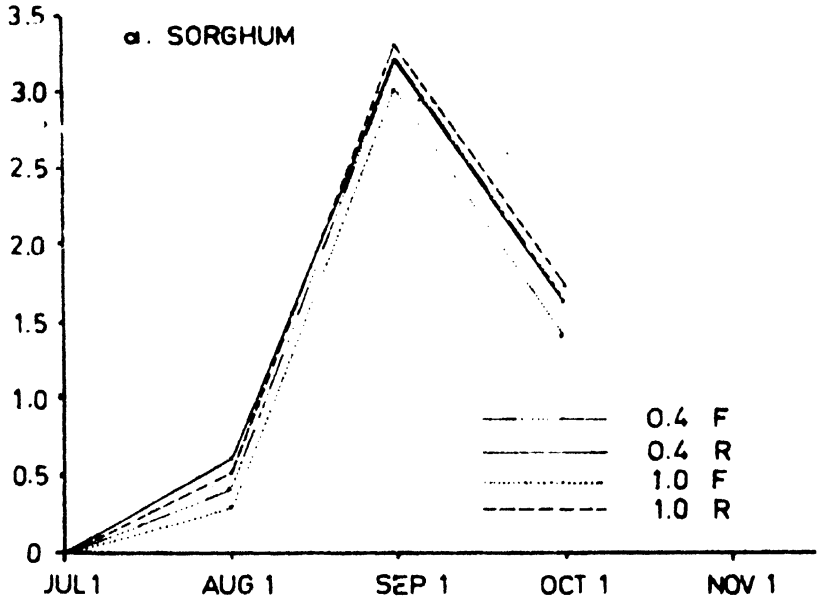
Plant height (in cm) at harvest (b) Pigeonpea

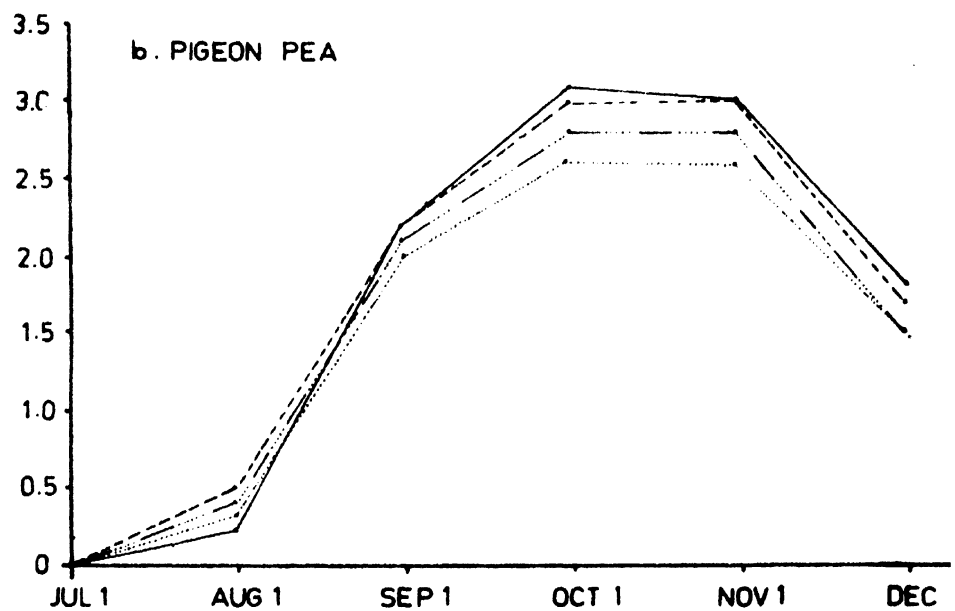
Cultivation	Percent slope 0.4	1.0	Mean
Flat	146	140	143
Ridge	160	152	156
Mean	153	146	

Results of Statistical Analysis

Source	F	S.E.	C.D. (0.05)
Slope	N,S.	1.09	-
Cultivation	N.S.	1.42	-
Interaction	N.S.	1.79	-

FIG 17: LEAF AREA INDEX OF





Increase of leaf number was observed in all treatments with increase in the age of the crop, up to 60 days in case of sorghum and to the age of 120 days in case of pigeonpea.

The main treatments, the sub-treatments and their interaction effects were not significant. However, the number of leaves per plant was more in 0.4% slope as compared to 1% slope and in broad ridges compared to flat method of cultivation in both crops.

(c) Leaf area index (LAI):

The crop leaf area index was recorded at 15 days interval. The data are given in Appendix-5, and the trends are shown in Fig. 17 and 21 (a&b).

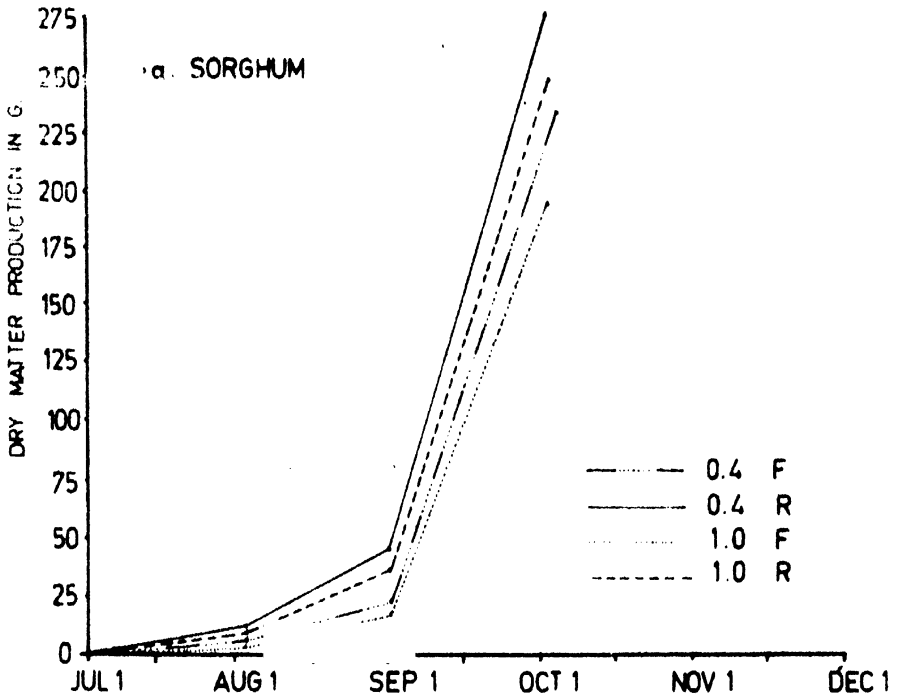
Maximum LAI was recorded for sorghum at the age of 60 days while for pigeonpea, it was recorded at 120 days after sowing. The data are given in Table 16(a) and 16(b).

The main treatment differences, subtreatments and interaction effects were not significant. However, peak LAI was recorded in 0.4% slope compared to 1% slope. Similarly LAI was higher in broad ridges method of cultivation as compared to flat method.

(d) Dry matter production:

Data on dry matter production recorded at 15 days interval are presented in Appendix-6, and the trends are shown in Fig.18 & 22. The data recorded at the final stage are presented in table-17. The trends are shown in Fig.18 (a & b).

FIG.18: DRY MATTER PRODUCTION IN HALF METER ROW LENGTH.



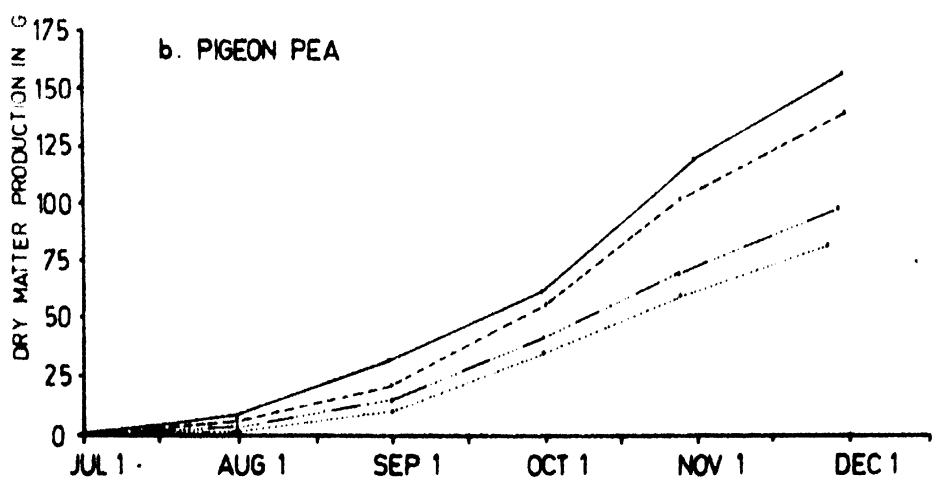


Table 16 (a)

Number of leaves per plant at final stage (a) Sorghum

Cultivation	Slope 0.4%	Slope 1.0%	Mean
Flat	4.0	3.6	3.8
Ridge	4.8	4.2	4.5
Mean	4.4	3.9	

Results of Statistical Analysis

Source	F	S.E.	c.d. (0.05)
Slope	N.S.	0.07	-
Cultivation	N.S.	0.15	-
Interaction	N.S.	0.17	-

Table 16 (b)

Number of leaves per plant at final stage (b) Pigeonpea

Cultivation	Percent slope 0.4	Percent slope 1.0	Mean
Flat	30	23	26.5
Ridge	35	33	34.0
Mean	32.5	28	

Results of Statistical Analysis

Source	F	S.E.	C.D. (0.05)
Slope	N.S.	1.00	-
Cultivation	N.S.	1.52	-
Interaction	N.S.	1.82	-

SORGHUM CROP

FIG.19 a: PLANT HT. AT HARVEST

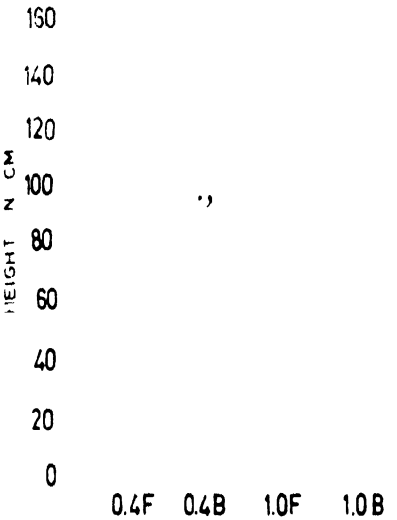


FIG.20 a: NO. OF LEAVES / PLANT (MAX)

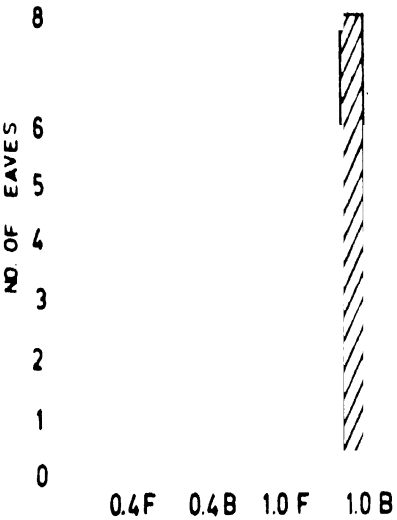


FIG.21a: LEAF AREA INDEX AT 60TH DAY

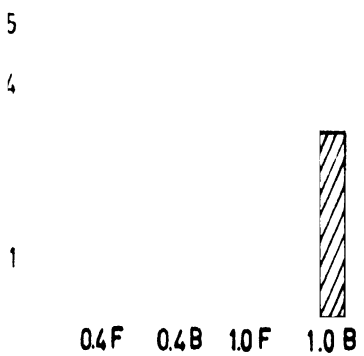
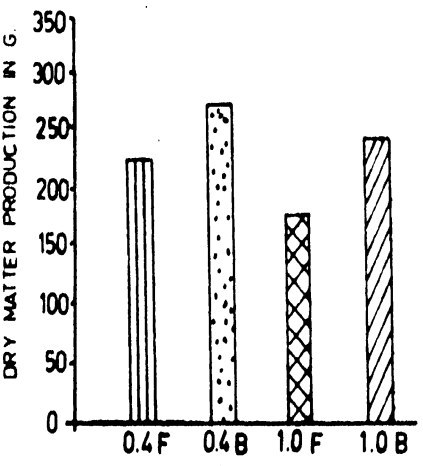


FIG.22 a: DRY MATTER PRODUCTION (IN HA M. ROW LENGTH) AT 90 DAYS.



PIGEON PEA CROP

FIG.19b: PLANT HT. AT HARVEST.

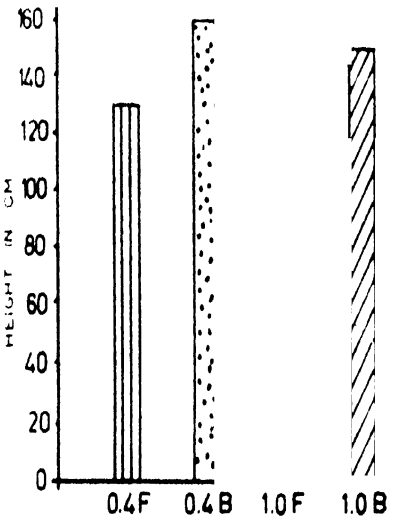


FIG.20b: NO. OF LEAVES/PLANT(MAX)

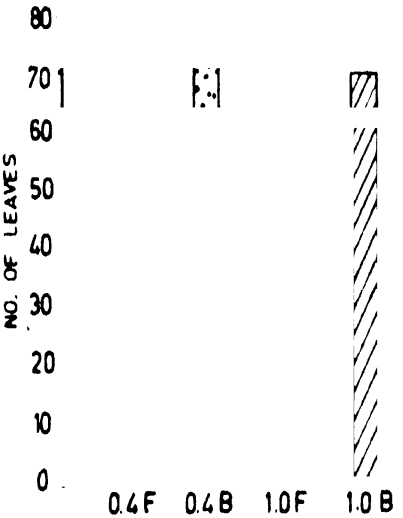


FIG.21b: LEAF AREA INDEX AT 90TH DAY.

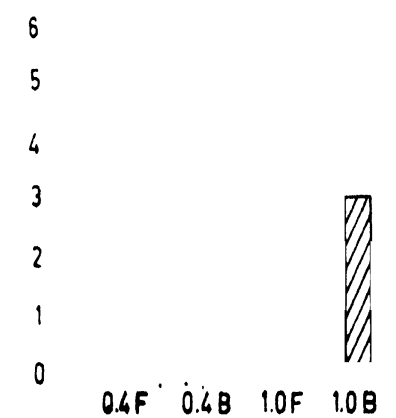
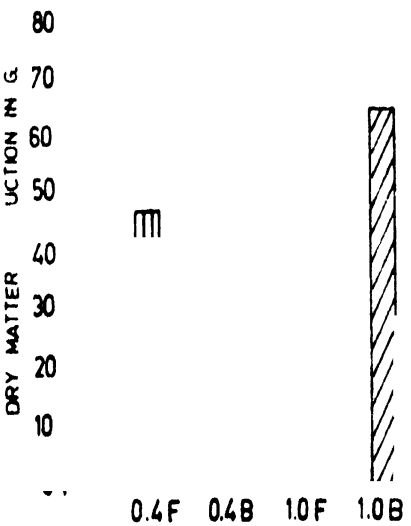


FIG.22b: DRY MATTER PRODUCTION (IN HALF M. ROW LENGTH) AT HARVEST.



Dry matter production increased throughout the crop growth in all the treatments. However, in case of sorghum, peak rate of production was between 60th to 90th day and for pigeonpea, between 105-135 days, in all the treatments (Fig.18).

The slope 0.4% with ridges recorded the maximum dry matter production at harvest while 1.0% slope on the flat produced lowest dry matter production. The slope of 0.4% did not increase the production significantly over 1% in case of pigeonpea but there was significant increase in case of sorghum. The interaction effect was not significant.

(e) Length of sorghum earheads:

Data on the length of earheads are presented in Table 18.

The main treatments, subtreatments and interaction effects were not significant. However, length of sorghum earheads was more in 0.4% slope compared to 1% slope and in broad ridges compared to flat method of cultivation in both the crops.

(f) Girth of sorghum earheads:

The data of girth of earheads are presented in table 19. The differences between the two slopes and the two methods of cultivation were not significant. However, the girth of earheads in 0.4% slope was more than in 1% slope and similarly in broad ridges, the girth was more than flat method of cultivation.

More growth was observed in 0.4% slope with broad ridges method of cultivation and lowest in 1% slope with flat method of cultivation. Interaction between slopes and methods of cultivation was not significant.

(g) Number of spikes per head, and pods per plant:

Data on the number of spikes per sorghum head, and the number of pods per plant of pigeonpea are presented in Table 21.

The difference in the number of spikes per head of sorghum and pods per plant of pigeonpea were not significant due to slopes of land, method of cultivation and their interactions. However, spikes per head and pods per plant in 0.4% slope were more than 1% slope and similarly in broad ridges, they were more than flat method of cultivation.

More spikes per earhead and pods per plant were observed in 0.4% slope with broad ridges method of cultivation and lowest in 1% slope with flat cultivation. Interactions between slopes and methods of cultivations were not significant.

(h) Number of spikelets per spike:

Data on the mean number of spikelets per spike of sorghum are presented in table 21 (a).

The difference between the number of spikelets per spike was not significant due to the slope of the land, the methods of cultivation and their interactions. However, the number of spikelets per spike in 0.4% slope was more than 1% slope. Similarly, in broad

ridges, the number of spikelets was more thanflat method of cultivation. More spikelets per spike were observed in 0.4% slope with broad ridges method of cultivation and lowest in 1% slope with flat cultivation.

Interaction between slopes and methods of cultivation was not significant.

(i) Number of grains per spikelet:

Data on the number of grains per spikelet in sorghum are presented in table 21.

Maximum number of grains per spikelet was recorded from 0.4% slope with broad ridges. These were superior to 0.4% slope on the flat and to 1% slope with flat cultivation. The differences between the slopes and methods of cultivation were not significant.

There was no significant difference between the interactions.

(j) Test weight (1000 seeds):

Data on test weight (1000 seeds) are presented in table 22 (a & b) while the trends are shown in fig.23 (a & b). The differences between the two slopes and the two methods of cultivation were not significant. However, the test weight in 0.4% slope was more than in 1% slope. Similarly in broad ridges, test weight was more than in flat method of cultivation.

FIG.23a: SORGHUM TEST WEIGHT (1000 SEEDS)

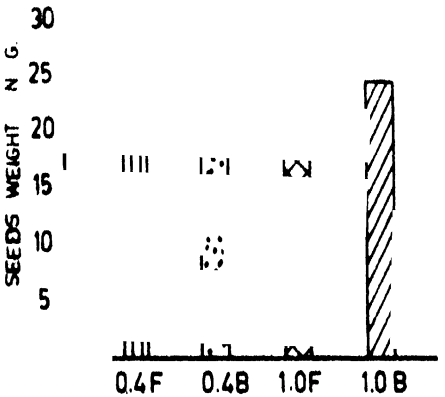


FIG. 23b: PIGEON PEA TEST WEIGHT (1000 SEEDS)

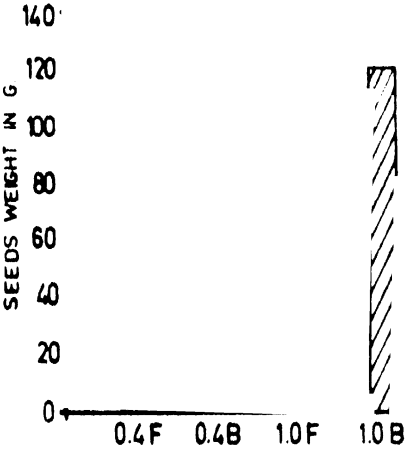


FIG. 24a: SORGHUM GRAIN YIELD

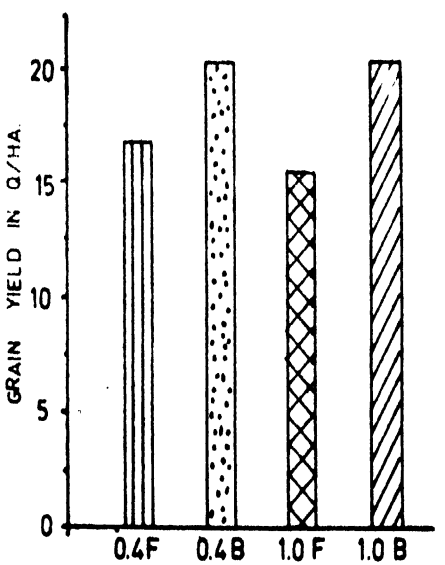
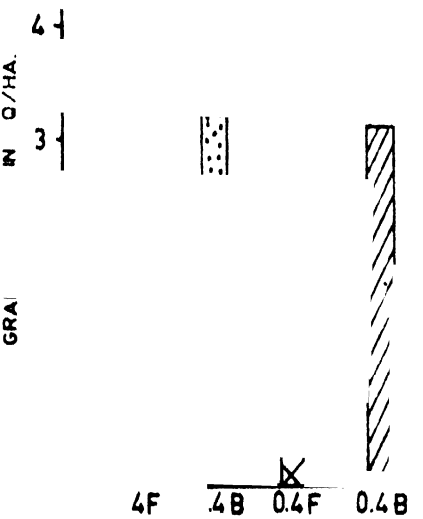


FIG. 24b: PIGEON PEA GRAIN YIELD



More test weight was observed in 0.4% slope with broad ridges, and lowest in 1% slope with flat cultivation. The interaction between slopes and methods of cultivation was also not significant.

(k) Grain yield:

Data on grain yield together with statistical analysis are presented in table 24 and trends are shown in fig. 24 (a & b).

The differences in the grain yield were not significant due to slope, cultivation methods or their interactions. However, the grain yield was more in 0.4% slope than 1% slope. Similarly in broad ridges, the grain yield was more than in flat method of cultivation.

More grain yield was observed in 0.4% slope with broad ridge method of cultivation and lowest was in 1% slope with flat cultivation.

Interactions between slopes and methods of cultivation were not significant. This trend was similar in both crops.

(l) Straw Yield(quintals per ha):

The data on straw yield are presented in Table 24.and the trends are shown in figure 25.

The main treatments, subtreatments and interaction effects were not significant. However, straw yield was more in 0.4% slope as compared to 1% slope, and in broad ridges compared to flat method of cultivation. Highest straw yield was recorded from 0.4% slope with broad ridge method of cultivation and the least recorded from 1% slope with flat method of cultivation.

FIG. 25a : SORGHUM STALK YIELD

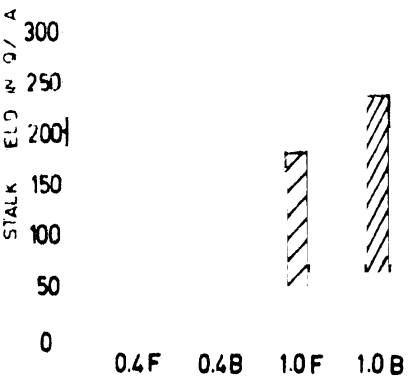


FIG. 25b : PIGEON PEA STALK YIELD

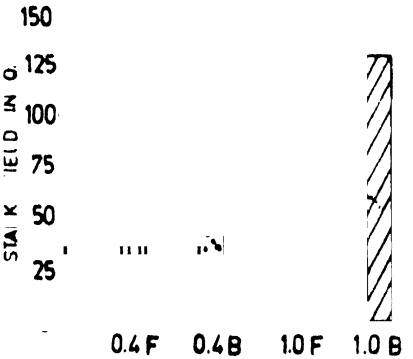
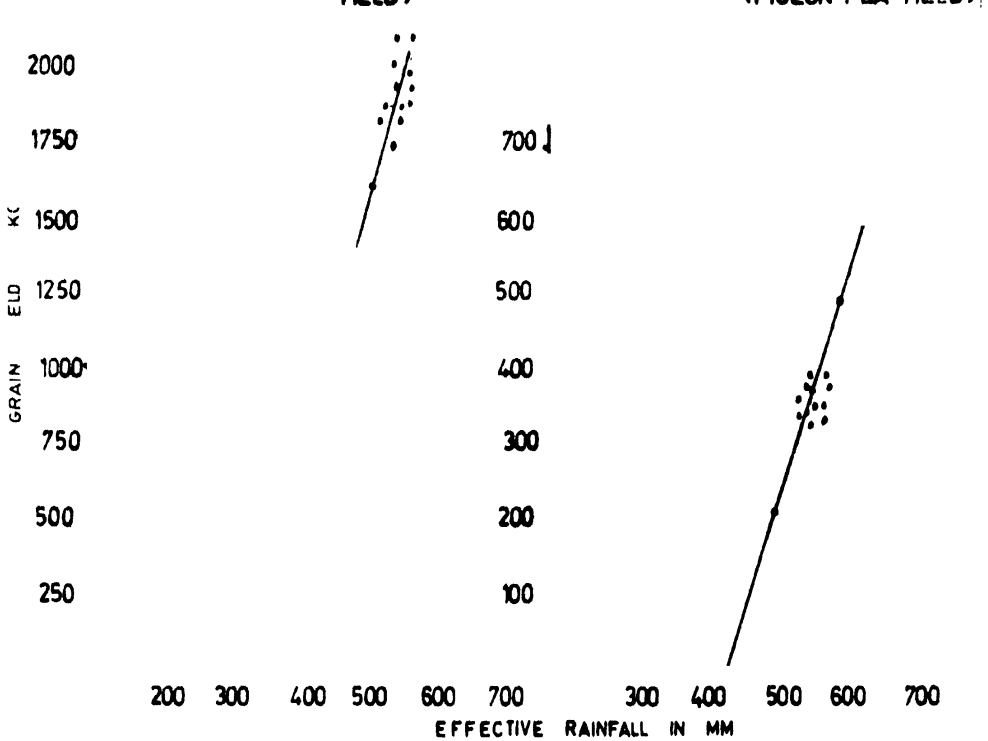


FIG. 26: THE INFLUENCE OF EFFECTIVE RAINFALL ON THE YIELD OF M AND PIGEONPEA.



The interactions between slopes and methods of cultivation were also not significant. Similar trend was observed in both crops.

Moisture use efficiency:

Moisture use efficiency based on effective rainfall (total rainfall minus runoff) was calculated for sorghum and pigeonpea and the data are presented in Table 26.

TABLE 26

Cultivation	Sorghum			Pigeonpea		
	Percent slope		Mean	Percent slope		Mean
	0.4	1.0		0.4	1.0	
Flat	3.7	3.8	3.75	0.65	0.59	0.62
ridge	3.5	3.2	3.63	0.59	0.60	0.60
Mean	3.6	3.5		0.62	0.59	

Moisture use efficiency of sorghum crop ranged from 3.52 kg/ha mm in 1% slope with flat cultivation to 3.8 kg/ha mm. in 0.4% slope and broad ridge cultivation. This represented an increase of 7.95% in moisture use efficiency.

Change of slope from 1% to 0.4% increased the efficiency by 3.81% and similar advantages in moisture use efficiency were also observed with a change from flat cultivation to broad ridges.

Table 17 (a)

'Leaf area index (60 days) Sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	2.5	2.3	2.4
Ridge	3.3	3.0	3.1
Mean	2.8	2.7	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.13	-
Cultivation	N.S.	0.10	-
Interaction	N.S.	0.17	-

Table 17 (b)

Leaf area index (120 days) Pigeonpea

Cultivation	Percent slope 0.4	1.0	Mean
Flat	2.0	1.8	1.9
Ridge	3.1	2.5	2.8
Mean	2.55	2.15	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.067	-
Cultivation	N.S.	0.18	-
Interaction	N.S.	0.10	-

Table 18 (a)

Dry Matter Production (in q/ha) at the final stage (90 days) (a) Sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	23.3	20.4	21.8
Ridge	29.0	25.6	27.3
Mean	26.1	23.0	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.46	-
Cultivation	Sig.	0.22	1.99
Interaction	N.S.	0.51	-

Table 18 (b)

Dry Matter Production (in Kg/ha) at final stage (180 days) (b) Pigeonpea

Cultivation	Percent slope 0.4	1.0	Mean
Flat	138	135	136.5
Ridge	153	144	148.5
Mean	145.5	139.5	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	4.4	-
Cultivation	N.S.	13.3	-
Interaction	N.S.	14.0	-

Table 19

Length of sorghum earheads

Cultivation	Percent slope 0.4	1.0	Mean
Flat	30	27	28.5
Ridge	34	33	33.5
Mean	32	30	

Results of Statistical Analysis

Source	F	S.E.	C.D. (0.05)
Slope	N.S.	1.15	-
Cultivation	N.S.	0.41	-
Interaction	N.S.	1.22	-

Table 20

Girth of earheads (cm)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	14	15	12.5
Ridge	18	17	17.5
Mean	16.0	16	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.29	-
Cultivation	N.S.	0.64	-
Interaction	N.S.	0.71	-

Table 21

Number of spikes per head (a) Sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	44	40	42.
Ridge	48	45	46.5
Mean	46	42.5	

Results of Statistical Analysis

Source	F	S.E.	C.D. (0.05)
Slope	N.S.	1.44	-
Cultivation	N.S.	2.32	-
Interaction	N.S.	2.74	-

Table 21 (a)

Number of spikelet per spike (Sorghum)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	27	16	21.5
Ridge	36	30	33
Mean	31.5	23	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	1.15	-
Cultivation	N.S.	0.91	-
Interaction	N.S.	1.47	-

Table 21 (b)

Number of pods per plant (b) Pigeonpea

Cultivation	Slope 0.4	1.0	Mean
Flat	66	45	55.5
Ridge	68	65	66.5
Mean	67	55	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	Sig.	0.00	0.00
Cultivation	N.S.	1.68	-
Interaction	N.S.	1.68	-

Table 22

Number of grains per spikelet (Sorghum)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	3.2	2.2	2.7
Ridge	3.8	3.2	3.0
Mean	4.0	2.7	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.86	0.372
Cultivation	N.S.	0.64	0.17
Interaction	N.S.	0.11	0.29

Table 23 (a)

Test weight (1000 seeds) (a) Sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	24.6	24.6	24.6
Ridge	24.8	24.7	24.8
Mean	24.7	24.7	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.06	-
Cultivation	N.S.	0.25	-
Interaction	N.S.	0.25	-

Table 23 (b)

Test weight (1000 seeds) (b) Pigeonpea

Cultivation	Percent slope 0.4	1.0	Mean
Flat	108	110	109
Ridge	118	118	118
Mean	113	114	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N,S.	0.50	-
Cultivation	N.S.	0.91	-
Interaction	N.S.	1.08	-

Table 24 (a)

'Grain yield (quintals/ha). (a) Sorghum

Cultivation	Percent slope 0.4	1.0	Mean
Flat	20.1	18.5	19.3
Ridge	20.9	20.3	20.6
Mean	20.5	19.4	

Results of Statistical Analysis

Source	F.F	S.E.	C.D. (0.05)
Slope	N.S.	0.29	-
Cultivation	N.S.	0.38	-
Interaction	N.S.	0.48	-

Table 24 (b)

Grain yield (quintals/ha) (b) Pigeonpea

Cultivation	Percent slope 0.4	1.0	Mean
Flat	3.7	3.2	3.5
Ridge	3.9	3.8	3.8
Mean	3.8	3.5	

Results of Statistical Analysis

Source	F.	S.E.	C.D. (0.05)
Slope	N.S.	0.15	-
Cultivation	N.S.	0.06	-
Interaction	N.S.	0.17	-

Table 25

Straw yield (quintals/ha)

Cultivation	Percent slope 0.4	1.0	Mean
Flat	20.1	16.5	18.3
Ridge	21.3	20.4	20.9
Mean	20.7	18.5	-

Results of Statistical Analysis

Source	'F' test	S.E.	C.D. (0.05)
Slope	N.S.	0.12	-
Cultivation	N.S.	0.10	-
Interaction	N.S.	0.16	-

PHOTO (3)
Comparison Between Broad
Ridges and Flat Cultivation
"Both at 0.4% Slope"

PHOTO (4)
Comparison Between Broad
Ridges and Flat Cultivation
"Both with 1.0% Slope"

Correlation studies:

In order to evaluate the contribution of surface runoff and soil erosion towards dry matter production and grain yield, correlations were done with the following results.

The crop dry matter production and grain yield were correlated with the first, fourth, fifth, sixth and seventh erosive showers and 'r' value were presented in table 27.

From the 'r' values (table 27) it is observed that the crop dry matter production and grain yield were significant and were negatively correlated with surface runoff and soil erosion from the above showers.

Regression analysis:

In order to evaluate the contribution of some of the highly erosive showers (x) towards the crop characters (y) and their interdependence, regression analysis were done with the following results:

Dependent variable (y)	Interdependent variable (x)	'r' values	(b) values
1. Sorghum dry matter production	Runoff one	-.95	-7.3
	Runoff four	-.86	-4.64
	Runoff five	-.71	-0.52
	Runoff six	-.84	-8.3
	Runoff seven	-.69	-0.61
2. Pigeonpea dry matter production	Runoff one	-.88	-6.3
	Runoff four	-.89	-3.2
	Runoff five	-.96	-0.64
	Runoff six	-.87	-9.1
	Runoff seven	-.89	-0.72

Dependent variable (y)	Independent rainfall (x)	'r' values	(b) values
3. Sorghum grain yield	Runoff one	-.87	- 9.4
	Runoff four	-.87	- 4.2
	Runoff five	-.76	- 0.72
	Runoff six	-.82	- 7.1
	Runoff seven	-.72	- 0.93
4. Pigeonpea grain yield	Runoff one	-.83	- 17.1
	Runoff four	- 89	- 10.3
	Runoff five	-.68	- 1.2
	Runoff six	-.77	- 1.4
	Runoff seven	-.79	- 2.8

These trends indicated that the above runoff effect on dry matter production and grain yield are inter-related among themselves and also collectively they influenced the crop characters. The magnitude of their additive effect was assessed by calculating regression equation between dry matter production and grain yield with the effective rainfall (where effective rainfall equals the rainfall received during the crop growth period minus the runoff from the plot under study).

Response analysis:

To evaluate the contribution of effective rainfall on the grain yield of sorghum and pigeonpea, response analysis was done. The linear relationship between grain yield and effective rainfall was established through the following equation:

$y = -3226.3 + 9.73x$ ----------for sorghum

$y = -1324.69 + 3.02x$ ----------for pigeonpea

Where y = yield of respective crop in kg/ha

x = effective rainfall in mm/ha

The observed and expected yield of these crops are shown in fig.26.

Table 27

Correlation

(a) Surface runoff Vs. Crop character

	Dependant Variables			
	Sorghum Dry matter	Pigeonpea Dry matter	Sorghum G. yield	Pigeonpea G. yield
Runoff one	-.95	-.88	-.87	-.83
Runoff four	-.86	-.89	-.87	-.89
Runoff five	-.71	-.96	-.76	-.68
Runoff six	-.84	-.87	-.82	-.77
Runoff seven	-.69	-.89	-.72	-.79

(b) Soil erosion Vs. Crop character

Erosion	Sorghum Drymatter	Pigeonpea Dry matter	Sorghum G. yield	Pigeonpea G. yield
Erosion one	-.65	-.66	-.81	-.71
Erosion four	-.65	-.85	-.81	-.75
Erosion five	-.68	-.64	-.62	-.64
Erosion six	-.68	-.71	-.72	-.76
Erosion seven	-.62	-.61	-.67	-.66

Summary Table - 28

Erosive showers during the crop growing period

Rain No.	Date	Erosive Rain depth (mm)	Intensity E_{30} mm/hr	Deficit mm	Crop LAI	Run-off %	Erosion Kg/ha	Run-off mm
1	21.7.76	90.0	8.0	14.8	0.3	16.6	739	14.4
2	28.7.76	12.9	3.5	11.1	0.5	1.6	12	0.2
3	3.8.76	31.3	7.0	27.6	0.70	2.5	45	0.8
4	4.8.76	18.8	19.0	Zero	0.70	14.5	263.0	2.7
5	9.8.76	19.6	22.0	Zero	0.8	15.7	279.0	3.1
6	19.8.76	102.3	57.0	26.2	1.2	18.0	985.0	18.4
7	20.8.76	39.0	23.0	Zero	1.2	15.8	188.0	6.2
8	24.8.76	17.2	7.0	12.8	1.5	4.3	32.0	0.7
9	30.8.76	28.5	3.5	19.2	2.0	4.0	29.0	1.1
10	4.9.76	19.5	11.0	Zero	2.2	14.0	139.0	2.7
11	11.9.76	20.0	18.0	16.8	2.7	3.3	38.0	0.6
Total		399.1					2749	50.9

DISCUSSION

DISCUSSION

In the arid and semi-arid tropics, rainfall during the crop growth period is limited and crop performance generally depends on the effective utilisation of the rainfall. This involves creating the conditions for more infiltration and less runoff. In this process, the slope of the land and the cultivation methods play a vital role. However, the rainfall distribution pattern and its intensity, together with the soil characteristics, are of great importance in the conservation of the rainfall for the purpose of crop growth.

In the present study, the soil is of sandy loam nature with shallow depth ranging up to 60 cm and having maximum water holding capacity of 60 mm in the top 60 cm soil. The pan evaporation during this period ranged from 2.4 mm to 7.2 mm/day, indicating fairly high evaporative demands during a part of the crop growth. The total rainfall of this region during the crop growth normally ranges between 600 to 800 mm. However, during the present crop period, there was total rainfall of 587 mm during the sorghum crop period spread over 50 rainy days; of these on 11 occasions, erosive showers were received consisting of 399.1 mm depth of rainfall; the rest being non-erosive showers. The rainfall pattern during this year was such that between the period from July 2nd to September 23rd, every week received rainfall ranging from 5.3 mm to 132.7 mm. This rainfall pattern helped sorghum and pigeonpea crops to great extent irrespective of differences in runoff under various treatments. The effect of such rainfall was evident in fairly high yields of sorghum ranging from 18.4 - 20.9 quintals/ha in

different treatments. This resulted in moisture use efficiency ranging from 3.52 kg/ha mm to 3.80 kg/ha mm. The effective rainfall (total rainfall minus runoff) has also shown a linear relationship with the grain yield of sorghum.

In case of pigeonpea, the crop encountered a drought period of 6 weeks between September 21th to November 7th; this seems to have adversely affected the pigeonpea crop as the drought period coincided with the flowering period of pigeonpea. This resulted in a low yield of pigeonpea ranging from 3.2 to 3.9 quintals/ha with moisture use efficiency of 0.59 to 0.70 kg/ha mm.

In the present study, data on the percentage of surface runoff and soil erosion is being collected from the eleven erosive showers which were received during the crop growing season. Simultaneously data on antecedent soil moisture deficit-before the rainfall was received - and on crop characters such as crop height, LAI, dry matter production and grain yield was also collected in order to study the relationship between each of the above with surface runoff and soil erosion.

It was observed that runoff and soil erosion from similar showers varied greatly with the variation in the rainfall maximum intensity (E30), the antecedent soil moisture deficit and the crop leaf area index.

A study of the effect of high rainfall intensity on runoff and erosion by comparing these parameters from the 5th and 10th erosive showers. They have shown that from rainfall of similar depth (19.6 mm and 19.5 mm) and same antecedent soil moisture (field capacity), the surface runoff was 15.7% and the erosion was 279 kg/ha when the intensity was 22 mm/ha as compared to 14% runoff but only 139 kg/ha soil erosion when the maximum rainfall intensity was 11.0 mm/hr i.e. when the intensity is doubled, the erosion was also doubled from similar rainfall depth.

The effect of the amount of rainfall can be visualized by comparing the first erosive shower (with depth 90.0 mm, maximum intensity 8.0 mm/hr and LAI 0.3) with the 3rd erosive shower (depth 31.3 mm, E30 of 7.0 mm/hr and LAI 0.7). The surface runoff from the first erosive shower was 16.0% and the erosion was 739 kg/ha as compared to 2.5% runoff and 45 kg/ha soil erosion from the 3rd showers. This shows that when the rainfall depth was extremely high, and exceeded by far the soil moisture holding capacity, the increase in runoff and erosion was not proportional to the depth of the rainfall.

The effect of the antecedent soil moisture deficit together with the ground cover was observed by comparing the 4th and 11th erosive showers which had similar depths (19.5 mm and 20.0 mm) similar maximum intensity (19.0 mm/hr and 18 mm/hr) but different antecedent soil moisture deficit (zero & 16.8 mm) and different LAI (0.7 and 2.7). Surface runoff from the 4th showers was 14.5% as compared to 3.3% from the 11th erosive showers while soil erosion from the 4th shower was 263 kg/ha but only 38 kg/ha from the 11th shower.

It was also observed that runoff affected crop growth and yield. This could be seen from the correlation studies which showed significant negative relationship between runoff percentage and the dry matter production as well as the grain yield. The effect of highly intensive rainfall on the dry matter production and the grain yield was observed from the highly significant and negative correlation of the first shower(with intensity 8.0 mm/hr). When compared to the sixth showers (with intensity 57.0 mm/hr). In which case the correlation was higher for the high intensity rainfall (-0.88) when compared to the low intensity rainfall (-0.77).

It was also observed that within-field-erosion of the coarse sand and small gravel was more from flat system of cultivation (627.2 kg/ha) when compared to broad ridges system (229.4 kg/ha). Also 1.0 per cent slope resulted in more erosion within the field (561.8 kg/ha) as compared to 295.4 kg/ha from 0.4 per cent slope..

The runoff among the treatments varied from 10.7% to 14.0% equivalent to 42.7 mm to 55.8 mm. As a result of variation in slopes and cultivation methods tested, conservation of runoff was to the extent of 4.1 mm to 13.0 mm/ha in different treatments with the crop yield variations ranging from 60 kg/ha to 250 kg/ha. This indicated that the extra yield due to the conservation of runoff ranged from 10.0 to 21.3 kg/ha.mm. in respect of sorghum and from 2.5 to 10 kg/ha.mm in respect of pigeonpea crop.

Generally,there were no significant differences in respect of crop growth characters and yield under the two slopes and the two methods of cultivation; this might be due to the good distribution of rainfall throughout the sorghum growth period (July to September) which period was followed by long dry spell during the flowering, fruit setting and maturity phases of pigeonpea. As a result, sorghum yield from all treatments was satisfactory but on the other hand, pigeonpea yield was uniformly poor.

SUMMARY AND CONCLUSIONS

Summary and Conclusions

The experiment on"the effect of ridged Vs flat cultivation at two slopes upon runoff, soil erosion, crop growth and yield" was conducted during kharif 1976 at the field RA19 of the ICRISAT. The experiment was laid out in split plot design replicated three times. Two slopes (0.4 per cent & 1.0 per cent) were the main plot treatments, and the two methods of cultivation (Flat Vs broad ridges with 150 cm between the furrows) were the sub-plot treatments.

Perodical observations on plant growth and yield attributes at crop harvest were studied. Data on the percentage of runoff and the quantity of soil erosion were collected from the eleven erosive showers which were received during the crop growing period.

Important results obtained are summerised below:-

1. Of the total rainfall of 616.2 mm, which was received during the crop growth period, the portion received in the form of erosive showers was 399.1 mm while the rest was non-erosive.

2. Among the 11 erosive showers, the depth of rainfall varied from 12.9 to 102.3 mm while the maximum 30 minutes intensity of rainfall (E_{30}) ranged from 3.5 to 57.0 mm/hr.

3. Generally sorghum and pigeonpea characteristics including the yield were not influenced by the two slopes and the two methods of cultivation to the extent of 5% level of significance.

4. The moisture utilization efficiency under the four treatment combinatiohs varied from 3.2 to 3.8 kg/ha.mm. for sorghum and from 0.59 to 0.65 kg/ha.mm. in case of pigeonpea.

As a result of different treatment combinations, there was conservation of runoff ranging from 4.1 to 13.0 ha.mm. The increase in grain yield among these treatments varied from 10 to 250 kg/ha; the resultant conserved runoff-moisture-utilization-efficiency was 2.4 to 3.1 kg/ha mm.

5. Between the two slopes tested, 1% slope resulted in 51.2 mm of runoff compared to 46.7 mm under 0.4% slope. Similarly, flat cultivation resulted in 53.2 mm runoff compared to 44.7 mm runoff under broad ridges cultivation.

6. Within-field erosion of the coarse sand and small gravels was more with 1.0%slope (561.8 kg/ha) as compared to 295.4 kg/ha from 0.4% slope. From Flat method of cultivation, erosion within the field was 627.2 Kg/ha as compared to 229.4 kg/ha from broad ridges.

7. Rainfall of more than 90.0 mm and with intensity around 10.0 mm/hr. resulted in nonsignificant difference between the slopes and the methods of cultivation asfar as surface runoff is concerned but significant differnce was observed for soil erosion.

8. When the depth of the showers was more than 90.0 mm and the intensity around 50.0 mm/hr, no significant differences was observed between the treatments and their interactions as far as surface runoff and soil erosion were concerned.

The broad ridges were found to be more effective in arresting the runoff and erosion when the depth of rainfall ranged from 20-40 mm and the intensity between 11-22 mm/hr.

10. The adverse effect of high intensity showers (more than 22 mm/hr) was negated by ground cover as may be seen by comparing runoff and erosion from the fourth and the eleventh showers.

Suggestions for Future work:

To reduce surface runoff and soil erosion from broad ridges system, it is recommended that the furrows may be partially tied (2/3rd tie). This will facilitate movement of water along the furrows during the highly intensive showers with less chances of overtopping the ridges.

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APPENDIX

APPENDIX - 1

Weekly mean temperature, relative humidity, sunshine hours and rainfall during the crop season (from 2nd July to 31st December, 1976)

PERIOD	WEEK	Mean max. temp. (C)	Mean Min. temp. (C)	Relative humidity I 7-16 hrs.	Relative humidity II 14-16 hrs.	Bright sunshine hours	Rain-fall (mm)	No. of rainy days	Average daily evapo-ration (mm)
July	2 - 8	31.5	22.1	90	61	3.7	50.2	6	5.6
	9 - 15	31.1	22.3	85	55	3.9	21.3	4	6.5
	16 - 22	27.7	22.1	89	77	1.3	132.7	5	5.0
	23 - 29	29.8	22.4	88	66	5.2	11.6	4	4.5
	30 - 5 Aug	28.3	21.6	89	74	2.2	71.3	5	3.7
Aug	6 - 12	29.9	21.4	87	58	7.2	17.0	2	5.2
	13 - 19	30.1	22.3	87	64	6.2	113.3	2	5.3
	20 - 26	27.2	22.1	93	78	2.1	79.3	6	2.8
	27 - 2 Sep	27.3	21.9	92	79	2.7	33.6	6	2.4
Sep	3 - 9	28.8	21.3	90	60	5.8	31.1	5	3.8
	10 - 16	30.2	22.0	86	57	8.3	20.4	3	5.2
	17 - 23	30.9	22.2	84	51	6.6	5.3	2	4.8
	24 - 30	32.7	20.5	84	34	9.4	-	-	5.7
Oct	1 - 7	33.0	21.8	84	39	9.3	-	-	6.6
	8 - 14	33.3	19.1	75	29	9.7	-	-	7.2
	15 - 21	30.6	18.7	78	38	5.5	-	-	5.6
	22 - 28	32.3	20.1	73	37	7.7	-	-	5.4
	29 - 4 Nov	30.4	16.1	77	32	10.7	-	-	5.9
Nov	5 - 11	28.9	20.5	91	56	6.8	20.4	1	3.5
	12 - 18	30.1	19.6	91	53	8.2	4.2	1	4.9
	19 - 25	27.7	20.5	92	66	4.6	4.5	1	2.9
	26 - 2 Dec	28.8	17.2	85	39	7.3	-	-	4.8
Dec	3 - 9	28.8	17.2	92	42	8.3	-	-	4.4
	10 - 16	28.5	17.1	88	38	9.8	-	-	4.8
	17 - 23	27.3	12.8	87	28	8.4	-	-	4.5
	24 - 31	30.3	14.0	79	21	10.2	-	-	5.6

APPENDIX 2

Calender of operations

Date	*Operation*
10.5.76	*Discing the whole area with double-offset-disc-harrow*
13.5.76	*Grading the whole area with wide-level-blade*
14.5.76	*Survey and preparation of the contour map*
17.5.76	*Selection of the site for plots and building their boundaries and opening drainage ditches*
20.6.76	*Broadcasting zinc phosphate in the plots*
27.6.76	*Seed test to determine its viability and germination percentage*
3.7.76	*Basal dose with 125 kg/ha diamonium phosphate (18:46) and sowing of the crops*
12.7.76	*Thinning and gap fillings*
20.7.76	*Application of granules for shootfly*
30.7.76	*Top dressing for sorghum with urea 77.5 followed by first weeding using green ridger and duck foot hoe*
20.8.76	*Second hand weeding*
3.9.76	*Spraying of sorghum with Endosulphan*
10.10.76	*Harvesting of sorghum crop*
20.10.76	*Threshing and cleaning of sorghum*
5.11.76	*Spraying of pigeonpea with Endosulphan*
31.12.76	*First picking of pigeonpea pods*
21.1.76	*Second picking for pigeonpea*
27.1.76	*Threshing and cleaning of pigeonpea*

Data on surface runoff and soil erosion was collected regularly after every erosive shower. Soil moisture down to 60 cm was also estimated after every shower and at weekly intervals during the dry weeks of the rainy season. The highest of the plants, the number of leaves and the dry matter production were recoreded at 15 days interval.

APPENDIX - 3

Plant height in cm. recorded at 15 days interval

(A) Sorghum Crop

Treat-ment	30th day	45th day	60th day	75th day	90th day
S1 C1	42	70	99	135	137
S1 C2	46	75	104	142	146
S2 C1	38	52	71	103	107
S2 C2	46	54	75	109	112

(B) Pigeonpea

Treat-ment	30th day	45th day	60th day	75th day	90th day	120th day	150th day	180th day
S1 C1	32	50	75	85	99	124	139	142
S1 C2	29	37	60	73	83	143	173	173
S2 C1	22	33	48	57	66	89	104	107
S2 C2	28	35	55	65	77	113	123	124

APPENDIX - 4

Mean number of leaves per plant recorded at 15 days interval

(i) Sorghum

Treatment	30th day	45th day	60th day	75th day	90th day
S1 C1	3.8	6.8	8.2	8.0	4.8
S1 C2	4.1	6.2	7.8	7.2	5.2
S2 C2	3.6	5.8	7.0	7.0	4.2
S2 C1	3.6	5.8	6.8	6.6	4.2

(ii) Pigeonpea

Treatment	30th day	45th day	60th day	75th day	90th day	120th day	150th day	180th day
S1 C1	15	25	31	43	63	75	66	41
S1 C2	17	23	30	36	52	83	73	52
S2 C1	10	15	23	27	48	72	60	42
S2 C2	9	12	17	21	41	70	65	46

APPENDIX - 5

Leaf area index recorded at 15 days interval

(i) Sorghum

Treatment	30th day	45th day	60th day	75th day	90th day
S1 C1	0.57	0.9	2.8	3.0	1.8
S1 C2	0.51	1.2	3.2	3.4	2.0
S2 C1	0.45	0.8	2.7	2.8	1.2
S2 C2	0.42	0.8	2.8	3.0	1.4

(ii) Pigeonpea

Treatment	30th day	45th day	60th day	75th day	90th day	120th day	150th day	180th day
S1 C1	0.41	0.72	2.17	2.8	3.02	4.1	3.2	1.92
S1 C2	0.46	0.75	2.36	2.8	3.20	.43	3.4	2.53
S2 C1	0.34	0.68	2.11	2.6	2.9	3.9	2.5	1.25
S2 C2	0.39	0.68	2.00	2.6	2.9	3.7	2.8	1.49

APPENDIX - 6

Dry matter production in Kg/ha recorded at a 15 days interval

(i) Sorghum

Treatment	30th day	45th day	60th day	75th day	90th day
S1 C1	84	215	993	2838	3228
S1 C2	142	322	1323	3036	3828
S2 C1	73	214	780	2210	2650
S2 C2	114	273	1248	2574	3030

(ii) Pigeonpea

Treatment	30th day	45th day	60th day	75th day	90th day	120th day	150th day	180th day
S1 C1	21	70	168	287	530	820	987	1008
S1 C2	35	91	245	392	662	931	1036	1070
S2 C1	19	63	140	259	490	812	882	945
S2 C2	28	77	203	350	630	840	903	966

APPENDIX - 7

Net plot yield of grains in kg/ha

(i) Sorghum

Treat-ment	Replications I	II	III	Mean
S1 C1	2114	2026	1870	2010
S1 C2	2108	2041	1835	2090
S2 C1	2070	1673	1787	1840
S2 C2	2353	1908	1815	2030

(ii) Pigeonpea

Treat-ment	Replications I	II	III	Mean
S1 C1	390	350	370	370
S1 C2	416	481	273	390
S2 C1	412	320	228	320
S2 C2	458	369	298	380

APPENDIX - 8

Analysis of variance for grain yield/plot (in Kg.)

Treatment	d.f.	s.s.	M.S.S.	'F' calculated
Replications	2	118.0	59.0	4.917
Slopes	1	940.0	940	78.33 N.S.
E(a)	2	24.0	12.0	-
Cultivation	1	1613.0	1613	179.2 "
S X C	1	13.0	13.0	1.44 "
E(b)	4	38.0	9.0	-

N.S: Not Significant

Treatment	d.f.	s.s.	M.S.S.	'F' calculated
Replications	2	8.0	4.0	40
Slopes	1	2.5	25.0	25.0 N.S.
E(a)	2	2.0	1.0	-
Cultivation	1	5.7	57.0	33.5 "
S X C	1	0.6	6.0	3.5
E(b)	4	0.7	1.7	

APPENDIX - 9

Analysis of variance for surface runoff from the eleven erosive showers

(i) Sorghum

Treatment	d.f.	s.s.	M.S.S.	'F' calculated
Replications	2	86.43	43.22	11.37
Slopes	1	465.89	465.89	122.6
E(a)	2	7.61	3.8	-
Cultivation	1	4872.27	4872.27	5766
S X C	1	16.81	16.81	19.89
E(b)	4	3.38	0.845	-

APPENDIX - 10

Analysis of variance for soil loss from the eleven erosive showers
(i) Sorghum

Treatment	d.f.	s.s.	M.S.S.	'F' calculated
Replications	2	261164	130582	63.26
Slopes	1	1081620	1081620	524.04 *
E(a)	2	4128	2064	--
Cultivation	1	4329579	4329579	364.52 *
S X C	1	79944	79944	6.73 N.S.
E (b)	4	47509	11877.3	-

N.S: Not significant

* Significant at 5% level.