EFFECT OF CONSERVATION TILLAGE AND VEGETATIVE BARRIER ON RUNOFF, SOIL MOISTURE AND YIELD OF CASTOR ON RAINFED ALFISOL IN A MICROWATERSHED

BY
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THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN THE FACULTY OF AGRICULTURE

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD - 500 030.

1995

CERTIFICATE

Sri C.NAGENDER RAO has satisfactorily completed the course of research and that the thesis entitled "**EFFECT OF CONSERVATION TILLAGE AND VEGETATIVE BARRIER ON RUNOFF, SOIL MOISTURE AND YIELD OF CASTOR ON RAINFED ALFISOL IN A MICROWATERSHED**" is a result of the original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF CONSERVATION TILLAGE AND VEGETATIVE BARRIER ON RUNOFF, SOIL MOISTURE AND YIELD OF CASTOR ON RAINFED ALFISOL IN A MICROWATERSHED"** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Sri.C.NAGENDER RAO** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

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ACKNOWLEDGEMENTS

I express my profound sense of gratitude to my Major Advisor and Chairman of Advisory Committee **Dr.M.Singa Rao**, Soil Physicist, Soil Physical Conditions Improvement Project (ICAR), Agricultural Research Institute, Rajendranagar, for his excellent guidance, valuable advice, encouragement, help and constructive criticism throughout the course of investigation.

I am very much indebted to **Dr.A.Padma Raju**, Associate Director of Research, Anakapalle, for his caring help, valuable suggestions and constructive criticism throughout the course of investigation.

I am highly thankful to **Dr.M.V.Shantaram**, Associate Director of Research, Rajendranagar, for his precious advice and help during the course of study.

I sincerely thank **Dr.I.V.Subba Rao**, Professor, Department of Plant Physiology, College of Agriculture, Rajendranagar, for his valuable suggestions and help during the course of study.

I wish to express my thanks to **Dr.A.Sreenivasa Raju**, Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar, for the help extended during the course of this investigation.

I take this opportunity to thank **Drs.Prabhu Prasadini** and **Jayashree**, Assistant Soil Physicists, Rajendranagar, for their valuable suggestions and help while carrying out my research work. I am also thankful to S/Sri **P.L.Narasimhan, C.Sathaiah, Sheik Osman** and other staff of Soil Physics Scheme, Agricultural Research Institute, Rajendranagar, Hyderabad for their assistance in carrying out the research work.

I also extend my thanks to the staff of Maheswaram Watershed and Ornithology Schemes for their help and assistance.

I acknowledge the Staff, Agromet Cell, Agricultural Research Institute, Rajendranagar, for their assistance during statistical analysis of the data.

I am profoundly indebted to my beloved parents, wife **Madhavi** and sons, **Mithun** and **Milind** for thier love, affection and constant encouragement throughout the course of this investigation.

I am thankful to **Sri Habib** and staff of **Sagar Computer Centre** for the pains taken in computer typing and neat printing of the thesis.

Finally, I am grateful to Andhra Pradesh Agricultural University for granting study leave to pursue higher studies.

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DECLARATION

I, **Sri. C. NAGENDER RAO** hereby declare that the thesis entitled **"EFFECT OF CONSERVATION TILLAGE AND VEGETATIVE BARRIER ON RUNOFF, SOIL MOISTURE AND YIELD OF CASTOR ON RAINFED ALFISOL IN A MICROWATERSHED"** is a result of the original research work done by me. I further declare that the thesis or part thereof has not been published earlier elsewhere in any manner.

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Degree to which it is submitted	:	DOCTOR OF PHILOSOPHY IN AGRICULTURE
Faculty	:	AGRICULTURE
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year of submission	:	1995

ABSTRACT

A field experiment entitled "Effect of conservation tillage and vegetative barrier on runoff, soil moisture and yield of castor on rainfed Alfisol in a microwatershed" was conducted in shallow Alfisol with 2.5 per cent slope during four kharif seasons from 1991-92 to 1994-95 at Agricultural Research Institute, Rajendranagar, Hyderabad. The experiment was laid out in randomised block design with four replications. There were six treatments viz., sowing along the contour (T_1), sowing along the contour with khus barrier (T_2), sowing along the contour with dead furrows (T_3), sowing along the contour with dead furrows and khus barrier (T_4), sowing along the contour with ridges and furrows and khus barrier (T_5) and sowing along the slope (T_6 - control). The test crop was castor. The tillage treatments were imposed at 30 days after sowing (DAS).

Conservation tillage practices have reduced runoff and soil loss, increased soil moisture content, improved plant characteristics and increased seed yield of castor. Ridges and furrows formed along the contour with khus barrier resulted in highest reduction in runoff and soil loss. The soil moisture content in 0-15, 15-30 and 30-45 cm depths throughout the crop

growth period was also highest in this treatment. Drymatter production, leaf area index, plant height, and yield parameters were highest in this treatment. Seed yield of castor was significantly superior in ridges and furrows with khus barrier over others. Dead furrows on contours with khus barrier was next to ridges and furrows with khus barrier in all the aspects. Soil moisture content above khus barrier was higher than below khus barrier. Seed yield of castor was also higher above khus barrier than below khus barrier. Soil water balance computed for each treatment indicated lesser water deficit in ridges and furrows with khus barrier. Water use efficiency was also more in ridges and furrows with khus barrier than other treatments. Regression model developed on the relationship between seed yield and runoff was significantly negatively correlated. Regression models developed on the relationships between rainfall, runoff and soil loss can be used to predict runoff and soil loss on the incident rainfall. Based on the results, sowing of castor on contours with ridges and furrows formed at 30 DAS in combination with khus barrier at 1 m vertical gradient is recommended for shallow Alfisols with a slope of 2.5 per cent under rainfed conditions.

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LIST OF ABBREVIATIONS

CD	:	Critical difference
cm	:	Centimetre
cm ha^{-1}	:	Centimetre per hectare
Cm hr^{-1}	:	Centimetre per hour
DAS	:	Days after sowing
d Sm^{-1}	:	Deci Siemen per metre
g	:	gram(s)
g cm^{-3}	:	gram(s) per cubic centimetre
K	:	Potassium
K_2O	:	Available potassium
kg ha^{-1}	:	kilogram(s) per hectare
m	:	metre
mm	:	millimetre
m ha	:	million hectare
M Pa	:	Mega pascals
m tonnes	:	Million tonnes
N	:	Nitrogen
P	:	Phosphorus
P_2O_5	:	Available phosphorus
q ha^{-1}	:	qunitals per hectare
SEm	:	Standard error of mean
t ha^{-1}	:	tonne(s) per hectare
% w/w	:	per cent on weight basis
WUE	:	Water use efficiency

INTRODUCTION

CHAPTER I

INTRODUCTION

India, with 2 per cent of the world's area has to support over 15 per cent of the world's human and about 16 per cent of the world's cattle population (Nair, 1994). With fast increasing human population estimated to cross one billion mark by the end of the century, India would need about 225 m tonnes of food grains to meet the domestic requirements. Meeting the food needs of the increasing population from a shrinking cropped area of about 144 m ha is a challenge before the present generation. It is therefore apparent that future increase in food production will come about only if the technologies aimed at production increase are integrated with those involved in protection of its resource base (Sehgal and Abrol, 1994). The scope for increasing the yields in the existing high input irrigated system is limited because of various reasons like water logging, salinisation, etc. This implies that large proportion of the incraese in food production will have to come from rainfed lands which account for 68 per cent in India. In Andhra Pradesh, out of 104 lakh ha of the net sown area, about 70 per cent is rainfed. There are several constraints for crop production in these areas. The rainfall is low, inconsistent with long dry spells and high intensity. Most of the drylands are undulating and slopy, shallow, low in water storage capacity and allow rapid surface runoff and soil erosion. Soil and rainwater are the two natural endowments in rainfed areas, conservation of which is the most important aspect in rainfed agriculture.

Production in rainfed areas can be increased substantially through watershed based appropriate soil and water management practices.

In rainfed Alfisols of Andhra Pradesh, more than 40 per cent of total rainfall is unutilised and lost as runoff. Large quantity of soil (upto 40 t ha^{-1} yr^{-1}) is also lost through erosion (El Swaify _et al._, 1984). Nearly 75 to 100 million tonnes of very valuable top soil is lost through erosion annually in Andhra Pradesh. Therefore, there is an urgent need to conserve rainwater and soil in about 70 lakh ha in Andhra Pradesh.

Construction of earthen bunds at regular intervals has been a well established practice for conservation of soil and water (Dhruva Narayana _et al._, 1990). But this practice of construction of bunds has certain disadvantages like loss of area for bunds, high cost of construction, difficulty in maintenance, stagnation of water near bunds, etc. Hence alternate measures involving low cost, easily adaptable conservation technologies need to be worked out. Low cost technologies like contour cultivation and conservation tillage are some of the practices that could be adopted in these soils with slope upto 5 per cent. Vegetative barriers in place of earthen bunds are economical (costing about Rs.200 per hectare) and easily maintanable (MWP, 1990-91).

In Southern Telangana zone of Andhra Pradesh, Alfisols are predominant soils. These soils have undulating topography with slopes upto 5 per cent at most places. They are shallow, coarse and gravelly with low profile water storage capacity. Crusting and hardening is a problem in these soils. More than 70 per cent of the area in this zone is under rainfed cultivation. The crop yields are poor in these areas due to lack of sufficient soil moisture. Castor is the most important commercial crop grown in these soils and the area of the crop is increasing every year. In Andhra Pradesh, castor is mostly grown in the districts of Nalgonda, Medak, Mahaboobnagar, Warangal and Prakasham of which the first three districts come under Southern Telangana zone. Though Andhra Pradesh ranks first in castor area in India, the crop yields are very poor. The yields can be substantially increased through appropriate soil and water conservation practices involving conservation tillage in combination with vegetative barriers.

However, data on the effect of conservation tillage practices like contour cultivation, dead furrows and ridges and furrows in combination with vegetative barrier in reducing runoff and soil loss, increasing soil moisture content and crop yields is very meagre. This type of information will be very useful in planning the watershed programme in dryland areas effectively.

Keeping this in view, a field experiment was conducted for four years in a microwatershed area on shallow Alfisol during kharif, 1991-92 to 1994-95 with different conservation tillage practices like dead furrows and ridges and furrows in combination with and without khus (vetiver) barrier with the following specific objectives.

1. To estimate runoff and soil loss under different conservation tillage practices viz., contour cultivation, dead furrows and ridges and furrows along with khus barrier in rainfed Alfisol.

2. To study the effect of the conservation tillage practices in combination with and without khus barrier on soil moisture content and performance and yield of castor.

3. To evaluate the effect of khus barrier in reducing runoff, soil loss and increasing soil moisture content and yield of castor.

4. To quantify the hydrological components under different treatments.

5. To estimate the rainwater that could be harvested under different conservation practices.

6. To develop models for predicting runoff and soil loss under different conservation tillage practices and khus barrier.

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REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The information on the effect of conservation tillage practices on runoff, soil loss, soil moisture and yield of castor is very meagre. Studies on the effect of vegetative barriers on reducing runoff and increasing the yield of rainfed crops, particularly castor are scanty. Hence, the information on related crops is also reviewed in this chapter.

2.1 CONSERVATION TILLAGE

Contour cultivation, contour ridging, formation of dead furrows, broadbed and furrow and deep ploughing are some of the conservation tillage practices being employed for conservation of rain-water and soil and obtaining better crop yields. The effect of these practices on runoff, soil loss, soil moisture and crop yields are reviewed below.

2.1.1 Effect of conservation tillage practices on runoff and soil loss

Surface runoff is inevitable in the tropical climate particularly on slopy lands, soils which are prone to surface crusting and black soils having low infiltration rates. The amount of runoff however, depends on soil type, land slope and amount and intensity of rainfall, besides physiography of land and may vary from 10 to 40 per cent (Oswal and Khanna, 1983). A portion of top soil is also carried away in the runoff water. Runoff and soil loss were reported by several workers (Lal, 1976; Obi, 1982; Dhruva Narayana and Ram Babu, 1983; CRIDA, 1985; El-Swaify et al., 1987; Sharma et al., 1988; ICRISAT, 1989; Adhikari et al., 1993; and Vangani, 1994) under different management practices. Based on the hydrological studies conducted at ICRISAT, Hyderabad on the traditional farming systems, El-Swaify et al. (1987) reported that on an average, 26 per cent of the total rainfall potentially available was lost through runoff, 33 per cent through deep percolation and only the balance of 41 per cent was utilised by crops. The influence of conservation tillage practices such as contour cultivation, dead furrows and ridges and furrows under variable soil and rainfall environments on runoff and soil loss is reviewed in this chapter.

2.1.1.1 Contour cultivation

Contour cultivation in Vertisols with sunflower crop at Chevella, reduced runoff to 95 mm compared to 118 mm with farmers' practice, although the number of runoff events were same in both the treatments (CRIDA, 1987). Similarly, in Alfisols of

Maheswaram watershed area, runoff with contour sowing was 15.2 and 1.8 mm when compared to that of 17.4 and 2.0 mm in sowing along the slope treatment when the rainfall was 122 and 11 mm, respectively (MWP, 1989-90).

Contour sowing of cowpea at Bhubaneswar reduced runoff and soil loss from 209 mm and 5.90 t ha^{-1} in farmers' practice to 198 mm and 4.93 t ha^{-1}, respectively (AICRPDA, 1991-92).

At Anantapur on an Alfisol, sowing groundnut on contour recorded soil loss of 0.47 t ha^{-1} compared to that of 1.26 t ha^{-1} in control plots (AICRPDA, 1989-90).

Contour cultivation in Vertisols at Sholapur recorded lower runoff and soil loss by 9.5 per cent of rainfall and 0.55 t ha^{-1} compared to that of 29.9 per cent of rainfall and 0.99 t ha^{-1}, respectively in flat bed cultivation (AICRPDA, 1989-90).

2.1.1.2 Dead furrows

Formation of furrows at 1.50 m after broadbed in maize grown in Vertisols at ICRISAT reduced soil loss by 76 per cent compared to flat sowing (2.1 t ha^{-1}) (ICRISAT, 1978-79).

Contour cultivation plus furrowing in Vertisols at Chevella with sunflower crop recorded 26 per cent reduction in runoff (120 mm) as compared to 163 mm under farmers' practice (CRIDA, 1988).

At Indore, formation of furrows at 1.50 m after broadbeds in soybean crop reduced runoff by 76 per cent compared to 10.8 mm recorded by flat bed control (AICRPDA, 1989-90).

2.1.1.3 Ridges and furrows

Contour sowing and ridging later recorded a runoff of 265.35mm compared to that of 307.27mm from without ridging in Alfisols with sorghum-pigeonpea intercropping in small watersheds at Hyderabad. The reduction in runoff due to ridging was 13.64 per cent (AICRPDA, 1984). Flat sowing on grade and ridging later reduced runoff by about 73 per cent over without ridging (CRIDA, 1986). Experiments conducted in a watershed at Chevella, Hyderabad in black soils showed that tied ridges reduced runoff compared to flat beds. The number of runoff events during the crop growth period were 5 with tied ridges compared to ten in control (CRIDA, 1987).

In Maheshwaram watershed area of Andhra Pradesh, sowing on contour with ridge and furrow and khus barrier at 1 m vertical interval reduced runoff to

29 mm from 64.5 mm recorded with sowing along the slope (MWP, 1989-90).

At Bhubaneswar, formation of ridges and furrows in red soil under cowpea crop, reduced runoff and soil loss by 25.8 and 43.4 per cent, respectively over 209 mm and 5.9 t ha^{-1} with farmers' practice (AICRPDA, 1991-92).

2.1.2 Effect of conservation tillage on soil moisture

2.1.2.1 Contour cultivation

Contour cultivation of jowar crop in Alfisols of Maheswaram watershed area recorded higher (2.30 cm) available soil moisture content upto 60 cm depth compared to 1.30 cm with sowing along the slope. (MWP, 1987-88). The increase in soil moisture upto 45 cm depth with castor crop sown on contours was 20 per cent when compared to that sown along the slope, on the second day after 122 mm rainfall. In an Alfisol, soil moisture content in 0-15 cm depth was 0.40 and 0.79cm at 40 DAS and 0.19 and 0.32 cm at harvest of sorghum when sowing was done along the slope and on contours, respectively (MWP, 1989-90).

At Bangalore, soil moisture content during a dry spell was more by 83.6, 24.6 and 15.9 per cent in 0-15, 15-30 and 30-45 cm depths, respectively when finger millet was sown on contours compared to local practice of sowing along the slope (AICRPDA, 1989-90).

2.1.2.2 Dead furrows

In red loamy soils of Anantapur, formation of dead furrows (deep furrows) at 3.6 m interval conserved more soil moisture in 0-15 cm depth compared to flat beds (AICRPDA, 1980).

In shallow Alfisols of Maheshwaram watershed area, formation of dead furrows along the contour recorded 2.62 cm of available soil moisture in the top 60 cm soil compared to 1.3 cm in sowing along the slope (MWP, 1987-88).

In Alfisols of Maheshwaram watershed area, higher soil moisture content of 0.92 and 0.47 cm at 60 DAS and harvest, respectively was recorded in 0-15 cm layer when dead furrows were opened in contour sown crop of sorghum compared to control i.e, sowing along the slope (0.40 and 0.19 cm) (MWP, 1989-90).

At Bangalore, dead furrows opened at 3.3 m interval in finger millet field, increased soil moisture content during a dry spell by 88.1, 33.3 and 24.6 per cent in 0-15, 15-30 and 30-45 cm depths, respectively, over local practice (AICRPDA, 1989-90).

Uma Devi et al. (1991) studied the effect of different conservation tillage practices at varying levels of nitrogen on soil moisture and yield of castor in an Alfisol at Hyderabad. They reported that formation of dead furrows at 1.5 m interval resulted in higher soil moisture content compared to flat bed cultivation. The mean soil moisture content was higher in dead furrows by 74.9 and 47.1 per cent in 0-15 and 15-30 cm depths, respectively over flat bed.

Reddy et al. (1991) reported 10.2 per cent increase in moisture content of Alfisol in 0-30 cm soil depth with dead furrows formed after every three rows of groundnut crop over flat bed treatment at Tirupati.

2.1.2.3 Ridges and furrows

Formation of ridges and furrows in shallow red chalka soils of Hyderabad, increased the moisture content by 8.6 per cent over flat bed with castor crop (SPCIP, 1984).

In the farmers' field trials, at Sardarnagar under Maheshwaram watershed area, formation of ridges in shallow Alfisols increased the soil moisture content by 11 per cent over control (MWP, 1987-88).

In Chickpea-safflower inter-cropping sown on contours (4:2) at Bijapur, formation of ridges and furrows recorded higher soil moisture content of 1.5 and 3.2 per cent in 15-30, and 30-60 depths, respectively over flat bed system (control) at one month after sowing (AICRPDA, 1991-92).

2.1.3 Effect of conservation tillage on crop yield

2.1.3.1 Contour cultivation

In Vertisols at Chevella, Hyderabad contour cultivation increased seed yield of sunflower by 14.6 per cent over 1.23 t ha^{-1} obtained with farmers' practice of sowing along the slope (CRIDA, 1987).

In red sandy loam soils with 2-3 per cent slope, contour cultivation increased the yield of castor by 60 per cent, sorghum by 56 per cent and vegetable crops like bhendi, cluster bean and tomato by 23 to 40 per cent compared to up and down cultivation (MWP, 1988-89 and 1989-90).

At Anantapur, contour cultivation resulted in higher groundnut yield by 47.6 per cent over along the slope cultivation which recorded 8.5 q ha^{-1} (AICRPDA,1989-90).

The yield of maize was increased by 35 per cent at Rakh Dhiansar and that of cowpea by 21 per cent at Bhubaneswar with contour cultivation over farmers' practice (AICRPDA, 1991-92).

In Vertisols of Indore, where mean annual rainfall was 990 mm, contour cultivation proved to be better compared to farmers' practice. The fodder yield of sorghum increased to 365 q ha^{-1} with contour cultivation from 305 q ha^{-1} obtained by farmers' practice (CRIDA, 1992-93).

2.1.3.2 Dead furrows

In a red loamy soil at Anantapur, formation of dead furrows at 2.4 m interval recorded 9.8 per cent higher yield of groundnut over control (AICRPDA, 1979).

Formation of dead furrows at 3.6 m interval in shallow Alfisols at Sardarnagar increased sorghum grain yield by 22 per cent over control (MWP, 1987-88).

In Alfisols of Maheshwaram watershed area, formation of dead furrows at an interval of 3.6 m in contour sown sorghum crop increased grain yield by 68.8 per cent compared to control plot without dead furrows (MWP, 1989-90).

At Bangalore, dead furrows opened at 3.3 m interval in red soils increased the finger millet grain yield by 54.6 per cent compared to control (AICRPDA, 1989-90).

Furrow opening (dead furrows) at 30 DAS resulted in 54 per cent higher yield of pigeonpea compared to that of control at Akola (AICRPDA, 1991-92).

Among the *in situ* moisture conservation practices tested in Alfisols with mean annual rainfall of 540 mm at Anantapur, dead furrows on contours at 3.6 m interval were found to be useful in obtaining higher pod yield of groundnut (6.25 q ha^{-1}) compared to 5.8 q ha^{-1} obtained by farmers' practice (CRIDA, 1992-93).

2.1.3.3 Ridges and furrows

In red chalka soils at Hyderabad, sowing of castor on grade with ridging later resulted in 23 per cent higher yields than flat bed system (AICRPDA, 1980).

In red sandy loam soils of Telangana region, Rao *et al*. (1981) reported that sunflower and castor yields increased by 72 and 34 per cent, respectively when the crops were sown on grade with ridging over contour cultivation.

Formation of ridges and furrows in red chalka soils at Rajendranagar, increased castor (Var. Aruna) yield by 52.6 per cent over 6.63 q ha^{-1} in flat bed cultivation (SPCIP, 1984).

In shallow Alfisols, sowing of sorghum and pigeonpea inter-cropping (2:1) on flat grade and ridging later, increased the yield of both the crops. On farm rainwater management was found to be more beneficial to longer duration pigeonpea (CRIDA, 1985).

Sharma (1986) reported that flat sowing on grade and ridging later in red chalka soil showed an increase in castor seed yield by 21.8 per cent over flat sowing on grade without ridging (4.6 q ha^{-1}).

Formation of ridges and furrows in the contour sown crop increased castor seed yield by 65.8 per cent when compared to sowing along the slope (547 kg ha^{-1}) in Alfisols of Maheshwaram watershed area. Ridging also recorded 44 to 54 per cent increased yields of bhendi, cluster beans and tomato over contour cultivatioin alone (MWP, 1989-90).

At Rakh Dhiansar, maize yields were increased by 60 per cent with ridging over the control yield of 24.0 q ha^{-1}. Higher yields of cotton at Akola and groundnut at Rajkot were also recorded with ridging (AICRPDA, 1991-92).

Oswal (1994) observed that on shallow soils, formation of ridges were beneficial to dryland crops by increasing soil depth. He reported higher yields of pearl millet and mustard by 39.1 and 79.1 per cent, respectively in low rainfall region at Hissar with ridge-furrow system over flat sown crop.

2.2 VEGETATIVE BARRIER

Several plant species like Leucaena leucocephala, Pennisitum ohinikere, Vetiveria zizanioides, Panicum repens, Sacharum spontaneum, Cynadon doctylon, Cymbopogan flexosus etc., have been tried as vegetative barriers to reduce runoff and soil loss and increase crop yields (AICRPDA, 1989-90 and CRIDA, 1991-92).

From 1985, the world bank has been promoting the use of vetiver grass or khus (Vetiveria zizanioides L.) as a plant species which is particularly well suited for use as a contour vegetative barrier.

Because of the density of barrier, vetiver can reduce runoff and act as a water spreading system, increasing plant available moisture. It is this function which can provide short term benefits to the farmers' through crop yields. Vetiver barrier minimises surface runoff from concentrating and create greater spatial and temporal opportunity for infiltration (Smyle and Magrath, 1990).

The effect of vegetative barrier (vetiver barrier) on runoff, soil loss, soil moisture and crop yield is reviewed below.

2.2.1 Effect of khus barrier on runoff and soil loss

On slopes under 5 per cent, contour barriers of khus, planted at 1m vertical intervals reduced surface runoff by 30 per cent and soil loss by 43 per cent compared to conventional practice of graded banks (Krishnappa ,1989 and Bharad and Bathkal, 1990). They have also reported an average reduction of 24 and 54 per cent in surface runoff and soil loss, respectively, with khus barrier compared to Leucaena spp. barrier. Bharad and Bathkal (1990) also reported an average reduction of 47 and 74 per cent in surface runoff and soil loss, respectively with khus barrier as compared to cultivation across slope without khus barrier.

Vetiver barrier coupled with contour cultivation resulted in minimum soil loss (0.07 q ha^{-1}) compared to vetiver alone (0.24 t ha^{-1}), contour cultivation alone (0.47 t ha^{-1}) and control (1.26 t ha^{-1}) in red soil under groundnut crop at Anantapur. At Bijapur, vetiver barrier reduced runoff and soil loss to 77 mm and 3.34 t ha^{-1} yr^{-1} from 133 mm and 6.04 t ha^{-1} yr^{-1} in control plots, respectively (AICRPDA, 1989-90).

Experiments conducted in Maheshwaram watershed area recorded an average reduction in runoff by 29.5 and 55.2 per cent due to khus barrier on contours and khus barrier on contours with ridges and furrows, respectively over sowing along the slope (MWP, 1989-90).

Bharad and Bathkal (1991a) based on three years data from black soils of Akola reported an average reduction in runoff and soil loss of 33.3 and 71.7 per cent, respectively with vetiver hedge on contours at 1 m vertical interval compared to across the slope cultivation.

Kon and Lim (1991) studied the effect of vetiver in Malaysia and reported 73.2 and 92.8 per cent reduction in runoff and soil loss, respectively over bare soil with maize crop.

Bharad and Bathkal (1991b) from the experiments on shallow soils of University farm at Akola, reported an average runoff and soil loss of 74.4 mm and 3.3 t ha^{-1}, in contour cultivation along with vetiver as against 133.9mm and 11.4 t ha^{-1}, observed in across slope cultivation.

Experiments conducted at CRIDA research farm, Huderabad showed about 25 per cent runoff in control (no vegetative barrier) while mechanical and vegetative barriers produced 10 to 11 per cent runoff only out of 422 mm rainfall which caused 8 runoff events (CRIDA, 1991-92). Vetiver barriers when planted at 0.5 m vertical interval reduced runoff to 93.9, 69.1 and 53.8 mm from 115.7, 85.2 and 69.9mm in control on Vertisols at Jabalpur with 2.0, 1.5 and 1.0 per cent slopes, respectively and also recorded lower soil loss of 662, 453 and 465 kg ha_{-1}, as against 986, 914 and 614 kg ha_{-1}, in check plots with 2.0, 1.5 and 1.0 per cent slope, respectively (SCWM, 1991-92).

At Sehore, Madhya Pradesh, measurements of soil loss/deposition at two contour vegetative vetiver hedges showed that over 6 years, soil deposition had increased form 6.8 cm to 19.1 cm and that by the fifth year (due to increased density of the hedge) soil erosion was reduced to zero (Nema, 1994). However, Sivamohan et al (1993) opined that high level of management in required for the success of vetiver as soil and water conservation measure.

2.2.2 Effect of khus barrier on soil moisture

Khus (Vetiver) hedges stop surface runoff from concentrating and create greater spatial and temporal opportunity for infiltration. As the major effect of runoff on productivity is due to the reduction in plant available water, this function of vetiver hedge-rows is most important.

Experiments conducted in Alfisols of Maheshwaram watershed area showed an increase in soil moisture content upto 45 cm depth by 14.7 and 22.7 per cent with khus barrier on contours and khus barrier on contours with ridges and furrows, respectively over sowing along the slope (MWP, 1989-90).

At Akola, higher soil moisture was recorded with Vetiver and Leucaena both in 30 and 60 cm depths over control. It was 89, 100 and 102 mm in 30 cm depth and 116, 131 and 128 mm in 60 cm depth with control, Leucaena keyline and vetiver keyline treatments, respectively. At Bijapur, vetiver increased soil moisture content in 90 cm depth by 39 per cent over control with sorghum as test crop. At Bangalore, vetiver barrier at 12 m interval increased soil moisture content during a dry spell by 50.7, 14.9 and 98.4 per cent in 0-15, 15-30 and 30-45cm depths, respectively over control (AICRPDA, 1989-90).

Woodhead and Chaudhury (1991) observed 2.21 per cent increase in soil moisture content upto 60 cm depth with vetiver hedges (324mm) established at 0.25 m vertical interval over non-hedged control (317mm) with mungbean crop.

An increase of 25.6 per cent in average soil moisture content (over six months) with vetiver hedge barrier over control was observed by Subramanian (1991) at Arappukottai Research farm, Tamilnadu.

Sagare and Meshram (1993) reported that mean moisture use (production per unit of water) in vetiver plots was 17.2 and 33.1 per cent higher (i.e greater production per unit of water) than that of graded bunding and across the slope treatments, respectively at Akola.

2.2.3 Effect of khus barrier on crop yield

Experiments conducted at various centres of All India Co-ordinated Project for Dryland Agriculture showed increased crop yields with vetiver barriers. Vegetative barrier with vetiver increased sorghum grain yield (45.1 q ha^{-1}) at Akola as compared to control (31.5 q ha^{-1}). Yields of seed cotton were increased by 19.2 and 18.3 per cent over control with Leucaena keyline and vetiver keyline, respectively. At Bijapur, vetiver barrier increased sorghum grain yield by 38.5 per cent over control. Vetiver barrier increased the pod yield of peanut by 35.6 per cent compared to control (16.3 q ha^{-1}) at Kovilapatti. At Bangalore, vetiver as vegetative barrier at 12 m distance increased finger millet grain yield by 58 per cent (AICRPDA, 1989-90). The increased crop yields were attributed to the increased soil moisture status due to khus barrier.

Experiments in Alfisols of Maheshwaram watershed area in Andhra Pradesh showed an increase of 41.8 and 55.3 per cent in seed yield of castor with khus barrier on contours at 1 m vertical interval and khus barrier on contours with ridges and furrows, respectively over sowing along the slope (10.3 q ha^{-1}) (MWP, 1989-90).

Crop yield data on sorghum and pearl millet comparing the conventional practices of graded bunds and across the slope cultivation with contour hedgerows of vetiver grass showed an average yield increase of 6 and 26 per cent higher with the vetiver hedgerows over graded banks and across slope cultivation, respectively in Vertisols at Akola. Compared to Leucaena hedgerows, yields with vetiver hedgerows averaged 10 per cent higher (Bharad and Bathkal, 1990).

Castor yield increased by more than 50 per cent with vetiver barrier with small mechanical bund (0.1 m^2) over no bund /barrier treatment in the experiments conducted at CRIDA Research farm, Hyderabad (CRIDA, 1991-92).

Woodhead and Chaudhury (1991) reported an increase in the yields of rainfed rice (13.6 per cent) and mungbean (11 per cent) with vetiver hedge at 0.25 m vertical interval over non-hedged control at International Rice Research Institute, Philippines.

Bharad and Bathkal (1991b) reported an average increase of 28.5 per cent in mean productivity of crops viz., green gram + pigeonpea - safflower, (1987-88), pearl millet-safflower (1988-89) and pearl millet (1989-90) with contour cultivation along vetiver hedgerows over across slope cultivation (15.23 q ha^{-1}).

In the studies on performance of vegetative barriers vs. earthen bunds on the yield of ragi and groundnut crops in Alfisols with mean annual rainfall of 806 mm at Bangalore, it was observed that khus live bund at 0.5 m vertical interval in between earthen bunds at 1 m vertical interval was superior to bund alone at 1 m vertical interval (CRIDA, 1992-1993).

Sagare and Meshram (1993) reported 25.5 per cent higher yield of seed cotton from vetiver with contour cultivation plots than that from across the slope cultivation without hedgerows. Highest gross monetary return and benefit-cost ratio (1.55) were recorded due to vetiver barriers.

2.3 RAINWATER HARVESTING

Water harvesting is a method of collecting surface runoff from a watershed area and storing it in reservoirs. The first definition of water harvesting comes from Geddes as quoted by Myers (1975). The use of microcatchments to harvest water was first proposed by De Angeles and later developed by Shannan and Tadmor (1979). The main advantage of microcatchment is the high specific runoff yield compared to small and large catchments (Boers and Ben Asher, 1982).

Sharma (1986) reported that it is possible to harvest 13.3 to 32.1, 36.1 to 45.4 and 26.5 to 44.3 per cent of rainfall as runoff from 0.5, 5 and 10 per cent slopes, respectively by proper selection of microcatchment area.

Storage is an integral part of water harvesting (Myers, 1975). The decision on which way to store water depends in the first place upon how the water is to be used. The reuse of harvested water can be planned depending upon the quantity of water for supplemental irrigation or growing of vegetables crops in post rainy season. Seepage and evaporation losses need to be accounted for efficient utilization of harvested water (Vijayalakshmi, 1983 and CRIDA, 1991-92). Work on rainwater harvesting and its utilization has been reported by Lallan Rai etal, (1989). Singh et al. (1989), AICRPDA (1989-90), CRIDA (1992-93), Krishnappa and Hegde (1994) and Katyal and Das (1994).

2.4 FIELD WATER BALANCE

Field water balance studies of cropped lands are useful in knowing the water surplus and deficiency periods and designing appropriate water harvesting and moisture conservation techniques. The water balance of a soil in a given period can be expressed as the difference between the input (precipitation and irrigation, if any) and output (runoff, evapotranspiration and deep percolation).

Studies on soil water balance under varying soil, climatic and crop conditions have been reported by several workers (Ben Asher and Warrick, 1987; Mallick and Nagaraja Rao, 1988; Thomas, 1992 and Klaij and Vachaud, 1992).

Patro and Misra (1985) determined *in situ* daily water balance for important crops viz., rice, ragi, black gram and groundnut during two five-day long dry spells coinciding with early vegetative and reproductive stages and also around every 10th day during 30-70 days of growing season at Bhubaneswar. The mean daily evapotranspiration observed during 30-70 days after sowing of these crops were 0.84cm for rice, 0.75cm for ragi, 1.28cm for black gram and 1.86cm for groundnut.

At Indore, seasonal water balance of 504, 108, 80.2, 45.2 and -14.44 mm under soybean with flat sowing as rainfall, runoff, deep percolation, water flow to root zone and change in profile moisture, respectively was recorded (AICRPDA, 1989-90).

Soil water balance for kharif cowpea at Hissar was reported to be 174,185,-7, 24, 22, 0, 172 and 798 mm as initial soil moisture content in root zone, rainfall, change in profile soil moisture, internal drainage, capillary contribution, runoff, evapotranspiration and pan evaporation, respectively during the crop growth period (AICRPDA, 1991-92).

Adhikari et al. (1993) reported that about 97 per cent of rainwater was intercepted in the catchment and about 3 per cent was lost as runoff in the treated red soil at G.R. Halli watershed, Karnataka.

Ramachandran and Rajegowda (1987) worked out the relationship between components of water balance and yield of groundnut in the tropical semi-arid climate at Bangalore. They reported a positive correlation between seed yield and rainfall, moisture index, water surplus and moisture adequacy ratio. Potential evapotranspiration, actual evapotranspiration, water deficit and aridity index were negatively correlated with seed yield.

2.5 FIELD WATER BALANCE MODELS

Field water balance models are based either on deterministic, stochastic or emperical approaches. The pure deterministic models can not estimate runoff adequately as the estimate of runoff calculated simply from water balance equations produces errors which can be explained by emperical models using partial area contribution concept (Chorly, 1978 and Karnieli et al., 1988).

Several workers developed and tested models on runoff, soil loss, soil moisture status and other components of field water balance (Victer et al., 1988; Robinson and Hubbard, 1990; Singh et al., 1993; Gupta et al., 1993; and Littleboy et al., 1994).

A simple model for runoff estimation was derived from daily rainfall occurence for red soil region of Hyderabad (CRIDA, 1985). The criteria for estimating runoff was developed from practical observations on runoff events from the cultivated lands in and around Hyderabad. It was observed that any rainfall greater than 20 mm per day resulted in surface runoff. Further, runoff was observed when the previous day received rainfall of 10 mm or more. The following model was assumed.

$$R = -20 - 5d + \sum_{i=1}^{d} r_i \quad \text{Where } r_i \geq 10 \text{ mm}, \; r_{i+1} \geq 5 \text{ mm}$$

Where R is runoff, "d" is rainy day, r_i is the rainfall on i^{th} day.

Boers et al. (1986) developed a linear regression model combined with a soil water balance model to design microcatchments for water harvesting in arid zones. Available rainfall and evaporation data were supplemented with soil physical data determined from samples taken on the spot. A linear regression model combined with a transient one dimensional finite difference water balance model was used to simulate the complete water harvesting process for a number of years. The water balance was simulated for two sets of soil physical properties and for extremely arid and arid conditions. The following conclusions were drawn.

1. Extremely arid conditions (true desert) were too dry for microcatchment water harvesting.

2. For arid conditions with average annual rainfall of 200 mm and, the trees and loose soil considered, a preliminary design should have a basin area of 40 m^2 and runoff area between 40 and 80 m^2.

Water requirement satisfaction index (WRSI) developed by Frere and Popov (1979) was used to quantify crop yield under rainfed conditions at Jodhpur

(CRIDA, 1987). The relationship between WRSI at the end of the growing season (x) and yield (y) of pearl millet cv. BJ-104 at Jodhpur (1971-1985) was reported as

$$Y = \exp(-15.721 + 4.173 \ln X) \quad r = 0.94$$

This indicates the exponential behaviour of the yield as affected by the water availability to the crop. The maximum possible yield of pearl millet was found to be 3300 kg ha^{-1} when WRSI was 100.

Engelhardt (1987) designed a discrete stochastic linear programming model (DSLP) based on a field survey in a watershed near Hyderabad. He combined DSLP model with water balance model and used to optimise agricultural production and investment on percolation reservoirs for various economic settings. In the combined model, the rainfall was divided into runoff and effective rainfall.

Sivakumar et al. (1987) using a simple water balance model of Keig and McAlpine (1974) in deep and medium deep Alfisols reported that under identical rainfall conditions, the effect of short term drought on crop moisture status will differ with the depth of the Alfisols. The effect of changes in seeding dates and the influence of different phenological characteristics on crop performance could be assessed on a first approximation basis using such analysis.

A parametric simulation model was developed at Utah State University, USA to predict runoff from small agricultural watersheds. The input data for it were the daily rainfall amount, storm duration or rainfall intensity, pan evaporation and soil moisture. By means of a univariate optimization procedure, measured runoff data were used to determine the proportion of rainfall that infiltrates and the part that runs off. The model was tested with data from ICRISAT and there was an excellent agreement between computed and observed runoff events. There were 12 runoff producing storms and the objective function (R^2) was 0.974 while the mass balance was 0.029 (ICRISAT, 1978-79).

Regression models were developed relating rainfall (R) runoff (Q) and soil loss (A) for different conservation treatments in cowpea field at Bhubaneswar (AICRPDA, 1991-92). The equatioins for ridge furrow planting (1), contour planting + vetiver barrier (2) and farmers' practice (3) are given below.

Rainfall - soil loss	Rainfall - Runoff
1) $A = -0.0554+0.0072R$	$Q = -1.6762 + 0.2967R$
$r = 0.9155$	$r = 0.9909$
	Runoff - soil loss
	$A = -0.022 + 0.02460Q$
	$r = 09254$
2) $A = -0.511 +0.0059R$	$Q = -0.7021 +0.258R$
$r = 0.9692$	$r = 0.9364$
	Runoff - soil loss
	$A = -0.0399 + 0.0217Q$
	$r = 0.9845$
3) $A = -0.1346+0.0139R$	$Q = -1.818 +0.395R$
$r = 0.9581$	$r = 0.9871$
	Runoff - soil loss
	$A = -0.0569+0.0339Q$
	$r = 0.9330$

These equations are useful in estimating the runoff and soil loss on the incident rain.

Adhikari <u>et</u> <u>al</u>. (1993) developed two equations for rainfall-runoff relationships at G.R. Halli watershed, Karnataka.

$$Y = 68.9\ X - 907.6 \text{ for } X > 50 \text{ mm and API} \geq 25 \quad \ldots. (1)$$

and

$$Y = 472 - 65.86\ X + 2.05\ X^2 \text{ for } 21.4 < X < 50 \text{ mm and API} < 25 \quad \ldots\ldots (2)$$

Where X = Daily rainfall in mm

Y = Runoff in mm

API = Antecedent precipitation index

The threshold value for rainfall to cause runoff is 14 mm and 22 mm, respectively for equations 1 and 2.

The foregoing review reveals that not much work was done on the influence of conservation tillage practices and vegetative barriers in reducing runoff and soil loss and increasing soil moisture and crop yield with special reference to castor in watersheds.

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MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The details of the materials used and the methods adopted in conducting the experiment on "Effect of conservation tillage and vegetative barrier on runoff, soil moisture and yield of castor on rainfed Alfisol in a microwatershed" are described in this chapter.

3.1 SITE OF THE EXPERIMENT

The experimental site was the microwatershed located in the Agricultural Research Institute farm, opposite College of Veterinary Sciences, Rajendranagar, Hyderabad. The farm is situated at an altitude of 543 m above the mean sea level with geographical bearing 77^{o} 55' E Longitude and 18^{o} 59' N Lattitude. The experiment was conducted in the upper region of the microwatershed. The slope of the land was 2.5 per cent.

3.2 CLIMATIC CONDITIONS

Data on mean maximum and minimum temperatures, relative humidity, rainfall, rainy days, sunshine hours and evaporation recorded during the crop growth period for four kharif seasons starting from 1991-92 are given in Appendices I to IV. The data on rainfall and evaporation are illustrated in Figs. 1 to 4. A total rainfall of 510.6 mm in 20 rainy days (1991-92), 485.9 mm in 34 rainy days (1992-93), 476.9 mm in 34 rainy days (1993-94) and 542.6 mm in 34 rainy days (1994-95) was recorded during the growth period of castor. The highest weekly mean maximum temperatures recorded were 32.9, 31.9, 33.6 and 31.9°C and the lowest weekly mean minimum temperatures were 8.8, 8.8, 8.7 and 7.8°C during the crop growth period in 1991-92, 1992-93, 1993-94 and 1994.95, respectively. Mean weekly maximum evaporation of 5.7, 4.8, 6.3 and 5.4 mm and minimum evaporation of 2.9, 1.8, 2.8 and 2.7 mm in the years 1991-92, 1992-93, 1993-94 and 1994-95, respectively were recorded during the growth period of castor.

3.3 SOIL CHARACTERISTICS

The soil properties of the experimental field are given in Table 1. The soil was neutral in reaction, non saline, gravelly red sandy loam upto 30 cm depth and gravelly red loam between 30 and 45 cm depth. The bulk density was 1.70, 1.73 and 1.79 g cm^{-3} in 0-15, 15-30 and 30-45 cm depths, respectively. The moisture retained (%w/w) at 0.01 M Pa and 1.5 M Pa was 16.80 and 3.50, 18.25 and 3.90 and 18.30 and 4.20, respectively in 0-15, 15-30 and 30-45 cm depths. The

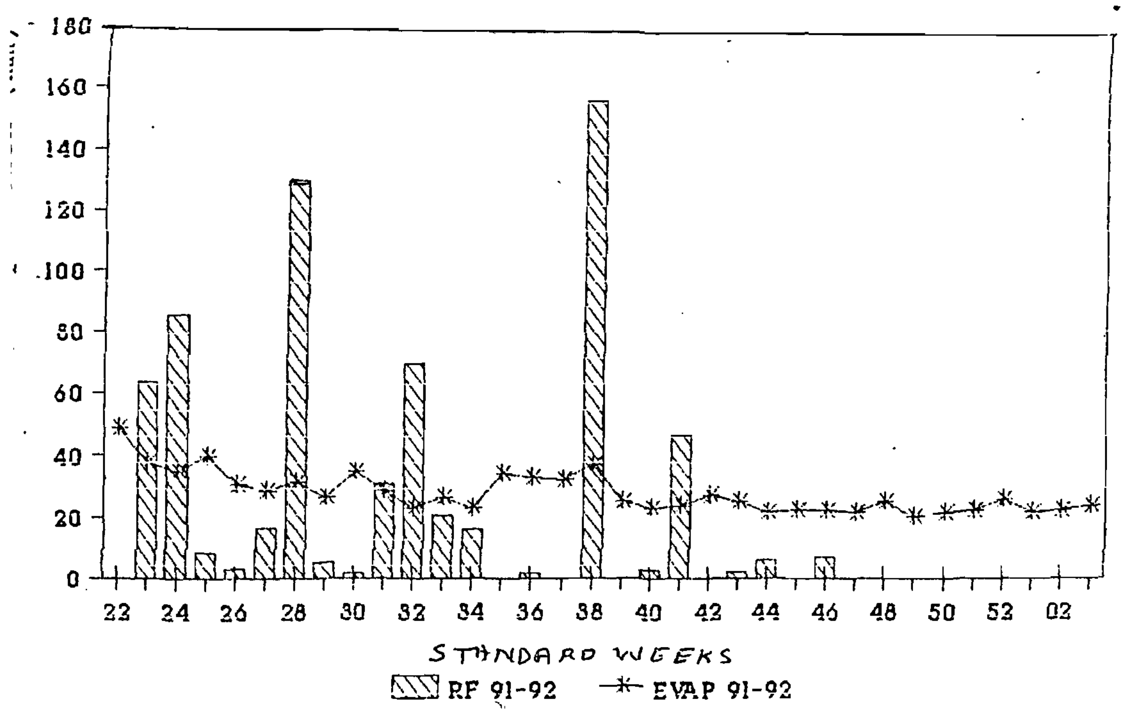


Fig.1 Weekly rainfall (mm) and evaporation (mm) during crop growth period (1991-92)

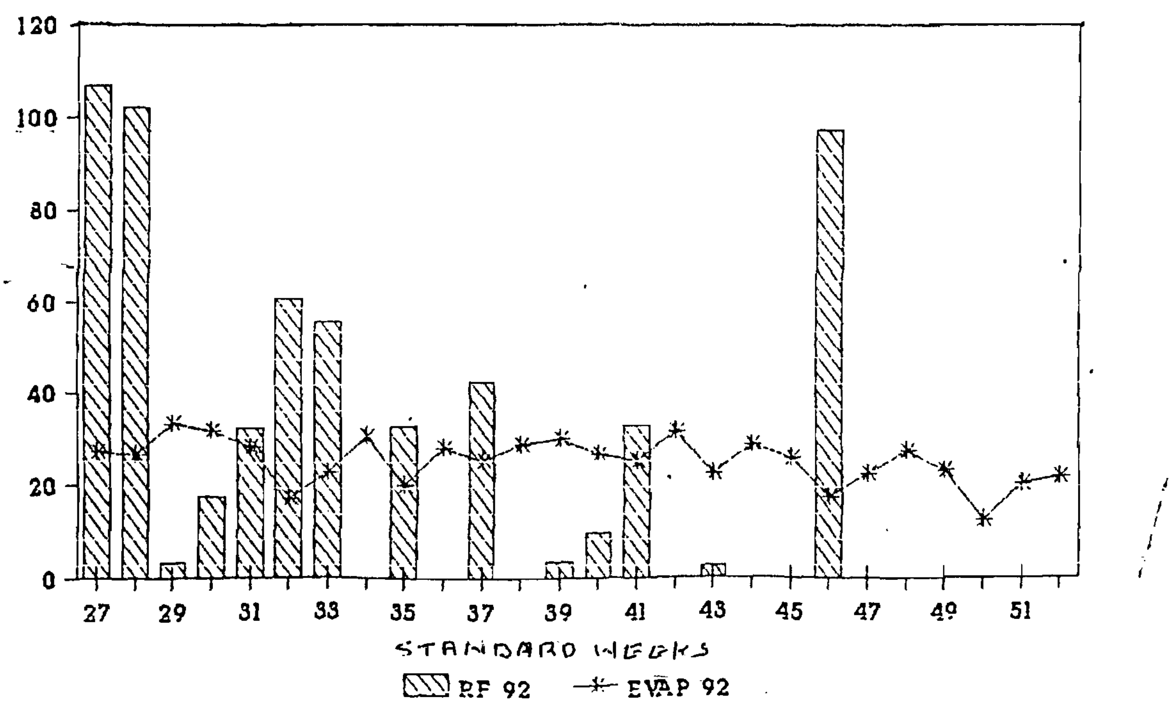


Fig.2 Weekly rainfall (mm) and evaporation (mm) during crop growth [redacted]

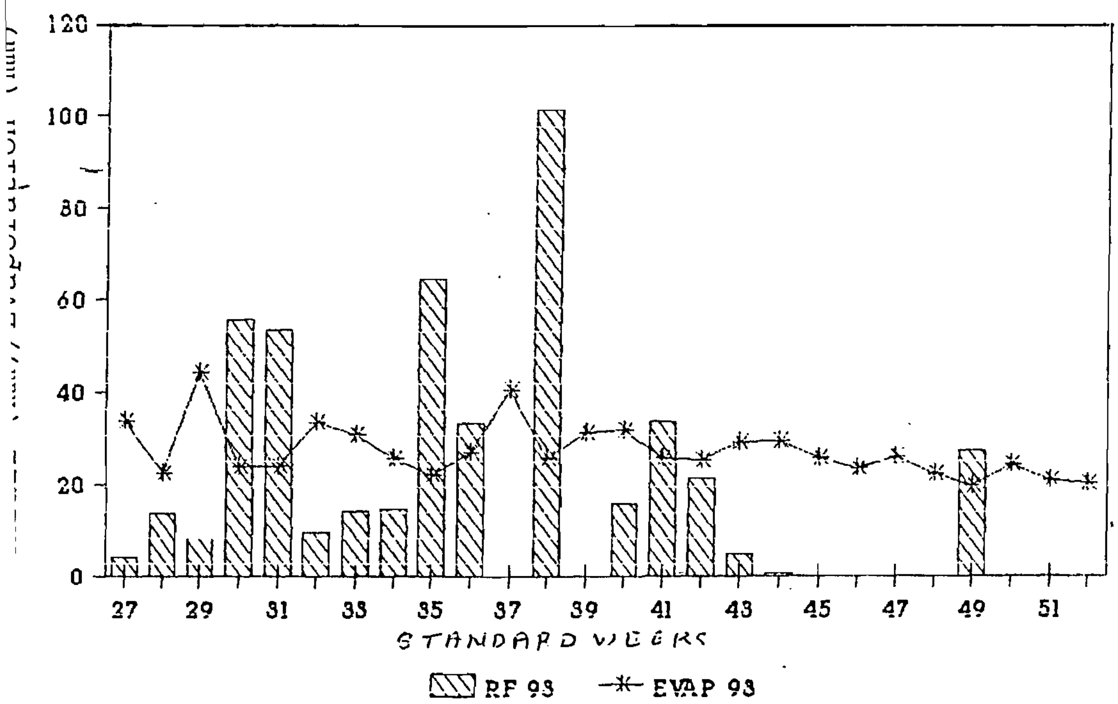


Fig.3 Weekly rainfall (mm) and evaporation (mm) during crop growth period (1993-94)

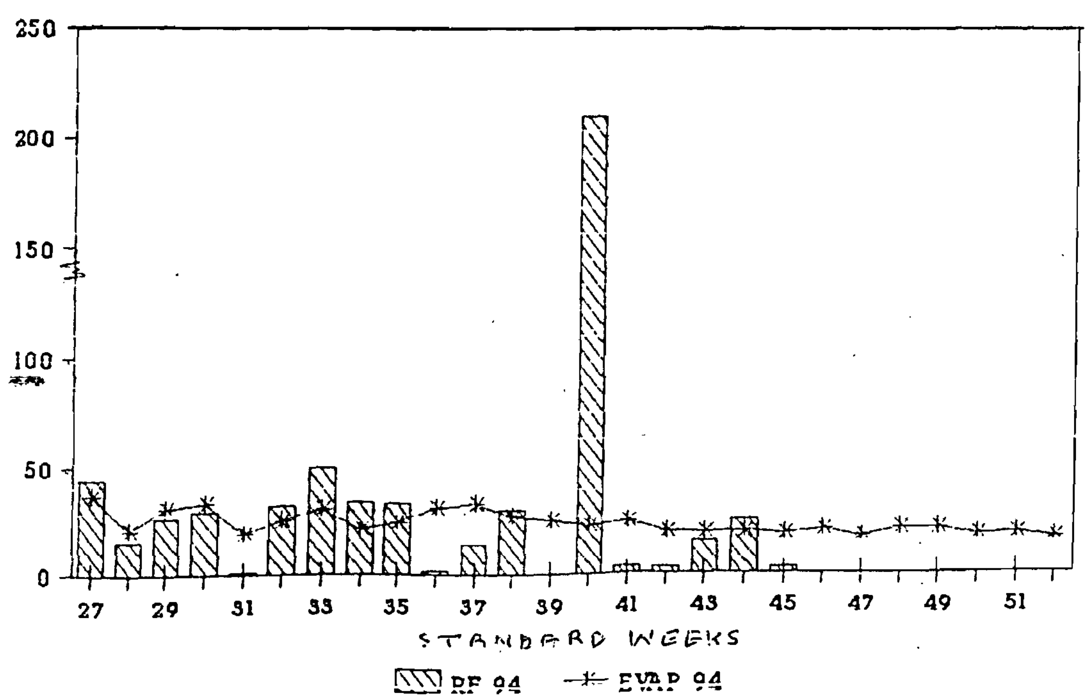


Fig.4 Weekly rainfall (mm) and evaporation (mm) during crop growth period (1994-95)

e 1. Initial soil characteristics

	DEPTH (cm) 0-15	15-30	30-45	Methods followed
PHYSICAL ANALYSIS:				
1. Mechanical analysis				
Sand %	80.25	73.40	64.9	International Pipette method (Day, 1965)
Silt %	9.75	11.00	17.0	
Clay %	10.00	15.60	18.1	
2. Gravel per cent	25.00	33.00	42.0	
3. Textural class	Gravelly Sandy Loam	Gravelly Sandy Loam	Gravelly loam	USDA Soil Survey Staff (1975)
4. Bulk density g cm^{-3}	1.70	1.73	1.79	Core method (Blake, 1965)
5. Moisture retained at (% w/w)				
0.01 M Pa	16.80	18.25	18.30	Pressure Plate Apparatus (Richards, 1965)
1.5 M Pa	3.50	3.90	4.20	
6. Hydraulic conductivity (cm hr^{-1})	6.6	6.2	6.0	Constant Head Method (Klute, 1965)
CHEMICAL ANALYSIS :				
1. Soil reaction (pH) 1:2 soil, water suspension	7.2	7.2	7.2	Glass electrode pH meter (Jackson, 1967)
2. Electrical conductivity (dSm^{-1})	0.1	0.17	0.14	Conductivity bridge (Richards,1954)
3. Organic carbon (%)	0.44	0.28	0.33	Walkley and Black (1934)
4. Available nitrogen kg ha^{-1}	244	432	383	Alkaline permanganate method (Subbiah & Asija, 1956)
5. Available phosphorus kg ha^{-1}	78.8	32.1	14.0	Ascorbic acid method (Watanabe & Olsen, 1965)
6. Available potassium kg ha^{-1}	145.6	177.0	177.0	Flame photometer (Muhr *et al.*, 1963)

soil was low in organic carbon content. Available nitrogen and potassium contents were low in 0-15 cm depth and medium in 15-30 and 30-45 cm depths. Available phosphorus was high in 0-15 cm, medium in 15-30 cm and low in 30-45 cm depths. The taxonomical classification of soil is as follows:

Order	:	Alfisol
Sub-order	:	Ustalfs
Family	:	Coarse loamy mixed isohyperthermic udic Rhodustalfs
Series	:	Rajendranagar series

3.4 DETAILS OF THE EXPERIMENT

3.4.1 Season

Experiment was conducted in kharif season under rainfed condition for 4 years i.e, 1991-92, 1992-93, 1993-94 and 1994-95.

3.4.2 Crop

In 1991-92 castor variety PCS-4 was sown. In the succeeding 3 years castor variety Aruna was taken up.

3.4.3 Experimental details

3.4.3.1 Treatments

T_1 Sowing along the contour

T_2 Sowing along the contour with khus barrier

T^3 Sowing along the contour with dead furrows

T^4 Sowing along the contour with dead furrows and khus barrier

T^5 Sowing along the contour with ridges and furrows and khus barrier

T^6 Sowing along the slope.

Khus (Vetiveria zizanioides) grass was planted in June 1988 at 1m vertical gradient on contours. Three slips were planted per rill at a distance of 15 cm which established well and formed continuous hedge of about 50 cm thickness by the time the experiment was started. These khus lines acted as keylines for contour cultivation except in T^6.

Dead furrows were opened after every four rows along the contour at 30 DAS (Plate 1).

Ridges and furrows were formed along the contour for each plant row at 30 DAS (Plate 2).

3.4.3.2 Replications Four

3.4.3.3 Design

Experiment was laid out in randomised block design. Layout was so made that the khus barrier was 4 m above the lower end of the plots where the treatment included khus barrier. Layout plan is given in Fig.5.

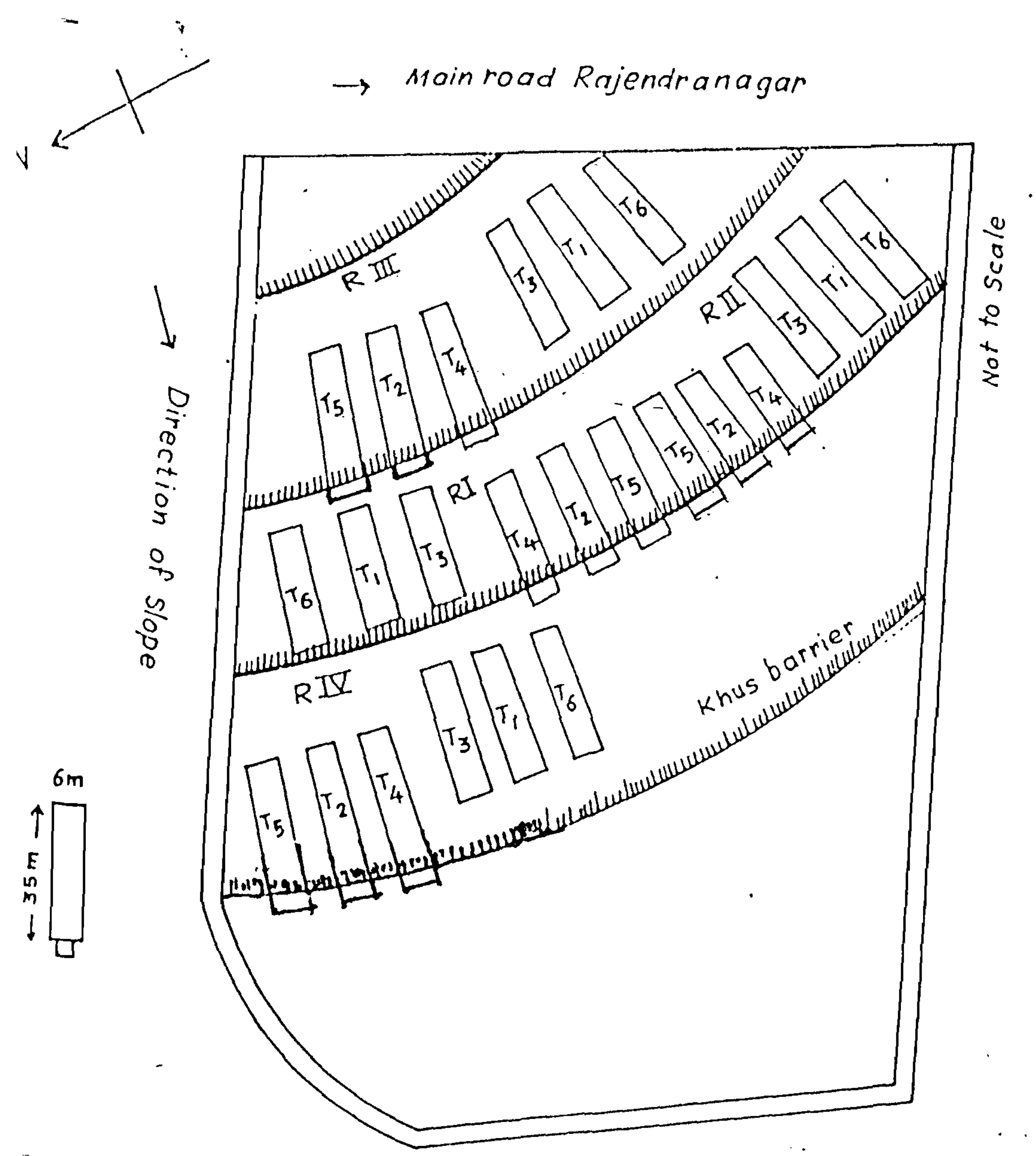
3.4.3.4 Plot Size 35 m x 6 m

3.4.3.5 Spacing 90 cm x 20 cm

3.4.3.6 Fertilizers 40 N, 60 P^2O^5 and 0 K^2O kg ha_{-1}

Plate 1 Dead furrows in castor

Plate 2 Ridges and furrows in castor



Treatments:

T1 - Sowing along contour
T2 - Contour + khus
T3 - Contour + dead furrows
T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Plot size: 35 m x 6 m

Fig. 5 LAYOUT PLAN OF THE EXPERIMENT

3.4.4 Sowing and harvesting

Dates of sowing and harvesting are given in Table 2. Contour sowing was done in all the treatments except T_6. Sowing was done behind country plough. Land preparation was done with cultivator and disc harrow. Hand weeding was done at regular intervals.

3.5 DATA COLLECTED

3.5.1 Soil parameters

3.5.1.1 Soil moisture content

Soil samples were collected twice in a week upto 45 cm depth at 15 cm intervals throughout the crop growth period and moisture content was estimaed gravimetrically.

To find out the effect of vegetative barrier on soil moisture, soil moisture was also estimated at 2 m above the khus and 2 m below the khus line in T_2.

3.5.1.2 Profile water storage

Soil moisture in terms of depth (cm) was calculated by multiplying fractional gravimetric soil moisture with thickness and bulk density of the layer. Summation of this upto the effective root depth was considered as profile water storage.

Table 2. Dates of sowing and harvest of castor.

Season	Date of sowing	Dates of Picking 1st	2nd	3rd
1991-92	22-6-91	06-10-91	15-11-91	05-12-91
1992-93	17-7-92	21-10-92	30-11-92	31-12-92
1993-94	04-07-93	25-10-93	29-11-93	27-12-93
1994-95	08-07-94	25-10-94	09-12-94	31-12-94

$$WS = \sum_{i=1} \frac{W}{100} \times l \times BD \quad \text{where,}$$

WS is profile water storage in cm, 1 to n are layers of profile, l is thickness of layer in cm, BD is bulk density of the layer in g cm_{-3} and W is per cent gravimetric soil moisture content.

3.5.1.3 Runoff

Trapezoidal shaped troughs (Fig.6) of 2.5 m length fabricated with G.I. metal sheet were fixed at the end of each plot in order to collect runoff with eroded soil. Five outlets were provided on the lower sidewall at 50 cm distance from the centre and 20 cm high from the bottom of the trough. The runoff was collected from one outlet (1/5th) into a big hard PVC drum (capacity 200 litres) fixed inside the soil. The observations were recorded after the imposition of treatments. The system as fixed in the field is shown in Plate 3.

Runoff of rain water was calculated from the volume of water collected in the trough and in the drum and expressed as mm.

3.5.1.4 Soil loss

For estimation of soil loss, the runoff water collected in the trough and drum were thoroughly mixed and 5 litre samples were collected from each treatment

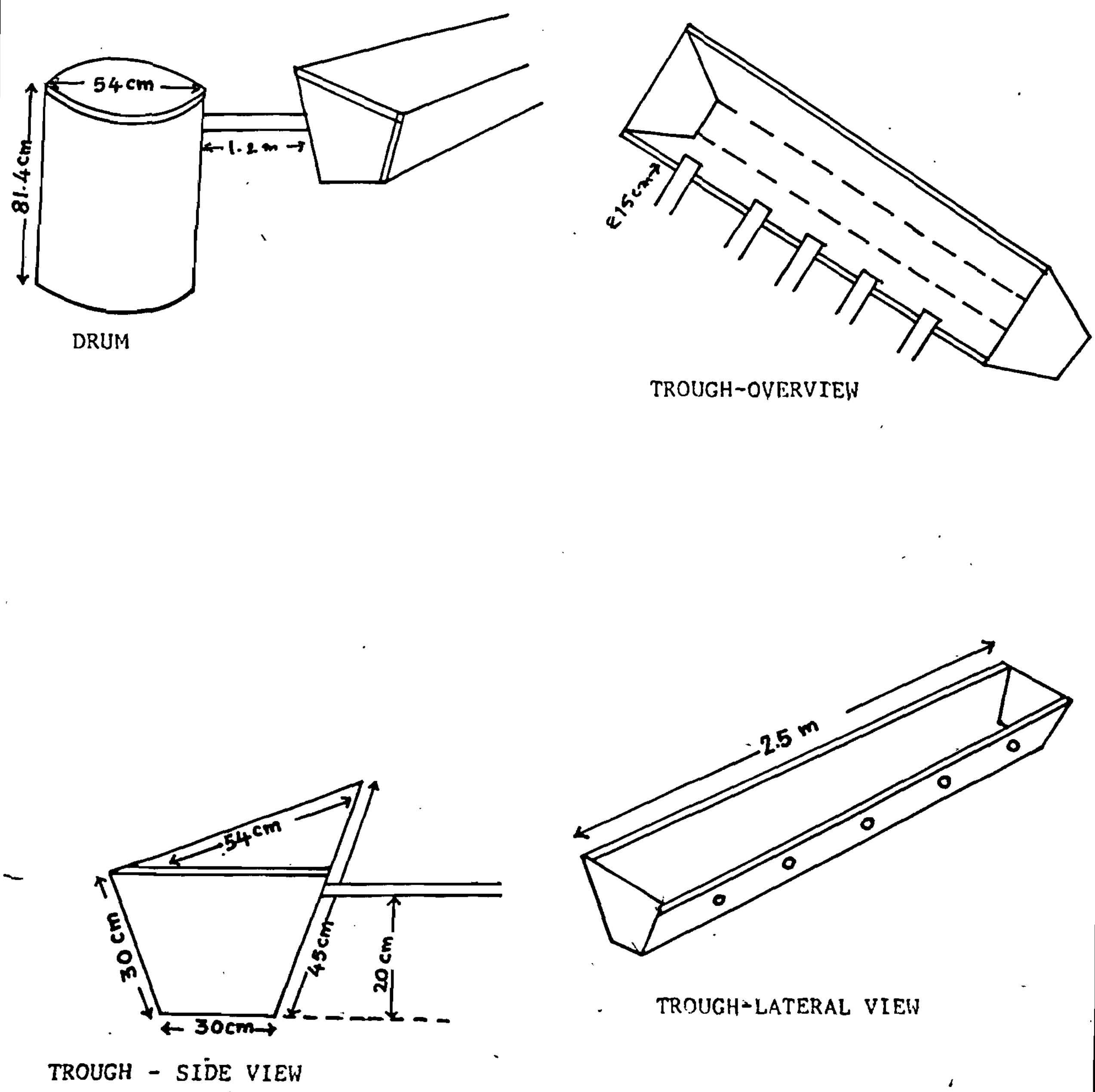


FIG. 6. RUNOFF AND SOIL LOSS MEASURING SYSTEM

Plate 3 Runoff and soil loss measuring system

after every runoff event. 20 ml of 10 per cent Alum solution was added to the runoff samples collected. After the soil was settled, the supernatant water was decanted without loss of soil. The soil remained at the bottom of the buckets was quantitatively transferred to 1 litre capacity beakers and dried on a hot plate. Dry weight of the soil was expressed as t ha^{-1}.

3.5.1.5 Field water balance

The water balance was calculated by the mathematical expression of S = P + I - R - AET - D as quoted by Garnier et al. (1986).

Where, ΔS = Change in stored water

P = Rainfall in a given period

I = Irrigation

R = Surface runoff

AET = Actual evapotranspiration during the period

D = Drainage (deep percolation)

Runoff was estimated with the help of runoff collection trough. Actual evapotranspiration was calculated by using potential evapotranspiration and crop coefficient values from the equation

$$AET = Kc \times PET$$

Where,

AET = Actual evapotranspiration

Kc = Crop coefficient

PET = Potential evapotranspiration

The crop coefficient values as reported by CRIDA, Hyderabad for different growth stages of castor were used (CRIDA, 1992-93). The PET values provided by the Agro-meteorological cell at Rajendranagar were used in the calculations. Deep percolation losses were considered as zero as the deep percolation reported is negligible (AICRPDA, 1991-92).

3.5.2 Plant parameters

3.5.2.1 Drymatter production

Ten plants above ground level were collected at random at 60, 90 and 120 DAS, and were oven dried at 65^{o}C till constant weight was attained. The dry matter was expressed in kg ha^{-1}.

3.5.2.2 Leaf area index (LAI)

Leaf area was estimated from the same plants collected for estimation of drymatter production at 60, 90 and 120 DAS using leaf area meter model CI-203. The leaf area index was calculated from the total leaf area of the plants for unit cropped area.

3.5.2.3 Plant height

In each plot 10 plants were randomly selected and tagged for recording height of plants at 60, 90 and 120 DAS.

3.5.2.4 Number of spikes

Number of spikes were counted on the 10 tagged plants at harvest and expressed as average number of spikes per plant.

3.5.2.5 Number of capsules per plant

Number of capsules were counted on 10 tagged plants at harvest and expressed as number of capsules per plant.

3.5.2.6 Seed yield

Spikes were harvested plotwise and after threshing, seed yield was recorded on air dry weight basis in kg ha^{-1}.

To find out the effect of vegetative barrier, spikes were collected from the plot of size 4 m x 4 m above the khus and below the khus in T_2 and seed yield was recorded separately in kg ha^{-1}.

3.5.2.7 Test weight

Test weight was recorded from each plot. 100 seeds were collected and air dry weights were recorded and expressed in grams.

3.5.3 Water use efficiency (WUE)

Water use efficiency was calculated taking average seed yield in kg per hectare and water used (cm) during the crop growth in all the treatments separately and expressed in kg ha^{-1} cm^{-1}. It was calculated as given below.

$$WUE = \frac{\text{Seed yield in kg ha}^{-1}}{\text{Water use in cm}}$$

Water use was calculated from the initial soil moisture content and rainfall and runoff and soil moisture content at harvest.

3.6 STATISTICAL ANALYSIS

The data obtained from the experiment were subjected to statistical analysis by following standard methods (Panse and Sukhatme, 1978) with the help of computer (Model Micro System, 11001).

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RESULTS

CHAPTER IV

RESULTS

The effect of conservation tillage practices in combination with and without khus barrier on runoff, soil loss, soil moisture content and crop yield was studied in a field experiment for four kharif seasons from 1991-92 to 1994-95 under rainfed conditions with castor as test crop in the microwatershed at Agricultural Research Institute farm, Rajendranagar. The results obtained are presented in this chapter.

4.1 CONSERVATION TILLAGE

4.1.1 Effect of conservation tillage on runoff and soil loss

The data on runoff and soil loss were recorded during the years 1993-94 and 1994-95 and are presented in Table 3. During 1993-94, one abnormal storm event has been deleted and results on eight runoff events were considered. The total rainfall of the eight runoff causing events was 234.1 mm. Among the treatments, highest runoff of 35.14 mm was recorded in the control treatment i.e. sowing along the slope (T_6). The treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) recorded the lowest runoff of 4.05 mm. The runoff recorded in other treatments was 30.80 mm in sowing along the contour, 10.55

Table 5. Effect of conservation tillage on runoff(mm) and soil loss(t ha) during kharif, 1993-94 *

Date	Rain fall (mm)	Sowing along contour T1		Contour + khus T2		Contour + dead furrow T3		Contour + dead furrow + khus T4		Contour + ridges & furrow + khus T5		Sowing along slope T6	
		Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss
04-08-1993	34.4	4.62	0.325	1.53	0.084	2.28	0.168	0.96	0.054	0.47	0.036	5.17	0.382
27-08-1993	21.8	4.98	0.432	2.01	0.114	2.72	0.208	1.59	0.066	0.91	0.044	5.35	0.496
29-08-1993	26.0	3.47	0.396	1.26	0.103	2.12	0.196	0.96	0.062	0.62	0.042	4.28	0.456
06-09-1993	21.9	3.23	0.304	0.98	0.075	1.82	0.146	0.67	0.042	0.36	0.030	3.88	0.372
17-09-1993	40.8	4.83	0.369	1.54	0.086	2.54	0.172	1.08	0.050	0.61	0.036	5.56	0.426
22-09-1993	54.8	5.02	0.358	1.76	0.082	2.59	0.166	1.19	0.048	0.66	0.034	5.66	0.416
10-10-1993	13.8	2.39	0.182	0.78	0.040	1.25	0.076	0.39	0.020	0.22	0.012	2.76	0.212
19-10-1993	20.6	2.26	0.172	0.69	0.038	1.12	0.074	0.34	0.018	0.20	0.010	2.48	0.206
Total	234.1	30.80	2.538	10.55	0.622	16.44	1.206	7.18	0.360	4.05	0.244	35.14	2.966

* Excluding one runoff event on 15/08/1993

mm in sowing along the contour with khus barrier, 16.44 mm in sowing along the contour with dead furrows and 7.18 mm in sowing along the contour with dead furrows and khus barrier. The per cent runoff of rain water under different conservation practices is illustrated in Fig.7. It was 13.16 in sowing along the contour, 4.51 in sowing along the contour with khus barrier, 7.02 in sowing along the contour with dead furrows, 3.07 in sowing along the contour with dead furrows and khus barrier, 1.73 in sowing along the contour with ridges and furrows and khus barrier and 15.01 in sowing along the slope.

The per cent reduction in runoff due to different conservation tillage practices compared to control (sowing along the slope) is given in Table 5. Sowing along the contour with ridges and furrows and khus barrier (T_5) resulted in highest reduction of 88.47 per cent in runoff compared to sowing along the slope. This was followed by sowing along the contour with dead furrows and khus barrier (79.57 per cent), sowing along the contour with khus barrier (69.98 per cent), sowing along the contour with dead furrows (53.22 per cent) and lowest (12.35 per cent) was recorded in the treatment, sowing along the contour (T_1).

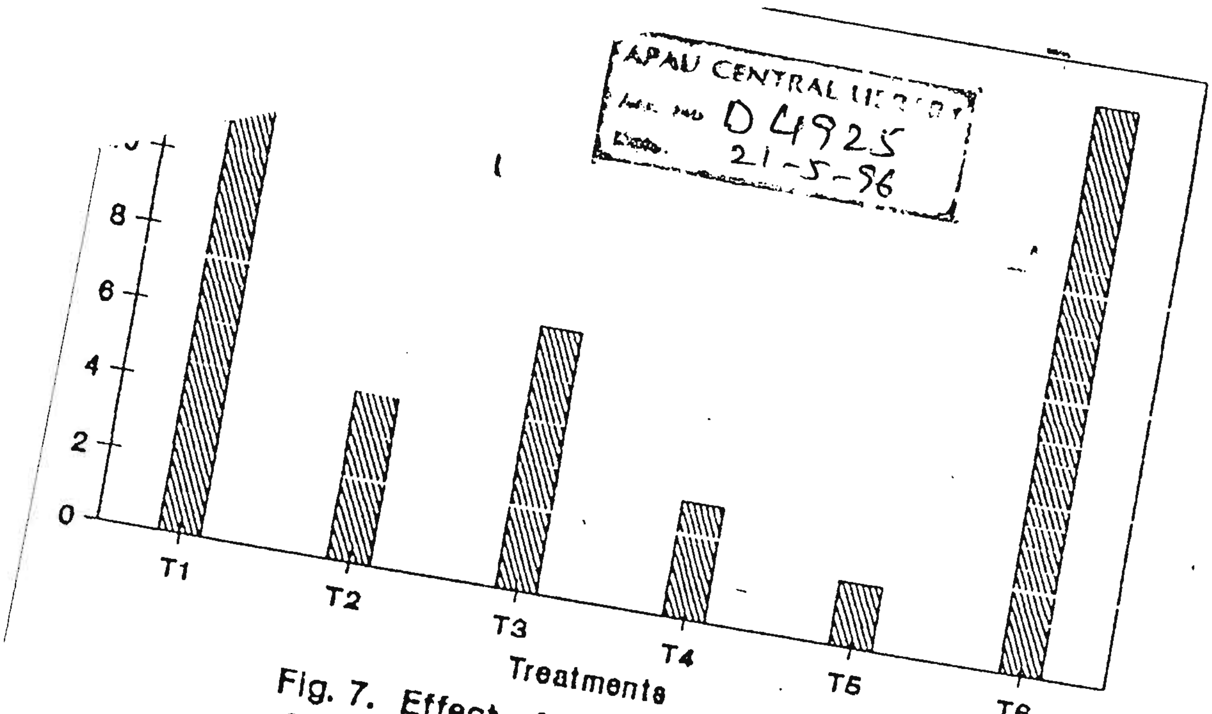
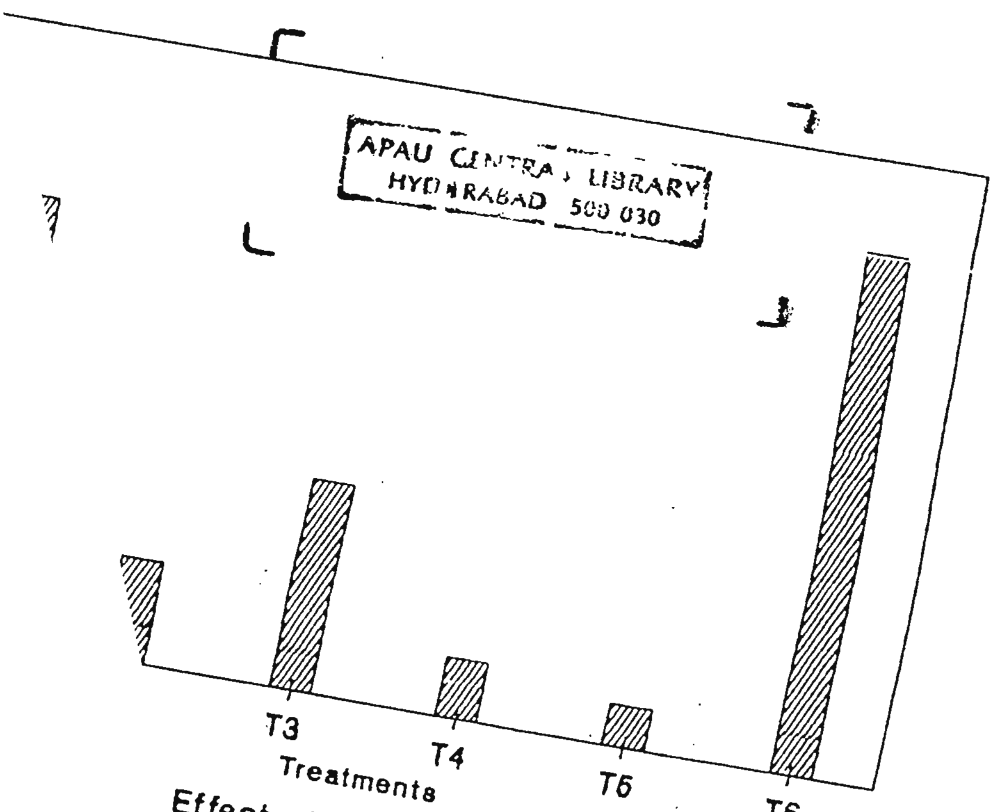


Fig. 7. Effect of conservation tillage on per cent runoff (kharif 1993-94)



Effect of conservation tillage
'oil loss (kharif 1993-94)

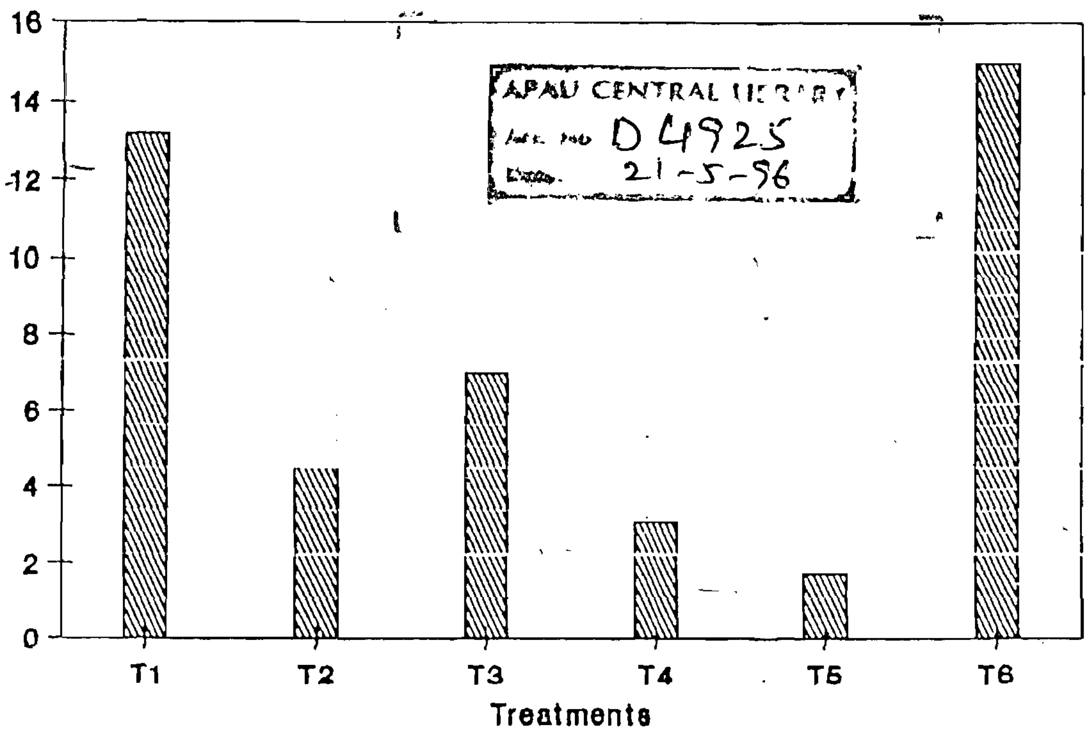


Fig. 7. Effect of conservation tillage on per cent runoff (kharif 1993-94)

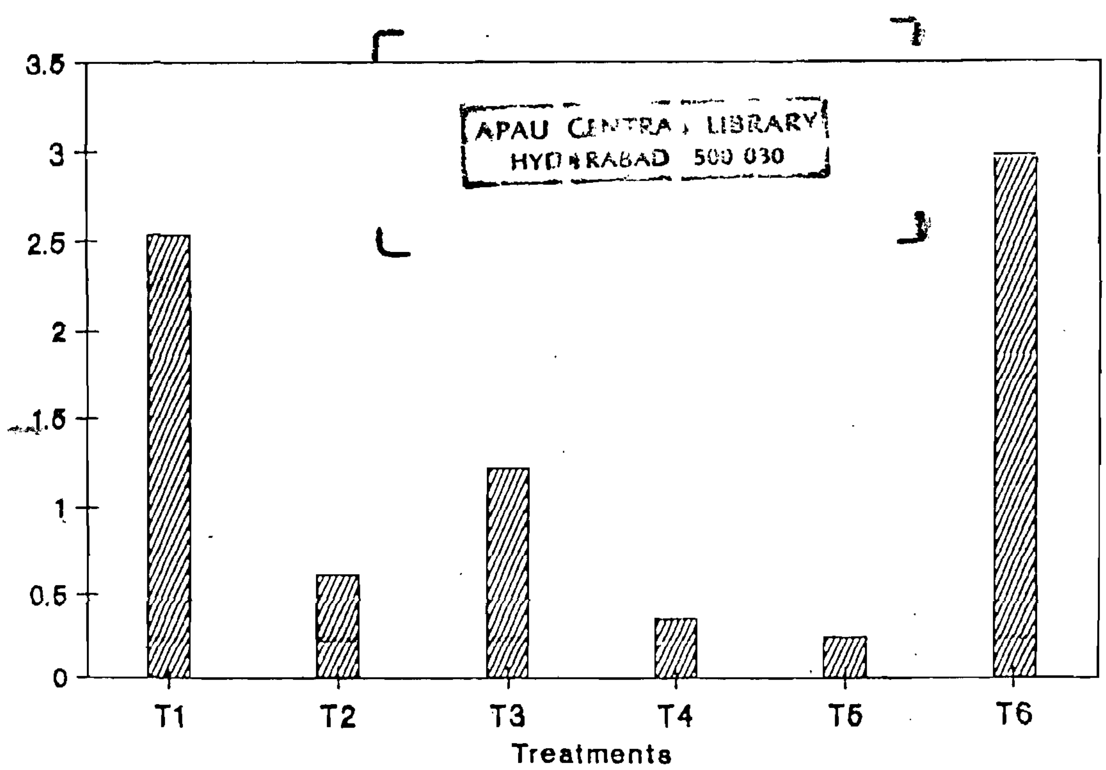


Fig. 8. Effect of conservation tillage on soil loss (kharif 1993-94)

The data on soil loss during 1993-94 is presented in Table 3 and illustrated in Fig.8. Sowing along the slope (T_6) recorded maximum cumulative soil loss of 2.966 t ha^{-1}. It was lowest (0.244 t ha^{-1}) in sowing along the contour with ridges and furrows and khus barrier. The soil loss (t ha^{-1}) recorded in other conservation tillage practices was 2.541 (sowing along the contour), 0.622 (sowing along the contour + khus barrir), 1.206 (sowing along the contour + dead furrows) and 0.360 (sowing along the contour + dead furrows and khus barrier).

The per cent reduction in total soil loss due to different conservation tillage practices over control (sowing along the slope) is given in Table 5. The reduction was maximum (91.77 per cent) in the treatment, sowing along the contour with ridges and furrows and khus barrier (T_5). This was followed by sowing along the contour with dead furrows and khus barrier (87.86 per cent), sowing along the contour with khus barrier (79.03 per cent), sowing along the contour with dead furrows (59.34 per cent) and the least (14.33 per cent) was recorded in the treatment of sowing along the contour.

The data on runoff and soil loss during the year 1994-95 are presented in Table 4. There were ten runoff events during 1994-95. Two runoff events were

Table 4. Effect of conservation tillage on runoff(mm) and soil loss(t ha) during kharif, 1994-95 *

Date	Rain fall (mm)	Sowing along contour T1		Contour + khus T2		Contour + dead furrow T3		Contour + dead furrow + khus T4		Contour + ridges & furrow + khus T5		Sowing along slope T6	
		Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss
12-08-1994	13.8	1.92	0.174	0.59	0.036	0.98	0.072	0.38	0.022	0.22	0.014	2.21	0.198
18-08-1994	24.8	2.08	0.242	0.61	0.058	1.02	0.108	0.47	0.032	0.26	0.018	2.36	0.284
19-08-1994	25.8	3.24	0.264	1.12	0.068	1.72	0.124	0.68	0.038	0.42	0.024	3.74	0.312
23-08-1994	17.2	1.32	0.130	0.46	0.026	0.78	0.052	0.31	0.016	0.12	0.010	1.56	0.142
27-08-1994	12.8	1.73	0.136	0.56	0.032	0.90	0.062	0.40	0.014	0.22	0.008	1.96	0.150
19-08-1994	18.4	2.08	0.204	0.73	0.046	1.28	0.112	0.51	0.028	0.29	0.022	2.61	0.246
18-09-1994	28.8	1.84	0.168	0.69	0.038	0.91	0.084	0.39	0.024	0.22	0.016	2.18	0.212
03-10-1994	19.0	1.20	0.074	0.38	0.016	0.57	0.036	0.26	0.012	0.16	0.006	1.36	0.088
Total	160.6	15.41	1.392	5.14	0.320	8.16	0.650	3.40	0.186	1.91	0.118	17.98	1.632

* Excluding two runoff eventson 06-10-1194 and 07-10-1994

Table 5. Effect of conservation tillage on runoff(mm) and soil loss (t ha)

Treatments	1993-94				1994-95			
	Runoff	% reduction over control	Soil loss	% reduction over control	Runoff	% reduction over control	Soil loss	% reduction over control
T1 Sowing on contour	30.80	12.35	2.541	14.33	15.41	14.29	1.392	14.71
T2 Contour + Khus	10.55	69.98	0.622	79.03	5.14	71.41	0.320	80.39
T3 Contour + Dead Furrow (DF)	16.44	53.22	1.206	59.34	8.16	54.62	0.650	60.17
T4 Contour + Dead Furrow + Khus	7.18	79.57	0.360	87.86	3.40	81.09	0.186	88.60
T5 Contour + Ridges & Furrows + Khus	4.05	88.47	0.244	91.77	1.91	89.38	0.118	92.77
T6 Sowing along slope	35.14	-	2.966	-	17.97	-	1.632	-

deleted because of heavy storms resulting in over flow and the data on eight runoff events were considered. The total runoff causing rainfall of these eight events was 160.6 mm. Highest runoff of 17.98 mm was recorded in the treatment, sowing along the slope (T_6). The treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) recorded the lowest runoff of 1.91 mm. The runoff (mm) recorded in other treatments was 15.41 in sowing along the contour, 5.14 in sowing along the contour + khus barrier, 8.16 in sowing along the contour + dead furrows and 3.40 mm in sowing along the contour + dead furrows and khus barrier. The runoff as per cent of rainwater under different conservation practices is illustrated in Fig.9. It was 9.60 in sowing along the contour, 3.20 in sowing along the contour + khus barrier, 5.08 in sowing along the contour + dead furrows, 2.18 in sowing along the contour + dead furrows and khus barrier, 1.19 in sowing along the contour + ridges and furrows and khus barrier and 11.20 in sowing along the slope.

The per cent reduction in runoff due to conservation tillage compared to control (sowing along the slope) is given in Table 5. The treatment, sowing along the contour with ridges and furrows and khus barrier recorded highest reduction of 89.38 per cent in runoff over control (sowing along the slope). This was

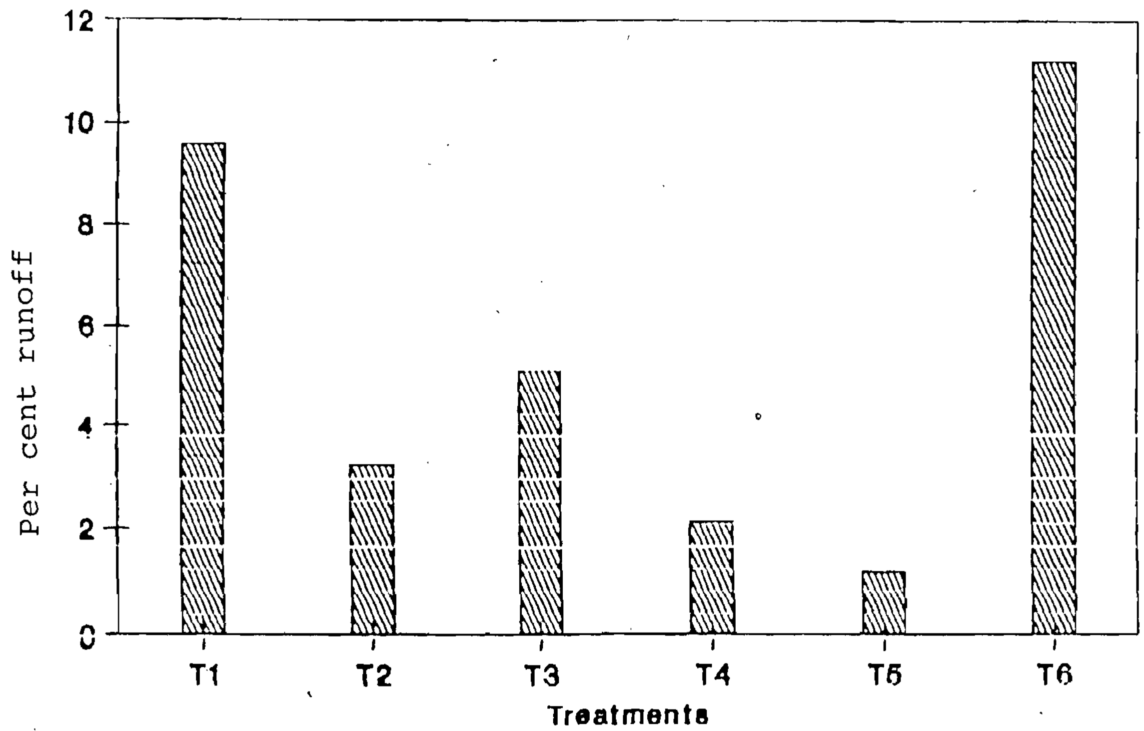
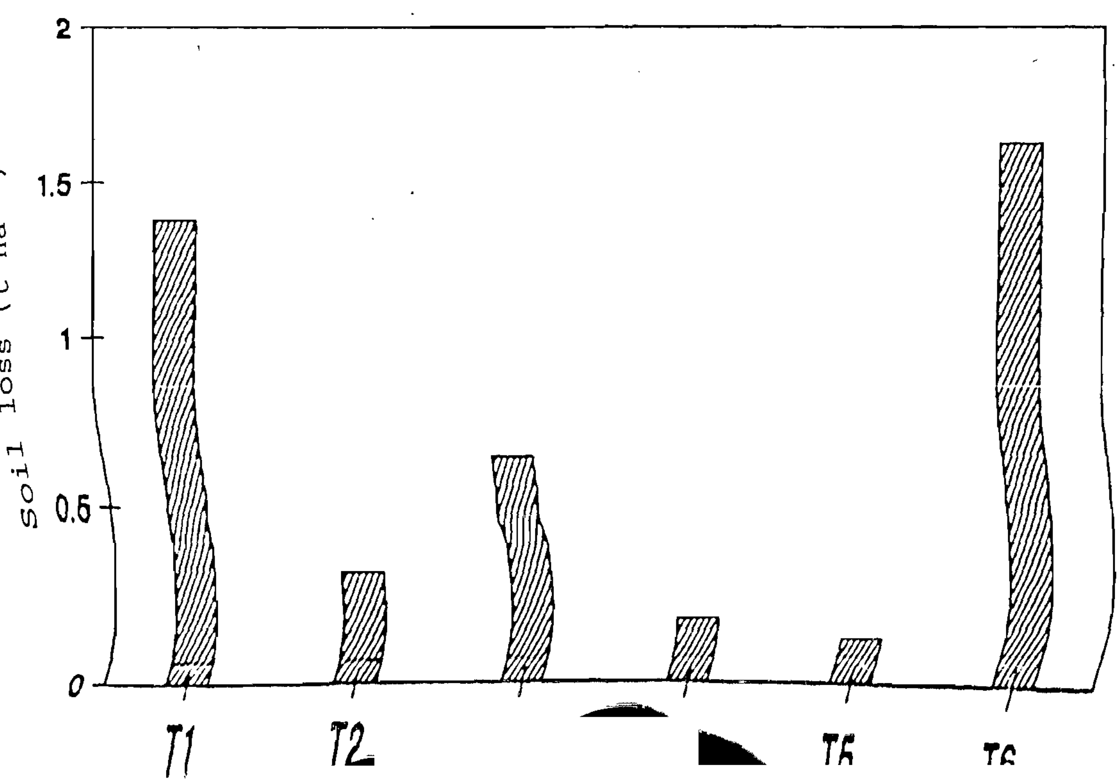


Fig. 9. Effect of conservation tillage on per cent runoff (kharif 1994-95)



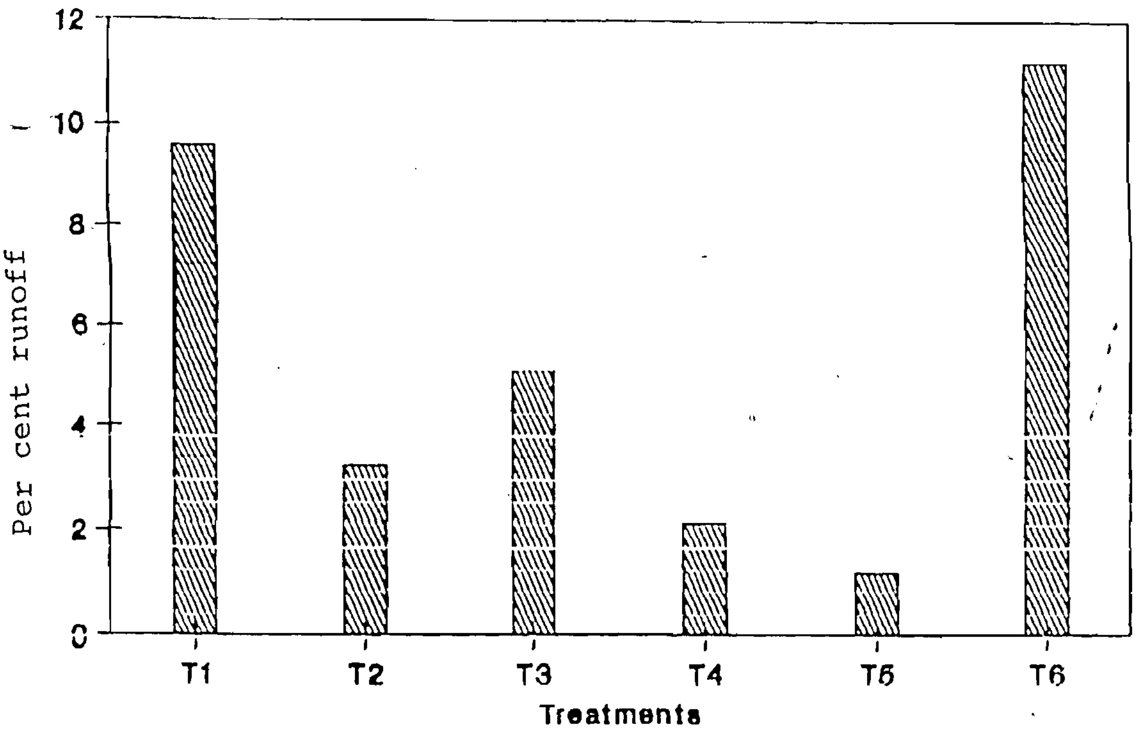


Fig. 9. Effect of conservation tillage
on per cent runoff (kharif 1994-95)

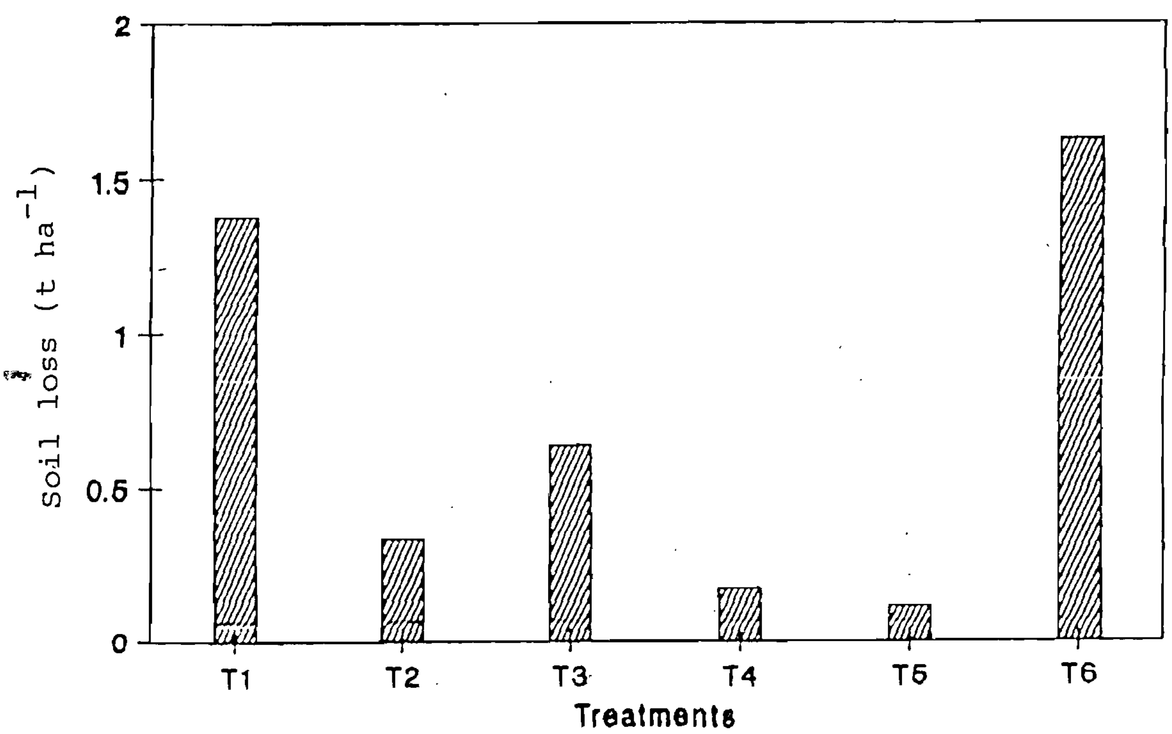


Fig. 10. Effect of conservation tillage

followed by sowing along the contour with dead furrows and khus barrier (81.09 per cent), sowing along the contour with khus barrier (71.41 per cent), sowing along the contour with dead furrows (54.62 per cent) and the least reduction (14.29 per cent) was observed in the treatment, sowing along the contour.

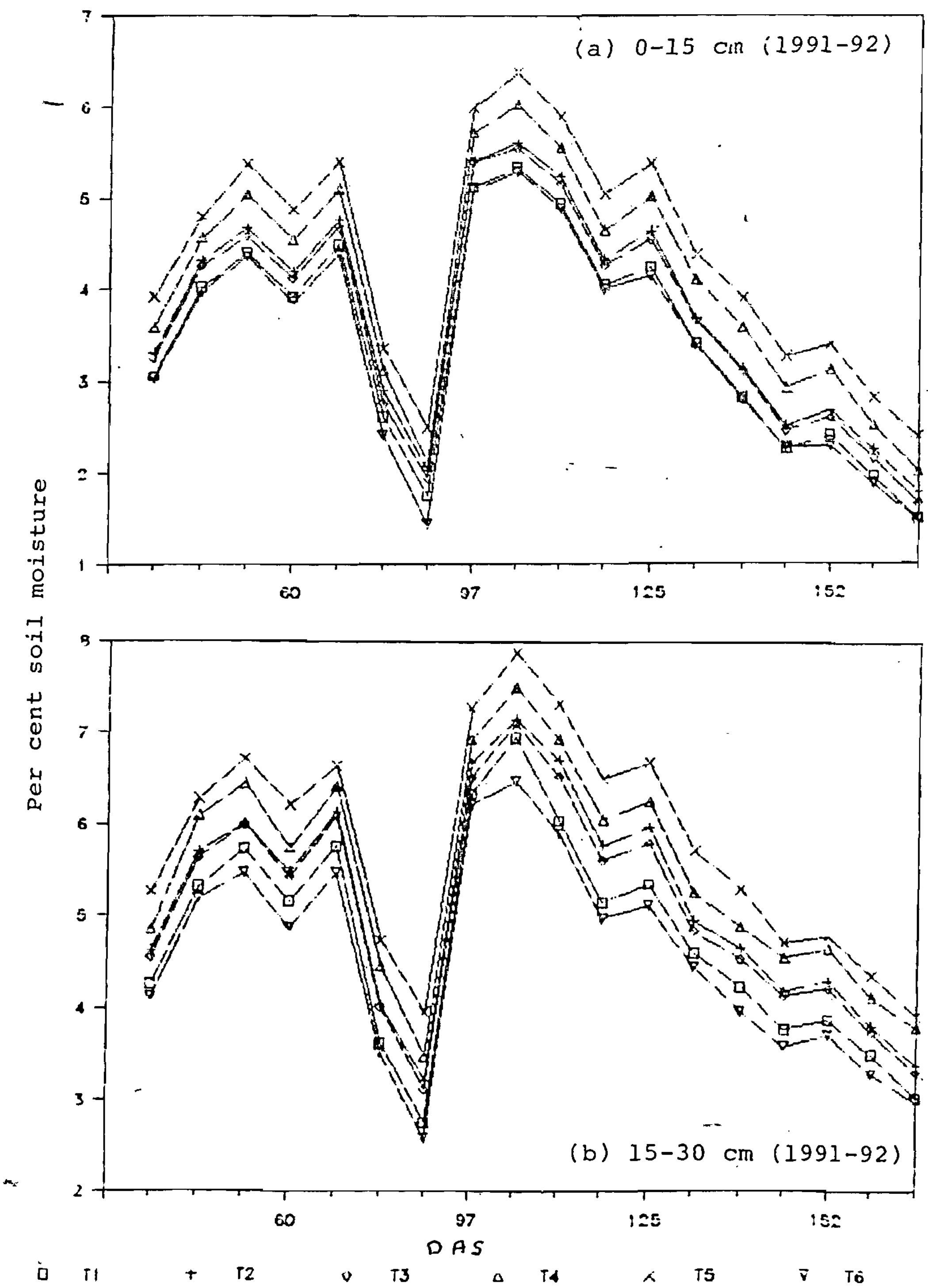
The data on soil loss during 1994-95 is presented in Table 4 and illustrated in Fig.10. Maximum cumulative soil loss of 1.632 t ha^{-1} was recorded in the treatment, sowing along the slope (T_6). It was lowest (0.118 t ha^{-1}) in the treatment, sowing along the contour with ridges and furrows and khus barrier (T_5). The soil loss (t ha^{-1}) recorded in other treatments was 1.392 (sowing along the contour), 0.320 (sowing along the contour + khus barrier), 0.650 (sowing along the contour + dead furrows) and 0.186 (sowing along the contour + dead furrows and khus barrier).

The per cent reduction in total soil loss during 1994-95 due to different conservation tillage practices over control (sowing along the slope) is given in Table 5. The treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) recorded highest reduction of 92.77 per cent in soil loss over T_6 (sowing along the slope). This was followed by sowing along the contour with dead furrows and khus barrier (88.60 per cent), sowing along the contour with khus barrier (80.39 per cent), sowing along the contour with dead furrows (60.17 per cent) and the least reduction (14.71 per cent) was recorded in the treatment, sowing along the contour.

4.1.2 Effect of conservation tillage on soil moisture content

The year-wise results on the effect of conservation tillage practices and khus barrier on soil moisture content during the growth period of castor for four kharif seasons are given in Appendices V to VIII and illustrated in Fig. 11 to 16. The figures indicated that highest soil moisture was recorded with sowing on contours with ridges and furrows and khus barrier throughout the crop growth period during all the years in all the depths viz. 0-15, 15-30 and 30-45 cm. This was followed by the treatment, sowing along the contour with dead furrows and khus barrier, (T_4), sowing along the contour with khus barrier (T_2), sowing along the contour with dead furrows (T_3) and sowing along the contour (T_1) and lowest was with sowing along the slope (T_6).

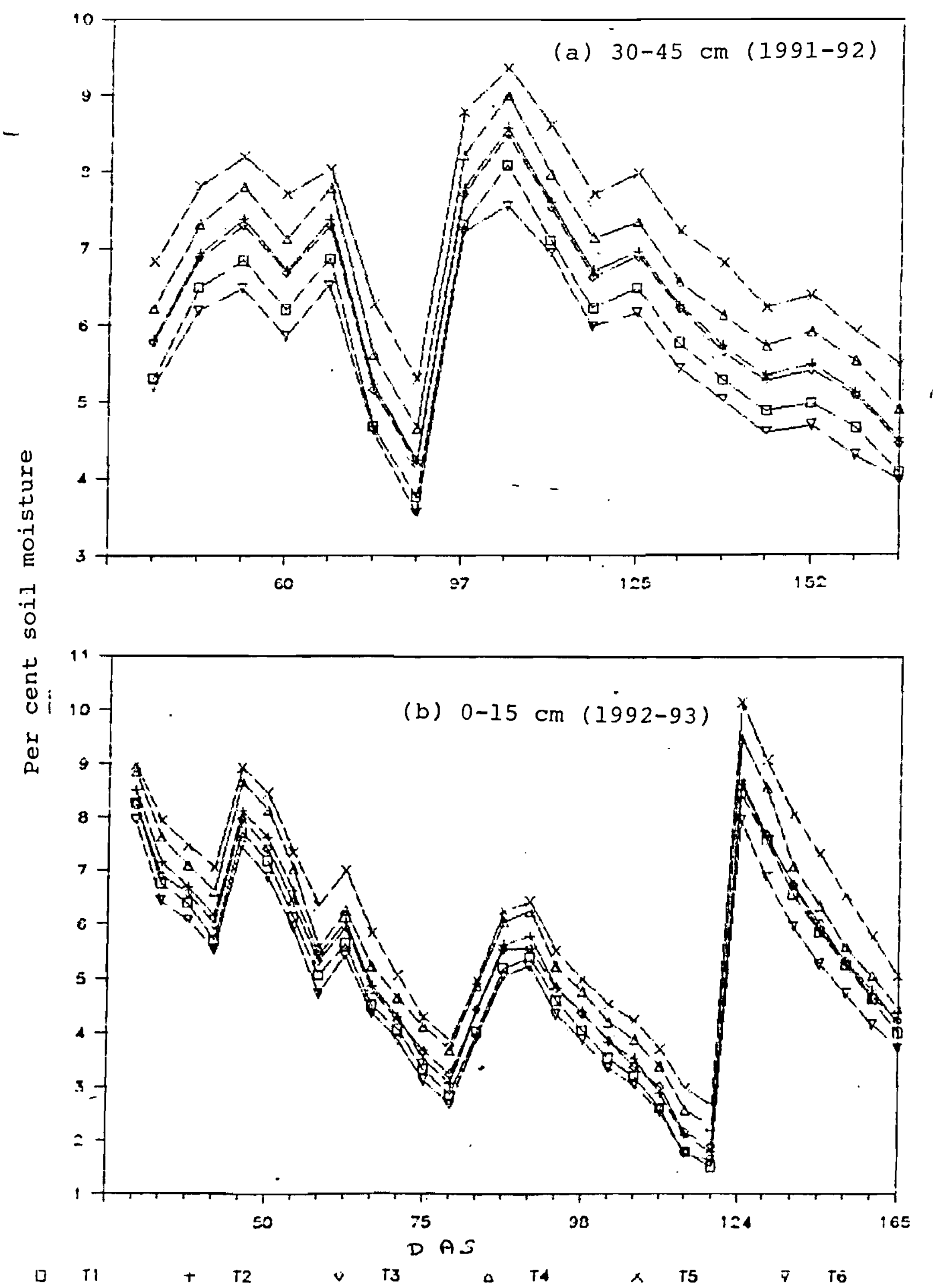
The data on mean soil moisture content under different treatments during crop growth period in



1 - Sowing along contour
2 - Contour + khus
3 - Contour + dead furrows
T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.11 Effect of conservation tillage on soil moisture content during crop growth period

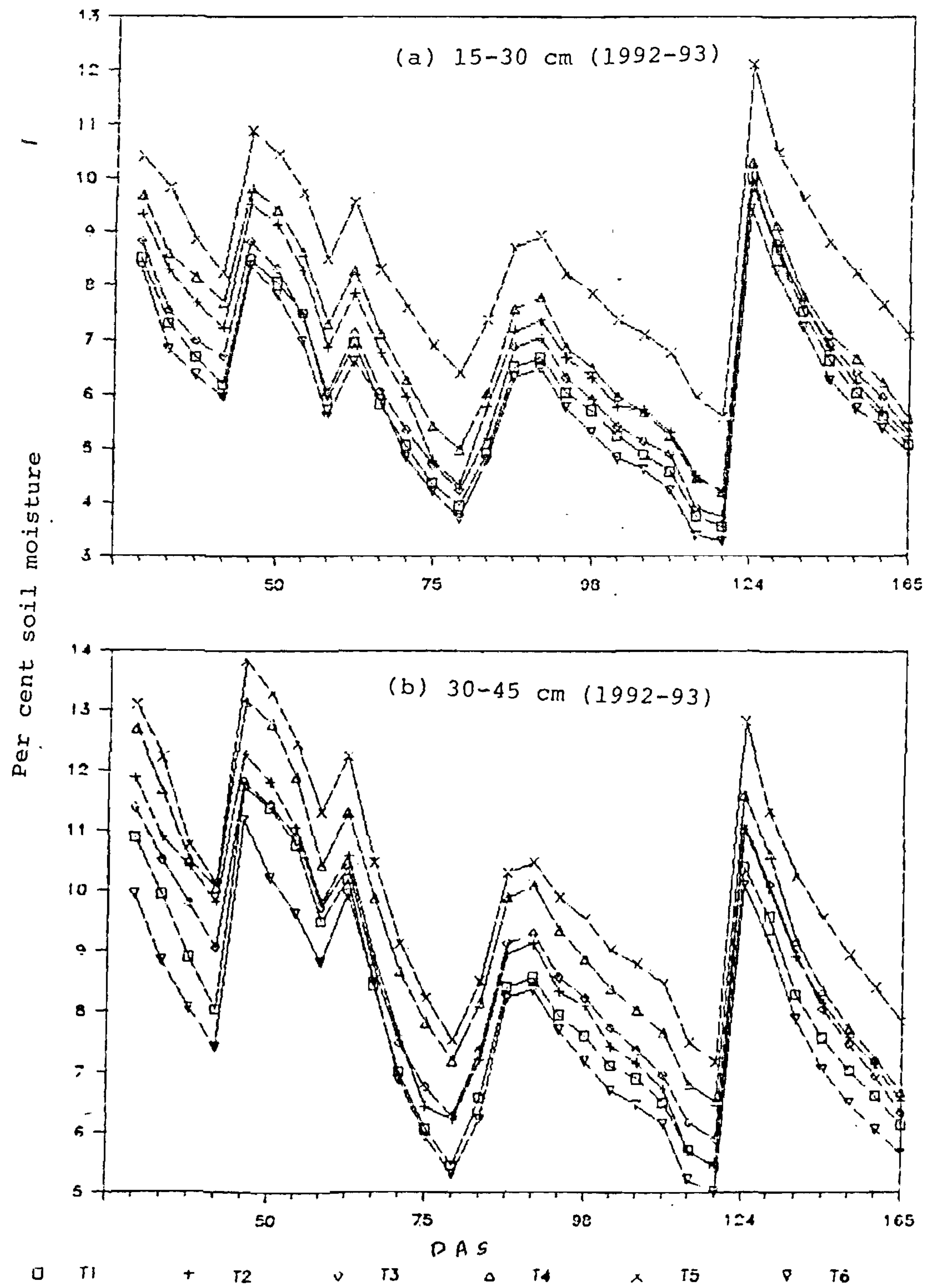
(a) 0-15 cm (1991-92) (b) 15-30 cm (1991-92)



T1 - Sowing along contour
T2 - Contour + khus
T3 - Contour + dead furrows
T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.12 Effect of conservation tillage on soil moisture content during crop growth period

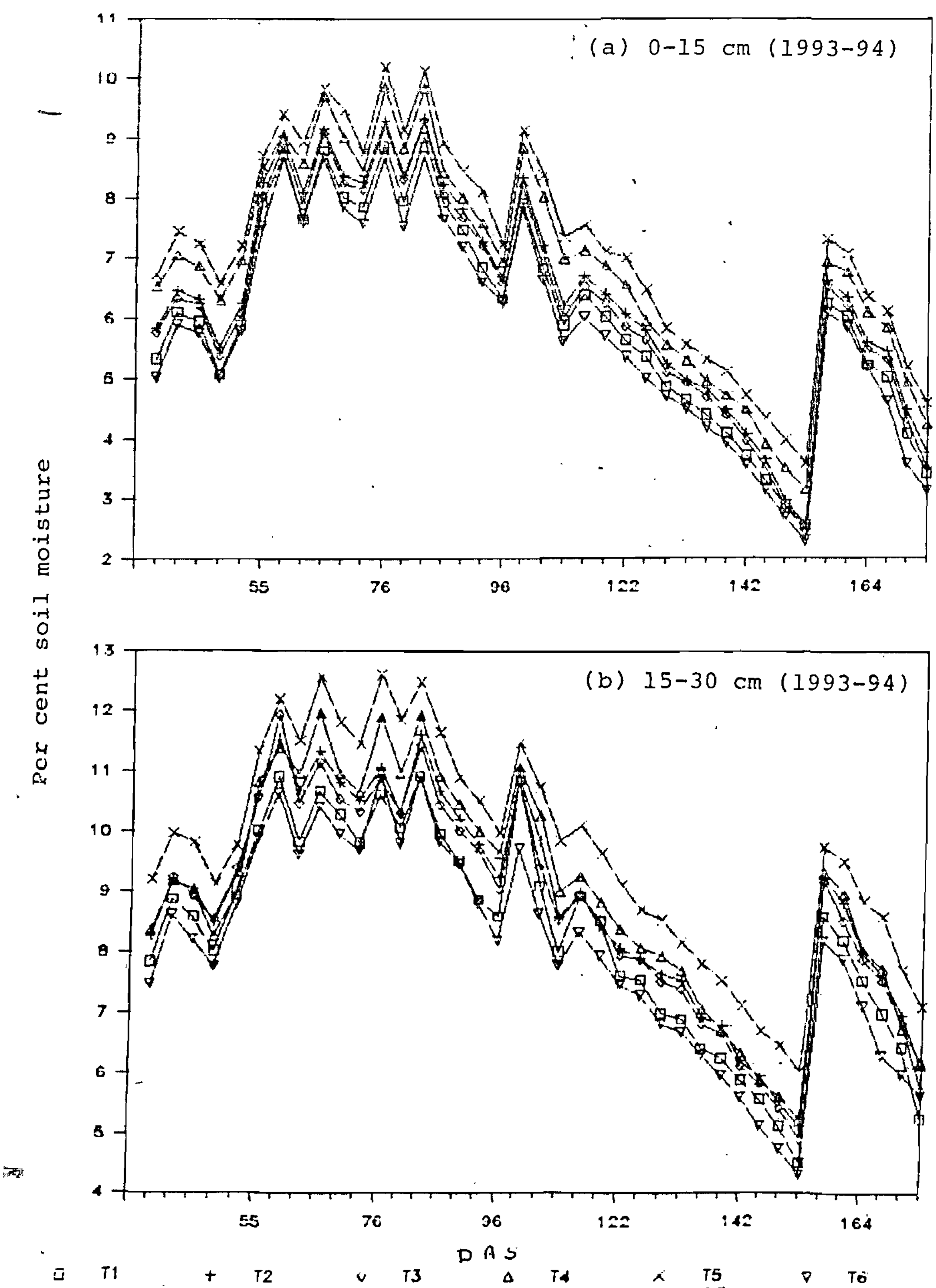
(a) 30-45 cm (1991-92) (b) 0-15 cm (1992-93)



T1 - Sowing along contour
T2 - Contour + khus
T3 - Contour + dead furrows
T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.13 Effect of conservation tillage on soil moisture content during crop growth period

(a) 15-30 cm (1992-93) (b) 30-45 cm (1992-93)

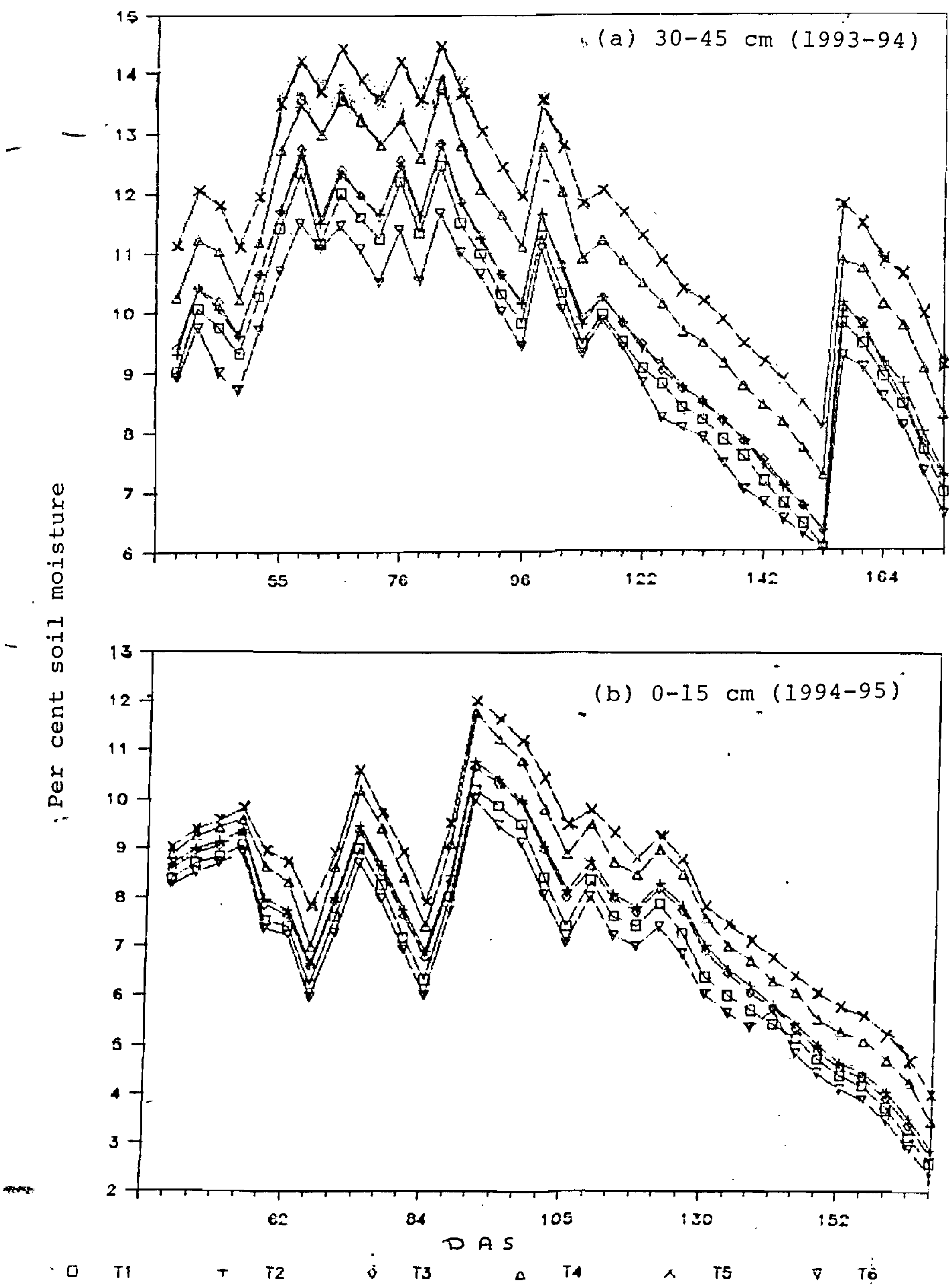


- Sowing along contour
- Contour + khus
- Contour + dead furrows

T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.14 Effect of conservation tillage on soil moisture content during crop growth period

(a) 0-15 cm (1993-94) (b) 15-30 cm (1993-94)

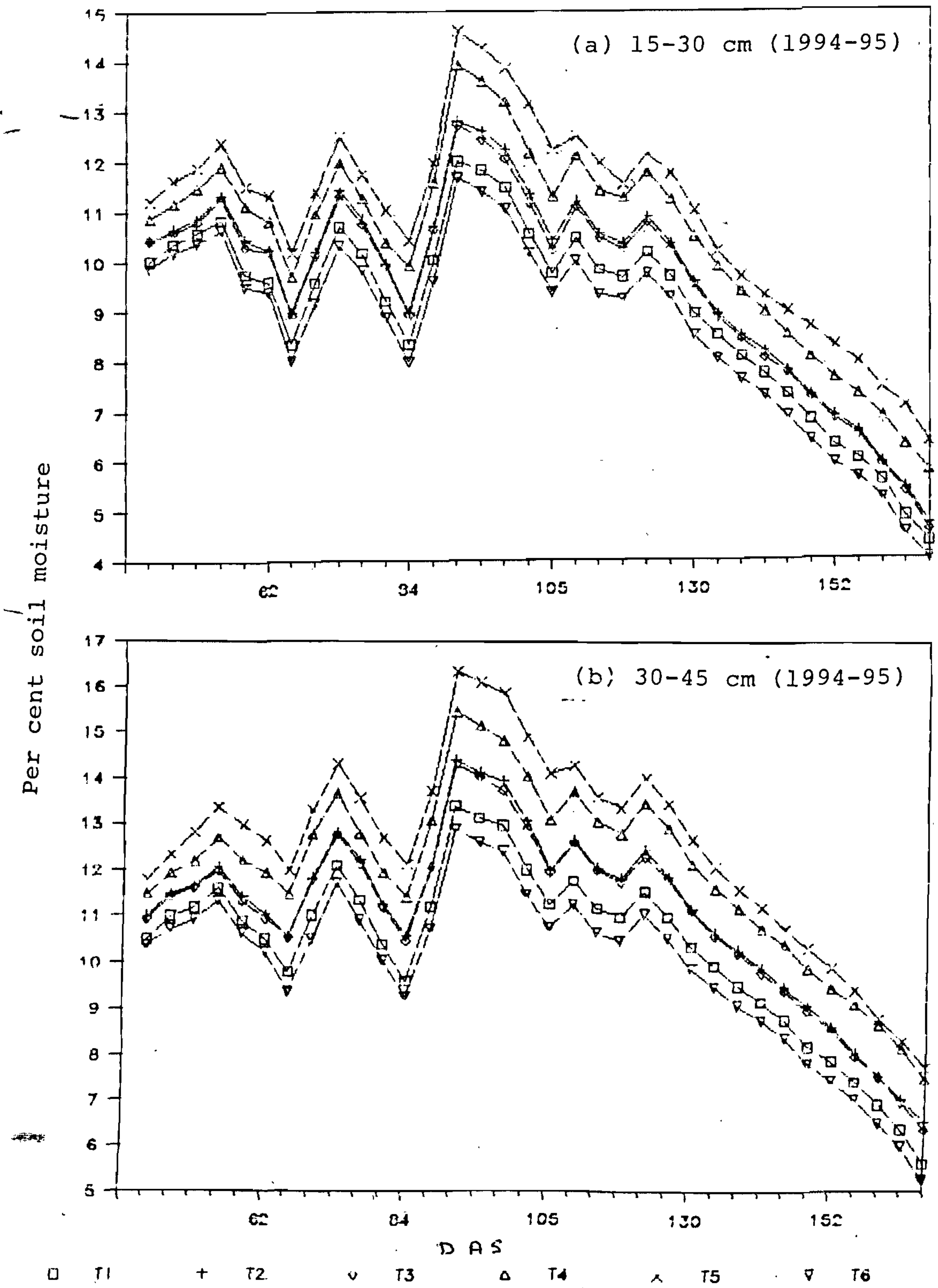


- Sowing along contour
- Contour + khus
- *Contour + dead furrows*

T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.15 **Effect of conservation tillage on soil moisture content during crop growth period**

(a) 30-45 cm (1993-94) (b) 0-15 cm (1994-95)



- Sowing along contour
- Contour + khus
- Contour + dead furrows

T4 - Contour + Dead furrows + khus
T5 - Contour + Ridges & Furrows + khus
T6 - Sowing along slope

Fig.16 Effect of conservation tillage on soil moisture content during crop growth period kharif, 1991-92 are given in Table 6. Highest soil moisture content of 4.39, 5.79 and 7.26 per cent in 0-15, 15-30 and 30-45 cm depths, respectively was recorded in sowing along the contour with ridges and furrows and khus barrier (T_5). This was followed by the treatments, sowing along the contour with dead furrows and khus barrier (4.07, 5.47 and 6.72 per cent), sowing along the contour with khus barrier (3.75, 5.16 and 6.32 per cent), sowing along the contour with dead furrows (3.68, 5.07 and 6.26 per cent), sowing along the contour (3.46, 4.75 and 5.83 per cent) and sowing along the slope with 3.39, 4.55 and 5.57 per cent, in 0-15, 15-30 and 30-45 cm depths, respectively. The per cent increase in mean soil moisture content in different treatments over control (sowing along the slope) was 2.06 with sowing along the contour, 10.62 with sowing along the contour + khus barrier, 8.55 with sowing along the contour + dead furrows, 20.06 with sowing along the contour + dead furrows and khus barrier and 29.50 with sowing along the contour + ridges and furrows and khus barrier in 0-15 cm; 4.40 with sowing along the contour, 13.41 with sowing along the contour + khus barrier, 11.43 with sowing along the contour + dead furrows, 20.22 with sowing along the contour + dead furrows and khus barrier and 27.25 with sowing along the contour + ridges and furrows and khus barrier in 15-30 cm and

Table 6. Effect of conservation tillage on mean soil moisture content (% w/w) during the crop growth period of castor

Treatments	Depth (cm)	1991-92	1992-93	1993-94	1994-95
T1 Sowing on contour	0-15	3.46	5.06	6.06	6.98
	15-30	4.75	6.20	8.31	9.03
	30-45	5.83	8.18	9.62	10.30
T2 Contour + Khus	0-15	3.75	5.75	6.42	7.41
	15-30	5.16	6.54	8.86	9.62
	30-45	6.32	8.64	9.94	11.07
T3 Contour + Dead Furrow (DF)	0-15	3.68	5.31	6.31	7.31
	15-30	5.07	6.46	8.73	9.54
	30-45	6.26	8.41	9.94	10.99
T4 Contour + Dead Furrow + Khus	0-15	4.07	5.79	6.81	8.01
	15-30	5.47	7.14	8.98	10.41
	30-45	6.72	9.44	10.93	11.96
T5 Contour + Ridges & Furrows + Khus	0-15	4.39	6.23	7.19	8.42
	15-30	5.79	8.45	9.70	10.93
	30-45	7.26	10.12	11.72	12.54
T6 Sowing along slope	0-15	3.39	4.80	5.78	6.71
	15-30	4.55	5.92	8.01	8.67
	30-45	5.57	7.66	9.22	9.88

4.67 with sowing along the contour, 13.46 with sowing along the contour + khus barrier, 12.39 with sowing along the contour + dead furrows, 20.65 with sowing along the contour + dead furrows and khus barrier and 30.34 with sowing along the contour + ridges and furrows and khus barrier in 30-45 cm depths. The average increase (per cent) upto 45 cm depth in different treatments over control (sowing along the slope) was 3.71 (1.40 mm) with sowing along the contour, 12.50 (4.52 mm) with sowing along the contour + khus barrier, 10.79 (3.95 mm) with sowing along the contour + dead furrows, 20.31 (7.22 mm) with sowing along the contour + dead furrows and khus barrier and 29.03 (10.32 mm) with sowing along the contour + ridges and furrows and khus barrier.

The data on mean soil moisture content in different depths as influenced by conservation practices during kharif, 1992-93 is presented in Table 6. The treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) recorded highest soil moisture content of 6.23, 8.45 and 10.12 per cent in 0-15, 15-30 and 30-45 cm depths, respectively. This was followed by sowing along the contour with dead furrows and khus barrier (5.79, 7.14 and 9.44 per cent), sowing along the contour with khus barrier (5.37, 6.54 and 8.67 per cent), sowing along the contour with dead furrows (5.31, 6.46 and 8.41 per cent) and sowing along the contour (5.06, 6.20 and 8.18 per cent) in 0-15, 15-30 and 30-45 cm depths, respectively. The mean soil moisture content was lowest in the treatment, sowing along the slope with 4.80, 5.92 and 7.66 per cent in the three depths, respectively. The per cent increase in mean soil moisture content in different treatments over control (sowing along the slope) was 5.42 (sowing along the contour), 11.46 (sowing along the contour with khus barrier), 9.84 (sowing along the contour with dead furrows), 21.49 (sowing along the contour with dead furrows and khus barrier) and 34.88 (sowing along the contour with ridges and furrows and khus barrier) in 0-15 cm; 4.73 (sowing along the contour), 10.47 (sowing along the contour with khus barrier), 9.12 (sowing along the contour with dead furrows), 20.61 (sowing along the contour with dead furrows and khus barrier), 42.74 (sowing along the contour with ridges and furrows and khus barrier) in 15-30 cm and 6.79 (sowing along the contour), 13.19 (sowing along the contour with khus barrier), 9.79 (sowing along the contour with dead furrows), 23.24 (sowing along the contour with dead furrows and khus barrier) and 32.11 (sowing along the contour with ridges and furrows and khus barrier) in 30-45 cm depths. The average per cent increase upto 45 cm depth in different treatments over control (sowing along the slope) was 5.65 (2.25 mm) with sowing along the contour, 11.71 (5.19 mm) with sowing along the contour + khus barrier, 9.84 (4.18 mm) with sowing along the contour + dead furrows, 21.49 (9.94 mm) with sowing along the contour + dead furrows and khus barrier and 34.88 (16.29 mm) with sowing along the contour + ridges and furrows and khus barrier.

The data on mean soil moisture during kharif, 1993-94 are presented in Table 6. Highest soil moisture content of 7.19, 9.70 and 11.72 per cent in 0-15, 15-30 and 30-45 cm depths, respectively was observed in the treatment, sowing on contour with ridges and furrows and khus barrier. The average soil moisture content recorded in other treatments was 6.06, 8.31 and 9.62 per cent with sowing along the contour, 6.42, 8.86 and 9.94 per cent with sowing along the contour + khus barrier, 6.31, 8.73 and 9.94 per cent with sowing along the contour + dead furrows and 6.81, 8.98 and 10.93 per cent with sowing along the contour + dead furrows and khus barrier in 0-15, 15-30 and 30-45 cm depths, respectively. Lowest mean soil moisture content of 5.78, 8.01 and 9.22 per cent in 0-15, 15-30 and 30-45 cm depths, respectively was observed in the treatment, sowing along the slope. The average per cent increase upto 45 cm depth in different treatments over control (sowing along the slope) was 4.31 (2.57

mm) with sowing along the contour, 9.83 (5.78 mm) with sowing along the contour + khus barrier, 8.66 (5.16 mm) with sowing along the contour + dead furrows, 15.80 (9.75 mm) with sowing along the contour + dead furrows and khus barrier and 24.20 (14.71 mm) with sowing along the contour + ridges and furrows and khus barrier.

Similar trend was observed during the year 1994-95 (Table 6). The average per cent increase upto 45 cm depth in different treatments over control (sowing along the slope) was 4.14 (2.76 mm) with sowing along the contour, 11.14 (7.46 mm) with sowing along the contour + khus barrier, 10.07 (6.78 mm) with sowing along the contour + dead furrows, 20.16 (13.43 mm) with sowing along the contour + dead furrows and khus barrier and 26.16 (17.39 mm) with sowing along the contour + ridges and furrows and khus barrier.

4.1.3 Plant parameters

4.1.3.1 Effect of conservation tillage on drymatter production

The data on drymatter production of castor during the four kharif seasons from 1991-92 to 1994-95 are presented in Table 7. Conservation tillage practices have considerably influenced drymatter production. During the year 1991-92, highest drymatter content of 405.78, 1233.63 and 2159.86 kg ha^{-1} at 60,

Table 7. Effect of conservation tillage on drymatter production of castor at different stages of crop growth (kg ha^{-1})

Treatments	1991-92			1992-93			1993-94			1994-95		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T1 Sowing along the contour	359.19	896.44	1645.96	388.63	980.46	1727.56	472.30	1080.32	1710.38	523.26	1112.68	1976.34
T2 Contour + Khus	372.44	978.68	1884.29	401.72	1078.18	1982.49	495.16	1183.12	1994.25	531.00	1208.75	2296.56
T3 Contour + Dead furrow	379.52	986.90	1965.13	408.99	1091.42	2020.48	497.36	1196.40	2025.42	537.28	1231.29	2325.48
T4 Contour + Dead furrow + Khus	386.30	1085.59	2067.50	414.45	1203.27	2149.54	514.97	1316.44	2149.53	552.52	1376.23	2439.57
T5 Contour + Ridges and furrows + Khus	405.78	1233.63	2159.86	443.53	1344.47	2296.14	550.81	1439.42	2272.47	592.47	1537.18	2544.72
T6 Sowing along the slope	338.86	822.42	1489.56	363.55	902.46	1562.44	446.42	996.78	1558.47	491.43	1020.16	1802.16
SEm ±	2.43	4.37	101.00	2.24	5.02	5.75	1.04	0.90	1.15	0.98	1.02	1.13
CD at 5%	7.33	13.16	30.44	7.14	15.14	13.72	3.13	2.70	3.46	2.94	3.07	3.40

90 and 120 DAS, respectively was recorded in the treatment , sowing along the contour with ridges and furrows and khus barrier. This was followed by the treatment, sowing along the contour with dead furrows and khus barrier (386.30, 1085.59 and 2067.50 kg ha^{-1}), sowing along the contour with dead furrows (379.52, 986.90 and 1965.13 kg ha^{-1}), sowing along the contour with khus barrier (372.44, 978.68 and 1884.29 kg ha^{-1}), sowing along the contour (359.19, 896.44 and 1645.96 kg ha^{-1}) and lowest of 338.86, 822.42 and 1489.56 kg ha^{-1} was recorded with sowing along the slope, respectively at 60, 90 and 120 DAS. Similar trend was observed in the other three years with highest and lowest drymatter production recorded in the treatments, sowing along the contour with ridges and furrows and khus barrier and sowing along the slope, respectively.

4.1.3.2 Effect of conservation tillage on leaf area index

The data on the leaf area index (LAI) of castor at various stages of crop growth during the years 1992-93 to 1994-95 are presented in Table 8. Conservation tillage practices have considerably influenced LAI at 60, 90 and 120 DAS. During the year 1992-93, maximum LAI of 0.88, 1.52 and 2.42 at 60, 90 and 120 DAS, respectively was observed in the treatment, sowing along the contour + ridges and

Table 8. Effect of conservation tillage on leaf area index at various stages of crop growth

Treatments	1992-93			1993-94			1994-95		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T1 Sowing on contour	0.63	1.22	2.19	0.59	1.25	2.21	0.65	1.32	2.33
T2 Contour + Khus	0.64	1.34	2.23	0.63	1.38	2.26	0.69	1.40	2.41
T3 Contour + Dead Furrow (DF)	0.64	1.36	2.26	0.64	1.39	2.29	0.68	1.41	2.42
T4 Contour + Dead Furrow + Khus	0.66	1.44	2.33	0.67	1.51	2.37	0.70	1.49	2.50
T5 Contour + Ridges & Furrows + Khus	0.68	1.52	2.42	0.69	1.61	2.49	0.73	1.58	2.63
T6 Sowing along slope	0.60	1.18	2.14	0.57	1.20	2.19	0.62	1.28	2.29
SEm ±	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02
CD at 5%	0.02	0.04	0.04	0.03	0.05	0.04	0.03	0.05	0.05

furrows and khus barrier. This was followed by sowing along the contour + dead furrows and khus barrier with 0.86, 1.44 and 2.33, sowing along the contour + dead furrows with 0.84, 1.36 and 2.26, sowing along the contour + khus barrier with 0.84, 1.34 and 2.23, sowing along the contour with 0.83, 1.22 and 2.19 and sowing along the slope with 0.80, 1.18 and 2.14 at 60, 90 and 120 DAS, respectively.

During the years 1993-94 and 1994-95 also treatmental effect was found to be similar with maximum LAI recorded in the treatment, sowing along the contour + ridges and furrows and khus barrier.

4.1.3.3 Effect of conservation tillage on plant height

The data on plant height of castor at various stages of crop growth during the years 1992-93 to 1994-95 are presented in Table 9. Conservation tillage practices have considerably increased the plant height. During the year 1992-93, maximum plant height of 75.50, 105.70 and 120.40 cm at 60, 90 and 120 DAS, respectively was observed in the treatment, sowing along the contour with ridges and furrows and khus barrier. This was followed by the treatment, sowing along the contour + dead furrows and khus barrier with 73.20, 100.30 and 114.10 cm, sowing along the contour + dead furrows with 68.40, 92.30 and 109.60 cm, sowing

Table 9. Effect of conservation tillage on plant height (cm) at various stages of crop growth

Treatments	1992-93			1993-94			1994-95		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T1 Sowing on contour	66.80	89.90	105.30	65.40	89.10	107.80	68.20	90.30	110.20
T2 Contour + Khus	67.90	91.40	109.20	66.40	91.00	112.40	69.60	93.40	115.60
T3 Contour + Dead Furrow (DF)	68.40	92.30	109.60	67.10	91.80	114.30	70.20	93.90	116.20
T4 Contour + Dead Furrow + Khus	73.20	100.30	114.10	71.40	99.80	121.20	74.60	103.40	120.30
T5 Contour + Ridges & Furrows + Khus	75.50	105.70	120.40	74.60	106.20	129.70	77.40	110.40	131.20
T6 Sowing along slope	66.40	88.20	101.30	65.00	87.90	103.40	67.50	89.10	108.10
SEm ±	0.31	0.37	0.53	0.38	0.55	0.53	0.55	0.59	0.59
CD at 5%	0.94	1.13	1.60	1.15	1.65	1.60	1.66	1.77	1.77

along the contour + khus barrier with 67.90, 91.80 and 109.20 cm, sowing along the contour with 66.80, 89.90 and 105.30 cm and sowing along the slope with 66.4, 88.2 and 101.3 cm, at 60, 90 and 120 DAS, respectively. Similar trend was observed in the other two years.

4.1.3.4 Effect of conservation tillage on number of spikes

The data on number of spikes per plant during 1992-93 to 1994-95 as influenced by the conservation tillage are presented in Table 10. During the year 1992-93, the treatment, sowing along the contour with ridges and furrows and khus barrier recorded the maximum number of spikes per plant (4.3). This was followed by the treatment, sowing along the contour + dead furrows and khus barrier with 4.1 spikes per plant. The treatments, sowing along the contour with dead furrows and sowing along the contour with khus barrier recorded 3.8 spikes per plant and the treatments, sowing along the contour and sowing along the slope recorded 3.7 spikes per plant.

During the years 1993-94 and 1994-95 also same trend was observed in respect of number of spikes per plant with maximum number of 4.5 and 4.4 spikes per plant recorded, respectively in the treatments, sowing

10. Effect of conservation tillage on number of spikes and capsules and test weight(g) in casto

Treatments	1992-93			1993-94			1994-95		
	Spikes	Caps-ules	Test weight	Spikes	Caps-ules	Test weight	Spikes	Caps-ules	Test weight
wing on contour	3.70	21.80	14.32	4.00	25.20	14.35	4.10	25.30	14.41
ntour + Khus	3.80	23.20	14.80	4.10	27.00	14.79	4.20	26.80	14.82
ontour + Dead Furrow (DF)	3.80	22.90	14.76	4.10	26.50	14.76	4.10	26.80	14.80
ontour + Dead Furrow + Khus	4.10	24.80	15.14	4.20	28.10	15.16	4.30	27.80	15.23
ontour + Ridges & Furrows + Khus	4.30	27.50	15.46	4.50	2.95	18.59	4.40	29.00	15.58
Sowing along slope	3.70	19.80	14.24	4.00	23.10	14.27	4.10	22.30	14.29
m ±	0.07	0.36	0.13	0.08	0.52	0.17	0.03	0.51	0.09
at 5%	0.21	1.08	0.39	0.24	1.56	0.51	0.09	1.52	0.27

along the contour with ridges and furrows + khus barrier.

4.1.3.5 Effect of conservation tillage on capsule number

The data on the number of capsules per plant during 1992-93 to 1994-95 as influenced by the conservation tillage are presented in Table 10. During the year 1992-93, the treatment, sowing along the contour with ridges and furrows and khus barrier recorded the maximum number of capsules (27.5) per plant. This was followed by the treatments, sowing along the contour with dead furrows and khus barrier (24.6), sowing along the contour with khus barrier (23.2), sowing along the contour with dead furrows (22.9), sowing along the contour (21.8) and sowing along the slope with 19.6 capsules per plant. Similar trend was observed during the year 1993-94.

During the year 1994-95, the treatment, sowing along the contour with ridges and furrows and khus barrier recorded maximum number of 29.0 capsules per plant. This was followed by sowing along the contour + dead furrows and khus barrier with 27.8, sowing along the contour + dead furrows and sowing along the contour + khus barrier with 26.8, sowing along the contour with

25.3 and sowing along the slope with 22.3 capsules per plant.

4.1.3.6 Effect of conservation tillage on test weight

The data on the test weight (100-seed weight) of castor during the years 1992-93 to 1994-95 as influenced by conservation tillage are presented in Table 10. During the year 1992-93, maximum test weight of 15.46 g was recorded in the treatment, sowing along the contour with ridges and furrows and khus barrier. This was followed by 15.14 g in sowing along the contour with dead furrows and khus barrier, 14.80 g in sowing along the contour with khus barrier, 14.76 g in sowing along the contour with dead furrows, 14.32 g in sowing along the contour and 14.24 g in sowing along the slope. Conservation tillage influenced the test weight in a similar way during the other two years also.

4.1.3.7 Effect of conservation tillage on crop yield

The data on seed yield of castor in different treatments (mean of 4 replications) for four years are given in Table 11 and illustrated in Fig. 17.

During the year 1991-92, seed yields in all the conservation tillage treatments were significantly superior over that of control (sowing along the

Table 11. Effect of conservation tillage on seed yield of castor (kg ha^{-1})

Treatments	1991-92	1992-93	1993-94	1994-95
T1 Sowing on contour	628.58	668.14	813.57	806.55
T2 Contour + Khus	695.25	715.18	878.51	871.43
T3 Contour + Dead Furrow (DF)	664.30	698.05	872.99	869.05
T4 Contour + Dead Furrow + Khus	707.16	755.89	923.23	927.38
T5 Contour + Ridges & Furrows + Khus	754.78	825.99	974.69	970.24
T6 Sowing along slope	571.44	625.01	747.40	740.48
S Em ±	7.79	13.46	7.03	7.93
C D at 5%	23.48	40.57	21.20	23.91

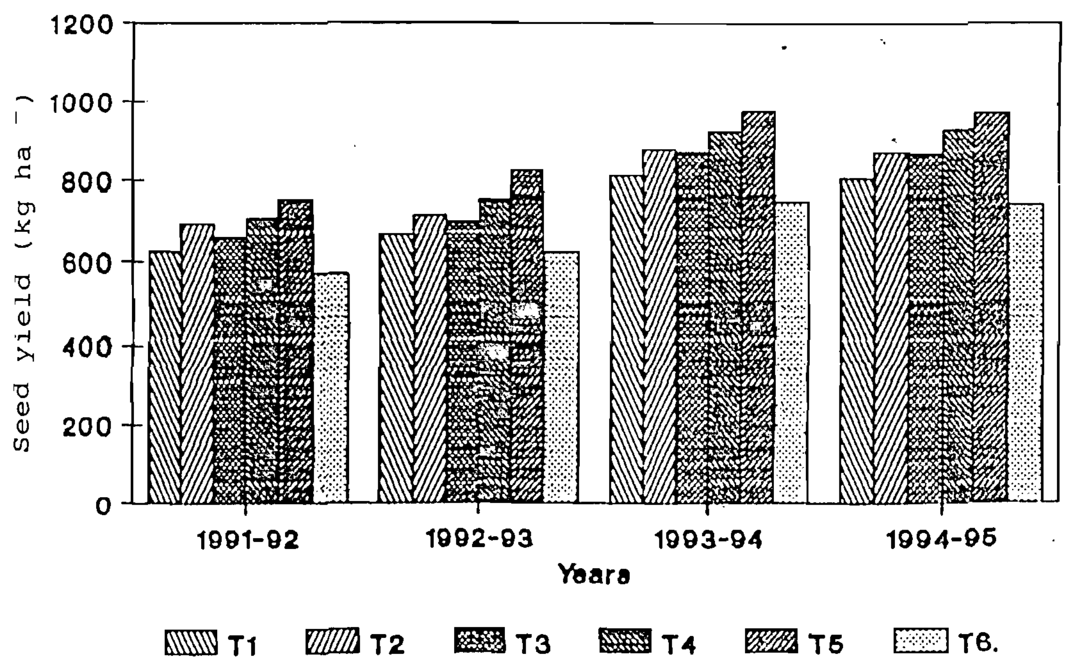


Fig. 17. Effect of conservation tillage on seed yield of Castor (kg. ha^{-1})

slope). The differences among the tillage treatments were also statistically significant.

Highest seed yield of 754.78 kg ha^{-1} was recorded in the treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) and was significantly superior to all other treatments. This was followed by the treatment, sowing along the contour + dead furrows and khus barrier (T4) with 707.16 kg ha^{-1} and sowing along the contour + khus barrier (T_2) with 695.25 kg ha^{-1} which were on par. The treatments, sowing along the contour with dead furrows (T_3) and sowing along the contour (T_1) recorded 664.30 and 628.58 kg ha^{-1}, respectively and were significantly superior to sowing along the slope (T_6) which yielded 571.44 kg ha^{-1}.

The highest (32.08) per cent increase in seed yield over control was recorded in the treatment, sowing along the contour with ridges and furrows and khus barrier. This was followed by the treatments, sowing along the contour with dead furrows and khus barrier (23.75 per cent), sowing along the contour with khus barrier (21.67 per cent), sowing along the contour with dead furrows (16.25 per cent) and sowing along the contour with 10 per cent.

During the year 1992-93, all the conservation tillage treatments gave significantly higher castor seed yield compared to control (625.01 kg ha^{-1}). Highest yield of 825.99 kg ha^{-1} was recorded in the treatment, sowing along contour with ridges and furrows and khus barrier which was significantly superior to all other treatments. This was followed by the treatments, sowing along the contour with dead furrows and khus barrier (755.89 kg ha^{-1}), sowing along the contour with khus barrier (715.18 kg ha^{-1}), sowing along the contour with dead furrows (698.05 kg ha^{-1}) and sowing along the contour with 668.14 kg ha^{-1}.

The highest per cent increase of 32.15 in seed yield over control was recorded in the treatment, sowing along the contour with ridges and furrows and khus barrier. This was followed by the treatment, sowing along the contour with dead furrows and khus barrier (20.94 per cent) and the lowest increase (6.90 per cent) was recorded in the treatment, sowing along the contour. The per cent increase in seed yield due to other treatments over control, was 14.43 in sowing along the contour with khus barrier and 11.69 in sowing along the contour with dead furrows.

During the year 1993-94, seed yields in all the tillage treatments were significantly superior to that of control (sowing along the slope). Among the tillage treatments, sowing along the contour with ridges and furrows and khus barrier recorded highest yield of 974.69 kg ha^{-1} followed by sowing along the contour + dead furrows and khus barrier with 923.23 kg ha^{-1} and were superior to other tillage treatments. Sowing along the contour + khus barrier with 878.51 kg ha^{-1}, and sowing along the contour + dead furrows with 872.79 kg ha^{-1} were on par and superior to sowing along the contour (813.57 kg ha^{-1}).

The treatment, sowing along the contour with ridges and furrows and khus barrier recorded highest increase of 30.41 per cent in seed yield over control (sowing along the slope). This was followed by the treatments, sowing along the contour with dead furrows and khus barrier (23.52 per cent), sowing along the contour with khus barrier (17.54 per cent), sowing along contour with dead furrows (16.80 per cent) and sowing along the contour (8.85 per cent).

In the year 1994-95, the effect of treatments on seed yield was similar to that in the year 1993-94. Seed yields in all the tillage treatments were significantly superior to that of control. Among the tillage treatments, sowing along the contour with ridges and furrows and khus barrier (970.24 kg ha^{-1}) was significantly superior to others. Sowing along the contour with dead furrows and khus barrier (927.38

kg ha^{-1}) was superior over sowing along the contour with dead furrows (871.34 kg ha^{-1}) and sowing along the contour with khus barrier (869.05 ha^{-1}) which were on par and superior to sowing along the contour.

The treatment, sowing along the contour with ridges and furrows and khus barrier recorded highest per cent increase of 31.03 in seed yield over control (sowing along the slope). This was followed by sowing along the contour with dead furrows and khus barrier (25.24 per cent), sowing along the contour with khus barrier (17.68 per cent), sowing along the contour with dead furrows (17.36 per cent) and the treatment, sowing along the contour with 8.92 per cent.

4.2 VEGETATIVE BARRIER

Khus barrier was included in combination with conservation tillage practices in two treatments. The results on the effect of khus barrier on runoff, soil loss, soil moisture content and seed yield are presented below.

4.2.1 Effect of khus barrier on runoff and soil loss

The runoff and soil loss were considerably reduced in the treatments where khus barrier was included in combination with tillage treatments. During the year 1993-94, the per cent runoff (of rain-water) was 4.51 in the treatment, sowing along contour in combination with khus barrier and 3.07 in sowing along the contour with dead furrows in combination with khus barrier compared to 13.16 and 7.02, respectively in the respective treatments without khus barrier (Fig. 7).

The per cent reduction in runoff (Table 5) was 65.75 in sowing along the contour in combination with khus barrier and 56.33 in sowing along the contour with dead furrows in combination with khus barrier compared to their respective treatments without khus barrier.

The cumulative soil loss (Table 3) during the year, 1993-94 was 0.622 t ha^{-1} in the treatment, sowing along the contour in combination with khus barrier and 0.360 t ha^{-1} in sowing along the contour with dead furrows in combination with khus barrier compared to 2.541 and 1.206 t ha^{-1}, respectively in the above conservation practices without khus barrier.

The per cent reduction in soil loss (Table 5) was 75.52 in sowing along the contour with khus barrier and 70.15 in sowing along the contour with dead furrows in combination with khus barrier compared to that in the respective treatments without khus barrier.

During the year 1994-95, the per cent runoff (Fig.8) was 3.20 in the treatment, sowing along the contour in combination with khus barrier compared to

9.60 without khus. It was 2.18 in sowing along the contour with dead furrows in combination with khus barrier compared to that without khus barrier (5.08).

The per cent reduction in runoff (Table 5) was 66.65 in sowing along the contour in combination with khus barrier compared to without khus and 58.33 in sowing along the contour with dead furrows in combination with khus barrier compared to without khus barrier.

The cumulative soil loss during the year 1994-95 (Table 4 and Fig. 10) was 0.320 t ha^{-1} in the treatment, sowing along the contour in combination with khus barrier and 0.186 t ha^{-1} in sowing along the contour with dead furrows in combination with khus barrier compared to that of 1.392 and 0.650 t ha^{-1} with the respective treatments without khus barrier.

The per cent reduction in soil loss was 77.01 in sowing along the contour in combination with khus barrier and 71.39 in sowing along the contour with dead furrows in combination with khus barrier (Table 5) compared to that in the respective treatments without khus barrier.

9.60 without khus. It was 2.18 in sowing along the contour with dead furrows in combination with khus barrier compared to that without khus barrier (5.08).

The per cent reduction in runoff (Table 5) was 66.65 in sowing along the contour in combination with khus barrier compared to without khus and 58.33 in sowing along the contour with dead furrows in combination with khus barrier compared to without khus barrier.

The cumulative soil loss during the year 1994-95 (Table 4 and Fig. 10) was 0.320 t ha^{-1} in the treatment, sowing along the contour in combination with khus barrier and 0.186 t ha^{-1} in sowing along the contour with dead furrows in combination with khus barrier compared to that of 1.392 and 0.650 t ha^{-1} with the respective treatments without khus barrier.

The per cent reduction in soil loss was 77.01 in sowing along the contour in combination with khus barrier and 71.39 in sowing along the contour with dead furrows in combination with khus barrier (Table 5) compared to that in the respective treatments without khus barrier.

4.2.2 Effect of khus barrier on soil moisture content

The soil moisture content estimated 2 m above khus and 2 m below the khus barrier in 0-15, 15-30 and 30-45 cm depths during the crop growth period of castor in four seasons are given in Appendices IX to XII and illustrated in Figs.18 to 23. The moisture content in terms of depth, in mm upto 45 cm depth of soil as given in parentheses below. From the figures, it could be observed that the soil moisture content above the khus barrier was higher than the soil moisture content below the khus barrier in all the three depths viz., 10-15, 15-30 and 30-45 cm throughout the crop growth period in all the years.

The mean soil moisutre content above and below khus barrier is presented in Table 12. During the year 1991-92, the soil moisture content above the khus barrier was 5.35 (13.65 mm), 6.74 (17.51 mm) and 8.23 (22.12 mm) per cent as compared to 4.99 (12.73 mm), 6.20 (16.11 mm) and 7.31 (19.65 mm) per cent below khus barrier in 0-15, 15-30 and 30-45 cm depths, respectively. The increase in soil moisture content above the khus barrier was 7.21, 8.71 and 12.59 per cent in the three depths, respectively compared to below the khus.

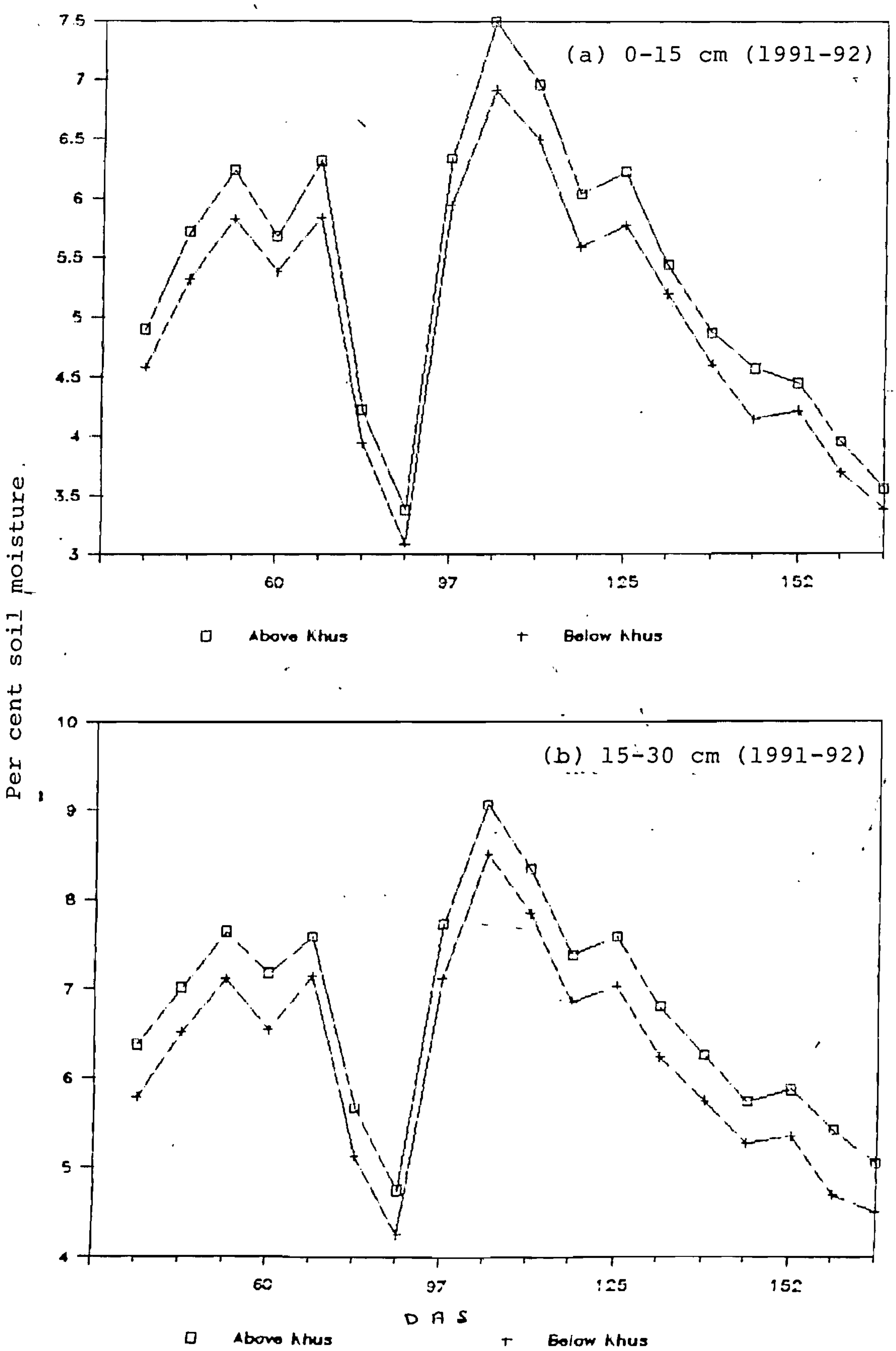


Fig.18 Effect of khus barrier on soil moisture content during crop growth period

(a) 0-15 cm (1991-92) (b) 15-30 cm (1991-92)

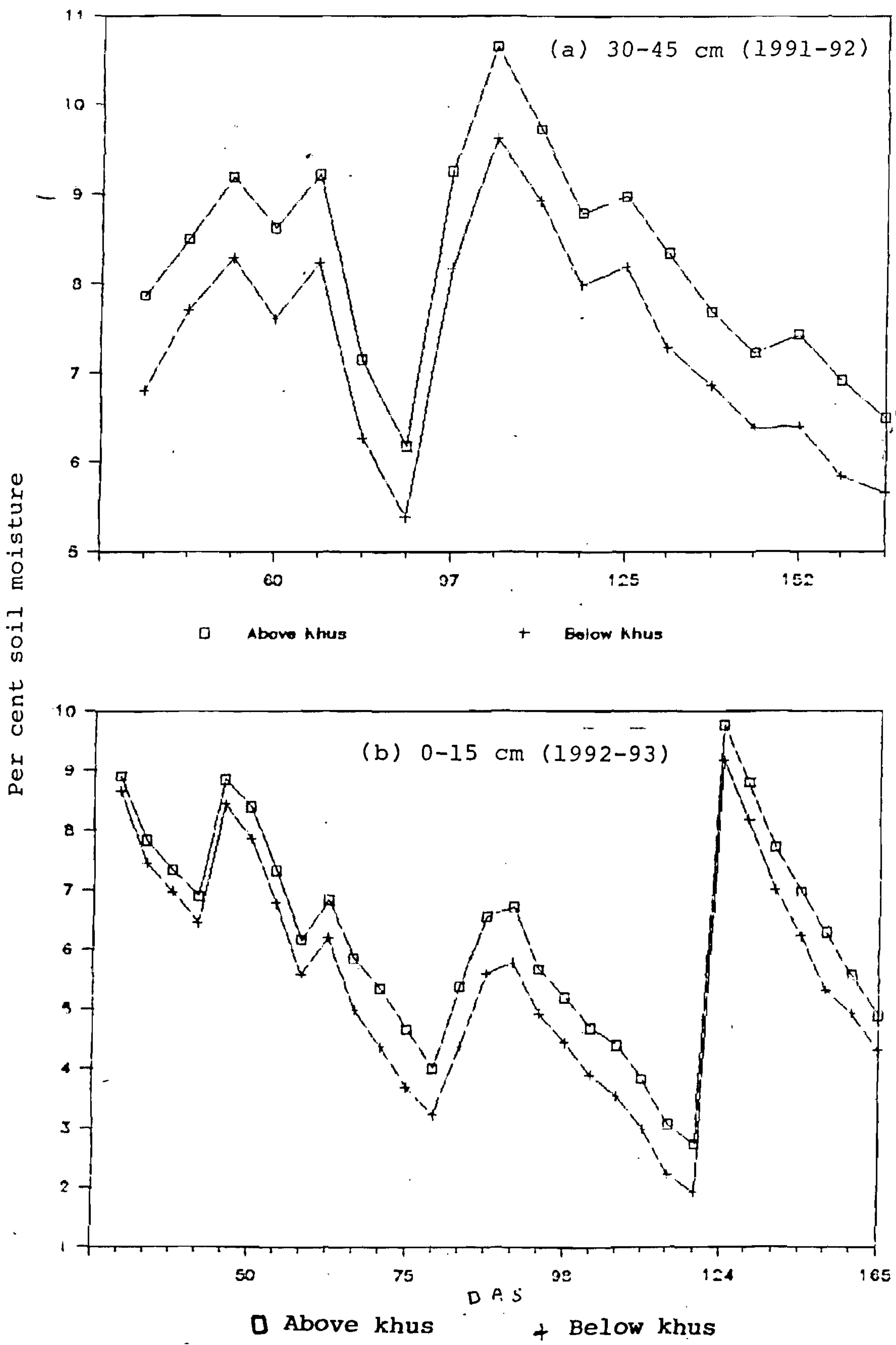


Fig.19 Effect of khus barrier on soil moisture content during crop growth period

(a) 30-45 cm (1991-92) (b) 0-15 cm (1992-93)

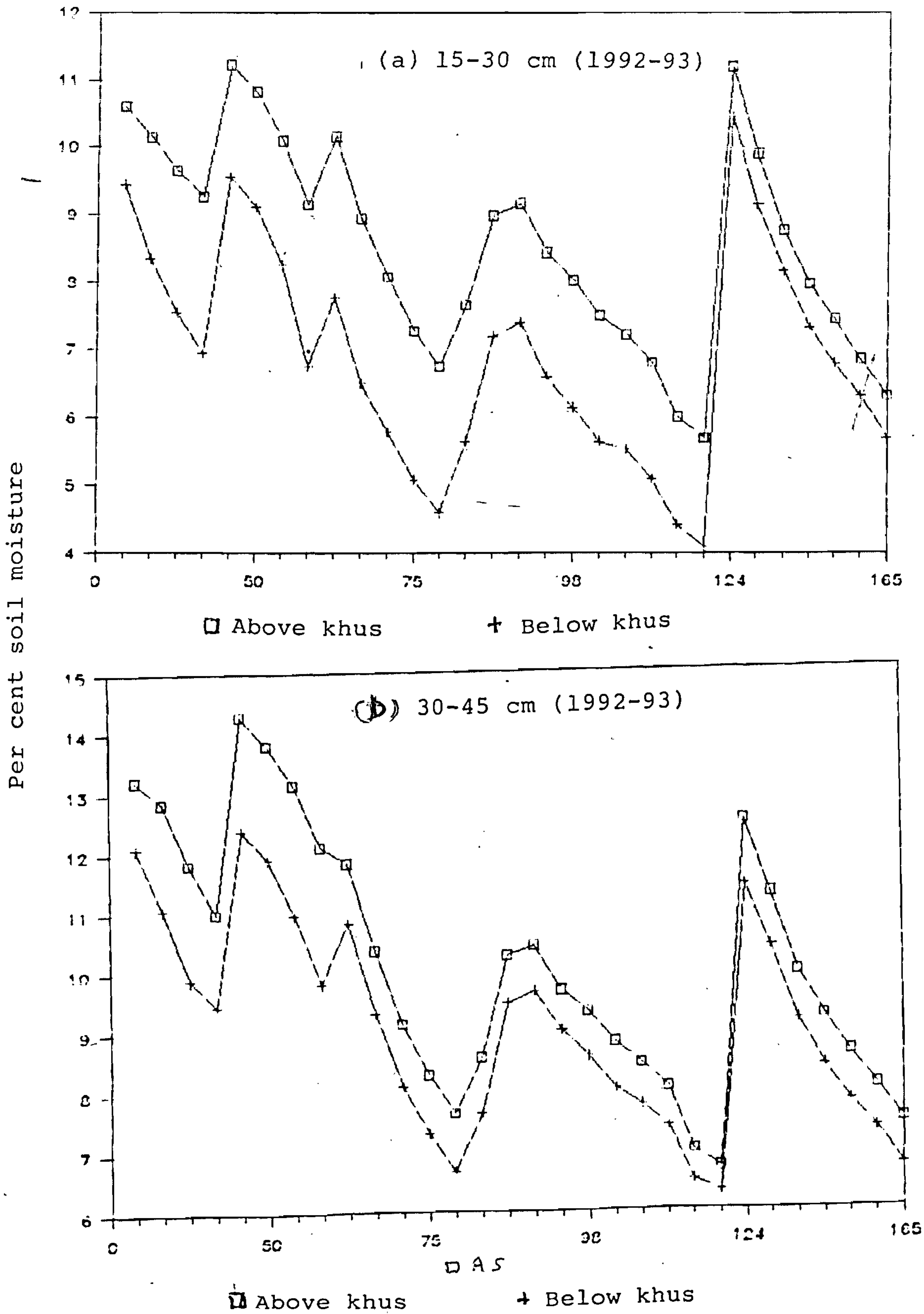


Fig.20 Effect of khus barrier on soil moisture content *during crop growth period*

(a) 15-30 cm (1992-93) (b) 30-45 cm (1992-93)

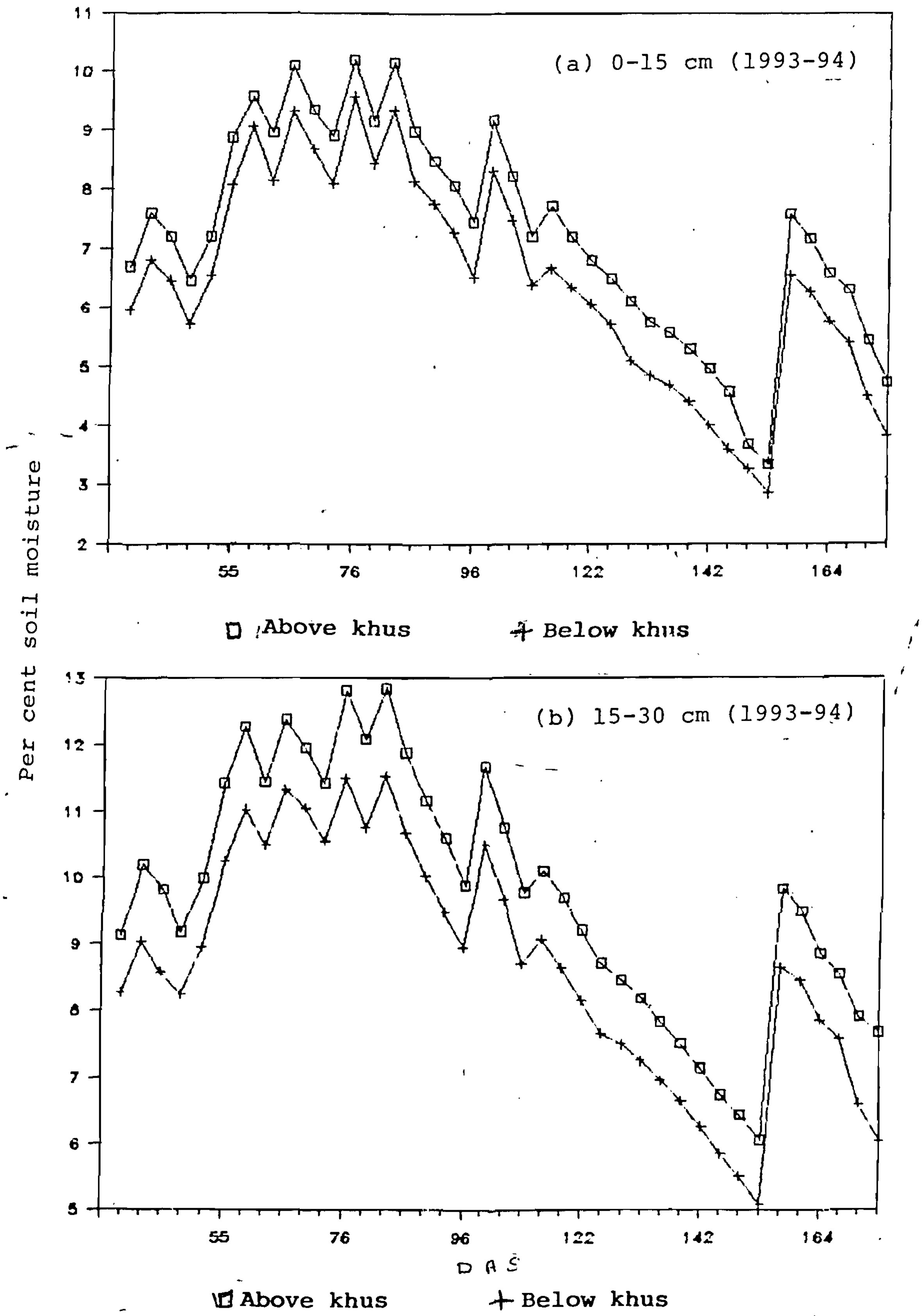


Fig.21 Effect of khus barrier on soil moisture content during crop growth period

(a) 0-15 cm (1993-94) (b) 15-30 cm (1993-94)

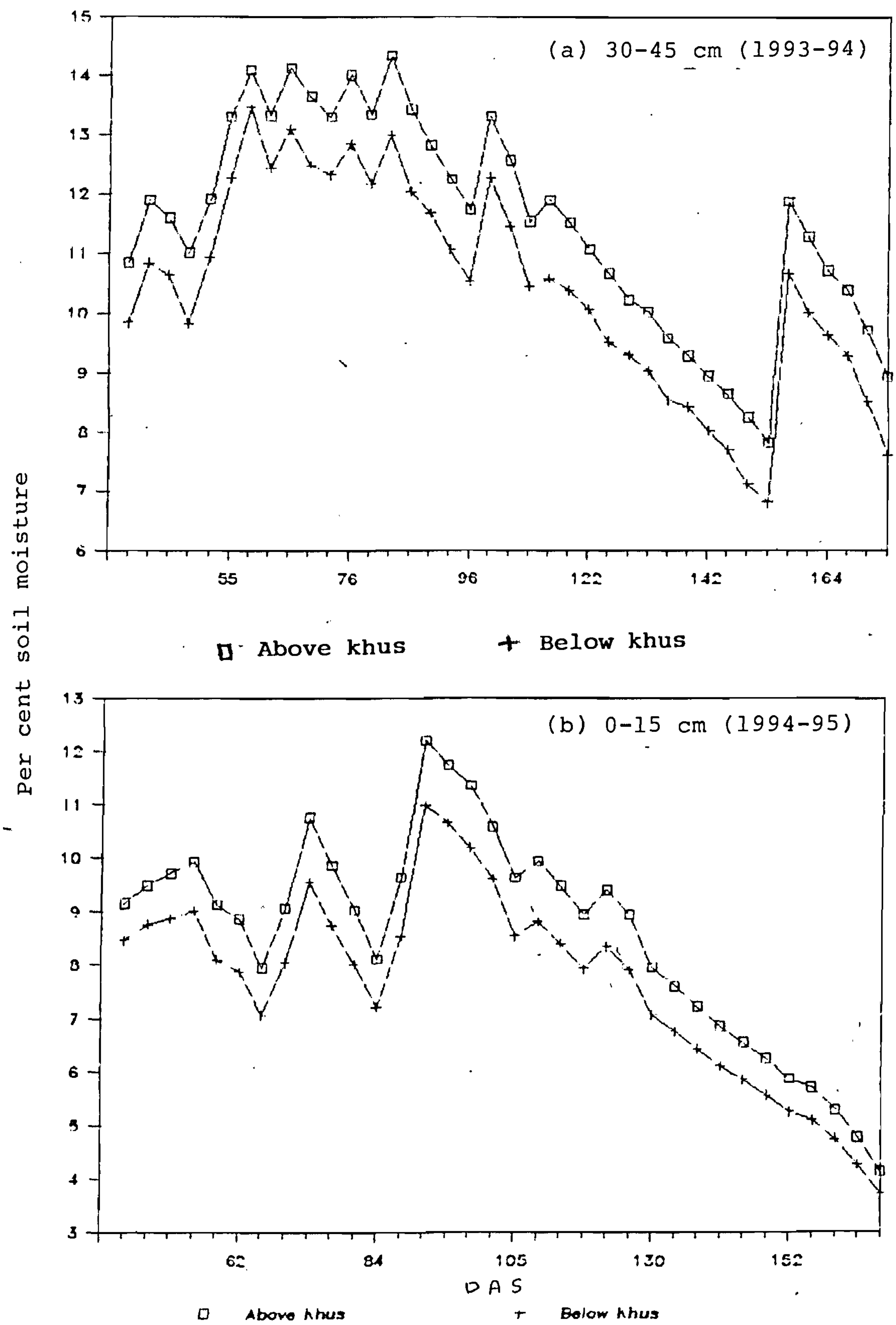


Fig.22 *Effect of khus barrier on soil moisture content during crop growth period*

(a) 30-45 cm (1993-94) (b) 0-15 cm (1994-95)

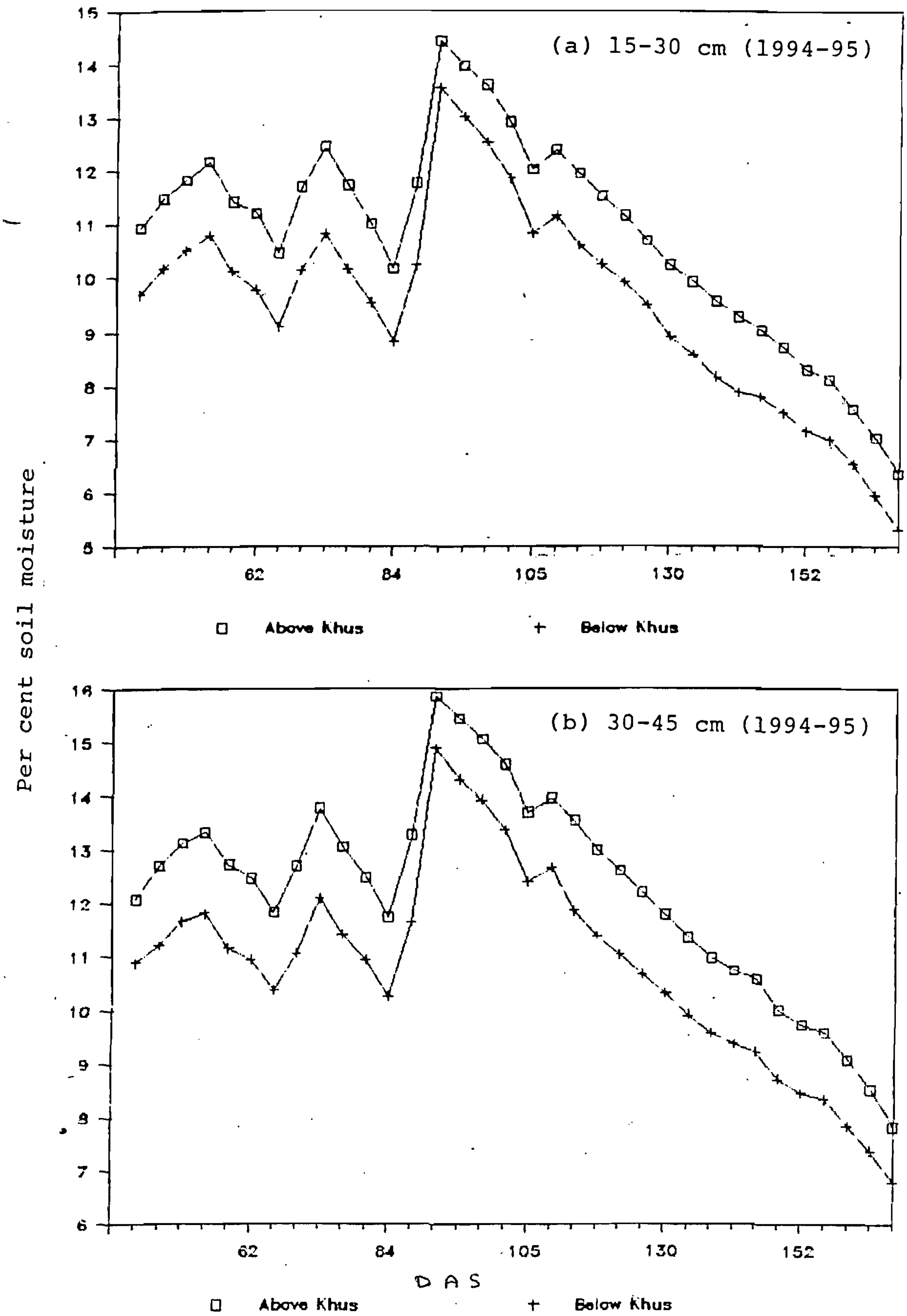


Fig.23 Effect of khus barrier on soil moisture content during crop growth period

(a) 15-30 cm (1994-95) (b) 30-45 cm (1994-95)

Table 12. Effect of khus on mean soil moisture content (% w/w) during crop growth period of castor

Location	Depth (cm)	1991-92	1992-93	1993-94	1994-95
Above Khus	0-15	5.35	6.22	7.21	8.55
Below Khus	0-15	4.99	5.52	6.46	7.65
Above Khus	15-30	6.74	8.54	9.74	10.79
Below Khus	15-30	6.20	6.88	8.65	9.52
Above Khus	30-45	8.23	10.12	11.52	12.21
Below Khus	30-45	7.31	9.04	10.44	10.81

In the year 1992-93, the soil moisture content above the khus barrier was 6.22 (15.87 mm) 8.54 (22.19 mm) and 10.12 (27.20 mm) per cent in 0-15, 15-30 and 30-45 cm depths, respectively. The soil moisture content above khus barrier was 12.68, 24.12 and 11.95 per cent higher in 0-15, 15-30 and 30-45 cm depths, respectively than the soil moisture content below the khus barrier.

During the year 1993-94, the soil moisture content above the khus barrier was 7.21, (18.40 mm), 9.74 (25.30 mm) and 11.52 (30.97 mm) per cent as compared to 6.46 (16.48 mm) 8.65 (22.47 mm) and 10.44 (28.06 mm) below khus barrier in 0-15, 15-30 and 30-45 cm depths, respectively. The soil moisture content above the khus barrier was 11.61, 12.60 and 10.35 per cent higher in the three depths, respectively than the soil moisture content below the khus barrier.

In the year 1994-95, the soil moisture content above the khus barrier was 8.55 (21.82 mm), 10.79 (28.03 mm) and 12.21 (32.82 mm) per cent as compared to 7.85 (20.03 mm), 9.52 (24.73 mm) and 10.81 (29.06 mm) below khus barrier in 0-15, 15-30 and 30-45 cm depths, respectively. The soil moisture content above the khus barrier was 11.76, 13.34 and 12.95 per cent higher in the three depths, respectively than the soil moisture below the khus barrier.

4.2.3 Effect of khus barrier on crop yield

The data on mean seed yield of castor recorded in 4 m x 4 m plots above and below the khus barrier in the treatment of sowing along the contour with khus barrier are presented in Table 13.

The seed yield of castor was higher above the khus barrier than below the khus barrier. During the year 1991-92, the yield of castor above the khus barrier was 783.34 kg ha^{-1} as compared to that of 672.93 kg ha^{-1} below the khus barrier. The increase in seed yield above the khus barrier over below the khus barrier was 16.41 per cent.

In the year 1992-93, the seed yield recorded was 915.63 kg ha^{-1} above the khus barrier as against 782.84 kg ha^{-1} below the khus barrier. The seed yield of castor above khus barrier was 16.96 per cent higher than that below the khus barrier.

During 1993-94, seed yield of castor above khus barrier was 959.36 kg ha^{-1} as compared to that of 822.66 kg ha^{-1} below khus barrier. The increase in seed yield above khus barrier over below khus barrier was 16.62 per cent.

During the year 1994-95, seed yield above the khus barrier was 921.67 kg ha^{-1} as compared to that of

Table 13. Effect of khus on yield of castor (kg ha^{-1})

Location	1991-92		1992-93		1993-94		1994-95	
	Seed yield	% increase	Seed yield	% increase	Seed yield	% increase	Seed yield	% increase
Above Khus	783.34	16.41	925.63	16.96	959.38	16.62	921.87	17.98
Below Khus	672.93		782.84		822.66		781.25	

781.25 kg ha^{-1} below the khus barrier. The seed yield above khus barrier was 17.98 per cent higher than that below the khus barrier.

The seed yield of castor as influenced by conservation tillage treatments in combination with khus barrier is given in Table 11. The average seed yield of castor was 790.09 kg ha^{-1} in contour sowing in combination with khus barrier as compared to 729.21 kg ha^{-1} in the respective treatment without khus barrier. The increase in seed yield due to khus barrier was 8.35 per cent. In the treatment with dead furrows in combination with khus barrier, the average seed yield was 828.42 kg ha^{-1} as against 776.10 kg ha^{-1} in dead furrows without khus barrier. The average increase in seed yield with khus barrier was 6.74 per cent.

4.3 SOIL WATER BALANCE

4.3.1 Efffect of conservation tillage on soil water balance

The data on components of soil water balance under different treatments computed at different growth stages of castor during the year 1993-94 is presented in Table 14. For the purpose of computation of water balance, the crop growth period was devided into 4 stages after the treatments were imposed i.e., 29-56, 57-91, 92-140 and 141-178 DAS. The change in soil

Table 14. Effect of conservation tillage on components of water balance at different stages of crop growth of castor during (Kharif, 1993-94)

Treatments	Days After Sowing	Rain-fall (mm)	Run-off (mm)	Evapo-trans piration (mm)	Change in soil mois-ture sto-rage (mm)
T1 Sowing on contour	29-56	107.0	9.60	108.8	(-)11.40
	57-91	191.3	16.55	115.2	59.55
	92-140	62.6	4.65	80.5	(-)22.55
	141-178	27.4	--	51.6	(-)24.20
T2 Contour + Khus	29-56	107.0	3.54	108.8	(-)5.34
	57-91	191.3	5.54	115.2	70.56
	92-140	62.6	1.47	80.5	(-)19.37
	141-178	27.4	--	51.6	(-)24.20
T3 Contour + Dead Furrow	29-56	107.0	5.00	108.8	(-)6.80
	57-91	191.3	9.07	115.2	67.03
	92-140	62.6	2.37	80.5	(-)20.27
	141-178	27.4	--	51.6	(-)24.20
T4 Contour + Dead Furrow + Khus	29-56	107.0	2.55	108.8	(-)4.35
	57-91	191.3	3.90	115.2	72.20
	92-140	62.6	0.73	80.5	(-)18.63
	141-178	27.4	--	51.6	(-)24.20
T5 Contour + Ridges & Furrows + Khus	29-56	107.0	1.38	108.8	(-)3.18
	57-91	191.3	2.25	115.2	73.85
	92-140	62.6	0.42	80.5	(-)18.32
	141-178	27.4	--	51.6	(-)24.20
T6 Sowing along slope	29-56	107.0	10.52	108.8	(-)12.32
	57-91	191.3	19.38	115.2	56.72
	92-140	62.6	5.24	80.5	(-)23.14
	141-178	27.4	--	51.6	(-)24.20

moisture (difference between moisture addition by rainfall and loss by runoff + evapotranspiration) status (mm) in different treatments was (-) 11.40, 59.55, (-) 22.55 and (-) 24.20 in sowing along the contour, (-) 5.34, 70.56, (-) 19.37 and (-) 24.20 in sowing along the contour with khus barrier, (-) 6.80, 67.03, (-) 20.27 and (-) 24.20 in sowing along the contour with dead furrows, (-) 4.35, 72.20, (-) 18.63 and (-) 24.20 in sowing along the contour with dead furrows and khus barrier, (-) 3.18, 73.85, (-) 18.32 and (-) 24.20. in sowing along the contour with ridges and furrows and khus barrier and (-) 12.32, 56.72, (-) 23.14 and (-) 24.20 in sowing along the slope between 29-56, 57-91, 92-140 and 141-175 DAS, respectively. The change in soil moisture was +ve indicating surplus soil water between 57 and 91 DAS and -ve indicating deficit soil water between 29-56, 92-140 and 141 to 175 DAS in the treatments. Conservation tillage practices have considerably reduced the water deficit when compared to control (sowing along the slope). The overall change in soil water status was +ve (surplus) in all the conservation treatments and -ve (deficit) in control. The overall surplus soil water was maximum in the treatment, sowing along the contour + ridges and furrows and khus barrier with 28.15 mm. This was followed by sowing along the contour + dead furrows and khus barrier (25.02 mm), sowing along the contour with khus barrier (21.65 mm), sowing along the contour with dead furrows (15.76 mm) and minimum of 1.40 mm was observed *in the treatment, sowing along the contour whereas in* the control treatment there was 2.94 mm deficit.

During the year 1994-95, the change in soil water status (mm) in different treatments was 33.63, 50.00, (-) 8.84 and (-) 50.30 in sowing along the contour, 41.93, 51.97, (-) 8.84 and (-) 50.30 in sowing along the contour with khus barrier, 39.32, 51.56, (-) 8.84 and (-) 50.30 in sowing along the contour with dead furrows, 43.23, 52.39, (-) 8.84 and (-) 50.30 in sowing along the contour with dead furrows and khus barrier, 44.47, 52.66, (-) 8.84 and (-) 50.30 in sowing along the contour with ridges and furrows and khus barrier and 31.56, 49.50, (-) 8.84 and (-) 50.30 in sowing along the slope between 29-56, 57-91, 92-140 and 141-178 DAS, respectively (Table 15). The change in soil moisture was +ve indicating surplus between 29-56 and 57-91 DAS and -ve indicating deficit between 92-140 and 141-178 DAS in all the treatments. The overall change in soil water status was +ve (surplus) in all the treatments. The overall surplus soil water was maximum (37.99 mm) in the treatement, sowing along the contour with ridges and furrows and khus barrier. This was followed by sowing along the contour with dead furrows and khus barrier (36.48 mm), sowing along the different stages of crop growth of castor during (Kharif, 1994-95)

Treatments	Days After Sowing	Rain-fall (mm)	Run-off (mm)	Evapo-trans piration (mm)	Change in soil mois-ture sto-rage (mm)
T1 Sowing on contour	29-56	153.2	12.37	107.2	33.63
	57-91	230.1	68.40	11.7	50.00
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30
T2 Contour + Khus	29-56	153.2	4.07	107.2	41.93
	57-91	230.1	66.43	11.7	51.97
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30
T3 Contour + Dead Furrow	29-56	153.2	6.68	107.2	39.32
	57-91	230.1	66.84	11.7	51.56
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30
T4 Contour + Dead Furrow + Khus	29-56	153.2	2.75	107.2	43.23
	57-91	230.1	66.01	11.7	52.39
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30
T5 Contour + Ridges & Furrows + Khus	29-56	153.2	1.53	107.2	44.47
	57-91	230.1	65.74	11.7	52.66
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30
T6 Sowing along slope	29-56	153.2	14.44	107.2	31.56
	57-91	230.1	68.90	11.7	49.50
	92-140	79.0	11.04	76.8	(-)8.84
	141-178	--	--	50.3	(-)50.30

contour with khus barrier (34.76 mm), sowing along the contour with dead furrows (31.74 mm), sowing along the contour (24.49 mm) and lowest was with sowing along the slope (21.92 mm).

4.3.2 Relationship between runoff and seed yield of castor

Relationship between runoff and seed yield was worked out using correlation and regression techniques. The pooled analysis over all the treatments in two years, 1993-94 and 1994-95 indicated that seed yield was significantly negatively correlated with runoff ($r = -0.8125^{**}$).

A regression model was developed for seed yield and runoff. The equation is given below:

$$Y = 942.5599 - 5.8601\ R$$

$$r = -0.8215^{**} \quad R^2 = 0.6602$$

Where,

Y = Seed yield (kg ha^{-1})

R = Runoff (mm)

4.4 WATER USE EFFICIENCY

The data on the water use and water use efficiency (WUE) calculated for different tillage treatments during the year 1993-94 are given in Table 16.

Table 16. Effect of conservation tillage on water use (cm) and water use efficiency (kg/ha/cm)

Treatments	1993-94		1994-95	
	Water use	Water use efficiency	Water use	Water use efficiency
T1 Sowing on contour	46.60	17.46	46.33	17.41
T2 Contour + Khus	48.54	18.10	48.13	18.11
T3 Contour + Dead Furrow	48.12	18.14	47.57	18.27
T4 Contour + Dead Furrow + Khus	48.46	19.05	47.83	19.39
T5 Contour + Ridges & Furrows+Khus	48.23	20.21	47.79	20.30
T6 Sowing along slope	46.54	16.06	45.95	16.12

The water use (cm) under different tillage treatemnts was 46.60 in sowing along the contour, 48.54 in sowing along the contour with khus barrier, 48.12 in sowing along the contour with dead furrows, 48.46 in sowing along the contour with dead furrows and khus barrier, 48.23 in sowing along the contour with ridges and furrows and khus barrier and 46.54 in sowing along the slope.

Conservation tillage increased the water use efficiency. The water use efficiency was highest in the treatment, sowing along the contour + ridges and furrows and khus barrier with 20.21 kg ha^{-1} cm^{-1}. This was followed by sowing along the contour with dead furrows and khus barrier (19.05 kg ha^{-1} cm^{-1}), sowing along the contour with dead furrows (18.14 kg ha^{-1} cm^{-1}), sowing along the contour with khus barrier (18.10 kg ha^{-1} cm^{-1}), sowing along the contour (17.46 kg ha^{-1} cm^{-1}) and sowing along the slope with 16.06 kg ha^{-1} cm^{-1}.

During the year 1994-95, water use ranged from 45.95 cm in sowing along the slope to 48.13 cm in sowing along the contour with khus barrier (Table 16). The tillage treatments influenced water use efficiency. Highest water use efficiency of 20.30 kg ha^{-1} cm^{-1} was recorded in the treatment, sowing along the contour with ridges and furrows and khus barrier. This was followed by the treatments, sowing along contour with dead furrows and khus barrier (19.39 kg ha^{-1} cm^{-1}), sowing along the contour with dead furrows (18.27 kg ha^{-1} cm^{-1}), sowing along the contour with khus barrier (18.11 kg ha^{-1} cm^{-1}), sowing along the contour (17.41 kg ha^{-1} cm^{-1}) and sowing along the slope with 16.12 kg ha^{-1} cm^{-1}.

4.5 MODELS ON RAINFALL, RUNOFF AND SOIL LOSS

The relationship between rainfall and runoff, rainfall and soil loss and runoff and soil loss were workedout using regression techniques for each treatment on pooled data over two years with sixteen runoff events. The equations are given below.

4.5.1 Relationship between rainfall and runoff

The relationship between rainfall and runoff was significant in all the treatments. The equations are given below:

$R = 0.7084 + 0.0884\ Q$ sowing along the contour (T_1) .... (2)

$R^2 = 0.5280$

$r = 0.7267^{**}$

$R = 0.2263 + 0.0306\ Q$ sowing along the contour + khus barrier (T_2) ... (3)

$R^2 = 4538$

$r = 0.6736^{**}$

$R = 0.4467 + 0.0442\ Q$ sowing along the contour + dead furrows (T_3) ... (4)

$R^2 = 0.4605$

$r = 6786^{**}$

$R = 0.1402 + 0.0211\ Q$ sowing along the contour + dead furrows + khus (T_4) ...(5)

$R^2 = 0.3628$

$r = 0.6023^{*}$

$R = 0.0864 + 0.0116\ Q$ sowing along the contour + ridges and furrows + khus (T_5) ...(6)

$R^2 = 0.3255$

$r = 0.5705^{*}$

$R = 0.8717 + 0.0992\ Q$ sowing along the slope (T_6) ... (7)

$R^2 = 0.5397$

$r = 0.7346^{**}$

Where,

Q = Rainfall (mm)

R = Runoff (mm)

4.5.2 Relationship between rainfall and soil loss

The relationship between rainfall and soil loss was significant in all the treatments. The equations treatmentwise are given below:

$S = 0.1024 + 0.0058\ Q$ sowing along the contour (T_1) .... (8)

$R^2 = 0.3545$

$r = 0.5954^{*}$

$S = 0.0238 + 0.0014\ Q$ sowing along the contour + khus barrier (T_2) ... (9)

$R^2 = 0.2873$

$r = 0.5360^{*}$

$$S = 0.0451 + 0.0029\,Q$$ sowing along the contour + dead furrows (T_3) ...(10)

$R^2 = 0.3421$

$r = 0.5849^{*}$

$$S = 0.0119 + 0.0009\,Q$$ sowing along the contour + dead furrows + khus (T_4) ...(11)

$R^2 = 0.3166$

$r = 0.5627^{*}$

$$S = 0.0059 + 0.0007\,Q$$ sowing along the contour + ridges and furrows + khus (T_5) ...(12)

$R^2 = 0.3427$

$r = 0.5854^{*}$

$$S = 0.1197 + 0.0068\,Q$$ sowing along the slope (T_6) .. (13)

$R^2 = 0.3625$

$r = 0.6021^{*}$

Where,

Q = Rainfall (mm)

S = Soil loss (t ha^{-1})

4.5.3 Relationship between runoff and soil loss

The relationship between runoff and soil loss was significant in all the treatments. The equations for each treatment are given below:

$$S = 0.0320 + 0.0740\,R$$ sowing along the contour (T_1) ....(14)

$R^2 = 0.8503$

$r = 0.9221^{**}$

$$S = 0.0066 + 0.0533\,R$$ sowing along the contour + khus barrier (T_2) ...(15)

$R^2 = 0.8373$

$r = 0.9128^{**}$

$S = 0.0062 + 0.0714\ R$ sowing along the contour + dead furrows (T_3) ...(16)

$R^2 = 0.8960$

$r = 0.9466^{**}$

$S = 0.0061 + 0.0424\ R$ sowing along the contour + dead furrows + khus (T_4) ...(17)

$R^2 = 0.8609$

$r = 0.9279^{**}$

$S = 0.0030 + 0.0527\ R$ sowing along the contour + ridges and furrows + khus (T_5) ...(18)

$R^2 = 0.8575$

$r = 0.9260^{**}$

$S = 0.0283 + 0.0780\ R$ sowing along the slope (T_6) ... (19)

$R^2 = 0.8719$

$r = 0.9338^{**}$

Where,

R = Runoff (mm)

S = Soil loss (t ha^{-1})

* significant at 5 per cent

** significant at 1 per cent

...

DISCUSSION

CHAPTER V

DISCUSSION

The results obtained are discussed in this chapter. While discussing only major trends of variation were kept in view rather than the individual variations.

5.1 CONSERVATION TILLAGE

5.1.1 Effect of conservation tillage on runoff and soil loss

Conservation of rainwater and soil are important aspects in dryland agriculture under watershed programme. The conservation tillage practices included in the present study viz., dead furrows and ridges and furrows in combination with and without khus barrier along with contour cultivation considerably reduced runoff and soil loss. Formation of ridges and furrows in combination with khus barrier resulted in highest reduction (Table 5) of runoff (88.93 per cent) and soil loss (92.30 per cent). Due to contour ridges and furrows, the rainwater was collected in furrows to a greater extent resulting in reduced runoff. As the runoff was less, the soil which is carried away along with the running water was also less. Khus grass which formed a dense hedge acted as a barrier and slowed down the velocity of running water. There was more infiltration time and more water entered into the soil. A reduction of 72.3 per cent in runoff due to ridging has been reported by CRIDA (1986) under castor crop. AICRPDA (1991-92) reported a reduction of 25.8 and 43.4 per cent of runoff and soil loss respectively due to ridges and furrows under cowpea in a red soil at Bhubaneswar.

Dead furrows in combination with khus barrier on contour was the next best conservation practice. The dead furrows formed on contour at a distance of 3.6 m acted as temporary reservoirs of water that was collected from the 3.6 m land above the furrow and retained rainwater till they were full. So the runoff was reduced and hence the soil loss was also low. CRIDA (1988) reported a reduction in runoff by 26 per cent due to contour sowing and furrowing.

When the cultivation was done on contours, the crop plants were on rows across the slope and on the same elevation. During interculture operations some soil was deposited along the plants in the lines forming a small bund along the lines. Due to this, the movement of runoff water was less. Whereas, in the treatment, along the slope, the rainwater moved without bstruction in between the lines along the slope and so here was more runoff. The velocity of running water s also more as it moved without obstruction. So, when more water moved with greater speed the soil loss also was more in the treatment, sowing along the slope. In Alfisols at Maheswaram watershed area runoff with contour sowing was reduced to 15.2 mm and 1.8 mm from 17.4 mm and 2.0 mm recorded with sowing along the slope when the rainfall was 122 and 11 mm, respectively (MWP, 1989-90). Reduction in runoff and soil loss due to contour cultivation has also been reported by AICRPDA (1991-92) and Sastry et al. (1994).

5.1.2 Effect of conservation tillage on soil moisture

Increasing the soil moisture under different management practices is the key factor for obtaining better crop yields in rainfed agriculture. Conservation tillage practices in the present study have shown higher soil moisture in all the years compared to control (sowing along the slope) throughout the crop growth period (Fig.11 to 16). Ridges and furrows in combination with khus barrier resulted in highest soil moisture content in the three depths viz., 0-15, 15-30 and 30-45 cm throughout the crop growth period of castor in all the years (Fig.11 to 16). The mean per cent increase in soil moisture content due to contour ridges and furrows and khus barrier (over four years) compared to control (sowing along the slope) was 26.89, 24.74 and 28.04 in 0-15, 15-30 and 30-45 cm depths, respectively (Table 6). Formation of ridges and furrows in contour sown crop retained rainwater in the furrows which acted as reservoirs of water. This provided more opportunity time for the rainwater to infiltrate into the soil thereby increasing profile soil moisture content. MWP (1987-88) reported 11 per cent higher soil moisture due to formation of ridges and furrows in Alfisols under Maheshwaram watershed area in farmers fields. Increase in soil moisture due to ridges and furrows has also been reported by SPCIP (1984) and AICRPDA (1991-92).

Dead furrows formed on contours at 3.6 m interval were the next best treatment with mean per cent moisture increase of 19.47, 18.25 and 20.06 in 0-15, 15-30 and 30-45 cn depths, respectively over cultivation along the slope. Dead furrows acted as temporary reservoirs and retained rainwater in them. This gave more opportunity time for the rainwater to enter the soil thereby increased the moisture content. Reddy et al. (1991) reported 10.2 per cent increase in soil moisture of an Alfisol in 0-30 cm depth with dead furrows opened after every 3 rows of groundnut. Higher soil moisture due to dead furrows has also been reported by MWP (1987-88) and Uma Devi et al. (1991).

When the plant rows were on contour, some soil was deposited along the plant rows during intercultural operations which resulted in slightly higher elevation along the rows. This provided some obstruction and slowed down the movement of rainwater which gave more time for the rainwater to enter the soil thereby increased soil moisture content. An increase of 20 per cent in soil moisture upto 45 cm depth in contour sown castor has been reported by MWP (1989-90) compared to that sown along the slope. AICRPDA (1989-90) also reported higher soil moisture due to contour cultivation.

In case of sowing along the slope, the rain-water moved faster without any obstruction in between the lines along the slope and resulted in more runoff and there was less time for the rainwater to enter the soil. Further, when water flows in red soils, the top soil becomes hard on drying due to crusting and reduces the infiltration of water (Weststeyn, 1983 and Arakeri and Donahue, 1989). As a result the soil moisture content was less in this treatment compared to the conservation treatments.

5.1.3 Effect of conservation tillage on plant parameters

5.1.3.1 Drymatter

The data on drymatter accumulation by castor during the four years (Table 7) showed significant increase with conservation practices over control (sowing along the slope) at all stages of crop growth. The treatment, ridges and furrows on contours with khus barrier recorded highest mean drymatter (kg ha^{-1}) at 60 (498.3), 90 (1388.7) and 120 (2318.3) DAS over four years. Dead furrows in combination with khus barrier were the next best with 467.0 (60 DAS), 1245.4 (90 DAS) and 2201.5 (120 DAS) kg ha^{-1}. Higher soil moisture content due to formation of ridges and furrows and dead furrows on contours in combination with khus barrier as discussed earlier might have contributed towards better plant growth resulting in higher drymatter production. Higher soil moisture might have helped in better root growth (Rao and Das, 1986) with more nutrient uptake and resulted in better plant growth leading to more drymatter production. With increased soil moisture, the penetration resistance is reduced (ICRISAT, 1988) which might have helped in better development of root system. The nutrient availability (Holliday, 1970) and nutrient uptake (Olsen et al., 1961; Viets, 1967 and Danielson, 1972) by plants increases with higher soil moisture content. Nalayini and Sankaran (1993) reported maximum uptake of nutrients by sunflower under high soil moisture regime. Increase in uptake of N, P and K have been reported by Rao and Venkateswarlu (1988) and Tomar et al. (1990). Both higher soil moisture and nutrient availability have synergistic effect on plant growth resulting in higher drymatter production. Khader and Bhargava (1984) reported higher drymatter production of leaves and stalks of mustard under high moisture regime. Increase in drymatter production in groundnut due to formation of dead furrows has been reported by Reddy et al. (1991).

5.1.3.2 Leaf Area Index

The leaf area index (LAI) was significantly increased by conservation practices (Table 8). The mean LAI was highest with ridges and furrows in combination with khus barrier (0.7, 1.57 and 2.51) followed by dead furrows with khus barrier (0.68, 1.48 and 2.43) at 60, 90 and 120 DAS, respectively over the three years when LAI was recorded. Higher soil moisture content recorded in the above treatments (Table 6) could be attributed to better plant growth resulting in greater LAI when compared to cultivation along the slope. Higher soil moisture content facilitated more nutrient uptake (Danielson, 1972) and helped in more plant growth with higher foliage resulting in greater LAI. Khader and

Bhargava (1984) reported higher LAI in mustard under higher soil moisture regime. Increase in leaf area due to higher soil moisture has also been reported by Rao and Das (1986) and CRIDA (1992-93).

5.1.3.3 Plant Height

Plant height was significantly increased by conservation tillage practices (Table 9). The mean plant height was highest in the treatment, ridges and furrows in combination with khus barrier (75.8, 107.4 and 127.1 cm) followed by dead furrows + khus barrier with 73.1, 101.2 and 118.5 cm at 60, 90 and 120 DAS, respectively. Higher soil moisture due to conservation tillage and khus barrier could have facilitated higher nutrient uptake and resulted in better LAI (Khader and Bhargava, 1984) which might be attributed to the increase in plant height in these treatments. Reddy et al. (1991) reported increased plant height in groundnut due to formation of dead furrows. Higher seed yield of castor through enhancement of plant height has been reported by Muthuveli et al. (1987).

5.1.3.4 Number of spikes per plant

Conservation practices have significantly increased the number of spikes per plant (Table 10). The average number of spikes per plant were highest

(4.4) in the treatment with ridges and furrows in combination with khus barrier when compared to along the slope cultivation (3.93). Higher soil moisture with increased LAI in these treatments might have resulted in higher photosynthesis and resulted in more number of branches. With more number of branches, the number of spikes per plant also increased. Muthuveli et al. (1987) reported higher seed yield of castor with higher number of spikes per plant.

5.1.3.5 Number of capsules

Number of capsules per plant (Table 10) were significantly increased by conservation practices. Ridges and furrows in combination with khus barrier have resulted in highest number of capsules per plant (28.8). Dead furrows in combination with khus barrier were next best with 26.9 capsules per plant. Better crop growth with the conservation tillage practices and khus barrier due to availability of higher soil moisture has resulted in more number of spikes per plant. With more number of spikes, the number of capsules per plant also increased in these treatments. Kale et al. (1986) and Muthuveli et al. (1987) attributed increase in castor yield to higher number of capsules per plant. Patel and Jaimini (1991) reported significant positive correlation of castor seed yield with number of capsules.

5.1.3.6 100-seed weight

Test weight (100-seed weight) was also significantly increased by conservation tillage practices and khus barrier (Table 10). Test weight was highest in ridges and furrows in combination with khus barrier (15.57 g). The test weight was higher in other conservation practices also compared to sowing along the slope (14.27 g). The increase in test weight may be attributed to better filling of seed in these treatments. Higher seed yield could be obtained when the crop is free from moisture stress during seed filling stage (Kale et al., 1986 and CRIDA, 1991-92).

5.1.3.7 Seed yield

Conservation tillage practices recorded significantly higher seed yield over control i.e., along the slope cultivation in all the four seasons (Table 11). Among the tillage treatments, ridges and furrows in combination with khus barrier gave significantly higher seed yield over other treatments in all the four years with an average of 881.5 kg ha^{-1}. Dead furrows in combination with khus barrier was the next best treatment with 828.4 kg ha^{-1}. Increase in seed yield due to ridges and furrows and khus barrier may be attributed to the reduction in runoff and increase in soil moisture content due to this treatment. Increase in soil moisture content has resulted in better crop growth interms of increase in drymatter production and LAI and also increase in number of spikes and capsules per plant and 100-seed weight which ultimately increased the seed yield. Increased crop yields due to higher soil moisture have been reported by Rao et al. (1986), Sharma (1991), Singh and Singh (1992), Patel and Patel (1993).

Formation of dead furrows on contours with khus barrier was next best in terms of better crop growth as a result of reduction in runoff and increase in soil moisture content influencing the plant parameters which ultimately resulted in next best crop yields. This was followed by sowing on contours with khus barrier, formation of dead furrows, sowing on contours and lowest (671.1 kg ha^{-1}) in cultivation along the slope. The increase in crop yields in the treatments was in accordance with their effect on soil moisture content influencing the plant parameters. Availability of more nutrients and higher nutrient uptake in the presence of higher soil moisture resulted in better crop growth leading to higher crop yields. The reduction in CEC because of more soil loss (ICRISAT, 1988) in sowing along the slope (control) could have resulted in lower crop yields. Increase in crop yields due to formation of dead furrows and ridges and furrows on contours has been reported by SPCIP (1984), CRIDA (1985), Uma Devi et al. (1990), AICRPDA (1991-92), CRIDA (1992-1993) and Oswal (1994).

5.2 EFFECT OF KHUS BARRIER

5.2.1 Effect of khus barrier on runoff and soil loss

The runoff and soil loss were considerably reduced in the treatments where khus barrier was included in combination with conservation tillage.

The per cent reduction in runoff (Table 5) was 65.75 (1993-94) and 66.65 (1994-95) in sowing along the contour in combination with khus barrier and 56.33 (1993-94) and 58.33 (1994-95) in sowing along the contour with dead furrows in combination with khus barrier. Khus grass which formed dense hedge, acted as a barrier and slowed down the velocity of rainwater. In addition soil was also deposited within the tillers of the khus. So the khus barrier together with soil acted as a bund and reduced runoff. Krishnappa (1989) reported a reduction of 30 per cent in surface runoff due to khus barrier planted at 1 m vertical interval compared to conventional practice of graded bunds in red soils. Bharad and Bathkal (1990) reported an average reduction of 47 per cent in surface runoff with khus barrier as compared to cultivation across the slope without khus barrier in a Vertisol. Reduction in runoff with vetiver hedge has also been reported by Rao et al.(1993), Bharadwaj (1994) and Sharma et al.(1994).In the present study also khus barrier reduced runoff to a greater extent.

The per cent reduction in soil loss (Table 5) was 75.52 (1993-94) and 77.01 (1994-95) in sowing along the contour in combination with khus barrier and 70.15 (1993-94) and 71.39 (1994-95) in sowing along the contour with dead furrows in combination with khus barrier when compared to their respective treatments without khus barrier. Khus grass which formed dense hedge acted as a filter and retained soil particles above the barrier and thus reduced soil loss. The velocity of running water was reduced by the dense khus barrier and hence the carrying capacity was reduced resulting in deposition of heavier particles above the khus. Bharad and Bathkal (1990) have reported an average reduction of 74 per cent in soil loss with khus barrier as compared to cultivation across the slope without khus barrier. Reduction in soil loss with khus barrier has also been reported by Bharadwaj (1994) and Chittarajan et al. (1994).

5.2.2 Effect of khus barrier on soil moisture

The soil moisture content 2 m above the khus barrier was higher than the soil moisture 2 m below the khus barrier in all the three depths, viz., 0-15, 15-30 and 30-45 cm throughout the crop growth period in all the years (Fig.18 to 23). The per cent increase in mean soil moisture content over four years (Table 12) in the three depths was 10.82 (0-15 cm), 14.70 (15-30 cm) and 11.96 (30-45 cm). Khus barrier prevented surface runoff from concentrating at one place and acted as water spreading system. This created greater spatial and temporal opportunity for infiltration of rainwater resulting in higher moisture storage in the soil above khus barrier. Below the khus barrier, there was greater runoff and hence the moisture stored was less. AICRPDA (1991-92) reported higher soil moisture content of 4.6, 5.6 and 3.95 per cent at 0.5 m above vetiver barrier over 0.5 m below vetiver barrier in 0-15, 15-30 and 30-60 cm soil depths, respectively. Increase in soil moisture due to khus barrier has also been reported by Woodhead and Chaudhury (1991) and Subramanian (1991). The results of the present study also indicated higher soil moisture content due to khus barrier.

5.2.3 Effect of khus barrier on crop yield

The seed yield of castor was higher above the khus barrier than below the khus barrier in all the years (Table 13). The per cent increase in seed yield above khus barrier compared to below khus barrier in four years was 16.41 (1991-92), 16.96 (1992-93), 16.62 (1993-94) and 17.98 (1994-95) with an average of 16.99 per cent over four years. Khus barrier which acted as water spreading system as discussed earlier increased soil moisture content above the barrier. Increase crop yields could be attributed to the increased soil moisture status due to khus barrier (AICRPDA, 1991-92). Availability of more nutrients and higher uptake of nutrients due to development of better root system in the presence of higher soil moisture resulted in better crop growth leading to higher seed yield of castor. Finger millet grain yield was higher by 11.2 per cent in 3 rows above vetiver barrier on 2 per cent slope than 3 rows below the barrier (AICRPDA, 1991-92).

Similarly the seed yield of castor in the conservation tillage treatments in combination with khus barrier was also higher than the treatments without khus barrier. The average per cent increase in seed yield was 8.35 and 6.74 in contour sowing and dead furrows in combination with khus barrier, respectively over their respective treatments without khus barrier. Increase in seed yield of castor due to conservation tillage and khus barrier have been reported by MWP (1987-88 and 1990-91). CRIDA (1991-92) and Sagare and Meshram (1993) also reported increased crop yields due to khus barrier.

5.3 SOIL WATER BALANCE

Water balance studies are important in knowing the water surplus and deficit periods and designing appropriate water harvesting and moisture conservation techniques in watershed areas. The conservation tillage practices adopted in the present study have shown considerable influence on the soil water balance. Soil water deficit was least in the treatment of sowing along the contour with ridges and furrows in combination with khus barrier in both the years of study (Table 14 and 15). This was closely followed by dead furrows on contours in combination with khus barrier. However, when overall water balance was computed considering all the stages, the soil water was in surplus in all the treatments in both the years except in sowing along the slope during 1993-94 which was slightly deficit (-2.94 mm). The surplus soil water was also highest in ridges and furrows in combination with khus barrier followed by dead furrows with khus barrier. In other treatments also the surplus was more than the control (sowing along the slope). The surplus soil water in the earlier stages has contributed to overcome the deficit in later stages in all the conservation tillage and khus barrier treatments. The ridges and furrows which have shown higher increase in soil moisture content when compared to other treatments resulted in least deficit. Considerable reduction in runoff due to ridges and furrows and dead furrows in combination with khus barrier which provided more opportunity time for the rainwater to infiltrate has helped in increasing the soil moisture storage which ultimately reflected on the soil water balance in those treatments. Runoff was more in cultivation along the slope (control) and soil moisture storage was less which resulted in higher deficit.

Relationship between seed yield of castor and runoff, a component of soil water balance, was worked out (equation 1). The equation revealed significant negative relationship between seed yield and runoff. It implies that with increase in runoff, there is redution in seed yield. When runoff was more, sufficient time was not available for the rainwater to enter the soil. So the soil moisture was less which affected crop growth ultimately leading to reduction in crop yield. Runoff was considerably reduced in ridges and furrows and dead furrows in combination with khus barrier which helped in increasing soil moisture storage. This inturn resulted in better crop growth leading to higher seed yield in these treatments. Whereas in cultivation along the slope, runoff was higher which resulted in lower soil moisture storage affecting crop growth and ultimately reduced crop yield.

Ben Asher and Warrick (1987), Mallick and Nagaraja Rao (1988), Thomas (1992) and Klaig and Vachaud (1992) have reported soil water balance under varying soil, climatic and crop conditions.

5.4 WATER USE EFFICIENCY (WUE)

Conservation tillage practices have shown considerable influence on the WUE. The water use efficiency was increased by the conservation tillage practices when compared to cultivation along the slope (control). WUE was highest (20.26) in the treatment consisting of ridges and furrows in combination with khus barrier (Table 16). Dead furrows on contours in combination with khus barrier were the next best (19.22). Though there was not much difference in the water use by the crop in different conservation tillage treatments, the WUE has incresed in all the conservation tillage practices over control. In the conservation tillage treatments sufficient soil moisture was available and hence the plants were not under stress or less affected. In cultivation along the slope, the soil moisture content was less and this might have caused stress at later stages after full leaf area development. At this stage, the transpirational demand is very high. Since the moisture supply was inadequate because of less moisture storage the crop yield was affected and WUE was reduced in cultivation along the slope.

Tomer et al. (1990) have reported higher WUE with higher soil moisture regime in mustard crop.

Crop water use efficiecy studies under different soil and crop management practices have also been reported by El-Swaify et al. (1987) and Sharma (1994) who opined that water stress at critical stage of crop affects the yield which ultimately reduces the WUE.

5.5 RAINFALL-RUNOFF-SOIL LOSS MODELS

The relationship between rainfall and runoff, rainfall and soil loss and runoff and soil loss was worked cut using regression techniques for each treatment (*Equations 2 to 19*).

5.5.1 Rainfall-Runoff

The relationship between rainfall and runoff was significant in all the treatments (Equations 2 to 7). The relationship was positive indicating increase in runoff with increase in rainfall. Highest 'r' value (r=0.7346) was observed in the treatment, cultivation along the slope where the runoff was highest (35.14 mm in 1993-94 and 17.98 mm in 1994-95). The 'r' value decreased in proportion to the reduction in runoff by the conservation treatments and lowest 'r' value (r=0.5705) was observed in sowing along the contour with ridges and furrows and khus barrier where the runoff was lowest (4.05 mm in 1993-94 and 1.91 mm in 1994-95). With increase in per cent reduction in runoff, there was decrease in 'r' value. The average per cent reduction in runoff was highest (88.93) in the treatment, sowing along the contour with ridges and furrows and khus barrier and this treatment recorded lowest 'r' value.

5.5.2 Rainfall-Soil loss

The relationship between runoff and soil loss was significant in all the treatments (Equations 8 to 13). The relationship was positive indicating increase in soil loss with increase in rainfall. Highest soil loss (2.97 t ha^{-1} in 1993-94 and 1.63 t ha^{-1} in 1994-95) was recorded in the treatment, cultivation along the slope. The 'r' value was highest (r=0.6021) in this treatment where the soil loss was highest. The 'r' value observed with the treatment, sowing along the contour + ridges and furrows in combination with khus barrier was r=0.5854 where the soil loss was lowest (0.24 t ha^{-1} in 1993-94 and 0.12 t ha^{-1} in 1994-95).

5.5.3 Runoff-soil loss

The relationship between runoff and soil loss was highly significant in all the treatments (Equations 14 to 19). The positive relationship indicates the increase in soil loss with increase in runoff. Highest runoff was recorded in the treatment, cultivation along the slope. The soil loss was also highest in this treatment and 'r' value observed with this treatment was r=0.9338.

With increase in rainfall, there was increase in runoff and with increase in runoff the soil loss also increased. Conservation treatments reduced runoff and soil loss to a great extent. The reduction in runoff and soil loss by the different conservation treatments reflected on the reduced 'r' values obtained in the respective treatments.

AICRPDA (1991-92) reported models on rainfall-runoff, rainfall soil loss and runoff-soil loss under ridges and furrows, contour + vetiver barrier and farmer's practice which can be used to predict runoff and soil loss on the incident rainfall. Chennappa (1994) developed models for predicting runoff and soil loss, Virendrakumar and Satyanarayana (1994) developed models for predicting runoff.

5.6 CONSERVATION PRACTICES AND RAINWATER HARVESTING

The data on rainwater that could be harvested under different treatments calculated from the runoff is presented in Table 17. During 1993-94, the runoff

Table 17. Effect of conservation tillage on rain water harvesting (hacm)

Treatments	1993-94	1994-95
T1 Sowing on contour	3.08	1.54
T2 Contour + Khus	1.06	0.51
T3 Contour + Dead Furrow	1.64	0.82
T4 Contour + Dead Furrow + Khus	0.72	0.34
T5 Contour + Ridges & Furrows + Khus	0.41	0.19
T6 Sowing along slope	3.51	1.80

causing rainfall was 234.1 mm. The amount of rainwater that could be collected in the treatment, sowing along the slope was 3.51 ha cm. This was followed by sowing along the contour (3.08 ha cm), sowing along the contour with dead furrows (1.64 ha cm), sowing along the contour with khus barrier (1.06 ha cm), sowing along the contour with dead furrows and khus barrier (0.72 ha cm) and lowest (0.41 ha cm) by the treatment, sowing along the contour with ridges and furrows and khus barrier. Same trend was observed during 1994-95. The runoff causing rainfall was 160.6 mm. The rainwater that could be harvested (ha cm) in different treatments was sowing along contour (1.54), sowing along the contour with khus barrier (0.51), sowing along the contour with dead furrows (0.82), sowing along contour with dead furrows and khus barrier (0.34), sowing along contour with ridges and furrows and khus barrier (0.19) and sowing along the slope (1.80). The amount of rainwater that could be harvested depends on the type of conservation practice adopted which determines the amount of runoff from the field. In case of cultivation along the slope, there was more runoff as the water moved without any obstruction in between lines and hence more rainwater could be harvested. With contour cultivation, small bund is formed along the plant rows during intercultural operations which obstructed the flow of rainwater resulting in reduction in runoff. Hence, the rainwater that could be harvested was reduced. Formation of dead furrows and ridges and furrows and presence of khus barrier, further reduced the runoff as discussed earlier resulting in reduction in the amount of rainwater that could be harvested. Thus the quantity of rainwater that could be harvested depends on the type of conservation practice adopted. The reuse of harvested rainwater can be planned depending upon the quantity for supplemental irrigation or for growing vegetable crops in the post rainy season (CRIDA, 1991-92 and 1992-93). The size of farm pond can be determined from the quantity of rainwater that could be harvested. Seepage and evaporation losses of harvested rainwater in the ponds also need to be accounted for efficient utilization of the harvested water (Vijayalakshmi, 1983 and CRIDA, 1992-93).

5.7 EFFECT OF CONSERVATION TILLAGE ON ADDITIONAL MONETARY RETURNS

The data on additional monetary returns derived due to different conservation tillage treatments during the years from 1991-92 to 1994-95 are presented in Table 18. It could be noticed from the table that the treatment, sowing along the contour with ridges and furrows and khus barrier (T_5) has resulted in highest additional monetary return in all

Table 18. Effect of conservation tillage on additional monetary return (Rs.)

Treatments	1991-92	1992-93	1993-94	1994-95	Mean
T1 Sowing on contour	343	259	430	429	365
T2 Contour + Khus	743	541	852	851	747
T3 Contour + Dead Furrow	557	438	816	836	662
T4 Contour + Dead Furrow + Khus	814	782	1143	1216	989
T5 Contour + Ridges & Furrows + Khus	1100	1206	1477	1493	1319
T6 Sowing along slope	-	-	-	-	-

the years compared to other treatments. The treatment, sowing along the contour (T_1) recorded lowest additional monetary returns. The mean additional monetary return over four years was highest by the treatment, sowing along the contour with ridges and furrows and khus barrier with Rs.1319. This was followed by sowing along the contour with dead furrows and khus barrier (Rs.989/-) sowing along the contour with khus barrier (Rs.747), sowing along the contour with dead furrows (Rs.662) and sowing along the contour (Rs.365) when compared to control (sowing along the slope). Patel et al. (1991) reported additional monetary return of Rs.467 per hectare due to ridges and furrows over flat bed system with sorghum-pigeonpea intercropping at Akola.

In conclusion, it can be said that the different conservation tillage practices adopted in this study viz., dead furrows and ridges and furrows along with contour cultivation in combination with and without khus barrier have resulted in reduced runoff and soil loss and increased the soil moisture content during the crop growth period leading to better crop growth as indicated by drymatter production, plant height, number of spikes and capsules per plant, test weight and seed yield. Among the treatments, the treatment, ridges and furrows on contours in combination with khus barrier has been more effective in reducing runoff and soil loss and increasing soil moisture content, drymatter production, number of spikes and capsules per plant, test weight, seed yield, WUE and additional monetary returns. Dead furrows at 3.6 m *interval on contours with khus barrier was next best* treatment. Considering the reduction in runoff and soil loss and increase in crop yield and additional monetary returns, ridges and furrows on contours with khus barrier at 1 m vertical gradient can be recommended for shallow Alfisols with a slope of 2.5 per cent under rainfed conditions.

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SUMMARY

CHAPTER VI

SUMMARY

A field experiment entitled "Effect of conservation tillage and vegetative barrier on runoff, soil moisture and yield of castor on rainfed Alfisol in a microwatershed" was conducted in shallow Alfisol with 2.5 per cent slope during four kharif seasons from 1991-92 to 1994-95 at Agricultural Research Institute, Rajendranagar, Hyderabad. The experiment was laid out in randomised block design with four replications. There were six treatments viz., Sowing along the contour (T_1), sowing along the contour with khus barrier (T_2), sowing along the contour with dead furrows (T_3), sowing along the contour with dead furrows and khus barrier (T_4), sowing along the contour with ridges and furrows and khus barrier (T_5), and sowing along the slope (T_6- control). The test crop was castor. The tillage treatments were imposed at 30 days after sowing.

Soil moisture content in 0-15, 15-30 and 30-45 cm depths was determined at regular intervals throughout the crop growth period after imposition of treatments 30 DAS. Runoff and soil loss were recorded after every runoff event. Observations on drymatter production, LAI, plant height were recorded at 60, 90, and 120 DAS. Data on number of spikes and capsules per

plant, test weight and seed yield in each treatment were recorded. Soil water balance for each treatment was computed at different stages of crop growth. Regression models on the relationship between seed yield and runoff, rainfall and runoff, rainfall and soil loss and runoff and soil loss were developed.

Following are the important findings and conclusions drawn:

1. Runoff and soil loss were considerably reduced with conservation tillage. Highest reduction in runoff (88.93 per cent) and soil loss (92.30 per cent) was recorded with sowing on contour with ridges and furrows in combination with khus barrier. This was followed by sowing on contour with dead furrows and khus barrier.

2. Ridges and furrows with khus barrier resulted in highest soil moisture content throughout the crop growth period in all the three depths viz., 0-15, 15-30 and 30-45 cm. This was followed by dead furrows in combination with khus barrier.

3. Drymatter production, LAI and plant height were highest in ridges and furrows on contours with khus barrier at 60, 90, and 120 DAS. Dead furrows with khus barrier were the next best.

4. Number of spikes and capsules per plant and test weight were also highest in ridges and furrows on contours with khus barrier, closely followed by dead furrows on contours with khus barrier.

5. Ridges and furrows on contours in combination with khus barrier resulted in significantly higher seed yield over others. The additional monetary returns were also highest (Rs.1319 per hectare) in this treatment. Dead furrows on contours with khus barrier was the next best in respect of yield and additional net returns.

6. Khus barrier has considerably reduced runoff and soil loss in combination with contour sowing and dead furrows on contours.

7. Soil moisture content above (2 m) khus barrier was higher than the soil moisture below (2 m) khus barrier in all the three depths viz., 0-15, 15-30 and 30-45 cm.

8. Seed yield of castor was also higher (16.99 per cent) above khus barrier than below khus barrier.

9. Soil water balance computed for each conservation tillage indicated lesser water deficit in ridges and furrows on contours in combination with khus

barrier. Dead furrows with khus barrier were next best.

10. Seed yield was significantly negatively correlated with runoff indicating reduction in yield with increase in runoff. A regression equation was developed to predict yield from runoff.

11. Water use efficienty was highest (20.26) in ridges and furrows on contours in combination with khus barrier followed by dead furrows on contour with khus barrier.

12. The relationship between rainfall and runoff was significantly positive in all the treatments. The 'r' value indicated sufficient reduction in runoff due to conservation tillage. Regression models were developed for each treatment on this relationship.

13. The relationship between rainfall and soil loss was positively significant in all the treatments indicating increase in soil loss with increase in rainfall. Regression models were developed on this relationship for each treatment.

14. Runoff and soil loss were significantly positively correlated in all the treatments indicating more soil loss with increased runoff.

Regression models were developed for each treatment on this relationship.

15. Considering the reduction in runoff and soil loss, increase in soil moisture content and crop yield, sowing of castor on contours with ridges and furrows formed at 30 DAS in combination with khus barrier at 1 m vertical gradient is recommended for shallow Alfisols with a slope of 2.5 per cent under rainfed conditions.

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*Original not seen

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APPENDICES

APPENDIX I

Mean weekly meteorological data during the crop growth period of castor (Kharif, 1991-92)

Month & Year	Standard Week	Period	Temperature (C)		Relative Humidity(%)		Rainfall (mm)	No. of Rainy days	Sunshine hours	Evaporation (mm)
			Max.	Min.	0720 Hr.	1420 Hr.				
June, 1991	25	18-24	32.9	23.4	41	31	8.5	1	4.2	5.7
July, 1991	26	25-01	32.0	23.5	41	36	3.2	0	8.2	4.4
	27	02-08	30.1	22.5	80	47	16.6	1	5.9	4.1
	28	09-15	29.1	22.3	85	54	129.8	3	5.9	4.5
	29	16-22	29.5	22.7	79	46	5.4	1	2.3	3.8
	30	23-29	30.7	23.1	83	44	1.8	0	5.8	5.0
Aug, 1991	31	30-05	30.1	22.7	83	44	30.6	2	4.8	4.1
	32	06-12	29.1	21.9	87	52	69.4	3	3.9	3.3
	33	13-19	29.9	22.3	84	44	20.8	2	4.8	3.8
	34	20-26	30.0	19.1	79	41	16.2	1	4.8	3.3
Sep, 1991	35	27-02	30.6	22.1	71	38	0.0	0	7.5	4.9
	36	03-09	31.6	22.8	70	38	1.8	0	7.1	4.7
	37	10-16	32.0	22.8	67	35	0.0	0	8.0	4.6
	38	17-23	31.3	22.5	76	41	155.4	2	5.5	5.3
	39	24-30	31.6	21.3	74	33	0.0	0	7.3	3.6
Oct, 1991	40	01-07	32.2	21.5	74	31	2.8	1	2.9	3.3
	41	08-14	32.1	19.7	87	30	46.4	1	8.7	3.4
	42	15-21	31.3	20.1	85	30	0.0	0	9.3	3.9
	43	22-28	30.4	15.8	70	32	2.2	0	9.4	3.6
Nov, 1991	44	29-04	27.2	21.0	85	55	6.0	0	4.1	3.1
	45	05-11	29.4	14.5	77	30	0.0	0	9.1	3.2
	46	12-18	27.1	15.4	79	28	7.2	2	5.4	3.2
	47	19-25	27.9	16.7	79	27	0.0	0	8.4	3.1
Dec, 1991	48	26-02	29.5	12.8	75	31	0.0	0	9.1	3.6
	49	03-09	28.1	9.8	72	35	0.0	0	9.2	2.9
	50	10-16	26.9	9.5	71	44	0.0	0	9.2	3.1
	51	17-23	27.6	11.9	75	38	0.0	0	8.8	3.2
	52	24-31	28.9	14.1	75	30	0.0	0	10.3	3.7

APPENDIX II

y meteorological data during the crop growth period of **castor** (Kharif, 1992-93)

	Standard Week	Period	Temperature (C) Max.	Temperature (C) Min.	Relative Humidity(%) 0720 Hr.	Relative Humidity(%) 1420 Hr.	Rainfall (mm)	No. of Rainy days	Sunshine hours	Evaporation (mm)
	29	16-22	31.0	22.7	76	34	3.4	1	6.3	4.8
	30	23-29	31.0	23.0	77	41	17.8	2	4.1	4.6
	31	30-05	30.5	22.3	76	41	32.9	4	5.4	4.1
2	32	06-12	30.1	21.9	81	46	60.8	6	4.1	2.5
	33	13-19	27.8	21.8	85	56	55.4	4	2.2	3.3
	34	20-26	30.5	22.4	77	50	0.0	0	6.2	4.4
	35	27-02	29.7	22.1	78	46	32.8	3	4.7	2.9
92	36	03-09	29.5	22.9	80	46	0.0	0	6.0	4.0
	37	10-16	30.3	21.9	85	38	42.2	4	6.9	3.6
	38	17-23	31.9	22.9	66	33	0.0	0	9.3	4.1
	39	24-30	32.2	20.8	72	34	3.6	1	9.8	4.3
	40	01-07	31.7	21.1	71	38	9.8	1	7.0	3.8
1992	41	08-14	29.9	22.1	79	47	32.8	4	6.8	3.6
	42	15-21	31.5	19.5	68	37	0.0	0	8.7	4.5
	43	22-28	31.8	19.4	73	41	2.6	1	6.7	3.2
	44	29-04	30.5	15.7	71	37	0.0	0	8.3	4.1
1992	45	05-11	30.7	19.4	76	42	0.0	0	7.2	3.7
	46	12-18	27.4	18.2	80	59	97.0	3	5.2	2.5
	47	19-25	28.3	19.7	79	39	0.0	0	5.0	3.2
	48	26-02	28.0	13.0	81	34	0.0	0	9.9	3.9
992	49	03-09	27.4	12.9	73	29	0.0	0	9.5	3.3
	50	10-16	19.6	8.8	54	23	0.0	0	6.7	1.8
	51	17-23	26.9	12.1	86	35	0.0	0	8.6	2.9
	52	24-31	28.5	10.3	72	35	0.0	0	9.6	3.1

APPENDIX II

Mean weekly meteorological data during the crop growth period of castor (Kharif, 1992-93)

Month & Year	Standard Week	Period	Temperature (C)		Relative Humidity(%)		Rainfall (mm)	No. of Rainy days	Sunshine hours	Evaporation (mm)
			Max.	Min.	0720 Hr.	1420 Hr.				
July, 1992	29	16-22	31.0	22.7	76	34	3.4	1	6.3	4.8
	30	23-29	31.0	23.0	77	41	17.8	2	4.1	4.6
Aug, 1992	31	30-05	30.5	22.3	76	41	32.9	4	5.4	4.1
	32	06-12	30.1	21.9	81	46	60.8	6	4.1	2.5
	33	13-19	27.8	21.8	85	56	55.4	4	2.2	3.3
	34	20-26	30.5	22.4	77	50	0.0	0	6.2	4.4
Sep, 1992	35	27-02	29.7	22.1	78	46	32.8	3	4.7	2.9
	36	03-09	29.5	22.9	80	46	0.0	0	6.0	4.0
	37	10-16	30.3	21.9	85	38	42.2	4	6.9	3.6
	38	17-23	31.9	22.9	66	33	0.0	0	9.3	4.1
	39	24-30	32.2	20.8	72	34	3.6	1	9.8	4.3
Oct, 1992	40	01-07	31.7	21.1	71	38	9.8	1	7.0	3.8
	41	08-14	29.9	22.1	79	47	32.8	4	6.8	3.6
	42	15-21	31.5	19.5	68	37	0.0	0	8.7	4.5
	43	22-28	31.8	19.4	73	41	2.6	1	6.7	3.2
Nov, 1992	44	29-04	30.5	15.7	71	37	0.0	0	8.3	4.1
	45	05-11	30.7	19.4	76	42	0.0	0	7.2	3.7
	46	12-18	27.4	18.2	80	59	97.0	3	5.2	2.5
	47	19-25	28.3	19.7	79	39	0.0	0	5.0	3.2
Dec, 1992	48	26-02	28.0	13.0	81	34	0.0	0	9.9	3.9
	49	03-09	27.4	12.9	73	29	0.0	0	9.5	3.3
	50	10-16	19.6	8.8	54	23	0.0	0	6.7	1.8
	51	17-23	26.9	12.1	86	35	0.0	0	8.6	2.9
	52	24-31	28.5	10.3	72	35	0.0	0	9.6	3.1

APPENDIX III

Mean weekly meteorological data during the crop growth period of castor (Kharif, 1993-94)

Month & Year	Standard Week	Period	Temperature (C) Max.	Temperature (C) Min.	Relative Humidity(%) 0720 Hr.	Relative Humidity(%) 1420 Hr.	Rainfall (mm)	No. of Rainy days	Sunshine hours	Evaporation (mm)
July, 1993	27	02-08	33.2	23.7	72	43	4.2	0.0	7.6	4.8
	28	09-15	31.5	23.5	79	50	13.8	3.0	2.7	3.2
	29	16-22	33.6	23.6	71	33	8.4	1	9.0	6.3
	30	23-29	30.7	22.4	81	58	55.5	4	3.5	3.4
Aug, 1993	31	30-05	28.8	22.4	86	61	53.3	3	2.6	3.4
	32	06-12	30.1	22.3	79	52	9.6	1	5.4	4.8
	33	13-19	20.2	22.1	85	53	14.2	2	5.9	4.4
	34	20-26	29.9	22.3	77	50	14.8	1	6.0	3.7
Sep, 1993	35	27-02	30.0	22.1	86	59	64.5	4	4.5	3.2
	36	03-09	29.2	21.7	85	65	33.2	3	4.9	3.9
	37	10-16	31.3	21.8	75	46	0.0	0	9.6	5.8
	38	17-23	31.1	25.6	85	55	101.4	3	7.2	3.7
	39	24-30	30.2	22.0	78	52	0.0	0	7.2	4.5
Oct, 1993	40	01-07	32.0	21.3	78	48	15.8	1	8.9	4.5
	41	08-14	29.4	22.0	84	64	33.7	3	6.2	3.7
	42	15-21	30.3	21.2	85	57	21.4	1	7.7	3.6
	43	22-28	31.2	19.3	84	48	5.0	1	9.2	4.2
Nov, 1993	44	29-04	30.7	18.2	74	43	0.7	0	10.5	4.2
	45	05-11	29.9	17.6	72	46	0.0	0	9.4	3.7
	46	12-18	30.3	16.4	79	40	0.0	0	8.4	3.4
	47	19-25	30.9	14.3	82	40	0.0	0	10.0	3.7
Dec, 1993	48	26-02	28.6	9.2	72	29	0.0	0	9.9	3.2
	49	03-09	25.6	14.7	79	50	27.4	2	5.0	2.8
	50	10-16	28.6	11.6	80	33	0.0	0	10.3	3.5
	51	17-23	26.4	8.7	78	35	0.0	0	10.3	3.0
	52	24-31	26.9	10.6	83	37	0.0	0	8.9	2.9

APPENDIX IV

Mean weekly meteorological data during the crop growth period of castor (Kharif, 1994-95)

Month & Year	Standard Week	Period	Temperature (C)		Relative Humidity(%)		Rainfall (mm)	No. of Rainy days	Sunshine hours	Evaporation (mm)
			Max.	Min.	0720 Hr.	1420 Hr.				
July, 1994	27	02-08	30.9	22.4	86	62	44.4	1	5.0	5.4
	28	09-15	27.9	22.4	88	72	15.8	4	0.6	3.1
	29	16-22	31.3	22.5	83	57	27.0	3	4.3	4.5
	30	23-29	30.6	22.5	87	55	30.0	3	3.6	4.8
Aug, 1994	31	30-05	30.4	23.0	84	53	1.0	0	11.4	2.9
	32	06-12	31.2	22.5	80	53	33.2	3	5.3	3.7
	33	13-19	30.3	22.2	83	54	50.6	2	5.5	4.5
	34	20-26	29.5	22.2	85	64	35.0	3	4.1	3.2
Sep, 1994	35	27-02	28.2	21.9	82	60	34.4	3	2.4	3.7
	36	03-09	30.8	22.2	81	52	1.7	0	4.8	4.6
	37	10-16	31.9	22.3	81	57	14.4	1	9.0	4.9
	38	17-23	30.1	20.1	81	52	31.6	2	7.3	4.1
	39	24-30	32.8	21.0	76	47	0.0	0	8.5	3.8
Oct, 1994	40	01-07	29.6	21.8	86	68	210.0	3	4.6	3.5
	41	08-14	30.6	21.1	83	49	2.8	1	7.3	3.7
	42	15-21	30.4	21.0	83	55	2.6	1	7.1	3.0
	43	22-28	29.8	20.5	87	63	16.2	2	7.1	3.0
Nov, 1994	44	29-04	26.2	18.8	86	67	27.4	2	4.4	3.2
	45	05-11	28.5	18.4	82	61	2.4	0	7.0	3.0
	46	12-18	29.3	17.7	78	52	0.0	0	9.6	3.3
	47	19-25	28.3	12.7	75	45	0.0	0	9.2	2.8
Dec, 1994	48	26-02	28.8	11.1	83	41	0.0	0	10.3	3.3
	49	03-09	27.9	9.9	85	39	0.0	0	10.3	3.3
	50	10-16	29.4	9.3	78	32	0.0	0	10.4	2.9
	51	17-23	27.4	9.1	79	33	0.0	0	10.1	3.0
	52	24-31	26.3	7.8	78	31	0.0	0	9.6	2.7

Appendix V. Effect of conservation tillage on soil moisture content (% w/w) during the crop growth period (kharif, 1991-92)

Treatments	Depth (cm)	DAS 38	45	51	60	64	72	80	97	112	115	122	125	131	139	146	152	161	168	Mean
T1	0-15	3.06	4.02	4.40	3.92	4.49	2.62	1.75	5.12	5.33	4.94	4.04	4.24	3.41	2.82	2.26	2.41	1.96	1.49	3.46
	15-30	4.26	5.32	5.73	5.16	5.76	3.63	2.76	6.35	6.96	6.05	5.15	5.35	4.61	4.24	3.78	3.88	3.50	3.02	4.75
	30-45	5.30	6.48	6.85	6.20	6.86	4.68	3.77	7.32	8.10	7.11	6.22	6.48	5.77	5.28	4.88	4.98	4.66	4.08	5.83
T2	0-15	3.32	4.31	4.67	4.19	4.76	2.90	2.04	5.41	5.60	5.23	4.32	4.64	3.68	3.12	2.51	2.68	2.25	1.78	3.75
	15-30	4.63	5.71	6.01	5.48	6.14	4.05	3.22	6.68	7.16	6.71	5.78	5.98	4.96	4.66	4.19	4.30	3.81	3.38	5.16
	30-45	5.81	6.93	7.39	6.71	7.38	5.22	4.25	7.79	8.59	7.60	6.71	6.96	6.26	5.73	5.34	5.49	5.12	4.52	6.32
T3	0-15	3.26	4.26	4.58	4.12	4.69	2.76	1.95	5.40	5.54	5.15	4.26	4.54	3.66	3.10	2.46	2.60	2.16	1.66	3.68
	15-30	4.56	5.64	6.00	5.42	6.10	4.02	3.12	6.52	7.11	6.53	5.61	5.80	4.85	4.54	4.14	4.22	3.74	3.30	5.07
	30-45	5.78	6.88	7.31	6.68	7.30	5.15	4.19	7.72	8.51	7.55	6.63	6.90	6.22	5.65	5.27	5.41	5.08	4.46	6.26
T4	0-15	3.60	4.56	5.04	4.54	5.10	3.12	2.12	5.72	6.03	5.55	4.64	5.02	4.10	3.58	2.92	3.12	2.52	2.01	4.07
	15-30	4.86	6.10	6.45	5.74	6.42	4.46	3.48	6.94	7.50	6.94	6.06	6.26	5.26	4.89	4.56	4.65	4.12	3.79	5.47
	30-45	6.22	7.32	7.81	7.12	7.79	5.61	4.66	8.23	9.01	7.98	7.14	7.35	6.56	6.12	5.72	5.91	5.53	4.90	6.72
T5	0-15	3.93	4.80	5.37	4.88	5.40	3.36	2.50	6.00	6.38	5.90	5.04	5.38	4.38	3.90	3.26	3.40	2.82	2.40	4.39
	15-30	5.27	6.29	6.72	6.22	6.64	4.74	3.96	7.28	7.88	7.32	6.51	6.69	5.72	5.30	4.72	4.79	4.36	3.92	5.79
	30-45	6.83	7.82	8.21	7.72	8.04	6.26	5.30	8.80	9.36	8.62	7.72	7.99	7.23	6.81	6.23	6.38	5.91	5.48	7.26
T6	0-15	3.04	3.97	4.36	3.86	4.38	2.42	1.44	5.09	5.29	4.89	4.00	4.14	3.40	2.78	2.28	2.29	1.88	1.47	3.39
	15-30	4.12	5.19	5.47	4.87	5.47	3.52	2.58	6.22	6.48	5.91	4.98	5.12	4.46	3.98	3.59	3.72	3.29	2.98	4.55
	30-45	5.20	6.18	6.48	5.85	6.51	4.62	3.56	7.22	7.56	6.95	5.98	6.16	5.44	5.02	4.60	4.70	4.31	3.98	5.57

Appendix VI. Effect of conservation tillage on soil moisture content (% w/w) during the crop growth period (kharif, 1992-93)

Treatments	Depth (cm)	DAS 33	36	39	42	47	50	53	56	62	67	70	75	78	80	88	91	95
T1	0-15	8.26	6.76	6.40	5.71	7.73	7.18	6.14	5.05	5.65	4.50	4.06	3.33	2.84	4.03	5.19	5.40	4.60
	15-30	8.51	7.29	6.67	6.18	8.49	8.07	7.49	5.89	6.94	5.81	5.04	4.35	3.94	4.91	6.50	5.67	6.02
	30-45	11.27	10.54	8.89	8.04	11.75	11.39	10.78	9.49	10.20	8.43	6.99	6.05	5.45	6.57	8.41	8.56	7.94
T2	0-15	8.51	7.16	6.69	6.16	8.12	7.62	6.62	5.44	6.04	4.86	4.30	3.52	3.05	4.43	5.63	5.80	4.84
	15-30	9.31	8.30	7.67	7.22	9.53	9.14	8.29	6.85	7.86	6.75	5.93	4.77	4.73	5.77	7.15	7.35	6.66
	30-45	11.89	10.90	10.40	9.82	12.28	11.81	11.06	9.20	10.09	8.92	7.60	6.42	6.22	7.21	8.95	9.12	8.33
T3	0-15	8.26	6.90	6.59	6.00	7.98	7.41	6.40	5.32	5.95	4.78	4.23	3.67	3.23	4.44	5.55	5.57	4.82
	15-30	8.83	7.53	6.98	6.71	8.83	8.32	7.42	6.01	7.11	6.05	5.73	4.70	4.23	5.21	6.85	7.03	6.30
	30-45	11.10	10.52	9.79	9.06	11.82	11.44	10.62	9.23	9.93	8.72	7.48	6.75	6.26	7.35	9.13	9.29	8.57
T4	0-15	8.85	7.62	7.10	6.61	8.68	8.13	7.04	5.56	6.26	5.22	4.65	4.11	3.68	4.87	6.06	5.25	5.23
	15-30	9.69	8.59	8.15	7.69	9.81	9.42	8.64	7.29	8.29	7.09	6.24	5.40	4.97	6.01	7.57	7.79	6.85
	30-45	12.71	11.68	10.51	10.05	13.16	12.78	11.91	10.42	11.32	9.88	8.65	7.80	7.19	8.15	9.89	10.10	9.34
T5	0-15	8.99	7.93	7.48	7.07	8.93	8.45	7.35	6.34	7.01	5.84	5.05	4.28	3.84	4.97	6.26	6.44	5.51
	15-30	10.41	9.82	8.86	8.24	10.89	10.46	9.75	8.51	9.56	8.31	7.60	6.88	6.39	7.37	8.71	8.93	8.23
	30-45	13.10	12.23	10.77	10.12	13.84	13.29	12.46	11.33	12.25	10.48	9.12	8.21	7.53	8.50	10.31	10.48	9.89
T6	0-15	7.95	6.44	6.08	5.54	7.47	6.88	5.94	4.72	5.43	4.37	3.87	3.12	2.67	3.91	5.05	5.24	4.35
	15-30	8.35	6.81	6.34	5.95	8.38	7.84	6.97	5.59	6.60	5.88	4.83	4.22	3.71	4.79	6.31	6.47	5.75
	30-45	9.64	8.84	8.05	7.41	11.20	10.23	9.62	8.80	9.95	8.49	6.88	5.93	5.31	6.23	8.22	8.36	7.70

pendix VI Contd....

eatments	Depth (cm)	98	102	109	113	117	121	D A S 124	129	136	141	148	157	165	Mean
T1	0-15	4.05	3.54	3.19	2.61	1.79	1.51	8.46	7.59	6.57	5.86	5.26	4.63	4.00	5.06
	15-30	5.69	5.22	4.88	4.57	3.74	3.54	10.03	8.69	7.53	6.61	6.03	5.59	5.06	6.20
	30-45	7.60	7.10	6.88	6.48	5.70	5.43	10.39	9.57	8.28	7.56	7.04	6.62	6.11	8.18
T2	0-15	4.40	3.85	3.54	2.89	2.11	1.80	8.64	7.65	6.74	5.90	5.33	4.79	4.19	5.35
	15-30	6.29	5.77	5.70	5.28	4.49	4.18	9.90	8.73	7.69	6.80	6.21	5.68	5.20	6.84
	30-45	8.10	7.41	7.13	6.71	5.68	5.45	11.04	10.05	8.91	8.14	7.58	7.15	6.52	8.67
T3	0-15	4.37	3.86	3.39	3.00	2.17	1.90	8.70	7.68	6.75	6.01	5.32	4.68	4.23	5.31
	15-30	5.90	5.40	5.12	4.89	3.91	3.71	9.87	8.81	7.71	6.90	6.40	5.94	5.29	6.46
	30-45	8.22	7.73	7.34	6.94	6.16	5.89	11.11	10.11	8.95	8.04	7.47	6.95	6.31	8.41
T4	0-15	4.77	4.20	3.89	3.38	2.59	2.28	9.47	8.57	7.09	6.35	5.59	5.05	4.45	5.79
	15-30	6.47	5.95	5.66	5.21	4.45	4.20	10.29	9.13	7.83	7.09	6.66	6.22	5.54	7.14
	30-45	8.87	8.37	8.01	7.63	6.79	6.51	11.61	10.62	9.17	8.34	7.72	7.24	6.66	9.44
T5	0-15	5.00	4.52	4.23	3.71	2.99	2.67	10.15	9.08	8.07	7.32	6.55	5.79	5.05	6.23
	15-30	7.86	7.36	7.08	6.74	5.92	5.57	12.11	10.50	9.60	8.82	8.26	7.65	7.07	8.45
	30-45	9.53	9.01	8.77	8.44	7.47	7.16	12.82	11.35	10.26	9.55	8.94	8.41	7.83	10.12
T6	0-15	3.89	3.36	3.04	2.55	1.76	1.63	7.97	6.91	5.98	5.27	4.73	4.16	3.72	4.80
	15-30	5.29	4.82	4.61	4.23	3.38	3.27	9.43	8.30	7.23	6.26	5.74	5.37	4.92	5.92
	30-45	7.18	6.69	6.44	6.13	5.21	5.01	10.09	9.20	7.87	7.05	6.50	6.05	5.64	7.66

...ect of conservation tillage on soil moisture content (% w/w) during the crop growth period (Kharif 1993-94)

tments	Depth (cm)	DAS 35	40	45	48	52	55	58	62	65	68	70	76	80	83
T1	0-15	5.32	6.09	5.94	5.07	5.88	7.94	8.72	7.66	8.79	8.02	7.86	8.88	7.96	9.02
	15-30	7.85	8.87	8.58	8.02	8.99	10.01	10.91	9.83	10.68	10.29	9.81	10.63	10.07	10.92
	30-45	9.03	10.07	9.76	9.32	10.28	11.43	12.36	11.18	12.01	11.61	11.26	12.21	11.34	12.48
T2	0-15	5.84	6.45	6.31	5.50	6.22	8.27	9.05	8.09	9.16	8.37	8.26	9.30	8.38	9.34
	15-30	8.26	9.19	9.04	8.49	9.30	10.61	11.53	10.69	11.34	10.82	10.52	11.08	10.32	11.62
	30-45	9.32	10.42	10.06	9.61	10.66	11.74	12.67	11.51	12.35	11.97	11.67	12.48	11.60	12.85
T3	0-15	5.76	6.32	6.22	5.37	6.07	8.04	8.91	7.89	9.09	8.25	8.15	9.23	8.32	9.30
	15-30	8.25	9.23	8.92	8.53	9.38	10.58	11.94	10.47	11.16	10.55	10.33	10.89	10.31	11.44
	30-45	9.42	10.42	10.18	9.63	10.65	11.71	12.76	11.59	12.42	11.98	11.62	12.57	11.63	12.84
T4	0-15	6.51	7.04	6.86	6.29	6.96	8.50	9.06	8.59	9.73	9.02	8.45	9.86	8.85	9.85
	15-30	8.36	9.16	9.01	8.25	8.97	10.83	11.40	10.96	11.97	10.96	10.66	11.90	10.99	11.93
	30-45	10.25	11.24	11.04	10.22	11.20	12.74	13.53	13.00	13.62	13.23	12.82	13.24	12.61	13.80
T5	0-15	6.71	7.44	7.25	6.57	7.21	8.73	9.41	8.94	9.85	9.49	8.78	10.19	9.15	10.13
	15-30	9.20	9.97	9.82	9.12	9.78	11.35	12.20	11.51	12.57	11.82	11.47	12.61	11.87	12.49
	30-45	11.14	12.06	11.81	11.12	11.96	13.46	14.24	13.68	14.45	13.92	13.49	14.21	13.50	14.49
T6	0-15	5.02	5.89	5.76	5.02	5.79	7.54	8.69	7.60	8.68	7.86	7.58	8.69	7.54	8.71
	15-30	7.46	8.61	8.21	7.76	8.79	9.89	10.64	9.61	10.42	9.96	9.69	10.96	9.81	10.91
	30-45	8.92	9.76	9.01	8.70	9.72	10.71	11.52	11.09	11.48	11.08	10.52	11.40	10.53	11.68

.. ...ix vii. Contd....

eatments	Depth (cm)	86	89	93	96	100	103	DAS 107	114	116	122	125	130	132
T1	0-15	7.94	7.48	6.84	6.32	7.92	6.82	5.88	6.38	6 02	5.63	5.35	4.85	4.63
	15-30	9.97	9.51	8.87	8.59	10.87	9.09	8.01	8.92	8.51	7.60	7.54	7.00	6.90
	30 45	11.51	10.99	10.31	9.83	11.31	10.31	9.47	9.96	9.50	9.06	8.81	8.40	8 21
T2	0-15	8.23	7.84	7 27	6.67	8.34	7.20	6.19	6 69	6 39	6 06	5 79	5 23	4.95
	15 30	10.68	10.22	9.79	9.24	10 91	9.85	8 57	8 98	8.43	8.06	7 89	7.64	7.52
	30 45	11 86	11 25	10.65	10.15	11.67	10 74	9 78	10.24	9.84	9.39	9.15	8.75	8.48
T3	0-15	8.06	7.69	7 22	6 58	8 22	7 02	6 00	6.53	6 24	5 86	5.64	5.10	4.91
	15 30	10 45	10.02	9.69	9.04	10 82	9.40	8 53	8 94	8.54	7.94	7.88	7.52	7.39
	30 45	11.87	11.30	10.65	10.18	11.62	10.79	9.90	10.23	9.81	9.47	9 03	8.71	8.52
T4	0 15	8.43	8 02	7.58	6 92	8.84	8.01	6 98	7 12	6 86	6.54	5 95	5.[illegible]5	5.29
	15 30	10.92	10.46	10.00	9.64	11.08	10 26	9 00	9 25	8.83	8.37	8.07	7.93	7.68
	30-45	12.81	12 07	11 65	11 12	12 79	12.01	10 89	11.22	10.86	10.49	10.14	9.67	9.49
T5	0-15	8.92	8.46	8.12	7.23	9.14	8.37	7.35	7.55	7.10	7.00	6.46	5.82	5.55
	15 30	11.66	10 91	10.51	9.98	11.48	10.74	9.85	10.10	9.64	9.11	8.70	8.53	8 15
	30 45	13 69	13 05	12.47	11.95	13.46	12.79	11.81	12.06	11.70	11 30	10.87	10.38	10 18
T6	0 15	7.66	7.20	6.59	6.26	7.84	6.62	5.61	6 01	5 70	5.36	5.00	4.70	4 50
	15 30	9 84	9.47	8.81	8.19	9.72	8.64	7.79	8.33	7.94	7.46	7.29	6.83	6.69
	30-45	11.01	10.65	10.01	9.44	11.08	10.03	9.31	9.87	9.42	8.83	8.23	8.06	7.91

Appendix VII. Contd...

Treatments	Depth (cm)	DAS 135	138	142	145	149	151	157	159	164	166	174	177	Mean
T1	0-15	4.39	4.10	3.72	3.30	2.89	2.54	6.23	6.03	5.21	5.02	4.08	3.41	6.06
	15-30	6.41	6.26	5.89	5.58	5.13	4.51	8.59	8.20	7.54	6.98	6.42	5.85	8.31
	30-45	7.88	7.60	7.18	6.81	6.46	6.07	9.81	9.46	8.91	8.46	7.69	6.98	9.62
T2	0-15	4.81	4.47	4.08	3.66	2.96	2.55	6.61	6.34	5.60	5.43	4.47	3.76	6.42
	15-30	6.94	6.80	6.21	5.95	5.54	5.12	9.22	8.01	7.99	7.62	6.95	6.08	8.86
	30-45	8.21	7.86	7.45	7.08	6.76	6.34	10.14	9.71	9.15	8.80	7.98	7.28	9.94
T3	0-15	4.69	4.39	3.96	3.52	2.86	2.46	6.50	6.20	5.47	5.30	4.32	3.50	6.31
	15-30	6.82	6.68	6.12	5.83	5.43	4.91	9.16	8.52	7.89	7.53	6.83	5.73	8.73
	30-45	8.19	7.84	7.53	7.14	6.75	6.33	10.03	9.81	9.10	8.54	7.78	7.23	9.94
T4	0-15	4.94	4.71	4.49	3.91	3.51	3.15	6.92	6.75	6.08	5.84	4.92	4.23	6.81
	15-30	7.07	6.72	6.34	5.89	5.63	5.25	9.31	8.97	8.03	7.73	6.74	6.19	8.98
	30-45	9.15	8.77	8.45	8.17	7.73	7.27	10.86	10.73	10.12	9.76	9.05	8.27	10.93
T5	0-15	5.31	5.11	4.71	4.34	3.98	3.59	7.31	7.07	6.35	6.10	5.18	4.58	7.19
	15-30	7.81	7.54	7.14	6.71	6.47	6.04	9.74	9.50	8.84	8.58	7.71	7.10	9.70
	30-45	9.87	9.47	9.17	8.87	8.50	8.07	11.82	11.48	10.85	10.63	9.97	9.11	11.72
T6	0-15	4.19	3.93	3.55	3.13	2.69	2.29	6.08	5.85	5.16	4.62	3.58	3.12	5.78
	15-30	6.31	5.96	5.61	5.14	4.75	4.31	8.18	7.89	7.12	6.29	5.98	5.64	8.01
	30-45	7.48	7.03	6.82	6.53	6.29	6.02	9.25	9.06	8.56	8.09	7.32	6.60	9.22

Appendix VIII. Soil moisture content (% w/w) during the crop growth period of castor (Kharif 1994-95)

Treaments	Depth (cm)	DAS 43	47	50	54	60	62	67	70	74	77	81	84
T1	0-15	8.37	8.70	8.82	9.05	7.52	7.39	6.22	7.60	9.00	8.26	7.16	6.32
	15-30	10.00	10.35	10.58	10.83	9.74	9.58	8.36	9.57	10.68	10.15	9.19	8.34
	30-45	10.49	10.99	11.19	11.60	10.89	10.49	9.77	10.99	12.09	11.33	10.37	9.59
T2	0-15	8.66	8.98	9.14	9.37	7.96	7.72	6.64	7.99	9.47	8.65	7.74	6.89
	15-30	10.42	10.65	10.86	11.32	10.43	10.23	8.98	10.18	11.40	10.84	9.93	8.96
	30-45	10.99	11.49	11.66	12.06	11.42	11.02	10.53	11.82	12.83	12.22	11.23	10.56
T3	0-15	8.57	8.91	9.06	9.31	7.84	7.62	6.58	7.91	9.36	8.53	7.61	6.78
	15-30	10.43	10.59	10.80	11.26	10.29	10.19	8.91	10.11	11.31	10.73	9.89	8.91
	30-45	10.93	11.43	11.62	11.98	11.32	10.93	10.52	11.74	12.76	12.13	11.18	10.47
T4	0-15	8.87	9.24	9.42	9.59	8.62	8.30	6.99	8.62	10.20	9.42	8.40	7.41
	15-30	10.87	11.16	11.47	11.90	11.10	10.80	9.69	10.94	11.96	11.24	10.36	9.89
	30-45	11.47	11.93	12.20	12.71	12.21	11.94	11.46	12.77	13.67	12.78	11.94	11.41
T5	0-15	9.02	9.39	9.58	9.81	8.96	8.72	7.80	8.91	10.60	9.74	8.90	7.91
	15-30	11.21	11.62	11.88	12.38	11.51	11.31	10.18	11.39	12.50	11.73	11.01	10.41
	30-45	11.79	12.34	12.83	13.38	12.98	12.64	11.98	13.29	14.32	13.57	12.70	12.12
T6	0-15	8.25	8.51	8.69	8.89	7.35	7.22	5.96	7.26	8.71	7.96	6.91	6.01
	15-30	9.86	10.18	10.37	10.63	9.49	9.38	8.02	9.16	10.30	9.81	8.86	7.98
	30-45	10.35	10.72	10.92	11.33	10.62	10.21	9.34	10.49	11.71	10.91	10.02	9.26

Appendix VIII. Contd......

Treaments	Depth (cm)	DAS 88	92	94	96	102	105	109	112	117	121	125	130
T1	0-15	8.01	10.20	9.87	9.50	8.40	7.39	8.34	7.60	7.41	7.86	7.24	6.36
	15-30	10.01	11.99	11.81	11.46	10.53	9.73	10.44	9.80	9.66	10.15	9.67	8.93
	30-45	11.21	13.40	13.15	12.98	12.02	11.25	11.77	11.17	10.98	11.82	10.98	10.33
T2	0-15	8.44	10.78	10.42	9.99	9.06	8.12	8.73	8.06	7.77	8.26	7.82	7.00
	15-30	10.70	12.80	12.61	12.24	11.32	10.36	11.18	10.54	10.34	10.86	10.32	9.56
	30-45	12.09	14.42	14.15	13.96	13.07	11.99	12.65	12.05	11.82	12.44	11.85	11.14
T3	0-15	8.32	10.66	10.33	9.93	8.97	7.99	8.59	7.96	7.69	8.16	7.71	6.88
	15-30	10.62	12.73	12.43	12.04	11.15	10.19	11.07	10.45	10.23	10.76	10.23	9.51
	30-45	12.07	14.32	14.04	13.75	12.93	11.95	12.60	12.00	11.74	12.29	11.78	11.10
T4	0-15	9.10	11.77	11.22	10.80	9.81	8.86	9.50	8.72	8.46	8.98	8.47	7.57
	15-30	11.57	13.91	13.59	13.18	12.16	11.26	12.12	11.40	11.24	11.76	11.20	10.47
	30-45	13.10	15.47	15.16	14.84	14.04	13.10	13.71	13.07	12.80	13.46	12.91	12.13
T5	0-15	9.53	12.02	11.64	11.21	10.44	9.48	9.82	9.32	8.80	9.26	8.78	7.81
	15-30	11.96	14.60	14.25	13.85	13.14	12.21	12.50	11.95	11.53	12.13	11.74	11.00
	30-45	13.73	16.34	16.10	15.87	14.93	14.12	14.30	13.61	13.37	14.04	13.45	12.67
T6	0-15	7.74	10.02	9.48	9.12	8.04	7.06	8.01	7.21	6.98	7.39	6.82	6.01
	15-30	9.58	11.65	11.38	11.04	10.16	9.35	9.98	9.31	9.23	9.73	9.24	8.50
	30-45	10.73	12.90	12.61	12.42	11.46	10.74	11.24	10.65	10.46	11.04	10.54	9.87

... viii. Contd......

Treaments	Depth (cm)	DAS 133	137	140	144	149	152	154	161	168	177	Mean
T1	0-15	5.98	5.69	5.40	5.12	4.70	4.36	4.14	3.70	3.10	2.59	6.98
	15-30	8.50	8.07	7.72	7.31	6.80	6.31	6.02	5.58	4.85	4.35	9.03
	30-45	9.91	9.48	9.12	8.72	8.15	7.84	7.39	6.91	6.34	5.59	10.30
T2	0-15	6.52	6.17	5.79	5.42	4.98	4.61	4.40	4.01	3.47	2.84	7.41
	15-30	8.91	8.49	8.17	7.80	7.27	6.88	6.57	5.93	5.42	4.69	9.62
	30-45	10.62	10.25	9.86	9.45	9.04	8.59	8.02	7.52	7.03	6.51	11.07
T3	0-15	6.43	6.04	5.73	5.32	4.88	4.52	4.31	3.88	3.35	2.72	7.31
	15-30	8.86	8.43	8.03	7.75	7.23	6.82	6.54	5.87	5.35	4.58	9.54
	30-45	10.56	10.20	9.76	9.38	8.93	8.53	7.95	7.50	6.95	6.35	10.99
T4	0-15	6.98	6.70	6.27	6.05	5.49	5.24	5.05	4.66	4.20	3.42	8.01
	15-30	9.86	9.37	8.95	8.51	8.03	7.62	7.30	6.87	6.30	5.77	10.41
	30-45	11.60	11.16	10.71	10.37	9.84	9.43	9.08	8.64	8.11	7.44	11.96
T5	0-15	7.44	7.09	6.76	6.39	6.04	5.74	5.56	5.17	4.65	3.98	8.42
	15-30	10.17	9.66	9.27	8.96	8.65	8.27	7.94	7.43	7.06	6.35	10.93
	30-45	12.05	11.58	11.17	10.71	10.28	9.87	9.39	8.76	8.29	7.71	12.54
T6	0-15	5.63	5.34	5.70	4.81	4.41	4.08	3.86	3.44	2.86	2.39	6.71
	15-30	8.03	7.63	7.29	6.88	6.39	5.93	5.64	5.22	4.51	4.01	8.67
	30-45	9.46	9.06	8.72	8.35	7.78	7.42	7.01	6.49	5.98	5.24	9.88

Appendix IX. Effect of khus on soil moisture content (% w/w) during Kharif, 1991-92

Treatments	Depth (cm)	DAS 38	45	51	60	64	72	80	97	112	115	122	125	131	139	146	152	161	168	Mean
Above Khus	0-15	4.90	5.72	6.24	5.68	6.32	4.22	3.38	6.34	7.49	6.96	6.04	6.22	5.43	4.86	4.56	4.44	3.95	3.55	5.35
Below Khus	0-15	4.58	5.32	5.83	5.38	5.84	3.94	3.09	5.94	6.91	6.50	5.59	5.77	5.19	4.59	4.14	4.21	3.69	3.38	4.99
Above Khus	15-30	6.38	7.02	7.64	7.18	7.58	5.66	4.74	7.72	9.06	8.33	7.38	7.58	6.80	6.25	5.72	5.85	5.40	5.03	6.74
Below Khus	15-30	5.78	6.52	7.12	6.54	7.14	5.12	4.26	7.12	8.50	7.84	6.86	7.03	6.23	5.73	5.26	5.33	4.68	4.50	6.20
Above Khus	30-45	7.88	8.50	9.19	8.62	9.22	7.15	6.18	9.26	10.65	9.72	8.79	8.98	8.34	7.69	7.22	7.43	6.92	6.49	8.23
Below Khus	30-45	6.81	7.71	8.29	7.61	8.24	6.27	5.39	8.18	9.61	8.92	7.99	8.19	7.29	6.86	6.38	6.40	5.84	5.66	7.31

Appendix X. Effect of khus on soil moisture content (% w/w) during Kharif, 1992-93

Treatments	Depth (cm)	DAS 33	36	39	42	47	50	53	56	62	67	70	75	78	80	88	91	95
Above Khus	0-15	8.91	7.84	7.34	6.90	8.85	8.40	7.33	6.16	6.83	5.85	5.34	4.66	4.00	5.38	6.55	6.71	5.66
Below Khus	0-15	8.66	7.46	6.98	6.45	8.44	7.87	6.78	5.57	6.20	4.98	4.36	3.69	3.22	4.37	5.59	5.77	4.91
Above Khus	15-30	10.59	10.13	9.64	9.26	11.22	10.82	10.09	9.14	10.15	8.93	8.08	7.28	6.75	7.67	8.98	9.16	8.43
Below Khus	15-30	9.44	8.34	7.55	5.95	9.55	9.11	8.26	6.75	7.77	6.50	5.78	5.08	4.60	5.65	7.20	7.41	6.60
Above Khus	30-45	13.22	12.85	11.82	10.99	14.27	13.79	13.14	12.11	11.83	10.36	9.13	8.29	7.66	8.56	10.26	10.41	9.67
Below Khus	30-45	12.09	11.05	9.88	9.46	12.37	11.90	10.97	9.81	10.83	9.32	8.11	7.31	6.68	7.65	9.47	9.65	9.01

Appendix X. Contd......

Treatments	Depth (cm)	DAS 98	102	109	113	117	121	124	129	136	141	148	157	165	Mean	% Increase
Above Khus	0-15	5.19	4.67	4.40	3.83	3.09	2.76	9.76	8.80	7.72	6.97	6.29	5.57	4.88	6.22	12.68
Below Khus	0-15	4.43	3.89	3.55	3.00	2.24	1.93	9.18	8.19	7.00	6.23	5.32	4.92	4.30	5.52	
Above Khus	15-30	8.03	7.50	7.22	6.81	6.01	5.69	11.19	9.90	8.76	7.98	7.46	6.86	6.32	8.54	24.13
Below Khus	15-30	6.14	5.63	5.52	5.09	4.41	4.09	10.44	9.15	8.17	7.33	6.80	6.32	5.69	6.88	
Above Khus	30-45	9.31	8.80	8.45	8.05	7.00	6.70	12.48	11.26	9.95	9.21	8.60	8.05	7.47	10.12	11.95
Below Khus	30-45	8.57	8.04	7.77	7.40	6.50	6.31	11.40	10.37	9.15	8.37	7.79	7.34	6.72	9.04	

Appendix XI. "Effect of khus on soil moisture content (% w/w) during Kharif 1993-94

Treatments	Depth (cm)	DAS 35	40	45	48	52	55	58	62	65	68	70	76	80	83
Above Khus	0-15	6.70	7.60	7.21	6.47	7.21	8.88	9.57	8.96	10.10	9.34	8.91	10.19	9.16	10.16
Below Khus	0-15	5.97	6.82	6.46	5.72	6.54	8.08	9.06	8.14	9.31	8.69	8.10	9.57	8.43	9.33
Above Khus	15-30	9.14	10.20	9.82	9.18	9.98	11.42	12.26	11.43	12.37	11.95	11.42	12.80	12.08	12.84
Below Khus	15-30	8.27	9.04	8.58	8.24	8.95	10.24	11.02	10.48	11.32	11.04	10.54	11.49	10.75	11.52
Above Khus	30-45	10.85	11.89	11.60	11.01	11.91	13.31	14.10	13.33	14.14	13.65	13.30	14.02	13.35	14.34
Below Khus	30-45	9.85	10.84	10.64	9.84	10.94	12.28	13.47	12.44	13.11	12.49	12.33	12.85	12.19	13.00

Appendix XI. Contd......

Treatments	Depth (cm)								DAS						
		86	89	93	96	100	103	107	114	116	122	125	130	132	135
Above Khus	0-15	8.99	8.48	8.07	7.45	9.17	8.22	7.21	7.72	7.21	6.81	6.50	6.11	5.76	5.58
Below Khus	0-15	8.14	7.76	7.29	6.52	8.31	7.48	6.39	6.67	6.35	6.06	5.72	5.10	4.84	4.67
Above Khus	15-30	11.88	11.16	10.59	9.87	11.67	10.75	9.76	10.09	9.69	9.21	8.72	8.46	8.19	7.83
Below Khus	15-30	10.67	10.01	9.48	8.95	10.49	9.66	8.70	9.07	8.65	8.16	7.66	7.50	7.25	6.96
Above Khus	30-45	13.44	12.82	12.25	11.72	13.31	12.57	11.53	11.90	11.52	11.07	10.67	10.22	10.02	9.59
Below Khus	30-45	12.04	11.68	11.06	10.53	12.27	11.45	10.44	10.57	10.38	10.05	9.53	9.30	9.04	8.55

Appendix XI. Contd....

Treatments	Depth (cm)	DAS 138	142	145	149	151	157	159	164	166	174	177	Mean	% Increase
Above Khus	0-15	5.30	4.96	4.56	3.68	3.33	7.38	7.16	6.58	6.30	5.45	4.73	7.21	11.61
Below Khus	0-15	4.40	4.00	3.60	3.26	2.84	6.55	6.26	5.76	5.41	4.49	3.82	6.46	
Above Khus	15-30	7.51	7.13	6.73	6.43	6.05	9.82	9.48	8.86	8.55	7.91	7.68	9.74	12.73
Below Khus	15-30	6.64	6.25	5.84	5.51	5.08	8.65	8.45	7.86	7.58	6.60	6.05	8.64	
Above Khus	30-45	9.29	8.95	8.65	8.26	7.82	11.87	11.27	10.70	10.38	9.71	8.92	11.52	10.35
Below Khus	30-45	8.43	8.03	7.71	7.13	6.81	10.66	10.00	9.62	9.28	8.53	7.63	10.44	

Appendix XII. Effect of khus on soil moisture content (% w/w) during Kharif, 1994-95

Treatments	Depth (cm)	DAS									
		43	47	50	54	60	62	67	70	74	77
Above Khus	0-15	9.14	9.48	9.71	9.92	9.12	8.86	7.94	9.06	10.76	9.85
Below Khus	0-15	8.46	8.76	8.87	9.00	8.09	7.88	7.05	8.04	9.54	8.73
Above Khus	15-30	10.93	11.48	11.81	12.16	11.42	11.21	10.46	11.68	12.45	11.72
Below Khus	15-30	9.69	10.18	10.51	10.79	10.12	9.78	9.10	10.14	10.82	10.17
Above Khus	30-45	12.08	12.71	13.12	13.32	12.72	12.46	11.80	12.69	13.76	13.04
Below Khus	30-45	10.89	11.22	11.65	11.81	11.15	10.93	10.36	11.05	12.05	11.41

Appendix XII. Contd.....

Treatments	Depth (cm)	DAS 81	84	88	92	94	96	102	105	109	112	117	121	125	130
Above Khus	0-15	9.02	8.10	9.62	12.21	11.73	11.34	10.57	9.62	9.94	9.47	8.93	9.40	8.93	7.95
Below Khus	0-15	8.01	7.20	8.53	10.98	10.65	10.18	9.59	8.54	8.82	8.40	7.92	8.35	7.91	7.06
Above Khus	15-30	11.01	10.18	11.76	14.43	13.96	13.60	12.91	12.02	12.39	11.94	11.51	11.14	10.68	10.23
Below Khus	15-30	9.55	8.83	10.23	13.55	13.02	12.54	11.84	10.83	11.15	10.60	10.24	9.91	9.49	8.90
Above Khus	30-45	12.48	11.73	13.26	15.86	15.44	15.05	14.56	13.68	13.95	13.52	12.98	12.59	12.18	11.77
Below Khus	30-45	10.94	10.25	11.64	14.88	14.29	13.91	13.35	12.39	12.66	11.85	11.37	11.02	10.65	10.30

Appendix XII. Contd.....

Treatments	Depth (cm)	133	137	140	144	D A S 149	152	154	161	168	177	Mean	%Inc-rease
Above Khus	0-15	7.60	7.21	6.84	6.54	6.25	5.86	5.70	5.28	4.78	4.12	8.55	11.76
Below Khus	0-15	6.76	6.42	6.09	5.83	5.54	5.24	5.09	4.73	4.27	3.70	7.65	
Above Khus	15-30	9.92	9.56	9.27	9.02	8.71	8.29	8.10	7.56	7.02	6.34	10.79	13.34
Below Khus	15-30	8.57	8.15	7.86	7.78	7.49	7.14	6.97	6.53	5.95	5.31	9.52	
Above Khus	30-45	11.35	10.96	10.72	10.56	9.98	9.70	9.56	9.07	8.51	7.82	12.21	12.95
Below Khus	30-45	9.88	9.55	9.36	9.21	8.69	8.44	8.32	7.83	7.39	6.79	10.81	