EFFECT OF AGRO-TECHNIQUES ON SOIL LOSS, SURFACE RUNOFF AND SOIL MOISTURE STORAGE IN HILL SLOPES-PART II

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes - Part II" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
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CERTIFICATE

Certified that this thesis entitled "Effect of Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes - Part II" is a record of research work done independently by Shri. M. AJITH KUMAR MENON, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

INTRODUCTION

Soil erosion is a worldwide problem. Signs of erosion are visible to everyone, but the magnitude of this problem is not apparent to many. The entire human civilization depends on top 15 cm of the surface soil for survival, since only this layer contains the vital nutrients that are essential for crop growth. Soil erosion leads to silting of rivers and lakes which in turn causes floods. The effects of erosion are most prominent in areas where high rainfall intensities are experienced and where the topography is undulating.

It is estimated that about 6,000 million tonnes of top soil are being lost in India annually. As a result, an estimated 5.7 million tonnes of soil nutrients disappear into the sea every year. The loss incurred varies between Rs.1,000 crores to Rs.7,000 crores annually (Shenoi, 1975). On an average about 10,000 hectares are being affected by erosion every year involving an average loss of about Rs.500 lakhs (Annon, 1971). Coming to Kerala out of the 15 lakh hectares which are prone to soil erosion menace a substantial area of 14.3 lakh hectares are yet to be brought under various soil conservation measures (Annon, 1980). This situation calls for urgent need in taking up soil conservation measures in the state.

In Kerala, which supports the highest population density, the per capita land availability is as low as 0.3 acre (Balakrishna Pillai, 1978). This situation necessitates utilisation of marginal and slopy lands for cultivation of high value crops.

Tapioca is the major subsidiary food of Kerala and is grown in an area of 3.29 lakhs hectares with a total production of 53.9 lakh tonnes (Ramakrishna Bhat, 1978). It is a major crop in hill slopes where as a labour saving measure ridges are taken along the slopes for planting. The faculty cultivation methods favour heavy soil erosion. Soil itself being leteritic in origin has very little binding material which further aggravates the soil erosion problems.

Soil conservation can be achieved both by agronomic measures as well as engineering practices. But these measures fail to get best results when applied separately. A proper blending of the two measures gives encouraging results (Reddi, 1960).

Tapioca is usually planted with the onset of monsoon in June-July or September-October. The usual cultivation practices like mounds or ridges loosen the soil very much which facilitate washing down of the soil during the rainy season. Its wide spacing and slow initial growth leave considerable area unutilised during early part of the crop growth and is subjected to severe erosion hazards. So it becomes highly necessary that the land between mounds or ridges which are left bare, should be protected with some kind of cover crops as to prevent or atleast reduce the runoff and soil loss.

Intercropping, growing two or more crops simultaneously on the same field, is the main crop production system in subsistence agriculture (Willey, 1979). Intercropping as a method of reducing soil loss was suggested by Bhola et al. (1975). Intercropping and mixed cropping reduce soil losses and in this way help to maintain the soil in good condition (Ives, 1951). Cowpea was the best intercrop for controlling erosion (Battawar and Rao, 1969). In a previous experiment at Vellanikkara, it was found that groundnut intercropping with tapioca in ridges across the slope was effective in reducing soil and water losses (Viswambharan, 1980). In the light of the above facts the present investigation was undertaken with the following objectives.

1. To assess the effects of various Agro-Techniques on soil loss and surface runoff.

2. To study the effects of various Agro-Techniques on subsoil and surface soil moisture storages.

3. To estimate the loss of nutrients through erosion under various Agro-Techniques.

4. To estimate the amount of retentive rainfall during the period of crop growth under various Agro-Techniques.

5. To assess the yield of tapioca and cowpea under various Agro-Techniques.

Review of Literature

REVIEW OF LITERATURE

Research works on soil erosion and the effect of intercropping on soil, water and nutrient losses and other related topics are briefly reviewed hereunder.

2.1. Soil Erosion

2.1.1. Definition of erosion and runoff

According to Bennet (1939) the vastly accelerated process of soil removal brought about by human interference with the normal disequilibrium between soil building and soil removal is designated as soil erosion. It was stated by Gorie (1946) as the theft of soil by the natural elements and is the removal of soil particles either singly or in mass. Ellison (1947) has described soil erosion as a destructive process in contrast to soil formation which is constructive. He defined soil erosion as a process of detachment and transportation of soil materials by erosive agents namely wind or water.

Runoff as defined by Eggar E.Foster (1948) is the water that drains from the land areas by surface channels into which the water collects from overland flow or subterranean passages. Hence runoff is the water retained after losses due to evaporation, transpiration and seepage.

2.1.2. **Factors influencing soil erosion**

Hudson (1977) stated that erosion occurs due to effects of rainfall on soil and is determined by:

a) Erosivity:- Specifically and solely a property of rainfall which can be quantitatively evaluated as the potential capacity of rain to cause erosion under given circumstances.

b) Erodibility:- Specifically and solely a property of the soil which can be quantitatively evaluated as the vulnerability of the soil to erosion under given circumstances.

c) Management:- A wide term covering all factors directly under man's control such as choice of land use, choice of crop, method of crop production down to details like plant population and manurial practices and

d) Landform :- which includes length and steepness of slope and their shape and uniformity of shape.

2.1.2.1. **Erosivity**

According to Neal (1938) the percentage of runoff increased at a decreasing rate with increase in rainfall intensity. He also observed that the soil loss from a saturated soil increased as the 2.2 power of the rainfall intensity. It was observed by Duley (1939) that the rain drops were responsible for sealing the soil surface resulting in hindrance to soil moisture storage and infiltration. When rain drops hit the soil they have a dispersive action

(Ellison, 1947; McIntyre, 1958; Yadav, 1961). Free (1952) reported that splash losses from elevated pans of bare soil were 50 to 90 times more than the runoff losses. The average soil loss per inch of rain was to the tune of five to seven tonnes per acre. According to Hudson (1957) the major factors contributing to the initiation of runoff and soil loss were the raindrop impact and splashes. Ballal and Deshpande (1960) suggested that the runoff and soil loss in the saturated condition of soil were generally higher than these caused by rains from air dry soil. Udai Kumar Yadav (1961) computed the total energy of raindrops as 250 H.P. at a rainfall rate of two inches/hr on an acre and 100 H.P. force generated by a rainfall rate of 0.1 inch/hr. The 250 H.P. force generated by a rainfall rate of ~~2 inches/hr~~ 0.0014 Cm/sec is sufficient to lift seven inches of top soil to a height of three feet, 86 times in one hour, which corresponds to 580 million foot pounds of work. This might be equivalent 1000 to 10,000 times the kinetic energy of the shallow sheets of runoff water resulting from the same storm. Raindrops were responsible for a soil loss of about 95 per cent in erosion process. Splash erosion leads to sheet erosion, puddle and fertility erosion. Lyles <u>et al.</u> (1969) found that wind driven rain substantially increased soil loss. Mutchler and Young (1975) opined that the principal agent in bringing about soil detachment and transport from inter-rill areas was the rain drop splash.

According to Ellison (1944) the splash erosion increased as the 0.65 power of the rainfall rate. Ekern and Muckenhirn (1947) reported that for a constant drop size and time, the amount of sand transported was directly proportional to the intensity of precipitation. Mookerjee (1950) concluded that a high correlation existed between the rainfall intensity and amount of eroded soil. Storm erosivity varied exponentially with the rainfall intensity (Ekern, 1954; Tamhane <u>et al.</u> 1959). According to Tamhane <u>et al.</u> (1959) and Bisal (1960) an exponential relationship existed between the rainfall intensity and soil erosion. Free (1960) reported that the relationship between splash erosion losses for both sand and soil with energy value for rainfall were exponential and parabolic type. Rose (1960) observed the rate of soil detachment per unit area was influenced by the momentum and kinetic energy of the storm per unit area and time.

Wischmeier (1955) stated that the important variable in effecting soil erosion was the combination of rainfall energy and quantity of rainfall. Wischmeier and Smith (1958) identified a close relationship between rainfall intensity and the total kinetic energy. Wischmeier (1959) found that the erosion index is the most precise single estimate of rainfall erosion potential. Wischmeier (1961a) also found that the relationship of soil loss from a fallow plot to EI values was linear, but for the slope of the regression line for any set of data dependent on soil type and land slope. Hudson (1971) reported from his work in Rhodesiax that the cumulative kinetic energy of storms greater than one inch/hr (KE > 1) was more significantly correlated with soil loss than EI_{30} index. Experiments in the tropics indicated a lower correlation coefficient between EI_{30} index and soil loss than was obtained for the original experiments in U.S.A. (Ahmad and Breckner, 1974). Lal (1976c) reported a better correlation with the product of total rainfall amount and peak storm intensity (AIm) than either EI_{30} or KE > 1 indices. However, Viswambharan (1980) observed that AIm index was better correlated with runoff as compared to other erosion indices and EI_{15} index was better correlated with soil loss.

The results as revealed by many field experiments showed that the correlation of soil loss with amount of rain in individual storms as well as with maximum amount falling in 5, 15 or 30 minute intervals was poor. But the product of kinetic energy and maximum 30 minute intensity was most significantly correlated with soil loss (Wischmeier <u>et al.</u> 1958). Wischmeier's EI_{30} index had subsequently been extensively used in predicting soil loss. Das <u>et al.</u> (1967) found that EI_{30} value had the best correlation with soil erosion as compared to EI_5, EI_{15} or EI_{60} indices. Rogers <u>et al.</u> (1967) computed the kinetic energy of rainfall from rainfall intensity using the equation, $KE = 210.3 + 89 \log I$ (metre tonnes/ha.cm).

Barnett (1958) found that EI_{60} index was closely related to soil erosion. Das et al. (1967) found that the use of EI_5 min. has been recommended for Nilgiris. For Dehra Dun Rambabu et al. (1969) found that EI_{30} values were significantly correlated with daily and monthly rainfall values, but the annual rainfall values were not significantly correlated with annual EI_{30} values. However, Dangler and Swaify (1976) observed that for most soil little or no erosion occurred during the first 30 minutes of the first storm even when the simulated rainfall intensity was 6.4 cm/hr. Sharma et al. (1976) found that irrespective of the nature of the crop, splash losses were better correlated with kinetic energy of the storm than its erosion index.

2.1.2.2. Erodibility

The different erosion of two soils under similar environment and management conditions is attributed to the inherent soil characteristics. This property of the soil is referred to as soil erodibility. Erodibility involves those soil properties that affect infiltration rate, permeability and the changes with time that occur in those soil properties and others that determine dispersion, splashing, abrasion and transporting forces of rainfall and runoff. According to Lal (1977) structure and structural stability are closely related to erodibility, but are different to define in such way that they provide a measure of erodibility. He also observed that the various properties which affect the detachability and transportability of soil involve particle size distribution, organic matter content, presence of cementing materials like Fe and Al oxides, nature of clay minerals and balance of cation on the exchange complex and properties which are themselves dependent on this such as permeability, soil structure and strength. The entrapped air may also be important.

Middleton and Bucyoos as described by Mehta et al. (1963) used dispersion ratio as a measure of soil erodibility. A soil erodibility monogram based on soil properties was developed by Wishmeier et al. (1969). Romkens et al. (1974) reported that the particle size and the percentage of citrate bicarbonate dithionate (CDB) extractable Fe, Al and Si were significant prediction parameters of subsoil erodibility on high clay subsoils studied. Based on subsoil data a prediction equation with a coefficient of determination $r^2 = 0.95$ was developed. Singer et al. (1974) from the studies of the relative erodibility of surface soil (0-15 cm) from 10 soil series found that the observed erodibility of the soils was in an order different from the order predicted by Wischmeier et al. monograph. Unlike the monograph predicted, two soils with high exchangeable sodium were much more erodible and two which had high dithionate extractible Fe content were less erodible. Further studies indicated that exchangeable sodium percentage, dithionate extractible Iron and Aluminium were additional useful indices in predicting the erodibility of those soils.

In contrast, Bruce-Okine and Lal (1975) found that erodibility varied directly with sand and inversely with clay content. Nema *et al.* (1978) established the soil erodibility factor K in the unversal soil loss equation for the soil and climatic conditions of Vasad as 0.0592 tonnes/ha/unit of rainfall factor. Singh and Verma (1978) reported that runoff and soil loss increased with increase in the fineness of soil texture.

2.1.2.3. Management

Baver (1961) classified the major effects of vegetation on runoff and erosion into five distinct categories. They are (1) Interception of rainfall by vegetative cover (2) decreasing the velocity and cutting action of runoff water (3) root effect in increasing granulation and porosity (4) biological activities associated with vegetative growth and their influence on soil porosity (5) transportation of water leading to subsequent drying out of the soil.

Ellison (1947) reported that the soil detachment hazard was inversely proportional to resistant factor of surface covers and mulches in reducing runoff velocity. Ellison (1952) reported that energy of falling raindrops is a significant factor in erosion. Thus interception of high energy raindrops by the canopy can be an important factor in soil erosion. Speer (1960) stated that the basis of soil and water conservation is the cover that protects land from the direct impact of raindrops and runoff water. Udai Kumar Yadav (1961) reported that the secret of preventing erosion is to remove the energy of raindrops by vegetative shield.

Mulching is an effective means to protect the soil surface from sealing under the impact of raindrops (Harold, 1947; Schaller and Evans, 1954). According to McAlister (1957) mulch farming considerably reduced wind and water erosion. Mannering and Meyer (1963) showed that mulch application at the rate of 2.49, 4.94 and 9.8 tonnes per hectare resulted in very high infiltration and essentially no erosion. Wischmeier (1966) found that improved soil and crop management reduced average plot runoff by about 40 per cent. Mannering et al. (1966) reported that the surface mulch which covered more than 95 per cent of the soil surface had striking effect on both infiltration and soil loss. Harrold and Edwards (1974) observed that mulch of about 1.23 tonnes/ha on the surface of no-tilled system was effective in reducing erosion. Megahan (1978) stated that erosion was reduced on an average of 75 per cent by straw mulching.

Smith (1946) reported that the energy of falling raindrops was considerably reduced by the crop cover and thereby creating a soil condition that will resist erosion. He classified crops into two groups viz. erosion resisting and erosion permitting. Hudson (1957) concluded that the ground cover is almost entirely responsible for reducing runoff and erosion from grassed areas and the same effect can be achieved by any cover such as a surface mulch, dense maize crops or a good early green manure crop. Natural covers and grasses were found to be effective in checking soil erosion (Gupta et al. 1963; Vasudevaih et al. 1965). Gurmel Singh et al. (1967 a) opined that groundnut gave minimum water loss and the fallow gave maximum water loss. They have attributed the reason that the fallow provide no cover and hence no obstruction to the flow of water and therefore rainfall received is lost through runoff. Water cannot flow through groundnut easily and there is more time for absorption of water in the soil as a result of which there is less water loss. Again, soil loss was maximum under fallow as it does not provide protection against falling rain drops. However, work conducted by Bhattawar and Rao (196[illegible]) revealed that cowpea was the best for controlling erosion. Misra <u>et al</u>. (196[illegible]) devised soil conservation methods for creating such conditions that more rain water would be absorbed and preserved into the soil, surface runoff would be minimized and excessive runoff would flow at a harmless speed. The best results are achieved if the land was kept covered under vegetation. Hudson (1971) suggested that soil erosion is proportional to the fraction of soil surface exposed to direct rain drop impact. Suraj Bhan and Misra (1971) reported that cultivation of erect groundnut variety A.K.K-24 in rows of 25 x 60 cm apart considerably reduced soil erosion losses. Bhola <u>et al</u>. (1975) reported that runoff and soil loss were highest under maize and lowest under <u>P</u>.tetragonoloba suggesting that maize on slopes should be intercropped with a legume. Pete (1976) reported that natural grasslands, vetch and oatscorn rotations gave the minimum soil erosion losses. Strongly eroded soils should be used only for pastures. Sharma <u>et al</u>. (1976) suggested that <u>Vigna mungo</u> and

<u>Cajanus</u> <u>cajan</u> + groundnut mixture were most effective in checking splash erosion. Aina et al. (1977) compared the effect of cassava alone and cassava and maize grown simultaneously on runoff and soil loss. The mean soil loss was higher for monoculture of cassava when compared to maize cassava mix. Similarly the mean water runoff decreased in case of maize + cassava when compared to monoculture. In general soil loss and water runoff decrease exponentially with increase in vegetative cover. Hong Ling (1978) revealed that runoff and soil loss on a soil of 10 per cent slope under natural cover, legumes and bare soil were considerably reduced under natural cover and legumes. Ling Ah Hong (1978) reported that soil loss and runoff were higher in soils left bare. Loss from plots of legume was greater than from plots allowed to establish with natural cover at first but became equally low as the canopy developed. Cover shape or distribution of intercover shape appeared to be important in affecting sediment loss. Runoff volume was significantly reduced by high cover levels which protected the soil from sealing. The cover percentage was related to sediment in surface runoff by a parabolic relationship (Singer and Blackard, 1978). Costin (1980) found that surface runoff and soil losses were inversely related to cover. Cover values less than 70 per cent were associated with some large increases in runoff and soil loss whereas at high cover values there was relatively little reduction in runoff and soil loss. Most soil losses were small when runoff was less than 15 per cent but increased rapidly

with increasing runoff. According to De Coursey (1980) the row spacing, land slope and tillage operations affected runoff and sediment yields more than factors such as plant population and levels of fertilizers. Viswambharan (1980) observed that groundnut intercropping significantly reduced runoff and soil loss.

Sattawar and Rao (1969) observed that the crop protection factor values were high in the initial stages due to poor cover. As vegetative cover increased C-factor values decreased and soil loss was reduced. Walkinson (1975) while experimenting with cowpea found that the actual soil loss was greater than the predicted soil loss by the universal soil loss equation in the early part of the season and much less during the crop maturity. Thus the cropping management factor consisted of a complexity of components which exert varied dominance on soil erosion during the season. Nema et al. (1978) reported that the crop management factor for mung, groundnut and cowpea were 0.46[illegible], 0.374 and 0.317 respectively.

Bennet (1939) reported that contour tilled sorghum plots gave an average grain yield of 589 kg/ha. Gupta et al. (1963) found that maximum water loss occurred under bare ploughed plots in a nine per cent slopy field. Agarwal and Indrapati Singh (1970) revealed that cultivation of cane on contour can save 23.6 inches of rainfall and 21.32 tonnes of soil from moderately slopy fields susceptible to erosion. Yield of cane planted on contour trenches followed by earthing up during rain was increased to the extent of about 27 per cent. John M.Tromble (1975) reported that increased roughness in microtopography provided additional detention storage resulting in decreased runoff when compared to the control. Significant increases in runoff were associated with bare soil. Crown cover and erosion pavement were significant in reducing runoff. Khybri et al. (1978a) reported that strip tillage reduced soil loss from 52 tonnes per hectare to 40 tonnes per hectare. Berg and Carter (1980) recorded a sediment loss ranging from 0.5 to 141 t/ha from furrow erosion on irrigated cropland. They found that erosion increased sharply on row cropped fields where slopes exceeded one per cent. Viswambharan (1980) reported that maximum runoff and soil loss occurred in uncultivated bare fallow plots. Among the various cultivation methods tapioca in mounds without intercrop registered maximum soil and water losses.

Williamson and Kingsley (1974) reported that cultivation across the slope decreased runoff and erosion. It also increased the yield of maize and oats in the two year rotation. Bonde et al. (1978) reported that ridges across the slope considerably reduced the runoff and soil loss over flat sowing in tobacco and cotton. Work conducted by James et al. (1978) revealed that inward gradient of bench terraces gave less runoff and soil loss than the outward gradient of bench terraces for potato crop. Viswambharan (1980) reported that groundnut intercropping as well as tapioca planting in ridges across the slope were effective in reducing soil and water losses.

2.1.2.4. Land Form

Cook (1936) stated that among the land forms, degree and length of slope were important controlling variables of water erosion process. However, Neal (1938) reported that the percentage of slope had no apparent effect on the percentage of runoff for slopes above one per cent. Soil loss from a saturated soil increased as the 0.7 power of the slope. Mathematically the relation is $E \propto S^a$ where E is erosion, S the slope and 'a' an exponent. Zingg (1940) attributed a value of 1.49 for the exponent 'a'. It was stated that doubling the degree of slope increased the total soil loss in runoff by 2.61 times. Doubling the horizontal length of slope increased the total soil loss in runoff by 3.03 times. Increasing the degree of slope increased the total runoff. Wischmeier (1966) observed that under normal field conditions runoff from row crops averaged a 10 per cent increase for each additional per cent of slope. He observed a logarithmic relationship between runoff and slope. Hudson (1977) reported that erosion generally increased exponentially with increase in slope, the exponent for tropical soils approached two though it has been reported to vary between 1.3 and 2.1. Length of slope has a similar effect on soil loss as degree of slope. Ishida *et al.* (1980) stated that erosion was marked where the soil surface was soft, the gradient steep, or mechanical reclamation had been carried out, but was less on surface sown sites.

Lewis (1981) indicated that erosion increases as the slope gradient increases. Results also indicate that losses of soil materials are greatest not on the steepest slopes but on the five per cent slopes. No relation was found between plot length and loss. Quansah (1981) reported that soil type, intensity of rain and slope steepness significantly influenced the amount of soil detached and transported.

2.1.3. <u>Universal Soil Loss Equation</u>

Development of equations and relationships as an aid to calculation of field soil loss has been attempted by many (Zingg, 1940; Smith, 1941; Smith and Whitt, 1947). The relationships developed were mainly for local use. Wischmeier (1959) made major contribution to the prediction of soil loss by his studies on rainfall erosion index and evaluation of crop management factor. In 1961 he came out with the universal soil loss equation (Anon, 1961).

Numerical assessment of soil loss by water under a particular management practice can be achieved with the help of universal soil loss equation as described by Wischmeier and Smith (1965). It is defined as

A = RKLSCP where,

A = Computed soil loss per unit area

R = Rainfall factor, the number of erosion index units in a normal year's rainfall. The erosion index is a measure of erosive force of specific rainfall.

K = Soil erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a nine per cent slope of 72.6 ft length.

L = The slope length factor is the ratio of the soil loss from field slope length to that from a 72.6 ft length on the same soil type and gradient.

S = Slope gradient factor, is the ratio of the soil loss from the field gradient to that from a nine per cent slope.

C = Cropping management factor, is the ratio of the soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated.

P = erosion control practice factor, is the ratio of the soil loss with the specific practice to that with straight row farming up and down the slope.

The science of soil conservation has advanced much with the introduction of universal soil loss equation. Walkinson (1975) suggested that a non canopy factor had to be introduced in addition to the soil exposure factor to adequately substitute for the cropping management factor in the universal soil loss equation.

2.1.4. Nutrient losses through erosion

Middleton *et al.* (1934) and Rogers (1941) reported that eroded soils are sometimes richer than the original soil in respect of nutrients. Bobko (1943) observed that loss of nutrients by erosion were considerable and in some cases exceeded the annual crop removal. Goel et al. (1968) found that nutrient losses in general were increased on steeper and longer slopes but the concentration of nutrients in the runoff is thereby decreased. Bruke et al. (1974) recorded that losses of P in runoff was low and were associated with heavy rainfall soon after fertilizers were applied. Substantial losses of nitrate nitrogen occurred when heavy rain followed soon after nitrogen was applied in their off growth season. Hanway and Laflen (1974) found that total phosphorus concentration in surface runoff were closely related to sediment concentration and were much higher in surface runoff. Annual losses averaged less than 1 kg/ha soluble inorganic phosphorus concentration in surface runoff were low and were independent of sediment concentration, but were directly related to the available phosphorus in surface soils. Losses of inorganic nitrogen varied from less than 1 to 30 kg/ha/year. Total nutrients discharged in runoff according to Olness et al. (1975) ranged from 2 to 15 kg/ha of nitrogen and 1 to 11.5 kg/ha of phosphorus. Runoff losses of soluble inorganic nitrogen were generally less than quantities received in rainfall. Kissel et al. (1976) reported that during runoff producing storms just after fertilizer application the concentration was lowest in the initial runoff and the highest near the end of the runoff event. Lal (1976a) observed that the maximum annual loss of nitrate nitrogen in runoff was about 15 kg/ha. Lal (1976b) also noted that total loss of nutrient elements in runoff and eroded soil materials was significantly affected by slope, soil and crop management treatments. Timmons and Holt (1977) pointed out that 68-88 per cent of the average annual nutrient losses were transported by runoff. Average nitrogen losses were 0.8 kg and phosphorus losses 0.1 kg/ha/yr. Sonde et al. (1978) reported that ridges across the slope considerably reduced nitrogen losses by 50.9 per cent and 45.8 per cent over flat sowing in tobacco and cotton respectively. Howeler et al. (1979) found that losses of phosphorus are relatively small. He attributed this to the low level of available phosphorus and high fixing capacity of the soil. Viswambharan (1980) recorded the maximum losses of nutrients (107.47 kg N, 28.47 kg P, and 82.479 kg K/ha respectively) from the uncultivated bare fallow plots during the entire cropping season. Among the agro-techniques, maximum losses of nutrients were recorded by tapioca alone in mounds (44.01 kg N, 14.8? kg P and 39.08 kg K/ha respectively) during the entire season.

2.1.5. Mechanical composition of eroded sediment

Middleton et al. (1934) and Rogers (1941) found that eroded soils are richer than the originals soil in respect of colloidal clay. Fine sand being the least resistant to splash action, detachment increases as the fine sand content of soil increases (Ellison, 1947; Bever, 1966). Tamhane et al. (195?) while studying the intensity of rainfall on soil loss and runoff observed that soil lost in runoff is much more clayey as compared to the original soil and that clay and silt were the main constituents carried away by runoff water. Wischmeier et al. (1971) reported that the particle size distribution of the soil is a major determinant of the susceptibility of soils to erosion. Alberts et al. (1977) found that the inter-rill erosion produced aggregates that were considerably smaller than those produced by rill erosion. Only 13 per cent of the inter-rill aggregates were larger than 0.5 mm while 36 per cent of the rill aggregates were larger than 0.5 mm. Solid transport in surface runoff according to Cha a bouni (1977) takes place in such a way that particles of clay and coarse sand are selected preferentially over loam. According to Jozefaciuk et al. (1979) erosion resulted in increased sand content and a decreased colloidal fraction content of soil. The presence of crop canopy according to Meyer et al. (1980) did not affect the sediment size distribution of eroded particles from crop row side slopes. Viswambharan (1980) recorded that under high intensity of rainfall conditions, the content of sand in runoff was found to be higher. Quansah (1981) reported that graded sand and three soils tested were significantly different in their mean weight of soil to be detached and transported. They can be placed in rank order of graded sand, sand, clay and clay loam, with increasing resistance to splash detachment. The amount of material transported is in the order graded sand > clay > sand > clay loams. For each soil there was significant increase in splash detachment and splash transport with increase in rainfall intensity.

2.2. Intercropping as a practice to resist erosion

Mirchandani (1958) reported that blackgram was used as an intercrop in Damodar Valley area to reduce soil loss. In another experiment Jain and Jain (1971) reported the beneficial effects of cowpea as an intercrop with maize in reducing loss of soil, water, nitrogen and phosphorus. In Udaipur groundnut was considered as a soil conserving crop since it provided a good canopy cover in short periods. Laxminarayana and Reddy (1972) reported that groundnut helped to cover the soil and prevent runoff in slopes when grown with shallow rooted and low water requiring crops like Jowar or Bajra. Bhola *et al.* (1975) suggested that maize on the contour should be intercropped with a legume to reduce runoff and soil loss. Viswambharan (1980) recorded that groundnut intercropping as well as tapioca planting in ridges across the slope were effective in reducing soil and water loss.

2.3. Intercropping in Cassava

The practice of inter-cropping in tapioca has been reported from almost all tapioca growing centres in the world. Singh *et al.* (1969) reported that the tuber yield of tapioca was not much affected by growing legumes like groundnut and cowpea as intercrops, but on the other hand gave an additional income. Katyal and Dutta (1976) found that growing of groundnut and cowpea in between tapioca rows did not affect the normal yield of the main crop and was found to be very profitable. Ramakrishna Bhat (1978) concluded that tuber and top yield of tapioca were not affected by growing groundnut, cowpea, blackgram and greengram as intercrops.

Both harmful and beneficial effects of intercropping have been reported by several workers. In a trial Singh and Mandal (1970) revealed that horsegram and sesamum as intercrops reduced the tuber yield of cassava. It has been noted in cases when intercropped with maize and soybean, the yield of cassava was 50 per cent less than those of the monocrop (CIAT, 1971). Deeratikasikorn and Wickham (1977) noted a decrease in cassava yield when oversown with stylo. A comparison of cassava intercropping pattern to sole crop of cassava revealed a decrease in total dry matter production of root, a reduction of 3.5 t/ha when intercropped with maize (Zandstra, 1978). Sheela (1981) observed that tuber yield, yield attributes and total dry matter production of tapioca were reduced by intercropping with cowpea and groundnut. Viswambharan (1980) recorded that growth and yield of tapioca were not significantly reduced by groundnut intercropping.

Contrary to the above reports, Singh and Mandal (1968) noted that groundnut as intercrop in Cassava did not substantially affect the growth and yield of the latter, but on the contrary provided additional gross income of Rs.1,150/ha. From the income point of view groundnut was found to be a more profitable intercrop for cassava (Singh et al. (196[illegible]). Intercropping cassava with stylosanthes increased the tuber yield of cassava but native grasses decreased yield of tuber (Nitis, 1978). Nambiar et al. (197[illegible]) noted an increase in cassava yield when short duration crops were raised in the inter-space in cassava during early stages, irrespective of the intercrops.

Materials and Methods

MATERIALS AND METHODS

The present investigation was undertaken with a view to study the effects of various agro-techniques on soil loss, surface runoff and soil moisture storage in hill slopes.

3.1. Materials

3.1.1. Location

The experiment was conducted at the Instructional Farm attached to the College of Horticulture, Vellanikkara which is situated at 10° 32'N latitude and 76° 10' longitude at an altitude of 22.25 metres.

3.1.1.1. Soil

The soil of the experimental area was deep, well drained, moderately acidic, sandy clay loam of lateritic origin and fairly rich in organic matter. The area having a uniform slope of 15.32 per cent facing north-east was selected for laying out the experiment. The soil had the following physico-chemical properties.

Percentage of coarse sand	-	29.35
Percentage of fine sand	-	21.32
Percentage of silt	-	14.56
Percentage of clay	-	30.14
Loss on ignition	-	4.63%
Percentage of total nitrogen in the top soil (0-20 cm)	-	0.103 (Micro-kjeldahl method)

Percentage of total P_2O_5 in the top soil (0-20 cm).	-	0.0916	(Vanado-molybdo phosphoric yellow colour method)
Percentage of total K_2O in the top soil (0-20 cm).	-	0.1350	(Flame photometrically)
Percentage of available P_2O_5 in the top soil (0-20 cm)	-	0.0031	(Bray's method)
Percentage of available K_2O in the top soil (0-20 cm)	-	0.0120	(Neutral normal ammonium acetate)
pH	-	5.8	(1:2 soil solution ratio using glass electrode)

3.1.2. Weather conditions

The meteorological parameters recorded were rainfall, maximum and minimum temperature, relative humidity, sunshine hours and number of rainy days. The average fortnightly values from planting to harvest were worked out and presented in Appendix I and illustration given in Fig.1.

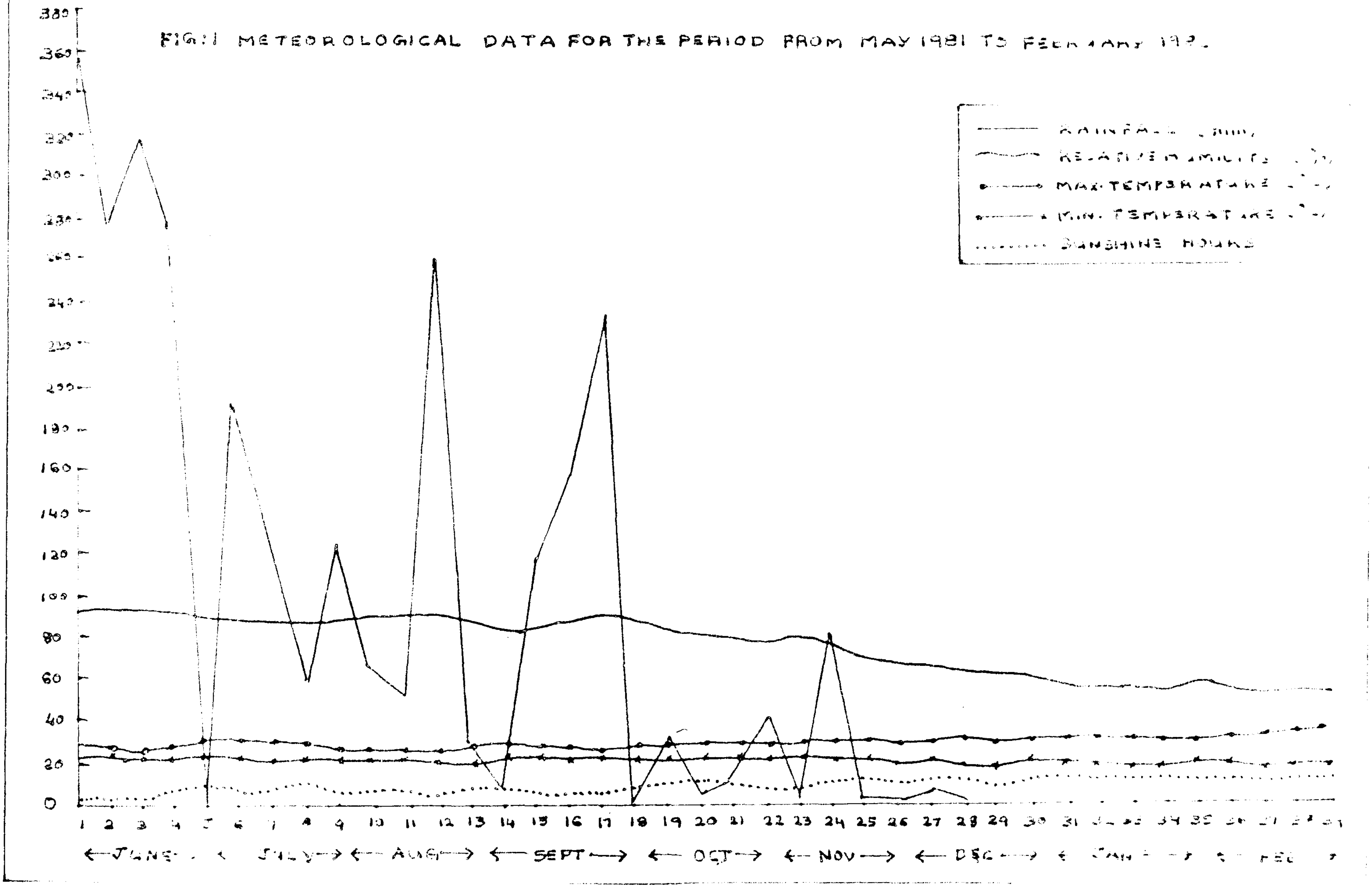
3.1.3. Season

The experiment was conducted during the period from 15th June 1981 to 17th February 1982.

3.1.4. Cropping history

The experimental area was lying fallow for about one year prior to the start of the present experiment and before

FIG: I METEOROLOGICAL DATA FOR THE PERIOD FROM MAY 1981 TO FEBRUARY 1982.



that a similar experiment with groundnut as intercrop was conducted in the same plot.

3.1.5. Varieties

Tapioca variety H_4 and cowpea cultivar Kanakamani were selected for the trial.

3.1.6. Fertilizers

Ammonium sulphate (20% N), Superphosphate (16% P_2O_5) and Muriate of potash (60% K_2O) were used to supply the required quantities of nitrogen, phosphorus and potassium respectively. Calcium oxide was used as the liming material.

3.2. Methods

The experiment was conducted in uniform field run off plots having a length of 24.3 metres and width of 2.7 metres. The plot edging was done with embedded polythene sheets. The runoff from each plot was collected directly into waterproof polyethylene lined earthern tanks having a length of 2.7 metres, width of 1 metre and depth of 1.3 metres.

3.2.1. Treatments

There were seven treatments consisting of six cultivation methods and one uncultivated control.

T1 - Tapioca alone on ridges along the slope,

T2 - Uncultivated bare fallow,

T3 - Tapioca on ridges along the slope with cowpea as intercrop,

T4 - Tapioca on ridges across the slope with cowpea as intercrop, T5 - Tapioca alone on mounds,

T6 - Tapioca alone on ridges across the slope,

T7 - Tapioca on mounds with cowpea as intercrop.

3.2.2. Lay out of the experiment

The experiment was laid out in Randomised Complete Block Design with three replications. The lay out plan is shown in Fig.2.

3.2.3. Runoff and soil loss collection

After each rain the runoff collected in the tanks were recorded. In order to determine the soil loss the runoff water was stirred thoroughly and a sample of 500 ml was quickly taken for sediment calculation (Balasubramanian, 1979). Sufficient amounts of runoff were collected to obtain enough soil samples for chemical analysis. Gravimetric method was followed to measure the sediment present. Runoff was calculated in terms of millimetres of rainfall and soil loss in terms of Kilograms per hectare.

3.2.4. Analysis of rainfall

Since a simple expression of relationship between rainfall and erosion was desired, only those characters which can be taken directly from a recording rain guage chart were considered. For this purpose an automatic recording rain-guage was installed at the centre of the experimental site. The rain guage chart observations were checked with an 122 mm ordinary rain guage. The recording rain guage chart was used

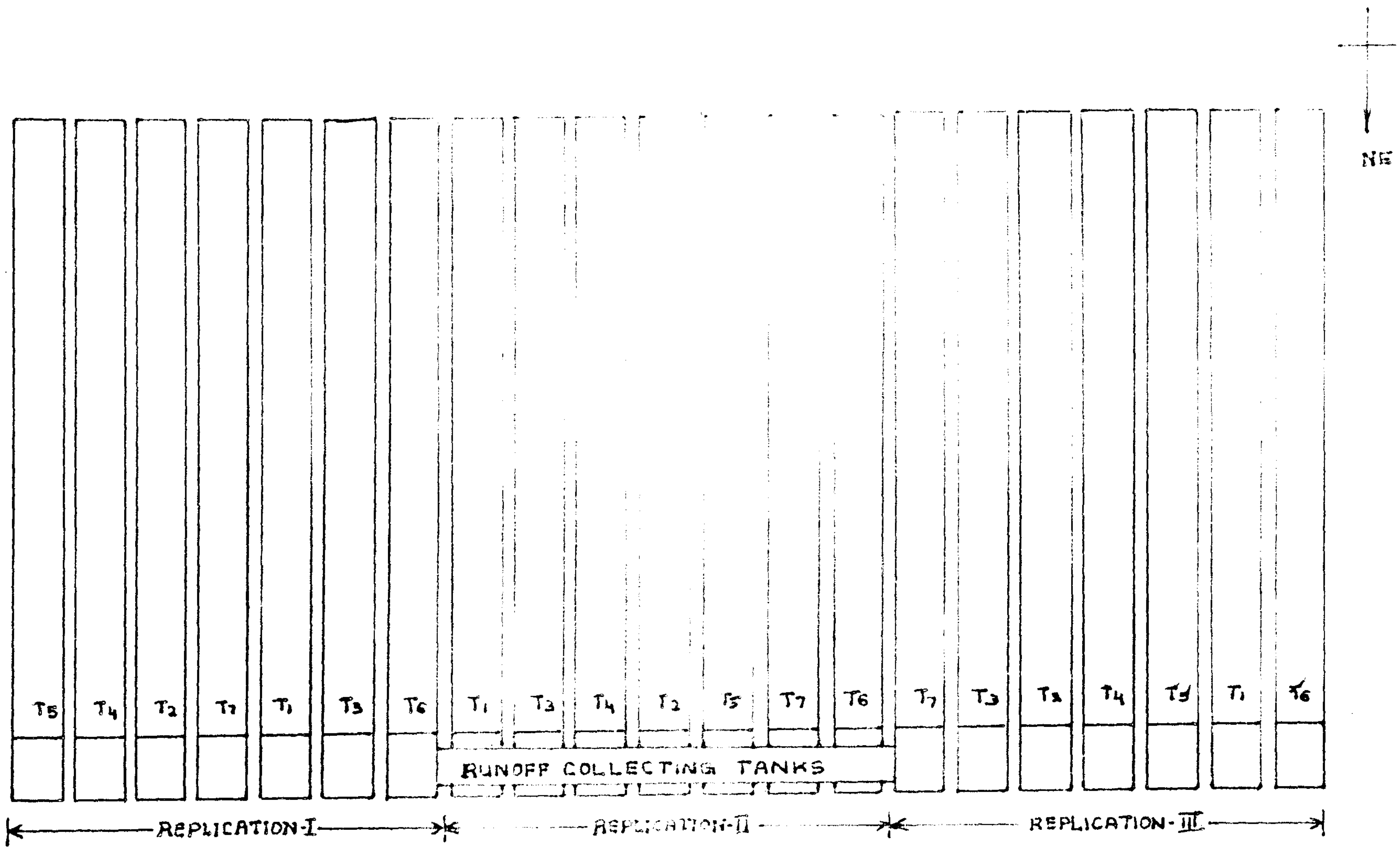


FIG:2 LAYOUT PLAN OF PLOTS AND RUNOFF COLLECTING TANKS

DESIGN: RANDOMIZED COMPLETE BLOCK

for studying the following specific characters and factors of rainfall.

1. Amount of rainfall in centimetres,
2. Maximum rainfall intensities in cm/hr for 5, 15, 30 or 60 minutes intervals,
3. The total kinetic energy of raindrops was calculated as per the equation given by Wischmeier and Smith (1958). According to them the kinetic energy is given by

   $Ek = 210.3 + 89 \log I$ where,

   Ek is the kinetic energy in metre tonnes per ha cm of rainfall and I is the rainfall intensity in cm/hr.
4. The kinetic energy thus obtained was multiplied by the maximum intensity recorded during 5, 15, 30 or 60 minutes intervals. The erosion indices thus obtained were termed EI_5, EI_{15}, EI_{30} and EI_{60} respectively. Where E is the kinetic energy and I_5, I_{15}, I_{30} and I_{60} were the rainfall intensities.
5. The cumulative kinetic energy of storms with intensities more than 2.5 cm/hr. (KE> 1) was recorded (Hudson, 1971).
6. The product of total amount of rainfall and the peak storm intensity (AIm was calculated for each storm (Lal, 1976).

3.2.5. Surface and subsoil moisture storages

The soil moisture stored at depths of (0-15 cm), (15-30 cm), and (30-45 cm) of the soil profile was measured at fortnightly intervals using gravimetric method. The moisture content measured was expressed in percentage.

3.2.6. Field culture

3.2.6.1. Preparation of main field

The field was tilled (except the control plot) with a spade and ridges and mounds were taken as per the treatments. Polyethylene lined earthern tanks were constructed at the lower end of each plot for the collection of runoff.

3.2.6.2. Liming and fertilizer application

Liming and fertilizer applications were done as per the package of practices recommendations of Kerala Agricultural University.

3.2.6.3. Planting and spacing

Tapioca and cowpea were planted on 15-6-1981. The spacing used for tapioca was 90 cm x 90 cm and that for cowpea was 30 cm x 30 cm. In the ridges cowpea was planted on both sides of the ridges and in mounds it was planted around it. The population of cowpea was maintained constant in all plots having cowpea as intercrop.

3.2.6.4. Plant protection

Two prophylactic sprays of Ekalux-25 were given.

3.2.6.5. Weeding and earthing up

Hand weeding and earthing up were done 31 days after planting.

3.2.6.6. Harvesting

Cowpea was harvested on 16-8-1981 when it was 60 days old. Tapioca was harvested on 17-2-1982 when it was 247 days old.

3.2.7. Observations

The following observations were recorded for tapioca and cowpea.

3.2.7.1. Observations for tapioca

Biometric observations of tapioca were recorded from a sample of 10 plants from each plot selected and tagged at random and their averages determined for each character. Subsequent observations were taken from the same plants at monthly intervals.

a) Total number of leaves per plant,

The total number of leaves produced by the plant at the time of observations was recorded.

b) Number of functional leaves per plant.

The number of green leaves present in each plant at the time of observation was recorded.

c) Height of plant.

The height of plant from the bottom to the terminal bud was recorded.

d) Canopy diameter of the plant.

The canopy diameter of the plant was determined as the average of the two measurements taken north-south and east-west.

e) Yield of tapioca tubers.

The fresh weight of tubers was recorded.

f) Yield of tops.

The fresh weight of tops was recorded.

g) Harvest index.

Samples of tubers and tops were dried for determining the dry matter percentage and this was used for finding out the harvest index. The harvest index was calculated using the following equation.

$$\text{Harvest index } (\%) = \frac{\text{Dry weight of tuber}}{\text{Dry weight of tops + tuber}} \times 100$$

3.2.7.2. <u>Observations of cowpea</u>

Biometric observations of cowpea were taken from 25 plants selected and tagged at random from each plot and the averages were determined. Subsequent observations were taken from the same plants at 20 days intervals. The following observations were taken.

a) Height of plants.

The height of the plants from the scar of the first cotyledonous leaves to the tip of the growing point was taken.

b) Number of functional leaves per plant.

The total number of green leaves present at the time of observation was noted.

c) Number of pods per plant.

The number of pods present in each plant was recorded and the average worked out.

d) Grain yield.

Yield of grain obtained from each plot was recorded after rejecting the yield of border plants and expressed in kg/ha adjusted to 12 per cent moisture.

e) Bhusa yield.

The yield of bhusa from each plot was recorded as above after rejecting outer rows. The weight was expressed in kg/ha.

f) Harvest index.

The harvest index was calculated using the following equation.

$$\text{Harvest index (\%)} = \frac{\text{Dry weight of grains}}{\text{Dry weight of grains + bhusa}} \times 100$$

3.2.8. Chemical analysis

The total nitrogen, total phosphorus and total potassium contents of runoff sediment were determined by methods given by Jackson (1958). Total nitrogen content was determined by macrokjeldahl's method. The phosphorus content of runoff sediment was determined colorimetrically using Vanadomolybdophosphoric yellow colour method in nitric acid system. The Perkin-Elmer-UV-Vis microcomputer controlled spectrophotometer was used for reading the colour intensity. The potassium was determined flame photometrically using Corning-Eel flame photometer.

The available phosphorus through runoff was determined using the procedure suggested by Jackson (1958). The sum of water soluble and pH3 extractable phosphorus was considered as available phosphorus in runoff.

The available potassium was also determined as per the method suggested by Jackson (1958). The sum of water soluble and neutral normal ammonium acetate extractable potassium was considered as available potassium in runoff.

The pH of the runoff sample was determined using systronics needle type pH meter. The electrical conductance of the runoff was determined using Elico digital conductivity bridge. The water samples were immediately used after collection for determination of pH and conductance.

3.2.9. Mechanical analysis

Mechanical analysis of the runoff sediment was conducted by the pipette method as reported by Piper (1942).

3.2.10. Statistical analysis

The data obtained were subjected to statistical analysis by the analysis of variance technique as suggested by Snedecor and Cochran (1967). Correlations and regressions were found out utilising the data from the control plot for predicting soil loss under varying rainfall conditions.

Results and Discussion

RESULTS AND DISCUSSION

The results and discussion of the present investigation are presented hereunder.

4.1. Runoff and soil loss as related to various rainfall characteristics

The data on runoff and soil loss were collected from uncultivated bare fallow runoff plots of 15.32 per cent slope and size of 24.3 m length and 2.7 m width. Simple correlations and regressions were worked out between runoff/soil loss and various rainfall characteristics such as amount of rainfall, average intensity of rainfall, EI_5 index, EI_{15} index, EI_{30} index, EI_{60} index, total kinetic energy of rainfall and AIm index. The data are presented in Table 1 and Fig.3 & 4.

The relationships were linear and could be represented by the equation y = a + bx. Where 'a' the intercept and 'b' slope of the line. With regard to runoff, maximum correlation was obtained with total rainfall (r = 0.5567) whish was closely followed by average intensity (r = 0.5566. Both were significant at 0.05 level. The correlation coefficients of runoff with all other rainfall parameters were not significant. The prediction equations were also worked out under experimental conditions of length and gradient factors and are presented in Table 1.

Table 1. Relationship between rainfall characteristics and erosion

Sl. No.	Relationship between: Independent variable (x)	Relationship between: Dependant variable (y)	Number of observations (n)	Coefficient of correlation (r)	Regression equation
1	2	3	4	5	6
1.	Amount of rainfall (mm)	Runoff (mm)	16	0.5567*	$y = 0.119^{*}x + 8.873$ ($r^2 = 0.3699$)
2.	-do-	Soil loss (kg/ha)	16	0.5274*	$y = 64.893^{*}x + 1662.154$ ($r^2 = 0.2781$)
3.	Average intensity (mm/hr)	Runoff (mm)	16	0.5565*	$y = 2.853^{*}x + 8.8733$ ($r^2 = 0.3095$)
4.	-do-	Soil loss (kg/ha)	16	0.5268*	$y = 1550.116^{*}x + 1696.253$ ($r^2 = 0.2775$)
5.	EI_5 index (metric units)	Runoff (mm)	16	0.3389	
6.	-do-	Soil loss (kg/ha)	16	0.2166	
7.	EI_{15} index (metric units)	Runoff (mm)	16	0.3905	
8.	-do-	Soil loss (kg/ha)	16	0.3637	

1. (Contd.)

1	2	3	4	5	6
9.	EI_{30} index (metric units)	Runoff (mm)	16	0.3781	
10.	-do-	Soil loss (kg/ha)	16	0.4192	
11.	EI_{60} index (metric units)	Runoff (mm)	16	0.3528	
12.	-do-	Soil loss (kg/ha)	16	0.2344	
13.	Total Kinetic Energy of rainfall (metric tonnes/ha)	Runoff (mm)	16	0.2796	
14.	-do-	Soil loss (kg/ha)	16	0.1407	
15.	AIm (units)	Runoff (mm)	16	0.0381	
16.	-do-	Soil loss (kg/ha)	16	0.3618	

* Significant at 5 per cent level.

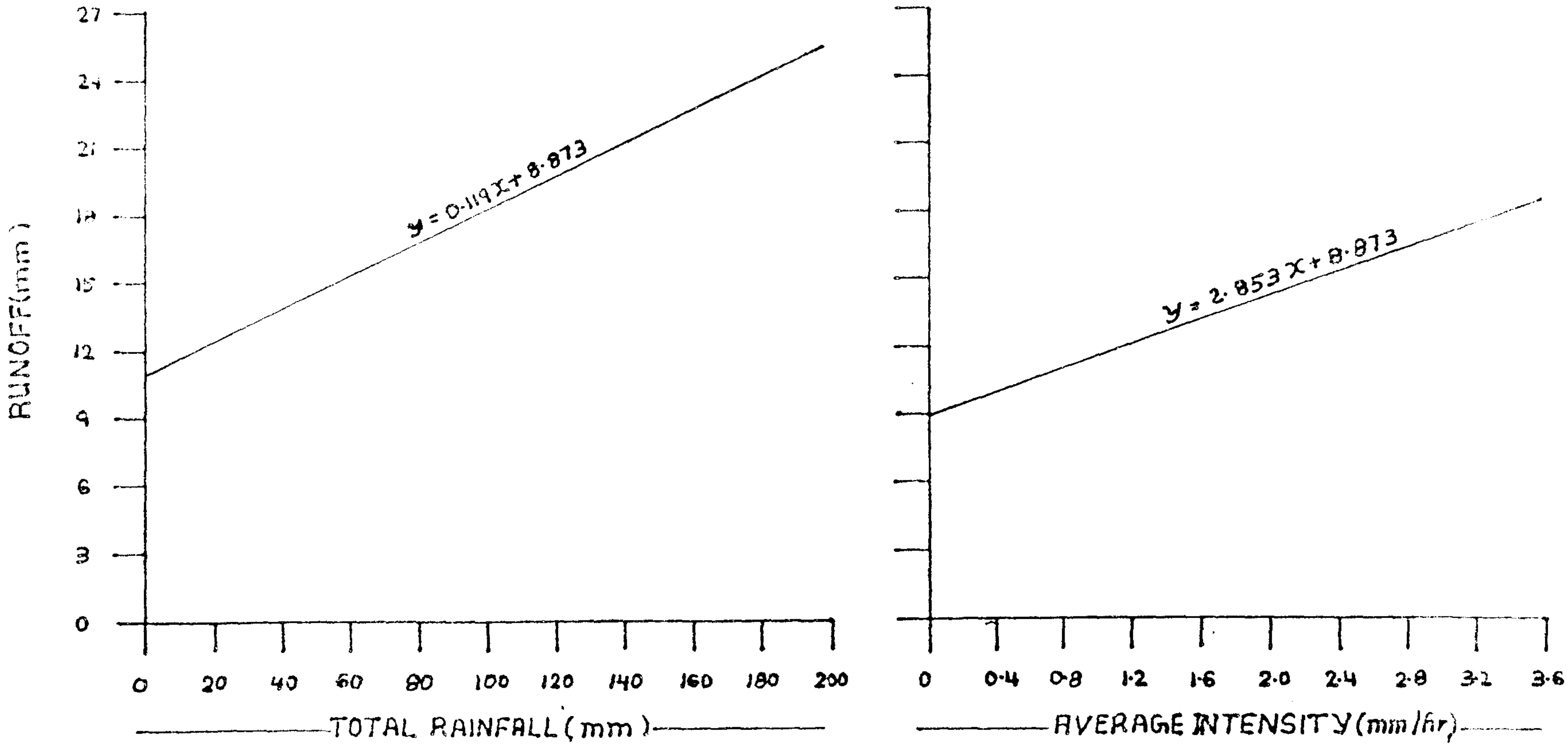


FIG: 3 RELATIONSHIP OF RUNOFF WITH TOTAL RAINFALL AND AVERAGE INTENSITY (SLOPE = 15.32%)

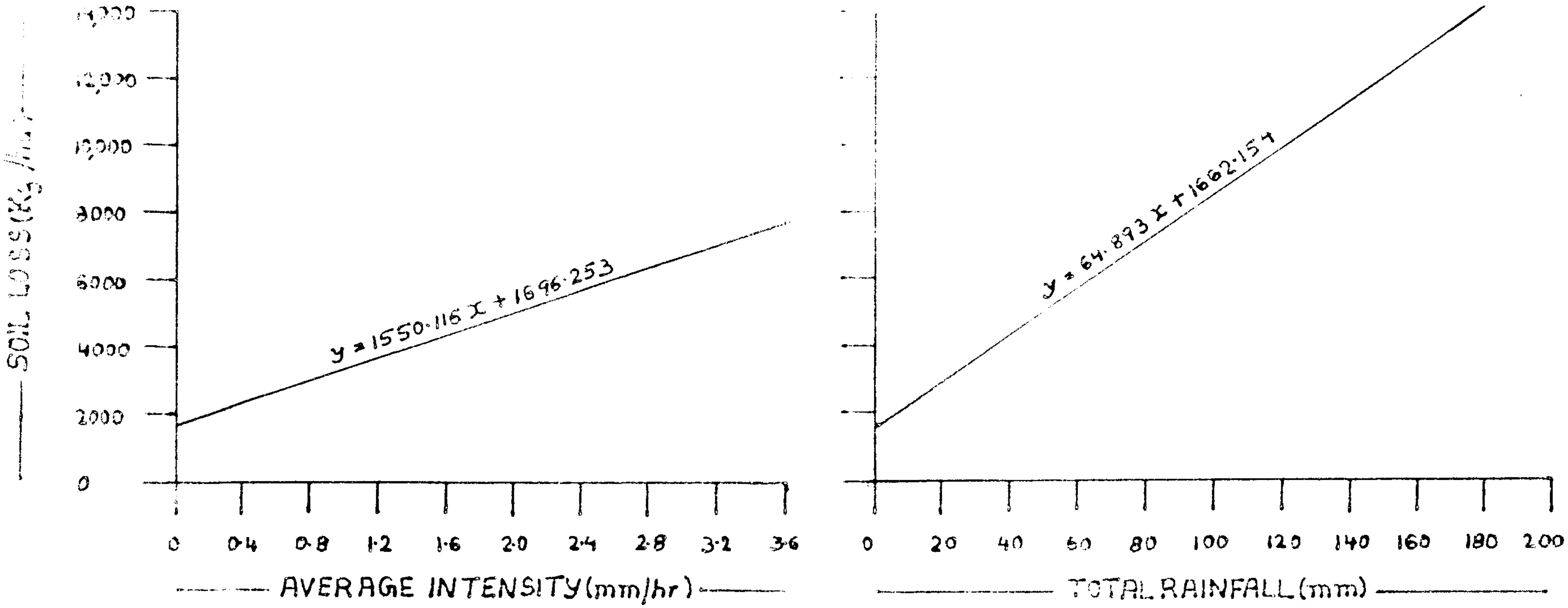


FIG. 4 RELATIONSHIP OF SOIL LOSS WITH AVERAGE INTENSITY AND TOTAL RAINFALL
(SLOPE = 15.32 %)

In the case of soil loss significant correlation was obtained with total rainfall (r = 0.5274) which was closely followed by average intensity (r = 0.5268) both of which were significant at 0.05 level. However, as in the case of runoff the correlation coefficient of soil loss with other rainfall characteristics were not found significant. The prediction equation of soil loss are also presented in Table 1.

Viswambharan (1980) has found significant correlation between both runoff and soil loss with all rainfall parameters except average intensity during North East Monsoon period. The present study was however conducted during South West Monsoon period. The discrepancy in the results may be probably due to the difference in the rainfall characteristics of the monsoons.

4.2. Runoff loss as influenced by different treatments

Runoff observed in different treatments during the occurrence of different rainfall are presented in Table 2. The total runoff observed are given in Table 4 and Fig.5.

From the Table 2 it is clear that maximum runoff was observed in T3 until the intercrop was established. After the establishment of the intercrop, till it is finally removed from the field, maximum runoff was observed in plots having ridges along the slope without intercrop. Generally runoff in plots having ridges along the slope and uncultivated bare

Table 2. Surface runoff* as affected by different treatments and dates of rainfall (10^{-3} mm)

Dates of observations	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	27983 (4.4468)	27091 (4.4[illegible]54)	30726 (4.4875)	1[illegible]162 (4.085)	22679 (4.3556)	32601 (4.513[illegible])	7910 (3.8981)	32967 (4.5180)
T2	23319 (4.3677)	20347 (4.3085)	23776 (4.3761)	8275 (3.9177)	13671 (4.1358)	1638[illegible] (4.2644)	8321 (3.9201)	24233 (4.3844)
T3	30040 (4.4776)	29492 (4.4677)	30389 (4.4[illegible]55)	19574 (4.0994)	22496 (4.3521)	26428 (4.42[illegible]0)	6584 (3.8184)	29309 (4.4670)
T4	4618 (3.6644)	8870 (3.9477)	8733 (3.9411)	2240 (3.3502)	4115 (3.6143)	7544 (3.8776)	868 (2.9385)	9510 (3.9981)
T5	24737 (4.3933)	23456 (4.3702)	24416 (4.3876)	9510 (3.9781)	17[illegible]1[illegible] (4.[illegible]433)	23319 (4.3677)	5989 (3.7773)	27524 (4.4397)
T6	6767 (3.8303)	9099 (3.9589)	11796 (4.0717)	3749 (3.5739)	4025 (3.6045)	12116 (4.0833)	1462 (3.1640)	14265 (4.1542)
T7	25056 (4.398[illegible])	24874 (4.3957)	27708 (4.4426)	10059 (4.0026)	16826 (4.2259)	21993 (4.3[illegible])	5212 (3.7170)	24096 (4.3819)
SEm ±	0.0[illegible]8	0.016	0.058	0.038	0.079	0.10[illegible]	0.116	0.038
C.D.(0.05)	0.0886	0.0526	0.1784	0.1136	0.[illegible]451	0.3173	0.3606	0.1190

(Contd..)

Table 2. (Contd.)

Dates of observations	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	4846 (3.6853)	28806 (4.4594)	2468 (3.3923)	11956 (4.0775)	16232 (4.2103)	22816 (4.3582)	11705 (4.0683)	16049 (4.2054)
T2	3977 (3.5995)	24051 (4.3811)	1874 (3.2727)	9144 (3.9611)	12939 (4.1119)	20393 (4.3094)	10653 (4.0274)	13671 (4.1358)
T3	3932 (3.5946)	25194 (4.4012)	1736 (3.3395)	8001 (3.9031)	8733 (3.9411)	12482 (4.0962)	7224 (3.8587)	26474 (4.4228)
T4	1691 (3.2281)	10562 (4.0237)	640 (2.8061)	3497 (3.5436)	3932 (3.5946)	5212 (3.7170)	2514 (3.4003)	7041 (3.8476)
T5	3612 (3.5577)	24279 (4.3852)	1553 (3.1911)	8344 (3.9213)	10333 (4.0142)	15317 (4.1851)	8093 (3.9081)	11019 (4.0421)
T6	1920 (3.2833)	13580 (4.1328)	1234 (3.0913)	4961 (3.6955)	4983 (3.6974)	6949 (3.8419)	3200 (3.5051)	4846 (3.6853)
T7	3246 (3.5113)	23045 (4.3625)	1508 (3.1784)	6950 (3.8419)	6858 (3.8361)	11568 (4.0632)	6218 (3.7936)	19250 (4.2844)
SEm ±	0.132	0.109	0.053	0.022	0.053	0.035	0.035	0.057
C.D.(0.05)	0.4070	0.3385	0.1656	0.0689	0.1658	0.1086	0.1082	0.1769

* Figures in brackets are logarithms.

fallow plots were not statistically significant. Observations during the first couple of weeks showed that runoff from plots having ridges along the slope both with and without intercrop, and plots with mounds with and without intercrop were on par. The effect of the intercrop was however evident about one month after the establishment of the intercrop. After one month, when the intercrop had attained appreciable growth, runoff from plots with ridges along the slope was significantly higher than the runoff from plots with ridges along the slope with intercrop and plots with mounds accompanied by the intercrop. During the same period runoff from plots with ridges along the slope and plots with mounds were statistically significant than the corresponding intercropped plots.

The minimum runoff was observed in plots with ridges across the slope except for the observation taken immediately after the removal of the intercrop. It is interesting to note that throughout the observation period runoff from plots with ridges across the slope both with and without intercrop were statistically on par. From this it is clear that total runoff from plots having ridges across the slope either intercropped or alone reduced the extent of runoff. The plots with ridges along the slope intercropped or free and plots with mounds intercropped or free showed higher runoff of water on par with plots kept fallow.

Maximum percentage of runoff from a single rainfall event occurred in T1 plots (85.67%) under a rainfall of 33.6 mm and the minimum of 31.34 per cent was observed in T4 plots on the same day. Minimum percentage of runoff in a single event (3.33%) was recorded in T4 under a rainfall of 117.6 mm and the minimum runoff the 13.79 per cent was observed in T1 plots on the same day. Lower runoff inspite of the heavy rainfall can be attributed to a preceding period of dry spell which has resulted in higher infiltration into the soil (vide Appendix II).

On examination of total rainfall during the period it was observed that maximum runoff (310.679 mm) was noted in T1 and was significantly higher than all the other treatments, which corresponds to 38.33 per cent of the total rainfall. The total runoff recorded in plots with ridges along the slope with and without intercrop, plots with mounds with and without intercrop and fallow plots were not statistically significant. The total runoff from plots having ridges along the slope with intercrop was significantly lower than the corresponding plot without intercrop. The total runoff from plots having mounds with and without intercrops did not show statistical significance. Minimum total runoff (81.501 mm) which corresponds to 10.18 per cent of the total rainfall was noted in plots having ridges across the slope with intercrop, and was significantly lower than the corresponding treatment without intercrop.

The reason for lower runoff in the intercropped fields may be attributed to the interception of rainfall by vegetative cover and thereby resisting the puddling action of raindrops, root effect in increasing granulation and porosity, biological activities associated with vegetative growth and their influence on soil porosity and transportation of water leading to subsequent drying out of the soil. According to Baver (1961) all the above factors increase infiltration and reduce runoff. Lang (1979) also observed that ground cover affects both the occurrence and magnitude of runoff and increased amounts of ground cover resulted in curvilinear decrease in runoff. Viswambharan (1980) in his experiments found that intercropping tapioca on mounds and in ridges across the slope with groundnut as intercrop significantly reduced runoff.

Taking ridges across the slope was effective in reducing runoff. The runoff collected were in between the ridges and the ridges prevented it from running away. It also prevented the buildup of runoff. Williamson and Kingsley (1974) had similar findings wherein they observed that cultivation across the slope decreased runoff and soil loss. Viswambharan (1980) also observed that ridges across the slope significantly reduced the volume of runoff and soil loss.

4.3. <u>Soil loss as influenced by different treatments</u>

The soil loss observed in different treatments under different rainfall during the period of investigation are presented in Table 3 and the total soil loss observed during the period of observation are given in Table 4 and Fig.6. In T1 (tapioca alone in ridges along the slope) the soil loss ranged from 725.967 kg/ha to 13544.96 kg/ha; in T2 (uncultivated bare fallow) from 460.069 kg/ha to 1[illegible]78[illegible].28 kg/ha;

Table 3. Soil loss* (kg/ha) as affected by different treatments and dates of rainfall

Dates of observations	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments**	1	2	3	4	5	6	7	8
T1	10094.902 (4.0041)	13544.968 (4.1317)	11205.154 (4.0494)	2131.127 (3.3268)	8323.031 (3.9202)	10339.787 (4.0145)	1550.045 (3.1903)	8542.281 (3.9315)
T2	9299.73 (3.9684)	12782.283 (4.1066)	8807.107 (3.9448)	1939.633 3.2877)	6451.492 (3.8096)	8125.685 (3.9098)	1755.174 (3.2443)	5135.029 (3.7105)
T3	10110.6014 (4.0047)	13910.1549 (4.1433)	10844.519 (4.0352)	2192.306 (3.3409)	7953.250 (3.9005)	9408.928 (3.9735)	1346.449 (3.1291)	7335.438 (3.8654)
T4	1195.848 (3.0776)	827.765 (2.9179)	551.1975 (2.7413)	257.718 (2.4111)	2115.678 (3.3254)	817.477 (2.9124)	241.347 (2.3826)	351.763 (2.5462)
T5	9295.181 (3.9682)	12324.734 (4.0907)	8457.519 (3.9272)	1917.1139 (3.2826)	6492.924 (3.8124)	8603.704 (3.9346)	1141.312 (3.0574)	7411.590 (3.8699)
T6	1972.707 (3.2950)	1032.154 (3.0137)	725.1082 (2.8604)	654.470 (2.8158)	784.922 (2.8948)	1460.602 (3.1645)	341.037 (2.5328)	557.305 (2.7460)
T7	8328.87 (3.9205)	9555.963 (3.9847)	7724.194 (3.8878)	1131.986 3.0538)	5475.394 (3.7384)	7581.446 (3.8797)	909.629 (2.9588)	4630.696 (3.6656)
SEm ±	0.014	0.039	0.087	0.161	0.154	0.098	0.076	0.071
C.D.(0.05)	0.0459	0.1216	0.2693	0.4976	0.4717	0.3043	0.2365	0.2186

(Contd..)

Table 3. (Contd.)

Dates of observations	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	1088.746 (3.0369)	2015.932 (3.3044)	725.967 (2.8609)	1210.479 (3.0829)	3167.183 (3.5006)	2934.546 (3.4675)	1586.685 (3.2004)	14919.090 (4.1737)
T2	1054.300 (3.0229)	1695.711 (3.2288)	460.069 (2.6628)	1147.486 (3.0597)	3095.701 (3.4907)	2414.659 (3.3828)	1332.512 (3.1246)	12970.516 (4.1129)
T3	846.665 (2.9277)	1856.932 (3.2687)	375.946 (2.5751)	993.389 (2.9971)	1996.889 (3.3003)	1451.752 (3.1618)	1047.853 (3.0203)	20013.714 (4.3013)
T4	357.001 (2.5526)	631.744 (2.8005)	260.065 (2.4150)	662.441 (2.8211)	384.893 (2.5850)	422.210 (2.6456)	272.563 (2.4354)	1620.765 (3.2097)
T5	787.010 (2.8959)	1570.869 (3.1961)	349.923 (2.5439)	1037.275 (3.0158)	2207.975 (3.3439)	1673.211 (3.2235)	1079.814 (3.0333)	8017.5319 (3.9040)
T6	523.393 (2.7188)	798.6713 (2.9020)	257.108 (2.4101)	730.418 (2.8635)	607.891 (2.7838)	558.600 (2.7491)	324.339 (2.5109)	1371.277 (3.1371)
T7	591.318 (2.7718)	1435.007 (3.1568)	307.4713 (2.4878)	888.2136 (2.9485)	1548.231 (3.1898)	1105.1154 (3.0434)	913.006 (2.9605)	18300.865 (4.2624)
SEm ±	0.147	0.101	0.58	0.016	0.183	0.073	0.051	0.130
C.D.(0.05)	0.4558	0.3110	0.1855	0.0520	0.5644	0.2269	0.1603	0.4026

* Figures in brackets are logarithms.

Table 4. Total runoff and soil loss as affected by different treatments during the period of observation

	Runoff (mm)*	Percentage of Total** rainfall	Soil loss (kg/ha)***
T1	310.679 (2.4923)	38.83 (38.54)	933[illegible].2 (4.9700)
T2	235.57 (2.4923)	29.44 (32.85)	78465.24 (4.8946)
T3	248.024 (2.3944)	31.003 (33.83)	91684.2 (4.9622)
T4	81.501 (1.9111)	10.18 (18.6)	10990.29 (4.0410)
T5	236.27 (2.3734)	29.53 (32.91)	71841.73 (4.8563)
T6	104.47 (2.0189)	13.05 (21.17)	12699.84 (4.1037)
T7	234.37 (2.3699)	29.29 (32.76)	70428.06 (4.8477)
SEm ±	0.029	1.259	0.028
C.D.(0.05)	0.0907	3.8815	0.0889

* Figures in brackets show logarithms of runoff in mm.
** Figures in brackets are angles.
*** Figures in brackets show logarithms of soil loss in kg/ha.

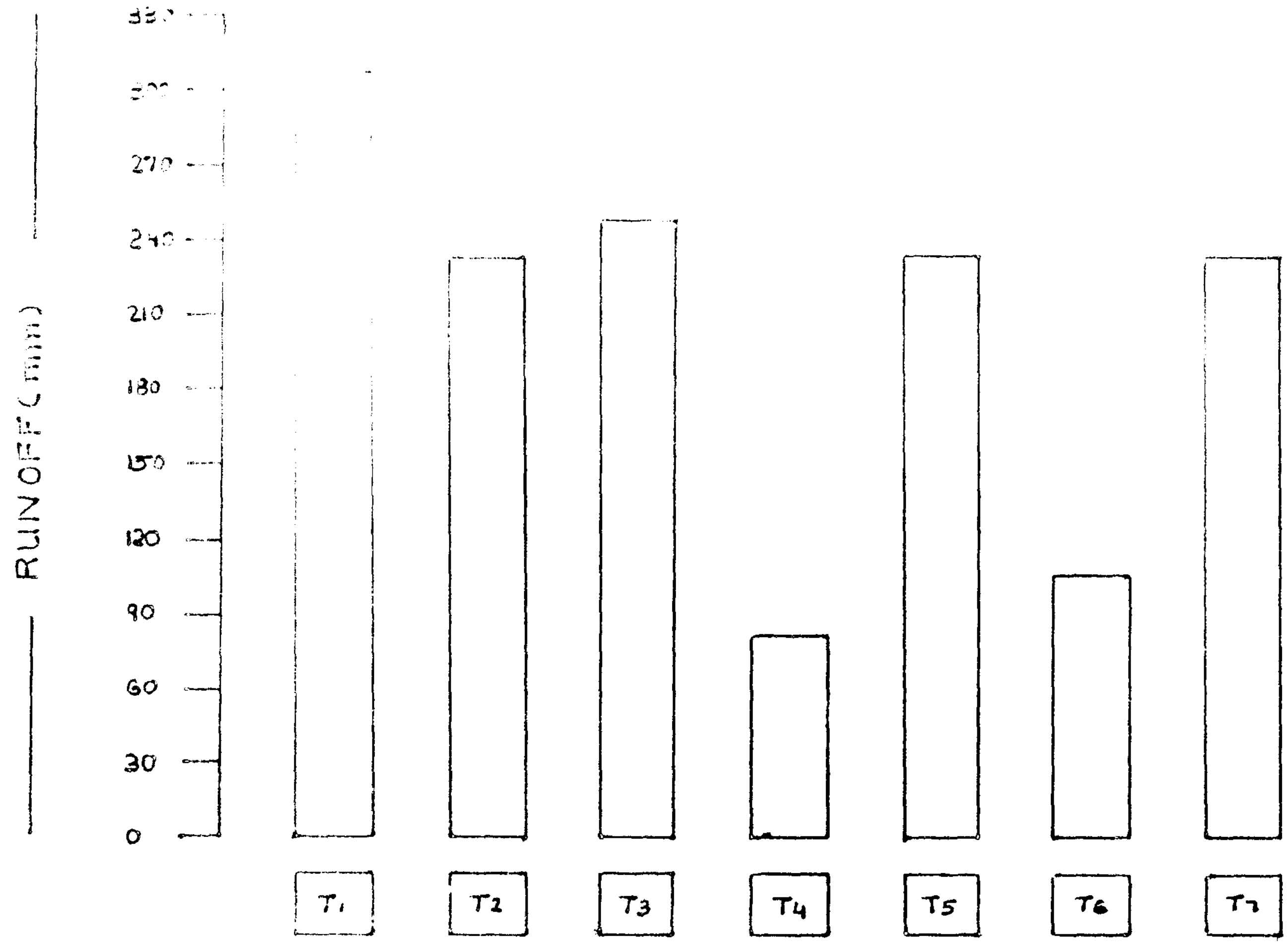


FIG.5 TOTAL RUNOFF AS AFFECTED BY DIFFERENT TREATMENTS DURING THE PERIOD OF OBSERVATION

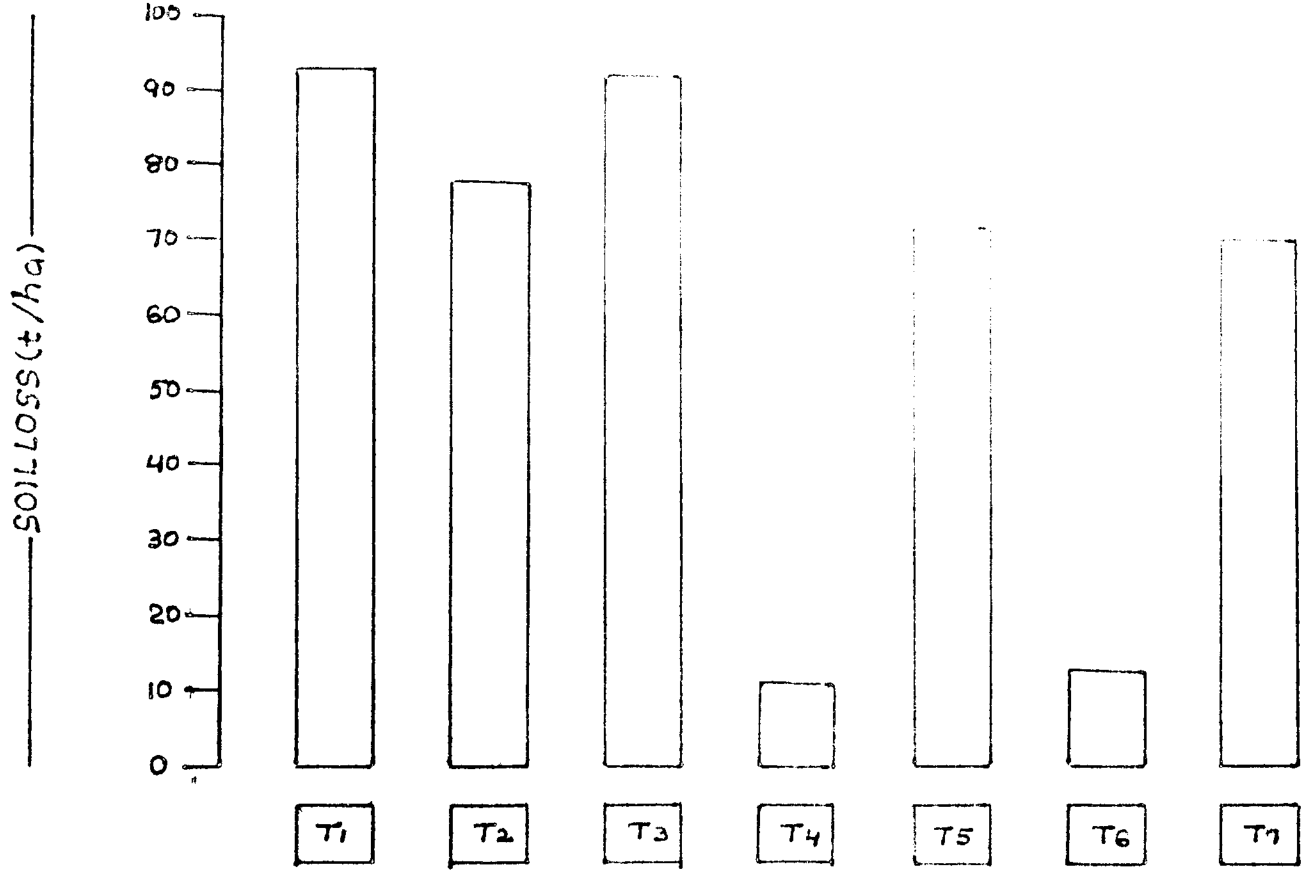


FIG:6 TOTAL SOIL LOSS AS AFFECTED BY DIFFERENT TREATMENTS DURING THE PERIOD OF OBSERVATION in T3 (tapioca in ridges along the slope with intercrop) from 375.946 kg/ha to 10844.519 kg/ha; in T4 (Tapioca in ridges across the slope with intercrop) from 260.06 kg/ha to 1195.848 kg/ha; in T5 (Tapioca alone on mounds) 349.923 kg/ha to 12324.73 kg/ha; in T6 (Tapioca alone on ridges across the slope from 257.108 kg/ha to 1972.70 kg/ha and in T7 (Tapioca on mounds with cowpea as intercrop) from 307.47 kg/ha to 9555.063 kg/ha. It is seen that maximum soil loss occurred in plots with tapioca on ridges along the slope without intercrop. This can be attributed to the smooth flow of water through the channel formed in between the ridges which favoured excessive detachment and transportation of soil materials. The loss of soil from bare fallow plots was found to be on par with plots with ridges along the slope without intercrop. This can be attributed to the direct effect of raindrop splashes. This is in agreement with the findings of Free (1952) who observed that splash losses from elevated pans of bare soil were 50 to 90 times the runoff losses.

The total soil loss during the period of observation was highest in plots with tapioca alone in ridges along the slope and this was on par with plots with tapioca on ridges along the slope intercropped with cowpea and bare fallow plots. Minimum total soil loss was observed in T4 which was on par with T6 and was significantly lower than all other treatments. The total soil loss in plots with tapioca on mounds alone and intercropped was on par and was significantly lower than T1 and T3. Heavy soil loss in bare fallow plots can be attributed to the absence of canopy effects, where as in other plots vegetation decreases soil loss as it resists the direct impact of raindrops. This is in agreement with the findings of Ellison (1947) who reported that soil detachment hazard was inversely proportional to the resistance factor of surface covers and mulches in reducing runoff velocity. But inspite of the vegetation effect the soil loss in plots with tapioca in ridges along the slope with and without intercrop was high. As explained earlier the uninterrupted flow of runoff water in the intervening channels would have contributed to this heavy soil loss. Between intercropped and non-intercropped plots with tapioca planted either on ridges along the slope, across the slope and on mounds, higher values of total soil loss were observed in non-intercropped plots. This clearly indicates the role of vegetative cover in resisting soil erosion.

Soon after the commencement of the experiment soil loss observed in treatment T1 (Tapioca in ridges along the slope without intercrop) was maximum and this was on par with treatments T2, T3 and T5, where as it was significantly higher than soil loss in T4 and T6. Generally soil loss in T1 and T5 were not statistically significant. After about one month, when the intercrop cowpea had attained luxuriant growth, the soil loss was comparatively lower in the intercropped plots. During the same period soil loss in T1 was significantly higher than that in T3, T4, T6 and T7. Generally soil loss in T3 was significantly lower than in T1. Comparing soil loss in T5 and T7, generally soil loss in T7 was lower than T5, but was not statistically significant. The soil loss in treatments T4 and T6 were comparable being not statistically significant. The reasons for the lower soil loss in intercropped fields were discussed earlier.

4.4. Mechanical composition of runoff sediment

Mechanical composition of runoff sediment was determined for different treatments and periods of observation and the data are given in Table 5. The mechanical composition of sediment varied only slightly between different treatments. But the runoff during high intensity rains contained more sand in the control plots (T2) as well as in plots where tapioca was planted on ridges along the slope without intercrop. The high amount of sand may be attributed to the high sediment carrying capacity of runoff during heavy rains. The data on weighted mean percentage of sand, silt and clay pooled over different rainfalls are presented in Table 8. Maximum sand content (59.9%) was registered by T1 (Tapioca in ridges along the slope) followed by T2 (uncultivated bare fallow). Minimum sand content (44.91%) was registered by T4 (Tapioca in ridges across the slope with intercrop). As explained earlier the high content of sand in T1 and T2 may be due to the high runoff observed resulting in high sediment carrying capacity.

Table 5. Mechanical composition and nutrient losses through runoff sediment as affected by different treatments and dates of rainfall

Dates of observation	Treatment No.	Mechanical composition of runoff sediment			Loss on ignition	Nutrient content of runoff sediment			Total N loss kg/ha	Total P loss kg/ha	Total K loss kg/ha
		Sand %	Silt %	Clay %		Total %	Total %	Total %			
1	2	3	4	5	6	7	8	9	10	11	12
16-6-81	T1	60.58	7.55	31.62	4.20	0.1420	0.0560	0.1213	14.33	3.44	12.24
	T2	64.25	8.75	26.25	4.10	0.1525	0.0339	0.1525	14.18	5.65	14.18
	T3	59.35	10.58	29.97	4.70	0.1215	0.0351	0.1236	12.28	3.54	12.49
	T4	45.55	12.60	37.85	4.40	0.1362	0.0382	0.1528	1.62	0.45	1.82
	T5	53.35	11.35	32.20	4.50	0.1391	0.0388	0.1458	12.92	3.60	13.55
	T6	48.85	12.65	36.75	4.20	0.1351	0.0375	0.1331	2.66	0.73	2.62
	T7	44.25	13.20	38.65	4.40	0.1200	0.0362	0.1260	9.99	3.01	10.49

(Contd..)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
17-6-81	T1	47.58	12.65	33.58	4.[illegible]0	0.1391	0.0388	0.1[illegible]57	18.84	5.25	17.02
	T2	48.30	13.65	34.65	4.00	0.1562	0.0412	0.15[illegible]2	19.[illegible]6	5.26	19.45
	T3	47.54	14.45	35.15	4.[illegible]0	0.1200	0.0312	0.1212	16.6[illegible]	4.39	16.85
	T4	42.62	14.48	37.30	4.10	0.13[illegible]7	0.0376	0.1215	1.15	0.31	1.005
	T5	45.05	14.10	36.55	4.30	0.1312	0.0312	0.1516	16.17	5.84	18.68
	T6	42.65	13.25	37.80	4.60	0.1411	0.0322	0.1321	1.45	0.33	1.36
	T7	49.82	12.05	34.53	4.20	0.1256	0.0212	0.1256	12.00	2.02	12.00
18-6-81	T1	51.62	12.97	32.58	4.10	0.1398	0.0438	0.1562	15.66	4.90	17.50
	T2	55.52	8.55	35.33	4.20	0.1512	0.5558	0.1512	13.31	4.91	13.31
	T3	50.65	11.57	34.58	4.70	0.1216	0.0220	0.1258	13.18	2.38	13.64
	T4	46.05	12.[illegible]7	35.83	4.50	0.1422	0.0451	0.15[illegible]	0.78	0.24	0.83
	T5	52.85	12.55	32.30	4.90	0.1560	0.0563	0.1346	13.19	4.76	11.38
	T6	47.55	1[illegible].40	34.85	4.[illegible]0	0.1465	0.0451	0.1321	1.06	3.48	0.95
	T7	47.35	8.92	38.35	4.10	0.1459	0.0215	0.1251	11.[illegible]6	1.66	9.66

(Contd..)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
19-6-81	T1	40.57	11.65	38.47	4.20	0.1318	0.0362	0.1118	2.80	0.77	2.38
	T2	51.20	11.25	36.45	4.00	0.1322	0.0365	0.1312	2.56	1.09	2.54
	T3	52.45	10.54	35.58	4.30	0.1231	0.0381	0.1216	2.69	0.83	2.66
	T4	44.45	12.20	38.15	4.10	0.1281	0.0425	0.1171	0.35	0.10	0.30
	T5	46.55	9.67	38.88	4.70	0.1464	0.0363	0.1156	2.80	0.69	2.21
	T6	45.45	14.40	33.85	4.30	0.1361	0.0372	0.1262	0.89	0.24	0.82
	T7	48.30	14.85	32.05	4.10	0.1356	0.0469	0.1291	1.53	0.53	1.46
20-6-81	T1	47.55	8.55	39.25	4.80	0.1386	0.0421	0.1215	11.53	3.50	10.11
	T2	47.52	7.55	36.18	4.30	0.1321	0.0368	0.1275	8.52	3.14	10.16
	T3	35.54	7.95	39.95	4.90	0.1218	0.0396	0.1289	9.68	3.14	10.25
	T4	43.55	12.97	37.78	4.20	0.1212	0.0362	0.1186	2.56	0.76	2.50
	T5	43.07	12.15	39.78	4.60	0.1565	0.0465	0.127[illegible]	10.16	3.01	8.25
	T6	40.62	12.40	42.50	5.30	0.1210	0.0356	0.1162	0.94	0.27	0.91
	T7	50.34	9.92	32.63	4.00	0.1250	0.0312	0.1282	6.84	1.70	7.01

(Contd.)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
22-6-81	T1	54.52	8.55	36.25	4.80	0.1418	0.0528	0.1381	14.66	5.45	14.27
	T2	55.52	7.55	32.73	4.10	0.1562	0.0412	0.1562	12.69	3.31	12.69
	T3	54.85	7.95	36.98	4.20	0.1245	0.0250	0.1255	11.71	2.35	11.80
	T4	48.05	12.97	37.48	4.20	0.1472	0.0561	0.1462	1.20	0.45	1.19
	T5	55.65	12.15	30.30	4.50	0.1481	0.0521	0.1322	12.74	4.48	11.37
	T6	44.45	12.40	37.75	4.40	0.1462	0.0455	0.1362	2.13	0.66	1.98
	T7	48.35	9.92	36.83	4.90	0.1210	0.0220	0.1359	9.17	1.66	10.30
23-6-81	T1	50.95	13.64	29.85	4.50	0.1319	0.0462	0.1275	2.04	0.71	1.97
	T2	51.45	15.32	28.83	4.00	0.1216	0.0455	0.1262	2.13	0.60	2.21
	T3	50.45	14.72	30.82	4.20	0.1252	0.0449	0.1256	1.68	0.60	1.69
	T4	45.95	13.20	38.85	4.20	0.1386	0.0398	0.1327	0.33	0.09	0.32
	T5	46.30	10.75	38.25	4.70	0.1275	0.0376	0.1398	1.45	0.42	1.59
	T6	42.20	13.27	39.63	4.90	0.1261	0.0452	0.1375	0.43	0.15	0.46
	T7	42.55	11.88	39.57	4.40	0.1358	0.0449	0.1288	1.23	0.40	1.17

(Contd.)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
24-6-81	T1	59.85	10.54	25.45	3.90	0.145[illegible]	0.0523	0.1292	12.46	4.46	11.03
	T2	63.05	8.[illegible]0	24.[illegible]5	3.80	0.1465	0.0456	0.1585	7.52	2.92	8.15
	T3	60.25	10.55	28.78	3.10	0.1200	0.0570	0.136[illegible]	8.80	2.65	9.99
	T4	44.[illegible]5	12.80	37.85	4.10	0.14[illegible]6	0.0423	0.1[illegible]60	0.52	0.14	0.44
	T5	53.35	11.65	32.50	4.40	0.1375	0.0361	0.1275	12.57	2.67	9.44
	T6	49.[illegible]5	13.10	35.75	4.50	0.1389	0.0325	0.1159	0.77	0.18	0.64
	T7	44.05	14.10	37.55	4.30	0.1398	0.0429	0.1298	6.47	1.98	6.01
25-6-81	T1	4[illegible].25	14.57	35.24	4.70	0.1295	0.0399	0.1119	1.40	0.43	1.21
	T2	48.28	16.12	31.48	4.[illegible]0	0.1288	0.0365	0.146[illegible]	1.35	0.38	1.54
	T3	46.40	15.25	32.45	4.10	0.1376	0.0479	0.1151	1.16	0.49	0.97
	T4	46.55	10.[illegible]0	39.48	4.90	0.1263	0.0452	0.1261	0.45	0.16	0.45
	T5	44.45	14.40	38.85	4.40	0.1355	0.0498	0.1289	1.06	0.39	1.01
	T6	41.[illegible]0	14.8[illegible]	37.28	4.[illegible]0	0.1361	0.039[illegible]	0.115[illegible]	0.71	0.30	0.62
	T7	47.05	10.97	37.48	4.50	0.1368	0.0372	0.1268	0.80	0.21	0.74

(Contd.)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
26-6-81	T1	48.25	12.56	38.58	4.30	0.1351	0.0418	0.1172	2.72	0.84	2.36
	T2	48.15	11.60	35.75	4.20	0.1362	0.0326	0.1251	2.30	0.55	2.11
	T3	47.15	12.50	37.25	4.70	0.1375	0.0465	0.1182	2.55	0.86	2.19
	T4	44.25	12.80	38.85	4.30	0.1459	0.0458	0.1351	0.92	0.28	0.85
	T5	49.75	11.82	37.78	4.50	0.1328	0.0419	0.1246	2.08	0.65	1.95
	T6	43.30	14.80	37.40	4.30	0.1361	0.0518	0.1248	1.08	0.41	0.99
	T7	48.52	13.00	35.28	4.50	0.1258	0.0373	0.1271	1.80	0.53	1.82
27-6-81	T1	40.85	12.67	39.85	4.10	0.1289	0.0378	0.1119	0.95	0.27	0.81
	T2	41.87	11.62	37.55	4.50	0.1272	0.0326	0.1172	0.58	0.14	0.53
	T3	42.15	12.56	38.72	4.40	0.1178	0.0336	0.1256	0.44	0.12	0.47
	T4	41.30	14.15	39.15	4.40	0.1269	0.0353	0.1259	0.33	0.09	0.32
	T5	43.22	13.88	38.30	4.60	0.1372	0.0425	0.1129	0.48	0.14	0.39
	T6	43.45	12.60	38.55	4.40	0.1271	0.0429	0.1135	0.32	0.11	0.29
	T7	45.44	12.88	39.10	4.60	0.1278	0.0351	0.1148	0.31	0.10	0.35

(Contd..)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
28-7-81	T1	48.55	12.62	38.58	4.10	0.1399	0.0390	0.1216	1.69	0.47	1.47
	T2	49.30	14.85	33.47	4.00	0.1372	0.0372	0.1115	1.59	0.42	1.27
	T3	47.55	12.42	39.45	4.20	0.1456	0.0456	0.1212	1.44	0.45	1.20
	T4	44.75	13.80	3[illegible].85	4.50	0.1362	0.0378	0.1216	0.90	0.25	0.80
	T5	48.15	10.87	36.58	4.50	0.1269	0.0499	0.1372	1.31	0.51	1.42
	T6	42.35	13.80	37.40	4.30	0.1258	0.0487	0.1165	0.91	0.35	0.85
	T7	48.52	13.15	38.28	4.30	0.1229	0.0375	0.1189	1.09	0.33	1.05
4-8-81	T1	55.60	8.15	34.72	4.70	0.1512	0.0451	0.136[illegible]	4.78	1.42	4.30
	T2	56.75	7.75	33.83	4.20	0.1468	0.3335	0.1359	4.54	1.03	4.20
	T3	54.85	8.92	32.[illegible]8	4.50	0.1379	0.0432	0.1548	3.15	0.86	3.09
	T4	49.05	12.57	35.48	4.10	0.1456	0.0328	0.145[illegible]	0.56	0.12	0.55
	T5	55.55	12.15	32.10	4.20	0.1369	0.0351	0.1361	3.02	0.77	3.00
	T6	44.85	14.25	38.75	4.40	0.1478	0.0448	0.1485	0.89	0.25	0.90
	T7	47.60	10.92	39.87	4.90	0.1454	0.0551	0.1356	2.[illegible]	0.69	2.09

(Contd..)

Table 5. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
11-3-81	T1	47.55	13.68	33.55	4.20	0.1278	0.0365	0.1355	3.75	1.07	3.97
	T2	49.25	1[illegible].85	32.98	4.00	0.1369	0.0525	0.1342	3.30	1.26	3.24
	T3	48.74	11.65	34.54	4.50	0.1356	0.0458	0.1259	1.96	0.66	1.82
	T4	44.62	16.48	38.30	4.60	0.1429	0.0352	0.1348	0.63	0.15	0.59
	T5	4[illegible].85	13.25	37.55	4.30	0.1338	0.0568	0.1349	2.23	0.95	2.25
	T6	43.87	16.35	38.90	4.20	0.1349	0.0372	0.1265	0.75	0.20	0.70
	T7	49.55	12.75	33.53	4.10	0.1458	0.0459	0.1502	1.61	0.50	1.65
14-3-81	T1	52.35	11.65	34.57	4.90	0.1225	0.0471	0.1312	1.94	0.74	2.08
	T2	53.25	10.37	32.95	4.10	0.1348	0.0385	0.1269	1.79	0.51	1.69
	T3	50.95	11.27	33.35	4.30	0.1342	0.0452	0.1256	1.40	0.47	1.31
	T4	45.55	12.75	39.85	4.40	0.1346	0.0469	0.1228	0.43	0.12	0.33
	T5	49.25	12.25	32.55	4.20	0.1264	0.0378	0.1172	1.37	0.40	1.26
	T6	48.05	11.87	36.48	4.30	0.1287	0.0456	0.1256	0.41	0.14	0.40
	T7	47.85	11.85	36.[illegible]	4.70	0.1288	0.0469	0.1124	1.17	0.42	1.03

(Contd..)

Table 5.(Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
20-8-81	T1	50.55	12.35	33.95	4.60	0.1459	0.0318	0.1469	21.76	7.72	21.91
	T2	51.25	8.56	31.65	4.20	0.1598	0.0560	0.1572	20.72	7.26	20.38
	T3	53.85	11.55	30.25	4.10	0.1262	0.0219	0.1259	25.25	4.38	25.19
	T4	46.05	11.75	38.15	4.50	0.1556	0.0358	0.1546	2.52	0.58	2.50
	T5	55.25	11.15	32.10	4.10	0.1468	0.0556	0.1492	11.76	4.45	11.96
	T6	44.45	14.24	36.75	4.40	0.1575	0.0375	0.1555	2.15	0.51	2.13
	T7	46.35	9.92	39.10	4.90	0.1220	0.0210	0.1259	22.32	3.84	23.04

The maximum percentage of silt loss was recorded by T4 followed by T1. Minimum silt loss was noted in T2. Maximum clay loss was observed in T7 and minimum in T2. Generally it is observed that as runoff decreases, the percentage loss of sand decreases and that of clay increases. This may be due to the fact that as runoff decreases, it is capable of detaching and carrying only the finer particles of soil.

4.3. Nutrient content and loss through erosion

The data on total nitrogen, total phosphorus and total potassium content of runoff sediments under different treatments and periods of observation are given in Table 5. The data indicated only small variations which were not consistent to explain. Hence their weighted mean percentage pooled over different periods of observation are presented in Table 8. Maximum nitrogen content was registered by T2 (0.1394%) and T4 (0.1418%) and minimum content by T6 (0.1360%). In the case of total phosphorus maximum content was registered by T3 (0.0493%) and minimum by T6 (0.0360%). Potassium content was maximum in T5 (0.1351%) and minimum in T1 (0.1042%). Thus it is seen that the nutrient concentration of runoff sediment showed only slight variations suggesting that total nutrient contents of runoff sediments were unaffected by different treatments.

The data on available phosphorus and available potassium in runoff are given in Table 6 and Table 7 respectively. Their weighted means under different treatments pooled over periods of observation are given in Table 8. It is seen from the data that definite relationship exists between the available nutrient content and the amount of soil contained in runoff. From the pooled means it is seen that maximum available phosperus content was observed in T2 (11.40 g/ha·cm of runoff) and minimum under T6 (7.426 g/ha·cm of runoff). In the loss of available potassium also similar differences were observed. Maximum available potassium content was observed under T1 (561.58 g/ha cm of runoff) and minimum under T6 (482.05 g/ha·cm of runoff). The high content of available potassium and available phosphorus observed in T2 and T1 may be due to the high content of sediment in the runoff in these treatments.

The total nutrient losses over the periods of observations under different treatments are given in Table 8 and Fig.7. It is seen that maximum loss of nutrients viz. 131.29 kg nitrogen, 41.44 kg phosphorus and 124.63 kg potassium were registered by T1 (Tapioca in ridges along the slope without intercrop) and minimum loss of nutrients, viz. 15.23 kg nitrogen, 4.[illegible] kg phosphorus and 14.79 kg potassium by T4 (Tapioca in ridges across the slope with cowpea as intercrop). The amount of nutrient lost through erosion can be explained with reference to the soil loss observed.

Table 6. Content of available P as affected by different treatments and periods of rainfall (g/ha cm)

Dates of observations	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	17.84	8.94	6.24	14.85	8.76	10.00	7.68	6.85
T2	18.90	8.65	11.84	14.92	6.78	11.39	8.71	9.39
T3	16.13	9.01	5.93	15.93	9.09	9.91	11.56	5.94
T4	12.84	7.454	6.13	26.92	12.63	5.146	50.50	2.37
T5	12.75	9.19	2.96	8.58	6.86	4.51	5.68	9.91
T6	11.19	8.50	7.84	5.24	6.57	3.65	22.63	5.79
T7	11.10	2.52	6.06	12.91	26.63	6.77	10.31	4.77
SEm ±	1.337	1.202	1.232	2.927	2.898	0.833	6.541	1.223
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	2.5694	20.1570	N.S.

(Contd..)

Table 7. Content of available Potassium as affected by different treatments and periods of rainfall (g/ha cm)

Dates of observation	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	938.28	310.49	392.72	797.26	583.37	550.72	1230.15	737.28
T2	1256.73	263.71	606.78	812.32	285.23	613.78	295.13	600.78
T3	986.74	34[illegible].10	450.76	643.50	498.12	603.78	954.16	806.30
T4	433.456	345.59	246.43	747.08	1052.58	253.43	3615.63	198.05
T5	739.28	330.49	586.18	1091.30	197.50	538.15	219.51	585.18
T6	645.60	1273.42	211.76	1270.10	1000.60	210.76	1213.66	218.76
T7	680.06	415.92	228.93	789.47	3127.89	227.93	375.15	227.95
SEm ±	103.426	169.268	88.611	100.36	207.624	105.672	534.839	16.788
C.D.(0.05)	318.7157	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	51.7588

(Contd.)

Table 6. (Contd.)

Dates of observations	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	6.64	6.94	10.95	11.97	12.38	8.63	10.93	12.38
T2	8.49	7.81	14.66	12.81	15.39	10.97	7.39	15.39
T3	8.58	7.17	9.94	11.83	11.90	10.01	9.22	13.91
T4	8.74	3.49	18.46	10.40	10.49	10.52	7.69	7.62
T5	7.91	8.94	11.24	13.94	15.91	11.77	9.70	15.91
T6	7.86	5.66	9.10	10.66	11.79	6.37	4.29	11.79
T7	8.71	4.61	9.86	8.15	10.77	13.98	7.24	10.77
SEm ±	0.468	0.964	1.724	0.769	1.078	1.414	1.023	1.707
C.D.(0.05)	N.S.	N.S.	N.S.	2.3737	N.S.	N.S.	N.S.	N.S.

Table 7. (Contd.)

Dates of observation	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	629.51	540.50	198.32	546.00	492.72	568.95	150.95	492.85
T2	412.60	368.56	283.55	365.85	615.75	265.75	475.75	640.54
T3	434.25	484.30	274.97	410.29	415.55	410.55	189.74	415.54
T4	432.90	159.34	4050.75	149.85	243.34	1606.75	217.78	253.45
T5	310.80	556.46	193.90	544.00	590.81	330.4[illegible]	654.25	593.85
T6	278.70	185.45	2250.60	185.50	218.76	936.26	198.62	218.78
T7	315.90	135.84	4915.35	135.84	230.93	614.29	215.28	235.93
SEm ±	66.270	52.082	1193.428	62.274	114.324	161.235	75.985	74.282
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 8. Mechanical composition* nutrient content* nutrient loss and sediment content* of runoff over the entire season as affected by different treatments

Treatments	Mechanical composition of runoff sediment (%)			Loss on ignitions (%)	N content of runoff sediment (%)	P content of runoff sediment (%)	K content of runoff sediment (%)	Available P loss (g/ha.cm of runoff
	Sand	Silt	Clay					
1	2	3	4	5	6	7	8	9
T1	59.909	12.48	33.699	4.426	0.1380	0.0433	0.1049	9.85
T2	53.987	9.522	32.755	4.1176	0.1394	0.0383	0.1305	11.40
T3	52.39	11.10	33.769	4.392	0.1364	0.0493	0.1264	10.088
T4	44.91	13.815	37.20	4.351	0.1418	0.0384	0.1344	8.24
T5	47.33	11.66	36.86	4.41	0.1382	0.0409	0.1351	9.185
T6	45.27	11.97	37.64	4.264	0.1360	0.0360	0.1111	7.426
T7	45.22	11.93	38.52	4.40	0.1335	0.0448	0.1095	8.77

(Contd..)

Table 8. (Contd.)

Treatments	Available K loss (g/ha·cm of runoff	Total N loss during the period of observation (kg/ha)	Total P loss during the period of observation (kg/ha)	Total K loss during the period of observation (kg/ha)	Available P loss during the period of observation (kg/ha)	Available K loss during the period of observation (kg/ha)	Sediment content of runoff (kg/ha cm)
	10	11	12	13	14	15	16
T1	561.88	131.29	41.44	124.65	303.8	17.32	2890.47
T2	548.37	117.02	38.43	117.65	277.29	13.33	2887.08
T3	515.439	114.06	36.02	115.61	282.87	14.40	2886.156
T4	485.05	15.23	4.29	14.79	66.66	3.924	1833.82
T5	529.96	105.30	31.73	99.71	218.69	12.618	2805.52
T6	482.05	17.55	8.31	16.62	77.30	5.018	1586.09
T7	527.453	89.92	19.58	88.82	202.85	12.19	2856.66

* Weighted mean

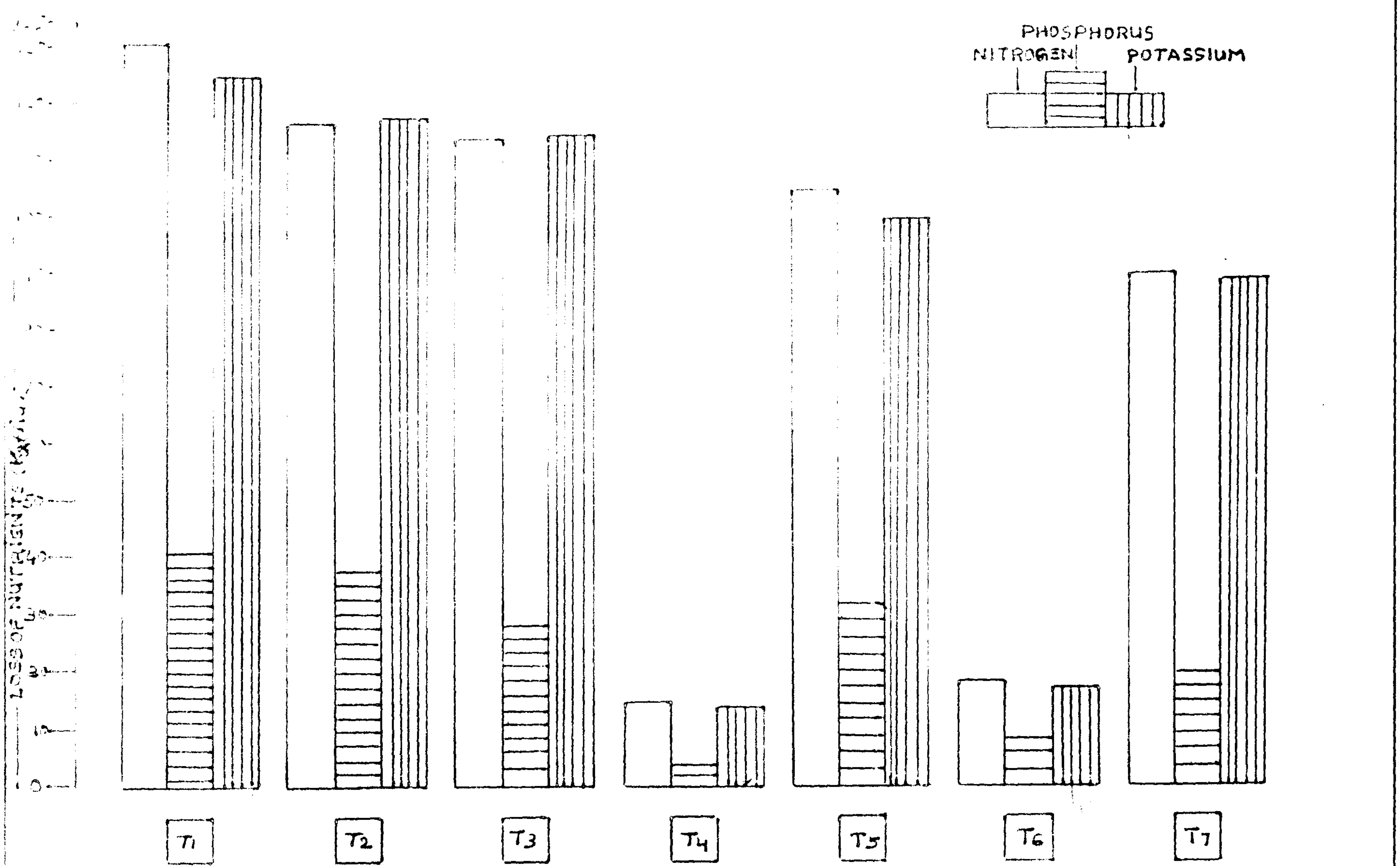


FIG. 7 LOSS OF NUTRIENTS AS AFFECTED BY DIFFERENT TREATMENTS DURING THE PERIOD OF OBSERVATION

Table 9. Percentage of runoff* during different rainfalls observed as affected by different treatments

Dates of observations	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	41.64 (40.17)	56.27 (48.64)	40.19 (39.27)	55.66 (48.36)	84.36 (67.40)	28.11 (32.00)	33.34 (38.28)	46.16 (42.79)
T2	34.70 (36.08)	41.04 (39.83)	31.09 (33.84)	37.87 (37.93)	50.85 (45.42)	15.81 (23.[illegible])	34.54 (34.80)	33.92 (35.57)
T3	44.70 (41.91)	59.50 (50.47)	40.01 (39.19)	57.54 (49.42)	83.67 (66.41)	22.79 (28.45)	32.73 (33.98)	41.03 (39.78)
T4	6.87 (15.01)	17.88 (25.00)	11.41 (19.53)	10.42 (18.61)	15.20 (22.31)	6.50 (14.21)	4.31 (11.96)	13.31 (21.27)
T5	36.80 (37.34)	47.32 (43.46)	31.93 (34.27)	43.50 (41.24)	65.13 (54.00)	20.10 (26.55)	29.66 (31.66)	38.53 (38.35)
T6	10.05 (18.45)	18.35 (25.35)	15.42 (23.06)	17.15 (24.43)	14.95 (22.69)	10.452 (18.11)	7.268 (15.58)	19.97 (26.43)
T7	37.27 (37.52)	50.18 (45.1)	36.23 (36.97)	46.04 (42.71)	62.57 (52.33)	18.97 (25.75)	25.91 (2[illegible].25)	33.73 (35.48)
SEm ±	1.419	1.163	1.965	2.513	3.934	8.621	5.247	1.401
C.D.(0.05)	4.3728	3.5940	6.0570	7.7470	12.1234	N.S.	16.1697	4.3178

(Contd..)

Table 9. (Contd.)

Dates of observations	29-6-81	26-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15
T1	48.06 (43.88)	85.67 (67.75)	37.35 (37.59)	13.79 (21.61)	43.80 (41.38)	46.44 (42.92)	21.24 (27.32)
T2	39.58 (38.91)	71.52 (57.90)	28.62 (32.31)	10.79 (19.14)	39.15 (38.53)	42.27 (40.41)	18.09 (25.13)
T3	38.63 (38.41)	74.95 (60.14)	25.03 (30.02)	74.42 (15.84)	23.96 (29.01)	28.66 (32.23)	35.05 (36.28)
T4	16.73 (23.95)	31.34 (33.19)	10.88 (19.11)	3.33 (10.50)	10.00 (18.39)	9.97 (18.01)	9.32 (17.47)
T5	35.51 (36.51)	62.98 (52.87)	26.11 (30.70)	8.77 (16.94)	29.40 (32.68)	21.58 (26.85)	14.58 (22.42)
T6	18.74 (25.46)	40.39 (38.58)	15.49 (23.07)	4.22 (11.80)	13.34 (21.40)	12.69 (20.55)	6.41 (14.43)
T7	32.03 (34.40)	68.55 (56.04)	21.76 (27.79)	5.82 (13.94)	22.20 (27.85)	24.69 (30.80)	25.48 (30.18)
SEm ±	2.158	5.630	1.762	1.182	2.0349	2.9300	1.4310
C.D.(0.05)	6.6516	17.3511	5.4312	3.6446	6.2707	9.0291	4.4097

* Figures in brackets are angles.

The losses of available phosphorus and available potassium during the period of observation are given in Table 8. The maximum loss of available phosphorus was recorded by T1(303.8 g) and minimum by T4 (66.66 g). In the case of available potassium, the maximum loss was observed in T1 (17.32 kg) and minimum in T4 (3.924 kg).

4.6. Quantity of runoff sediment

The data on mean sediment content (weighted) of runoff under different treatments are given in Table 8. The maximum sediment content was observed in T1 (2890.47 kg/ha·cm of runoff) and minimum in T6 (1586.09 kg/ha·cm of runoff). It can be seen that the higher sediment content of runoff was observed in T1, which accumulated large volume of runoff. Treatments T2 (bare fallow plots) recorded the next highest sediment content of runoff. This may be partly due to the splash effect in detaching soil particles and partly due to high sediment carrying capacity of runoff in these plots. The lowest sediment content of runoff was recorded by T6 (Tapioca on ridges across the slope without intercrop). The lowest sediment content in T6 can be attributed to lower runoff and consequently lower sediment carrying capacity in this treatment.

4.7. Retentive rainfall

The data on the percentage of retentive rainfall under different treatments and periods of observation are given in Table 10. In T1, the percentage of retentive rainfall under

Table 10. Percentage of retentive rainfall* during different rainfalls observed as affected by different treatments

Dates of observations	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	58.36 (49.82)	43.73 (41.35)	5[illegible].81 (50.71)	44.33 (41.62)	15.65 (29.81)	71.58 (57.98)	60.65 (56.24)	53.83 (47.20)
T2	65.30 (53.91)	58.95 (50.16)	68.90 (56.14)	62.12 (52.05)	49.14 (44.56)	84.19 (66.70)	65.46 (53.19)	62.74 (54.41)
T3	55.31 (48.05	40.[illegible]0 (39.51)	59.98 (50.80)	42.45 (40.56)	16.31 (23.57)	77.20 (61.53)	67.26 (56.00)	58.96 (52.10)
T4	93.28 (74.97)	82.11 (64.98)	88.58 (70.45)	89.78 (71.51)	84.80 (67.68)	93.50 (75.78)	95.68 (7[illegible].02)	86.69 (68.71)
T5	63.06 (52.64)	5[illegible].67 (46.53)	68.06 (55.75)	56.4[illegible] (48.74)	34.86 (35.98)	79.89 (63.43)	70.34 (58.32)	61.46 (57.63)
T6	89.94 (71.53)	81.64 (64.62)	84.67 (66.93)	82.85 (65.56)	85.05 (67.29)	89.54 71.71)	92.73 (74.40)	80.03 (65.72)
T7	62.72 (52.46)	4[illegible].81 (44.88)	63.76 (53.02)	53.95 (47.27)	37.43 (37.65)	81.02 (64.23)	74.08 (60.73)	66.26 (54.50)
SEm ±	1.422	4.560	1.957	1.732	3.943	1.931	5.1[illegible]7	2.306
C.D.(0.05)	N.S.	N.S.	6.0313	7.7487	12.1510	5.9517	16.0168	7.1071

(Contd.)

Table 10. (Contd.)

Dates of observations	25-6-81	26-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	12	14	15
T1	51.94 (46.17)	14.33 (22.24)	62.65 (52.40)	86.20 (68.38)	56.20 (48.60)	53.55 (47.06)	78.75 (62.67)
T2	60.42 (51.07)	28.47 (32.00)	71.38 (57.65)	89.01 (70.84)	60.85 (51.45)	57.73 (49.58)	81.90 (64.85)
T3	61.36 (51.57)	25.04 (30.85)	74.96 (59.97)	92.58 (74.35)	76.04 (60.98)	71.33 (57.77)	65.85 (54.24)
T4	83.26 (66.03)	68.65 (56.79)	89.78 (70.88)	96.66 (79.49)	83.99 (54.98)	90.02 (71.97)	90.68 (72.51)
T5	64.49 (53.48)	37.01 (37.10)	73.88 (59.28)	91.22 (73.04)	70.59 (57.31)	79.41 (63.13)	85.41 (67.56)
T6	81.25 (64.50)	59.60 (51.40)	84.51 (66.92)	95.77 (78.18)	86.66 (68.71)	87.50 (69.10)	93.59 (75.56)
T7	67.96 (55.58)	31.44 (33.94)	78.24 (66.23)	94.17 (76.04)	77.79 (62.13)	75.33 (60.30)	74.51 (59.81)
Sem ±	2.161	5.548	1.756	1.173	7.098	3.337	1.380
C.D.(0.05)	6.6616	17.0975	5.4133	3.6152	N.S.	10.2841	4.2552

* Figures in brackets are angles.

different rains ranged from 15.63 to 78.75, in T2 from 49.14 to 89.01, in T3 from 16.34 to 92.58, in T4 from 68.65 to 96.66, in T5 from 34.36 to 91.22, in T6 from 59.6 to 95.77 and in T7 from 37.43 to 94.17. Considering the total rainfall and total runoff during the periods of observation, the total retentive rainfall and its percentages were determined for various treatments. In T1, the total retentive rainfall was 489.85 mm (61.19%), in T2 564.96 mm (70.57%), in T3 552.50 mm (69.01%), in T4 719.02 mm (89.84%), in T5 564.26 mm (70.48%), in T6 696.06 mm (86.95%) and in T7 566.16 mm (70.72%). From the results it is seen that maximum retentive rainfall was recorded by T4 (Tapioca in ridges across the slope with intercrop cowpea) followed by T6 (Tapioca in ridges across the slope without intercrop). Minimum retentive rainfall was observed in T1 (Tapioca in ridges along the slope without intercrop). It was also observed that the retentive rainfall figures are inversely related to the amount of runoff occuring in these plots. In T1 the retentive rainfall was low because of higher runoff (Table 9) occuring in these plots.

4.8. <u>pH and conductivity of runoff water</u>

The data on pH and conductivity of runoff water under different treatments and periods of observation are presented in Table 11 and Table 12 respectively.

It is seen from the data that pH of runoff was not significantly affected by different treatments. The conductivity of runoff water also was not significantly

Table 11. pH of runoff water as affected by different treatments and dates of rainfall

Dates of observation	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	5.50	5.60	5.45	5.63	5.58	5.35	5.63	5.58
T2	5.68	5.50	5.50	5.78	5.60	5.50	5.75	5.68
T3	5.45	5.45	5.43	5.58	5.70	5.58	5.75	5.63
T4	5.70	5.40	5.45	5.65	5.63	5.45	5.78	5.70
T5	5.90	5.40	5.40	5.75	5.48	5.40	5.75	5.90
T6	5.68	5.48	5.33	5.78	5.48	5.33	5.70	5.78
T7	5.65	5.40	5.40	5.73	5.48	5.40	5.65	5.65
SEm ±	0.0988	0.0918	0.0428	0.138	0.086	0.050	0.129	0.155
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	0.1544	N.S.	N.S.

(Contd.)

Table 11 (Contd.)

Dates of observation	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	5.60	5.45	5.85	5.38	5.38	5.48	5.50	5.45
T2	5.55	5.35	6.03	5.50	5.50	5.50	5.58	5.50
T3	5.58	5.50	5.90	5.48	5.48	5.50	5.58	5.48
T4	5.33	5.48	5.95	5.45	5.45	5.40	5.65	5.45
T5	5.58	5.43	5.95	5.40	5.40	5.40	5.43	5.40
T6	5.58	5.50	5.93	5.33	5.33	5.48	5.48	5.33
T7	5.58	5.58	5.98	5.40	5.40	5.40	5.48	5.40
SEm ±	0.070	0.067	0.858	0.058	0.058	0.057	0.054	0.0539
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 12. Electrical conductance of runoff water as affected by different treatments and dates of rainfall (micromhos/cm)

Dates of observation	16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Treatments	1	2	3	4	5	6	7	8
T1	33.68	44.65	40.50	42.38	43.46	48.85	48.00	46.68
T2	43.38	47.75	42.38	49.35	47.25	4[illegible].45	4[illegible].35	49.45
T3	37.83	44.00	42.93	43.48	45.70	46.23	48.83	48.85
T4	37.00	37.40	47.00	37.38	40.91	46.68	37.38	46.68
T5	36.28	48.55	36.28	36.38	42.91	46.23	36.38	46.23
T6	34.23	37.83	34.23	35.10	46.23	44.35	35.10	44.35
T7	36.75	3[illegible].73	36.73	38.18	35.45	43.48	38.18	43.48
SEm ±	1.516	0.945	1.870	2.658	1.944	1.080	2.958	1.086
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 12 (Contd.)

Dates of observations	25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Treatments	9	10	11	12	13	14	15	16
T1	53.15	39.73	46.63	40.50	48.85	47.25	46.68	48.00
T2	47.30	42.93	47.00	42.93	49.45	47.75	47.25	49.45
T3	53.20	38.18	47.38	44.65	45.73	49.45	46.23	49.73
T4	50.25	44.00	53.20	44.00	46.68	37.40	40.93	47.68
T5	52.20	48.13	55.98	48.25	46.23	48.55	42.90	48.23
T6	39.55	38.68	44.38	38.68	44.35	37.83	46.23	46.35
T7	40.83	44.65	46.63	44.68	43.48	39.73	35.45	44.48
SEm ±	3.073	2.060	2.111	2.119	1.252	2.782	1.760	1.018
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

affected by various treatments in all the rainfall events.

4.9. Storage of soil moisture as affected by different treatments

The data on soil moisture storage in the upper layer (0-15 cm) under different treatments and periods are given in Table 13 and Fig.8. It is seen from the data that soil moisture storage in this layer was highest in treatments T4 (Tapioca in ridges across the slope with intercrop) followed by T6 (Tapioca in ridges along the slope without intercrop) and was lowest in T2 (uncultivated bare fallow). Soil moisture was lowest under T2 because the land was bare and as such there was heavy evaporation loss from the soil. This is similar to the findings of Viswambharan (1980) in experiments conducted at Vellanikkara. Between intercropped and non-intercropped plots under various planting methods of tapioca, the storage of soil moisture was generally not affected by various treatments in the surface soil layer (0-15 cm).

In 15-30 cm soil layer (Table 14 and Fig.9) maximum retention of soil moisture was observed in T4 and T6. Upto the establishment of the intercrop, higher storage of soil moisture was observed in T6 and thereafter higher storage of soil moisture was noted in T4 (Tapioca on ridges across the slope with intercrop). It was seen that after the establishment of the intercrop more moisture was stored in plots with intercrops compared to treatments without intercrops.

Table 13. Moisture Storage* as affected by different treatments and periods of observation (%) (0 to 15 cm)

Dates of observation	2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	[illegible]-81	23-9-81	7-10-81
Treatments	1	2	3	4	5	6	7	8	9	10
T1	29.15 (32.46)	29.50 (32.89)	23.40 (28.92)	17.54 (24.75)	17.91 (25.02)	18.97 (25.81)	17.65 (24.83)	20.25 (26.74)	19.98 (26.54)	8.69 (17.12)
T2	28.90 (32.51)	28.20 (32.07)	18.[illegible]4 (25.57)	16.52 (23.97)	17.61 (24.80)	18.08 (25.16)	17.10 (24.42)	19.92 (26.49)	19.85 (26.45)	6.48 (14.58)
T3	29.36 (32.80)	29.09 (32.63)	22.19 (28.09)	17.62 (24.81)	18.06 (25.14)	19.57 (26.24)	17.96 (25.07)	20.87 (27.18)	20.01 (26.56)	7.65 (15.96)
T4	33.94 (35.62)	31.16 (33.[illegible]7)	26.14 (30.74)	25.70 (30.45)	21.96 (27.93)	26.23 (30.80)	21.58 (27.67)	25.35 (30.22)	25.02 (30.00)	13.94 (21.91)
T5	29.80 (33.08)	30.06 (33.24)	25.09 (30.04)	18.47 (25.44)	18.55 (25.99)	19.91 (26.49)	18.34 (25.34)	21.09 (27.34)	20.55 (26.94)	11.09 (19.37)
T6	34.25 (35.81)	33.71 (35.49)	27.09 (31.36)	21.93 (27.[illegible])	21.25 (27.4[illegible])	24.59 (29.72)	22.09 (28.02)	24.68 (29.78)	22.95 (28.61)	13.49 (21.54)
T7	30.65 (33.61)	30.94 (33.65)	24.78 ([illegible].84)	19.70 (26.35)	19.72 (26.47)	20.52 (26.93)	19.02 (25.89)	21.76 (27.80)	21.14 (27.35)	11.42 (19.69)
SEm ±	0.625	0.470	0.239	0.254	0.184	0.196	0.216	0.146	0.011	0.851
C.D.(0.05)	1.928	1.449	0.737	0.782	0.569	0.607	0.667	0.437	0.038	2.625

* Figures in brackets are angles.

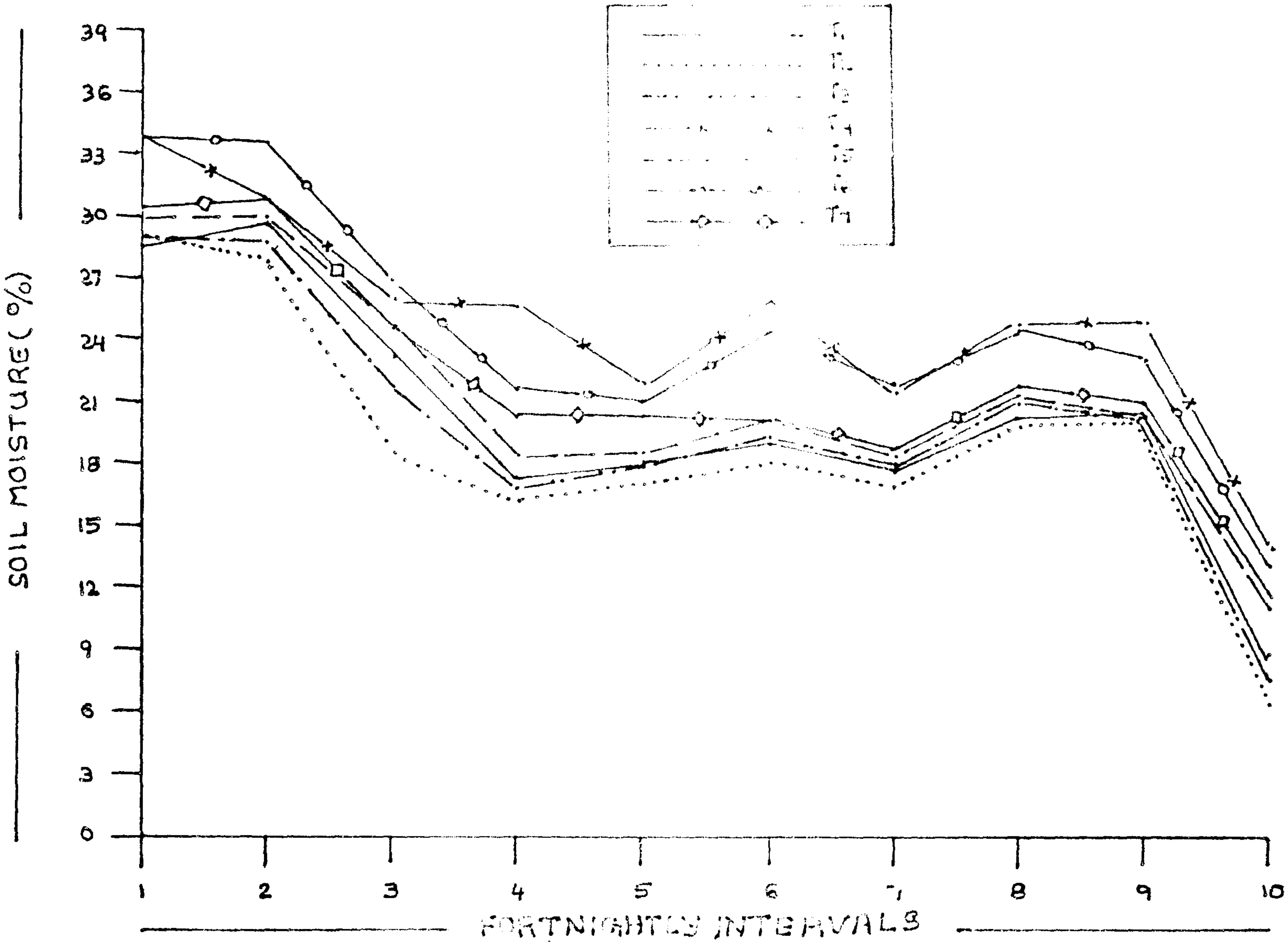


FIG:8 SOIL MOISTURE STORAGE IN 0-15 Cm LAYER AS AFFECTED BY DIFFERENT AGROTECHNIQUES

Table 14. Moisture storage* as affected by different treatments and periods of observation (%) (15 to 30 cm)

Dates of observation	2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	9-9-81	23-9-81	7-10-81
Treatments	1	2	3	4	5	6	7	8	9	10
T1	28.82 (32.46)	29.71 (33.02)	23.32 (28.86)	17.85 (24.98)	17.14 (24.45)	19.60 (26.27)	17.94 (25.04)	21.81 (27.83)	19.99 (26.55)	11.06 (19.42)
T2	27.33 (32.22)	28.86 (32.48)	20.08 (26.61)	17.26 (25.54)	16.69 (24.10)	18.95 (25.80)	17.37 (24.65)	20.39 (26.83)	17.95 (25.05)	9.91 (18.37)
T3	28.14 (32.66)	29.18 (32.69)	22.66 (28.41)	18.40 (25.39)	18.79 (25.67)	19.69 (26.33)	18.12 (25.17)	20.75 (27.09)	18.95 (25.79)	10.59 (18.96)
T4	34.38 (35.88)	31.81 (34.32)	25.54 (30.33)	26.06 (30.69)	23.80 (29.19)	26.48 (30.96)	22.34 (28.27)	25.76 (30.67)	30.57 (33.56)	14.82 (22.63)
T5	30.35 (33.42)	30.51 (33.52)	25.42 (30.67)	19.14 (25.94)	22.19 (28.10)	20.52 (26.93)	18.78 (25.67)	22.80 (28.51)	23.75 ([illegible])	12.43 (20.62)
T6	35.94 (36.82)	34.36 (35.89)	26.41 (30.90)	22.64 (28.41)	22.45 (28.27)	24.93 (29.95)	22.55 (28.34)	25.89 (30.57)	24.03 (29.32)	14.10 (22.04)
T7	30.84 (33.72)	31.40 (34.08)	24.66 (29.75)	20.21 (26.69)	22.21 (28.14)	21.18 (27.39)	19.17 (25.95)	22.29 (28.16)	20.81 (27.13)	14.00 (21.77)
SEm ±	0.535	0.125	0.339	0.276	0.024	0.200	0.339	0.865	0.025	0.822
C.D.(0.05)	1.649	0.387	1.047	0.849	0.076	0.618	0.047	2.667	0.079	2.535

* Figures in brackets are angles.

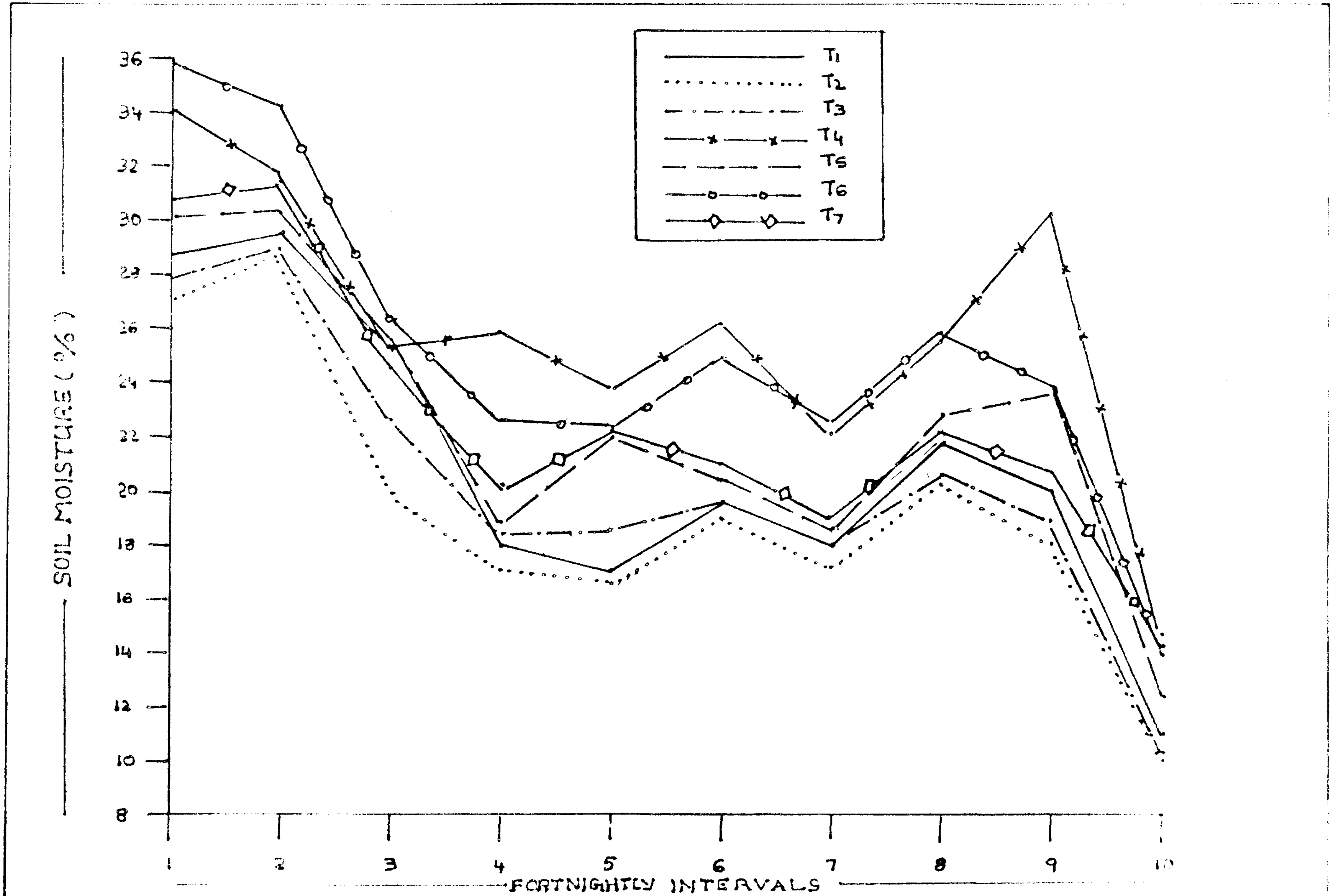


FIG:9 SOIL MO... ...STORAGE AS AFFECTED BY DIFFERENT AGROTECHNIQES IN 15-30Cm LAYER.

This may be due to the higher retention of runoff water by the intercrop canopy enabling more infiltration into the soil which is in conformity with the results obtained by Viswambharan (1980).

The sub soil moisture storage (30-45 cm) as affected by different treatments and periods of observation are given in Table 15 and Fig.10. During early period when there was frequent occurrence of rainfall, maximum storage of sub soil moisture was seen in T6 and minimum in T2. The maximum quantity of sub soil moisture storage observed in T6 can be attributed to the high retention of rainfall in this treatment. In T2, the storage was minimum due to high runoff as the field was kept fallow. During subsequent periods when the rainfall was scanty, the study revealed that there was gradual and continuous depletion of sub soil moisture during this period and cultivated plots showed maximum depletion where as depletion was minimum in bare fallow. Among the cultivated plots the higher rate of depletion and thereby minimum storage was observed in T3 (Tapioca on ridges along the slope with cowpea as intercrop). The maximum storage of sub soil moisture by uncultivated bare fallow can be attributed to the lack of root extraction of sub soil moisture and subsequent evapo-transpiration which is in agreement with the findings of Viswambharan (1980). In other treatments the roots of tapioca which extends to approximately 50 cm below the soil could have extracted much of the sub soil moisture resulting in maximum depletion.

Table 15. Moisture storage* as affected by different treatments and periods of observation (%) (30 to 45 cm)

Dates of observation	2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	9-9-81	23-9-81	7-10-81
Treatments	1	2	3	4	5	6	7	8	9	10
T1	29.74 (33.04)	30.72 (33.64)	25.24 (30.14)	18.36 (25.36)	22.72 (28.18)	21.02 (27.28)	19.05 (25.87)	22.55 (28.34)	21.91 (27.89)	13.22 (21.57)
T2	29.32 (32.77)	29.35 (32.80)	21.67 (27.74)	17.54 (24.75)	24.58 (29.71)	27.43 (31.57)	23.63 (29.07)	26.76 (31.14)	21.76 (27.79)	15.47 (23.12)
T3	30.96 (33.80)	30.22 (33.34)	24.01 (29.33)	19.04 (25.86)	19.87 (26.46)	19.80 (26.40)	17.66 (24.84)	20.47 (26.89)	22.55 (26.34)	10.31 (18.71)
T4	35.90 (36.80)	32.40 (30.69)	28.05 (31.97)	26.46 (30.50)	18.88 (25.74)	20.82 (27.14)	18.77 (25.66)	21.77 (27.80)	31.29 (34.00)	14.47 (22.21)
T5	32.00 (34.43)	30.92 (33.78)	26.97 (31.28)	19.63 (26.29)	23.96 (29.29)	22.12 (28.01)	19.89 (26.48)	23.99 (29.32)	22.97 (28.63)	13.81 (21.80)
T6	37.60 (37.81)	34.79 (36.04)	28.68 (32.37)	23.39 (28.89)	24.15 (29.09)	25.63 (30.04)	22.00 (28.64)	25.67 (30.44)	29.85 (33.11)	14.25 (22.16)
T7	33.27 (35.22)	31.82 (34.33)	27.15 (31.39)	20.64 (27.01)	19.48 (26.18)	20.49 (26.91)	18.04 (25.11)	21.07 (27.32)	28.03 (31.95)	11.07 (19.41)
SEm ±	0.392	0.112	0.184	0.362	0.155	0.287	0.329	0.213	0.754	0.939
C.D.(0.05)	1.208	0.346	0.568	1.117	0.480	0.885	1.015	0.658	2.325	2.896

* Figures in brackets are angles.

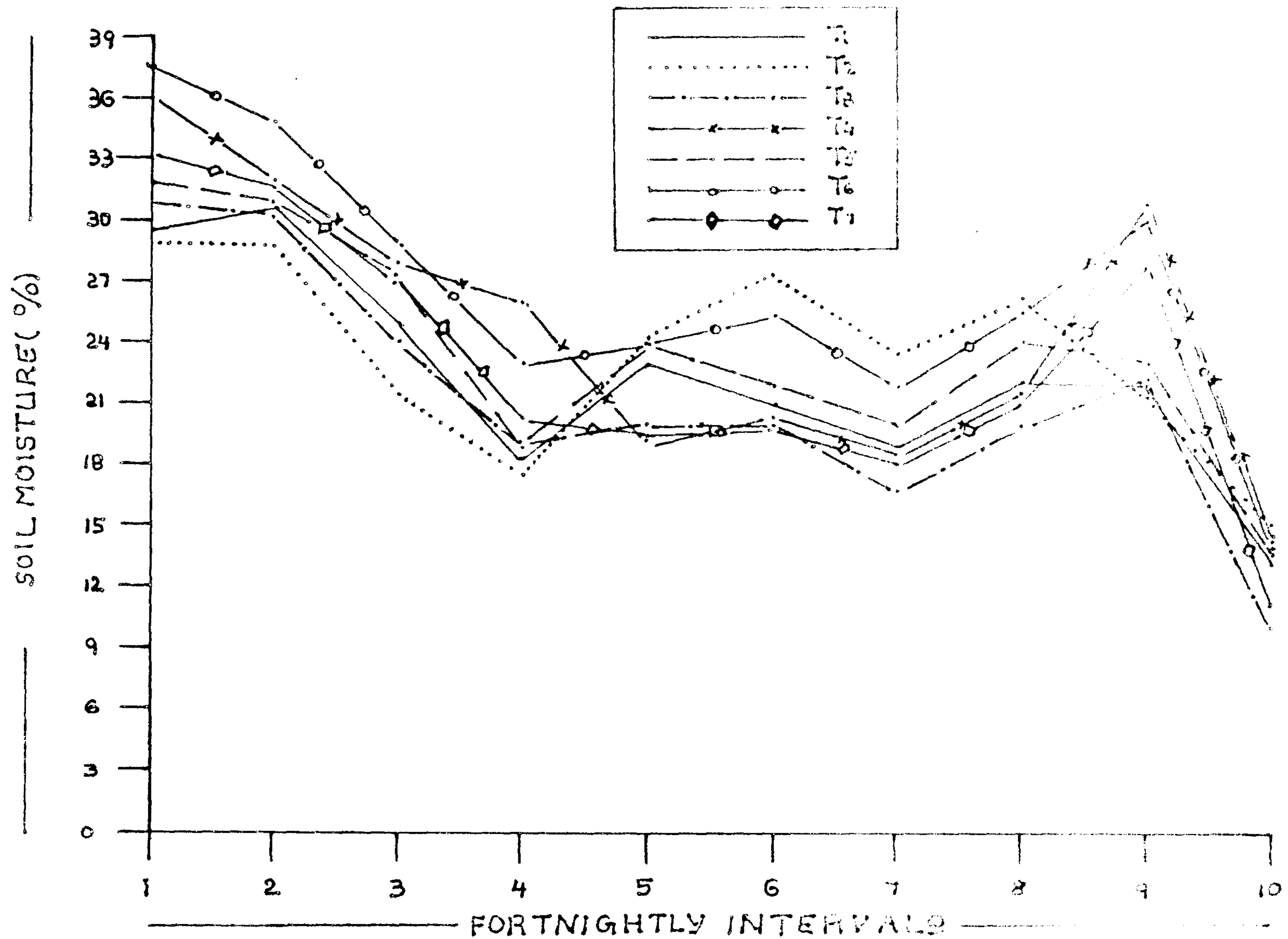


FIG.10 SOIL MOISTURE STORAGE IN 30-45 Cm LAYER AS AFFECTED BY DIFFERENT AGROTECHNIQUES

4.10. Biometric observations of maincrop (Tapioca)

Biometric observations such as height of plant, number of functional leaves per plant and canopy diameter of tapioca were studied at monthly intervals.

4.10.1. Height of plants

The data on height of plants recorded at monthly intervals are given in Table 16. There was no significant difference in the height of plants between the treatments 30 days after planting. However after 2 months of planting significantly increased height of plants was observed in T6 followed by T4. Minimum height was observed in T1. On 31st day after planting maximum height of plants was observed in T1 and T6. Thereafter upto the harvest, maximum height was observed in T6 closely followed by T4 and T7. This may be due to higher moisture storage favourably influenced either by the intercrop or by planting in ridges across the slope.

4.10.2. Number of functional leaves

The data on functional leaves of tapioca at monthly intervals are given in Table 17. It is seen that the number of funcational leaves per plant was influenced by various treatments except on 31st day after planting. During the period, the maximum number of functional leaves per plant was recorded by T6 and minimum by T3. Between intercropped and non-intercropped plots with tapioca, either planted on ridges across the slope or on mounds, more number of functional leaves was recorded in non intercropped plots. This is clearly

Table 16. Height of tapioca plant at monthly intervals (cm) as affected by different Agro-techniques

Treatments	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
T1	21.70	65.35	125.67	135.24	138.80	140.60	160.25	192.08
T2								
T3	23.35	66.75	128.00	144.96	140.30	149.25	159.95	198.67
T4	21.95	71.58	128.24	134.25	145.58	153.37	168.25	202.67
T5	23.73	69.38	129.33	138.50	148.50	150.92	167.25	196.05
T6	22.93	74.58	135.50	148.58	149.17	153.50	172.85	203.93
T7	23.25	68.88	138.92	141.88	145.67	151.45	168.85	204.50
SEm ±	0.668	0.646	1.345	0.433	2.884	3.439	2.558	0.968
C.D.(0.05)	N.S.	2.012	4.187	1.350	N.S.	N.S.	7.964	3.013

Table 17. Functional leaves per plant at monthly intervals

Treatments	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
T1	12.60	31.16	53.00	60.53	52.75	50.00	48.25	46.20
T2								
T3	13.25	30.12	56.24	59.75	51.42	48.20	46.50	44.75
T4	13.14	32.25	53.50	61.42	56.38	54.38	52.80	49.25
T5	14.75	34.42	54.24	64.50	58.42	56.42	54.50	53.10
T6	13.10	35.09	59.09	61.75	62.50	60.50	58.25	55.70
T7	13.00	31.25	50.42	62.67	54.92	52.80	50.10	49.00
SEm ±	0.696	0.924	1.114	0.998	0.856	1.779	0.816	1.997
C.D.(0.05)	N.S.	2.878	3.467	3.107	2.665	5.538	2.541	6.216

a reflection of competition between the maincrop and the intercrop.

4.10.3. Canopy diameter

The data on canopy diameter of tapioca at monthly intervals are given in Table 18. No specific pattern of canopy diameter was observed in any of the treatments.

4.11. Yield attributes and yield of main crop (tapioca)

The data on yield attributes and yield of tapioca are given in Table 19.

4.11.1. Number of productive tubers per plant

It is seen from the data (Table 19) that the number of productive tubers per plant was not affected by the different treatments. This means that there is no significant effect on the number of productive tubers per plant either by inter-cropping with cowpea or by ridge or mound method of cultivation of tapioca.

4.11.2. Length of tubers

The data on length of tubers are presented in Table 19. It is seen from the data that the length of tubers was significantly influenced by different treatments. The maximum length of the tubers was observed in T6 and minimum in T1. There was significant difference in the length of tubers between T4 (Tapioca in ridges across the slope with intercrop) and T6 (Tapioca alone on ridges across the slope). Thus the influence of the intercrop in reducing the length of tubers (T4) by competition with the main crop was evident in the result.

Table 13. Canopy diameter of Tapioca at monthly intervals (cm) as affected by different Agro-techniques

Treatments	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
T1	46.92	88.92	116.84	98.50	98.25	45.50	58.25	101.84
T2								
T3	42.17	86.50	112.50	102.75	70.27	42.92	61.75	103.44
T4	42.34	89.17	117.92	107.84	71.50	41.92	60.34	98.50
T5	49.42	96.75	120.33	108.50	74.25	42.27	56.09	94.42
T6	48.00	92.58	116.33	105.92	76.00	46.33	59.83	95.34
T7	45.17	93.84	118.75	110.84	71.84	40.50	58.92	104.83
SEm ±	0.862	1.194	0.535	2.220	1.094	0.632	0.526	1.756
C.D.(0.05)	2.685	3.717	1.668	6.912	3.407	1.967	1.636	5.467

Table 19. Yield attributes and yield of Tapioca as affected by different Agro-techniques

Treatments	Number of productive tubers/plant	Length of tubers (cm)	Mean girth of tubers (cm)	Yield of tubers (fresh weight (kg/ha)	Dry weight of tops (kg/ha)	Harvest index * (%)
T1	12.00	23.58	13.00	12987.85	2056.7	66.32 (54.52)
T2						
T3	11.33	25.78	13.95	12663.53	2240.8	64.96 (53.70)
T4	12.92	24.87	13.49	15684.15	2335.7	67.03 (54.95)
T5	13.66	29.58	14.58	14183.58	2550.9	64.75 (53.57)
T6	14.33	32.75	14.48	17840.35	2630.6	67.14 (55.02)
T7	13.00	29.00	14.18	138[illegible]0.45	2440.4	65.01 (53.73)
SEm ±	1.191	1.767	1.142	505.159	126.519	0.972
C.D.(0.05)	N.S.	~~54.97~~ 5.497	N.S.	1572.2468	N.S.	N.S.

* Figures in brackets are angles.

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4.11.3. Mean girth of tubers

The data on girth of tubers are given in Table 19. It is seen that the girth of tubers was not significantly influenced by different treatments. It can be concluded that neither the different methods of cultivation of tapioca nor intercropping with cowpea had any significant influence on the mean girth of tubers.

4.11.4. Yield of fresh tubers

It is seen from the data that the yield of tubers was significantly influenced by different treatments (Table 19). The yield of tubers in T6 was significantly superior to all the other treatments. In T1, T3 and T7 the yields of tubers were on par. The yields of tubers in T4 and T5 were on par and were significantly higher than that in T1, T3 and T7. The maximum tuber yield of 17,840.35 kg/ha in T6 was observed due to the significantly higher mean length of tubers and higher number of productive tubers per plant. From the data it can be concluded that the various methods of cultivation except planting tapioca on ridges across the slope without intercrop have no influence on the yield of tubers.

4.11.5. Dry weight of tops

The data on the dry weight of tops are given in Table 19. The dry weight of tops was not significantly influenced by different treatments. However, maximum dry weight of tops was recorded by T6 and minimum by T1.

4.11.6. Harvest Index

From the data given in Table 19 it is seen that the maximum harvest index was recorded by T6 (67.14%) and minimum by T5 (64.75%). However, this was not statistically significant suggesting that the different methods of cultivation and intercropping with cowpea have no significant influence on the harvest index of tapioca.

4.12. Biometric observations of intercrop (Cowpea)

The data on the biometric observations such as height and functional leaves were recorded at 20 days intervals and presented in Table 20.

4.12.1. Height of plant

The data indicated that there were only very small differences in the height of cowpea between the treatments. This indicates that ridge method, both along and across the slope and mound method of cultivation do not have any marked effect on the height of the intercropped cowpea during the entire period of growth.

4.12.2. Functional leaves per plant

The data indicated only small difference between treatments. This reveals that the various planting methods of tapioca do not have any marked effect on the functional leaves of the intercropped cowpea.

4.13. Yield attributes and yield of intercrop (Cowpea)

The data on the yield attributes and yield of the intercropped cowpea are given in Table 21.

Table 20. Periodical biometric observations of Cowpea as affected by different Agro-Techniques

Characters	Height of plant (cm)			Functional leaves/plant		
Dates of observation / Treatments	20 days	40 days	60 days	20 days	40 days	60 days
T3	15.38	38.27	97.44	4.16	12.00	8.66
T4	15.55	39.71	97.21	4.23	11.66	9.66
T7	15.82	38.66	98.33	4.40	12.00	9.00
SEm	0.995	0.435	0.754	0.471	0.608	0.509

Table 21. Yield attributes and yield of Cowpea as affected by different agro-techniques

Treatments	Number of pods/plant	Grain yield (kg/ha)	Dry weight of bhusa (kg/ha)	Harvest index* (%)
T3	5.36	801.69	1443.04	35.71 (36.69)
T4	6.20	818.43	1483.17	35.55 (36.60)
T7	5.53	815.50	1488.90	35.38 (36.49)
SEm ±	0.508	50.663	56.447	0.478

* Figures in brackets are angles for comparison.

4.13.1. Number of pods per plant

The number of pods per plant exhibited only small differences between the treatments. This suggests clearly that the different methods of cultivation of the main crop do not have marked effect on the number of pods of the intercropped cowpea.

4.13.2. Grain yield

The maximum grain yield was recorded by T4, the difference was only very small. This suggests that the different methods of cultivation of tapioca do not have any marked effect on the yield of the intercropped cowpea.

4.13.3. Dry weight of bhusa

In the case of dry weight of bhusa also difference between the treatments were only very small. Thus the data clearly indicate that the different methods of cultivation of tapioca do not have significant influence on the dry yield of bhusa of the intercropped cowpea.

4.13.4. Harvest Index

The harvest index recorded by the various treatments showed meagre difference again suggesting that the different methods of cultivation of tapioca do not have marked effect on the harvest index of the intercropped cowpea. The vegetative as well as the productive attributes of the intercrop showed only minor difference between the treatments. Hence it is natural that the harvest index also showed no significant difference between treatments.

Summary

SUMMARY

An experiment was conducted at the Instructional Farm, Vellanikkara from June 1981 to February 1982 to study the effect of different agro-techniques on soil loss, surface runoff and soil moisture storage in hill slopes. The treatments consisted of (1) tapioca alone in ridges along the slope, (2) uncultivated bare fallow as control (3) tapioca in ridges along the slope with cowpea as intercrop (4) tapioca in ridges across the slope with cowpea as intercrop (5) tapioca alone in mounds (6) tapioca alone in ridges across the slope and (7) tapioca on mounds with cowpea as intercrop. The experiment was conducted in runoff plots of size 2[illegible].3 m x [illegible].7 m. The runoff and soil loss were determined under 18 erosive rainfalls which occurred during the period under the study. The data were subjected to statistical analysis and the results are summarised below.

1. The total rainfall was better correlated with runoff and soil loss followed closely by the average intensity. The correlation coefficient of runoff with all other rainfall parameters were not significant.

2. Maximum runoff and soil loss were observed in plots with tapioca in ridges along the slope without intercrop which was significantly superior to all the other treatments.

3. Cowpea intercropping could significantly reduce runoff and soil loss.

4. The planting of tapioca in ridges across the slope was found to be effective in reducing soil and water losses.

5. Under high intensity rainfall conditions the content of sand in runoff sediment was found to be higher.

6. Maximum loss of nutrients viz. 131.29 kg nitrogen, 41.44 kg phosphorus and 124.63 kg potassium per hectare were registered by the treatment with tapioca in ridges along the slope without intercrop.

7. Maximum retention of rainfall was recorded by tapioca in ridges across the slope with cowpea as intercrop.

8. The pH and conductivity of runoff water were not significantly influenced by different treatments.

9. During the dry periods maximum storage of moisture in 30-45 cm soil layer was recorded by uncultivated bare fallow plots. The depletion of soil moisture in the 30-45 cm soil layer was higher in cultivated plots as compared to uncultivated bare fallow plots.

10. The height of tapioca was maximum in plots with tapioca in ridges across the slope.

11. The number of functional leaves per plant in tapioca was maximum in plots with tapioca in ridges across the slope.

12. The maximum length of tapioca tubers was recorded in plots with tapioca in ridges across the slope.

13. The yield of tapioca tubers was maximum in plots with tapioca in ridges across the slope.

14. The biometric characters and yield of the intercropped cowpea was not markedly affected by the various agro-techniques.

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* Originals not referred.

Appendices

APPENDIX - I

Weather data (weekly averages) from 30th May 1981 to 26th February 1982.

Date	Weeks	Temp. C Max.	Temp. C Mini.	Relative humidity (%)	Total rain fall (mm)	Number of rainy days	Hours of bright sunshine	Wind speed km/hour	Evaporation mm/day
May 30 - June 5	1	28.6	22.7	91	360.2	7	0.4	1.8	0.4
June 6 - June 12	2	29.9	22.9	92	280.7	7	1.6	1.0	0.8
June 13 - June 19	3	27.5	22.2	91	319.4	7	0.6	0.6	0.2
June 20 - June 26	4	28.1	22.1	88	276.6	7	3.5	3.0	0.7
June 26 - July 3	5	29.9	22.7	86	-	-	5.5	1.5	1.2
July 4 - July 10	6	29.2	22.5	87	194.3	7	3.7	2.0	0.9
July 11 - July 17	7	29.3	22.0	86	127.3	5	3.8	2.1	1.5
July 18 - July 24	8	30.0	23.4	86	61.0	3	6.2	5.1	3.4
July 25 - July 31	9	27.9	22.8	90	130.1	5	1.8	3.1	0.6
Aug. 1 - Aug. 7	10	28.9	21.6	91	68.6	4	4.1	3.2	2.6
Aug. 8 - Aug. 14	11	28.4	22.4	87	50.0	4	2.8	2.2	1.2
Aug. 15 - Aug. 21	12	27.5	22.3	89	257.1	7	1.6	2.0	0.7
Aug. 22 - Aug. 28	13	29.8	21.5	84	29.2	2	5.4	2.8	3.2
Aug. 29 - Sept. 4	14	30.4	23.4	79	3.0	1	6.3	3.0	3.4
Sept. 5 - Sept. 11	15	29.24	22.9	84	117.6	6	3.2	1.8	1.2
Sept. 12 - Sept. 18	16	28.9	22.5	87	162.1	7	2.8	1.1	1.8
Sept. 19 - Sept. 25	17	28.1	23.0	91	240.1	7	2.6	0.9	0.6
Sept. 26 - Oct. 2	18	30.6	22.9	82	-	-	5.8	2.4	3.6
Oct. 3 - Oct. 9	19	30.9	22.5	77	331.2	2	6.9	1.6	3.5
Oct. 10 - Oct. 16	20	30.8	23.0	79	5.0	1	5.9	1.1	2.5
Oct. 17 - Oct. 23	21	31.7	23.0	79	10.2	1	5.4	1.0	1.5
Oct. 24 - Oct. 30	22	29.7	22.9	79	40.0	3	4.2	3.5	1.6
Oct. 31 - Nov. 6	23	30.4	22.5	82	1.6	1	4.8	1.3	2.2
Nov. 7 - Nov. 13	24	31.2	22.1	73	76.4	3	7.3	1.1	3.0

Contd..2.

Appendix - I Contd.

Date	Weeks	Temp. C		Relative humidity (%)	Total rain fall (mm)	Number of rainy days	Hours of bright sunshine	Wind speed km/hour	Evaporation mm/day
		Max.	Mini.						
Nov. 14 - Nov. 20	25	32.3	22.6	68	-	-	9.4	4.3	3.6
Nov. 21 - Nov. 27	26	31.9	20.2	66	-	-	7.7	1.4	3.9
Nov. 28 - Dec. 4	27	31.0	23.4	67	2.2	1.0	9.0	8.4	4.7
Dec. 5 - Dec. 11	28	32.7	19.3	61	-	-	10.0	2.4	3.8
Dec. 12 - Dec. 18	29	31.2	19.6	62	-	-	6.7	7.1	5.2
Dec. 19 - Dec. 25	30	30.9	23.4	65	-	-	9.8	16.4	8.1
Dec. 26 - Jan. 1	31	31.9	22.0	57	-	-	9.8	10.9	6.4
Jan. 2 - Jan. 8	32	31.5	21.5	55	-	-	9.9	14.3	7.7
Jan. 9 - Jan. 16	33	32.3	20.3	59	-	-	10.1	8.2	5.8
Jan. 16 - Jan. 22	34	32.7	20.7	52	-	-	10.1	8.5	7.5
Jan. 23 - Jan. 29	35	33.2	22.5	69	-	-	9.9	10.8	6.8
Jan. 30 - Feb. 5	36	34.6	21.7	55	-	-	9.5	10.1	7.2
Feb. 6 - Feb. 12	37	36.0	21.3	54	-	-	9.9	5.3	6.3
Feb. 13 - Feb. 19	38	35.9	21.3	62	-	-	9.9	4.0	4.7
Feb. 20 - Feb. 26	39	37.1	20.7	53	-	-	10.2	5.8	7.7

APPENDIX II

Dates of observation	Total rainfall in mm	Average intensity in mm/hr
1	2	3
16-6-81	67.2	2.8
17-6-81	49.56	2.065
18-6-81	76.44	3.185
19-6-81	21.84	0.91
20-6-81	26.88	1.12
22-6-81	115.92	4.83
23-6-81	20.1	0.837
24-6-81	71.4	2.975
25-6-81	10.08	0.42
26-6-81	33.6	1.4
27-6-81	4.2	0.18
28-7-81	31.92	1.33
4-8-81	117.6	4.9
11-8-81	52.08	2.17
14-8-81	25.27	1.052
20-8-81	75.2	3.13

APPENDIX III

ANALYSIS OF VARIOUS RAINFALL PARAMETERS FOR EROSION CHARACTERISTICS

Serial No.	Rainfall in mm	Maximum 5 minutes intensity (mm/hr)	Maximum 15 minutes intensity (mm/hr)	Maximum 30 minutes intensity (mm/hr)	Maximum 60 minutes intensity (mm/hr)	EI_5 (metric units)
	1	2	3	4	5	6
1.	29.92	78.00	26.00	23.50	12.70	29.92
2.	37.30	43.20	14.40	14.85	13.35	15.35
3.	49.56	69.00	28.60	19.00	11.60	30.954
4.	49.23	39.60	10.80	8.00	5.50	51.12
5.	27.21	51.60	17.20	12.00	7.40	13.23
6.	21.84	33.60	3.60	3.60	4.20	6.892
7.	26.88	66.00	32.80	21.00	9.60	30.525
8.	70.40	70.80	23.60	15.60	12.40	53.19
9.	45.52	80.40	26.80	13.40	10.50	32.32
10.	20.10	78.00	26.00	13.00	9.40	17.977
11.	20.90	72.00	24.00	10.60	7.70	21.52
12.	50.50	114.00	38.00	19.00	12.50	60.09
13.	10.08	0.18	0.60	2.10	5.30	2.537
14.	33.60	67.20	22.40	16.20	10.30	26.684
15.	52.08	54.00	18.00	4.50	7.50	21.418
16.	25.27	32.40	10.80	9.40	10.20	9.971

APPENDIX III (Contd.)

EI_{15} (metric units)	EI_{30} (metric units)	EI_{60} (metric units)	Total kinetic energy of rainfall in metric tonnes/ha.	AIm (units)
7	8	9	10	11
9.97	9.01	5.69	383.678	7.774
5.11	4.51	4.74	355.416	5.222
12.83	8.523	4.497	448.613	13.148
13.94	10.32	7.10	1290.949	7.089
4.41	3.07	1.89	256.584	5.024
0.738	0.738	0.861	205.144	10.483
15.17	9.712	4.44	462.515	5.053
17.73	11.72	9.37	751.292	16.896
10.77	5.38	4.22	402.082	7.510
5.992	2.996	2.166	230.481	1.849
7.17	3.169	2.30	299.007	3.762
20.03	10.01	6.58	527.149	9.595
0.845	0.296	0.747	140.969	10.281
8.894	6.432	4.09	397.088	5.130
7.139	1.784	2.974	396.645	4.010
3.323	2.892	3.139	307.759	5.821

APPENDIX IV

Mean Squares of Analyses of Variance for runoff in 10^{-3}mm (transformed data)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df								
Block	2	0.0071	0.0018	0.0150	0.0139	0.00007	0.06165	0.4207**	0.0149
Treatment	6	0.3301**	0.1488**	0.1475**	0.2399**	0.3457**	0.1863**	0.3348**	0.1170**
Error	12	0.0024	0.00087	0.01006	0.0044	0.0189	0.0318	0.0410	0.0044

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df								
Block	2	0.0566	0.0391	0.0074**	0.0667	0.0766**	0.1256**	0.2126**	0.0539*
Treatment	6	0.1055	0.1168*	0.1013**	0.1304**	0.1369**	0.1639**	0.2051**	0.2103**
Error	12	0.0523	0.0362	0.0086	0.0015	0.0086	0.0037	0.0037	0.0098

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX V

Mean Squares of Analysis of Variance for Soil loss in kg/ha (Transformed data)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df								
Block	2	0.0012	0.0003	0.0101	0.1831	0.1992	0.3854**	0.2246**	0.1006*
Treatment	6	0.4559**	0.9306**	1.0517**	0.3023*	0.6155**	0.7467**	0.2915**	0.9917**
Error	12	0.0006	0.0046	0.0229	0.0782	0.0702	0.0292	0.0176	0.0150

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df								
Block	2	0.0882	0.5031**	0.0002	0.1073**	0.8714**	1.2384**	1.8287**	1.0490**
Treatment	6	0.1515	0.1554**	0.0723**	0.0315**	0.3463*	0.3939**	0.3206**	0.7859**
Error	12	0.0650	0.0305	0.0103	0.00085	0.1006	0.0162	0.0081	0.0512

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VI

Mean Squares of Analyses of Variance for Total runoff, Total soil loss and Runoff as percentage of Total rainfall during the period of observation

Source	df	Total runoff during the period of observation (mm) (Transformed data)	Total soil loss in kg/ha during the period of observation (Transformed data)	Runoff as percentage of total rainfall during the period of observation
Block	2	0.0083	0.1485**	18.8352*
Treatment	6	0.1495**	0.5309**	172.6472**
Error	12	0.0026	0.0025	4.7596

APPENDIX VII

Mean Squares of Analyses of variance for available P loss (g/ha.cm)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-82
Source	df	1	2	3	4	5	6	7	8
Block	2	62.8503**	2.8417	29.4003*	112.6309*	64.4714*	28.2362*	290.6513	8.8831
Treatment	6	5.7131	7.8437	5.8964	56.3096	75.1065	16.7624**	435.9922*	12.1353
Error	12	5.3632	4.3416	4.5579	25.7177	25.2053	2.0838	128.3695	4.4887

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df	9	10	11	12	13	14	15	16
Block	2	4.4865*	4.2578	5.9706	18.9548**	9.9280	15.9658	3.7171	11.5509
Treatment	6	0.8576	5.7696	20.8456	8.8376**	7.2098	8.9403	16.9437	7.9751
Error	12	0.6574	2.7911	8.9251	1.7785	3.4863	6.0042	3.1415	8.7460

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VIII

Mean Squares of Analyses of Variance for available K loss (g/ha.cm)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df	1	2	3	4	5	6	7	8
Block	2	64991.758	2067.0541	12617.5726	11502.794	75078.35	55768.479	61759.233	9387.6096**
Treatment	6	215971.627**	216681.73	32822.546	70321.668	278360.56	448169.97	2494382.0	204778.72**
Error	12	32091.0377	85955.125	23535.908	30219.500	129324.39	401998.32	858161.08	845.5672

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df	9	10	11	12	13	14	15	16
Block	2	11863.751	297102.45**	92639.1093	142357.17**	163078.5*	141556.47	72381.325*	59281.935
Treatment	6	25406.118	23233.433	3898992.5	25424.50	42571.806	94166.05	50231.65	44168.66
Error	12	13165.152	8137.805	4272813.6	11634.33	39210.416	77990.918	17321.259	16553.506

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX IX

Mean Squares of Analyses of Variance for runoff percentages (Transformed data) as affected by different treatments and dates of observation

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df								
	2	14.5285	7.3767	35.8857	61.0573	49.3297	128.9377	991.6485**	32.9108*
	6	355.8419**	330.5717**	186.2798**	414.5072**	1036.6877**	182.4558	307.0267*	176.5694**
	12	6.0408	4.0581	11.5902	18.9604	46.4330	223.0134	82.6008	5.8900

Dates of observation		25-6-81	26-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df							
	2	47.5921	20.0266	2.2832	34.6237**	114.0817**	147.6579*	34.3337*
	6	159.9679**	449.5810*	111.1630**	46.6967**	227.7019**	261.7770**	167.0371**
	12	13.9777	95.1111	9.3191	4.1965	12.4228	25.7553	6.1433

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX X

Mean Squares of Analyses of Variance for retentive rainfall percentage
(Transformed to angles)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df								
Block	2	14.8929	207.3823	35.2533	60.9836	50.4502	33.5796	1075.2385**	50.1714
Treatment	6	354.7443**	147.7845	185.5405**	414.3180**	1039.9937**	111.2345**	268.7976*	185.8978**
Error	12	6.0710	62.3821	11.4924	18.9686	46.6452	11.1907	81.0455	15.9578

Dates of observation		25-6-81	26-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df							
Block	2	47.7970	21.7555	2.2103	33.5911**	0.9195	172.9076*	33.0666*
Treatment	6	159.7361**	443.2515*	111.3427**	46.8178**	146.5347	234.6464**	159.8868**
Error	12	14.0199	92.3520	9.2579	4.1290	151.1684	33.4127	5.7204

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XI

Mean Squares of Analyses of Variance for the pH of runoff water

Dates of observation		16-6-81	17-6-81	18-5-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df								
	2	0.4471**	0.4642**	0.4133**	1.0133**	0.3290**	0.4247**	0.5790**	0.4947*
	6	0.0674	0.0163	0.0107	0.0198	0.0242	0.0253*	0.0082	0.0385
	12	0.0293	0.0253	0.0055	0.0572	0.0223	0.0075	0.0501	0.0730

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df								
	2	0.5633**	0.4747**	0.9404**	0.3776**	0.3776**	0.5676**	0.2433**	0.4576**
	6	0.0319	0.0160	0.0085	0.0149	0.0149	0.0065	0.0098	0.0120
	12	0.0150	0.0136	0.0221	0.0103	0.0103	0.0098	0.0088	0.0087

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XII

Mean Squares of Analyses of Variance for electrical conductance of runoff water (micromhos/cm)

Dates of observation		16-6-81	17-6-81	18-6-81	19-6-81	20-6-81	22-6-81	23-6-81	24-6-81
Source	df	1	2	3	4	5	6	7	8
Block	2	28.1837*	174.6594**	32.9019	83.9273*	139.1	15.0996*	16.5291	24.2189*
Treatment	6	16.4937	8.0104	11.4688	44.1078	28.983	9.3035	70.3641	9.6906
Error	12	6.8976	2.6823	10.4909	21.2071	11.3465	3.5642	26.2643	3.5415

Dates of observation		25-6-81	26-6-81	27-6-81	28-7-81	4-8-81	11-8-81	14-8-81	20-8-81
Source	df	9	10	11	12	13	14	15	16
Block	2	234.74**	20.2289	21.4983	71.2215*	14.7189	82.8501	68.9508**	6.1676
Treatment	6	9.8215	15.6865	46.7344*	35.6073	10.5239	34.0488	25.6357	7.7176
Error	12	28.33	12.7414	13.3579	13.4791	4.7082	23.2212	9.2968	3.1134

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XIII

Mean Squares of Analyses of Variance for Soil moisture storage (%) (0-15 cm)

Dates of observation		2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	9-9-81
Source	df								
	2	1.8514	5.2922**	1.8684**	3.1525**	2.3483**	0.8501**	0.6862*	0.6714**
	6	6.9241**	8.1247**	11.3057**	14.8557**	4.9865**	13.4317**	5.9844**	6.5700**
	12	1.1743	0.6637	0.1718	0.1936	0.1033	0.1164	0.1404	0.0643

Dates of observation		23-9-81	7-10-81
Source	df		
	2	3.1084**	8.3740
	6	5.3656**	24.0430**
	12	0.0004	2.1764

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XIV

Mean Squares of Analyses of Variance for Soil moisture storage (%) (15-30 cm)

Dates of observation		2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	9-9-81
Source	df								
	2	10.2709**	1.8993**	15.4744**	2.5936**	3.2522**	0.8190*	0.3160	2.9901
	6	9.5690**	4.1018**	6.9405**	14.3680**	12.7121**	11.2463**	6.9779**	13.5801**
	12	0.8599	0.0473	00.3465	0.2280	0.0018	0.12066	0.3463	2.2471

Dates of observation		23-9-81	7-10-81
Source	df		
	2	3.0262**	9.9939*
	6	25.1868**	8.3153*
	12	0.0019	2.0305

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XV

Mean Squares of Analyses of Variance for Soil moisture storage (%) (30-45 cm)

Dates of observation		2-6-81	16-6-81	30-6-81	13-7-81	27-7-81	11-8-81	25-8-81	9-9-81
Source	df								
	2	5.4613**	2.2611**	5.3192**	2.5321*	2.1617**	0.6655	0.4035	1.3264**
	6	10.8071**	3.3694**	7.9779**	12.7555**	8.1714**	11.5601**	8.5071**	7.7537**
	12	0.4614	0.0378	0.1020	0.3943	0.0827	0.2479	0.5254	0.1368

Dates of observation		23-9-81	7-10-81
Source	df		
	2	3.9244	1.2436
	6	27.0299**	7.7519
	12	1.7077	2.6488

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XVI

Mean squares of Analyses of Variance for height of tapioca at monthly intervals (cm)

Source	df	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
Block	2	26.7872**	29.8505**	38.2968*	12.8754**	91.3026	102.0726	53.5279	32.2309**
Treatment	5	1.9542	22.5865**	78.4468**	93.2949**	54.1241	69.0518	78.605*	111.5562**
Error	10	1.3400	1.2545	5.4302	0.5650	24.9573	35.4948	19.6434	2.8131

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XVII

Mean Squares of Analyses of variance for Canopy diameter of tapioca at monthly intervals (cm)

Source	df	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
Block	2	87.305**	73.3437**	114.3809**	256.1660**	143.461**	89.8093**	70.8776**	190.6521**
Treatment	5	26.7855**	42.6193**	21.7638**	55.0968*	313.0433**	14.8754**	11.4945**	53.1493**
Error	10	2.2333	4.2785	0.8613	14.7983	3.5955	1.1989	0.8301	9.2580

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XVIII

Mean Squares of Analyses of Variance for functional leaves per plant at monthly intervals (tapioca)

Source	df	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
Block	2	93.7222**	132.166**	103.722**	172.0555**	116.666**	112.166**	210.666**	121.5**
Treatment	5	1.5222	11.6*	26.3555**	39.9555**	47.7333**	56.9333**	56.9333**	50.266*
Error	10	1.4555	2.566	3.7222	2.9888	2.2000	9.5000	2.0000	11.966

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XIX

Mean Squares of Analyses of Variance for yield and yield attributes of tapioca

Source	df	Number of productive tubers/ plant	Number of unproductive tubers/ plant	Length of tubers (cm)	Mean girth of tubers (cm)	Yield of fresh tubers (kg/ha)	Dry weight of tops (kg/ha)	Harvest index (percentage converted to angles)
Block	2	41.7222**	22.7222**	28.6233	19.9534*	10084535.7**	1545078.02**	57.3783**
Treatment	5	3.5555	14.9888**	35.7780**	1.1113	11241489.10**	132920.786	1.4292
Error	10	4.2555	1.1888	9.3674	3.9162	765558.573	48021.307	2.8378

* Significant at 5 per cent level

** Significant at 1 per cent level

EFFECT OF AGRO-TECHNIQUES ON SOIL LOSS, SURFACE RUNOFF AND SOIL MOISTURE STORAGE IN HILL SLOPES-PART II

BY

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment was conducted at the Instructional Farm, Vellanikkara during June 1981 to February 1982, to study the effect of various Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes. The experiment was conducted with the main objective of studying the effect of cowpea intercropping as well as the different methods of planting of tapioca on reducing soil and water loss in hill slopes.

The experiment was laid out in Randomised Block Design with seven treatments and three replications. The treatments consisted of (1) tapioca alone in ridges along the slope, (2) uncultivated bare fallow as a control, (3) tapioca in ridges along the slope with cowpea as intercrop, (4) tapioca in ridges across the slope with cowpea as intercrop, (5) tapioca alone in mounds, (6) tapioca alone in ridges across the slope and (7) tapioca in mounds with cowpea as intercrops.

The experiment was conducted in field runoff plots of 24.3 m x 2.7 m size. The runoff from the field were collected directly into water proof polyethene lined earthen tanks and measured after each rainfall.

From the experiment it is observed that total rainfall was better correlated with runoff and soil loss followed by average intensity.

Maximum runoff and soil loss occurred in plots with tapioca alone in ridges along the slope.

Cowpea intercropping as well as tapioca planting in ridges across the slope were effective in reducing soil and water losses.

Tapioca alone in ridges along the slope recorded the maximum losses of N, P and K being 131.29 kg, 41.44 kg and 124.63 kg/ha respectively.

Maximum retention of rainfall was recorded by tapioca in ridges across the slope with cowpea as intercrop.

The pH and conductivity of runoff water were not significantly influenced by different treatments.

During the dry periods maximum storage and thereby minimum depletion of moisture in 30-45 cm soil layer were recorded by uncultivated bare fallow plot.

The treatment with tapioca alone in ridges across the slope recorded greater height of plants, more number of functional leaves per plant, maximum length of tubers and highest yield of tubers.

The biometric characters and yield of the intercropped cowpea were not affected by various cultivation methods of tapioca.