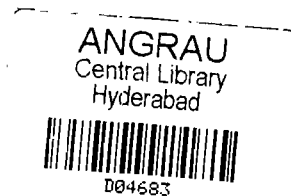


**EFFECT OF DIFFERENT PLANT POPULATION DENSITIES
ON EVAPOTRANSPIRATION, SOIL STRUCTURE AND
YIELD OF GROUNDNUT (Arachis hypogaea L.)**

BY

M.S.S. NAGARAJU

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



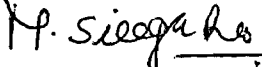
**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
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Submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Sri. M.S.S. NAGARAJU** 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 has been fully acknowledged by the author of the thesis.

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CONTENTS

CHAPTER NO	TITLE	PAGE NO.
I	INTRODUCTION	1 - 4
II	REVIEW OF LITERATURE	5 - 24
III	MATERIALS AND METHODS	25 - 51
IV	RESULTS	51 - 120
V	DISCUSSION	121 - 129
VI	SUMMARY	130 - 132
	LITERATURE CITED	133 - 141
	APPENDICES	142 - 145

LIST OF TABLES

Table No	Title	Page No.
1a	Physical, Physico-chemical and hydrological properties of experimental site (Kharif 88)	31
1b	Physical, Physico-chemical and hydrological properties of experimental site (Rabi 88)	32
1c	Physical, Physico-chemical and hydrological properties of experimental site (Kharif 89)	33
2	Groundnut crop growth stages and their duration	46
3	Crop and reference evapotranspiration (cm) at different growth stages as influenced by different plant population densities of groundnut	53
4	Crop coefficients (K_c) for groundnut at specific growth stages as influenced by different plant population densities of groundnut	56
5a	Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (kharif 88)	59
5b	Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (rabi 88)	60
5c	Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (kharif 89)	61
6	Daily ET (mm day^{-1}) of groundnut crop at different growth stages as influenced by different plant population densities	64
7	Influence of different plant population densities on soil moisture extraction (%) pattern in groundnut	67
8	Water use efficiency of groundnut ($\text{kg pods ha}^{-1} \text{mm}$) as influenced by different plant population densities	70
9	Empirical estimates for the relationship between crop evapotranspiration and reference crop evapotranspiration	72
10	Empirical estimates for the relationship between crop evapotranspiration and evaporation from U.S.W.B. class A pan and evaporation from Cans	78
11	Empirical estimates for the relationship between evaporation from U.S.W.B. class A pan and Can evaporimeters	83
12	Length of main root (cm) of groundnut as influenced by different plant population densities	84

Table No.	Title	Page No.
13	Lateral spread of roots (cm) of groundnut as influenced by different plant population densities of groundnut	87
14	Shoot dry matter (kg ha^{-1}) as influenced by different plant population densities of groundnut	90
15	Root dry matter (kg ha^{-1}) as influenced by different plant population densities of groundnut	93
16	Pod and Haulm yields (kg ha^{-1}) of groundnut as influenced by different plant population densities	96
17	Gross, net returns and benefit-cost ratio as influenced by different plant population densities of groundnut	98
18	Pod yield-crop evapotranspiration relationship in groundnut	100
19	Percent aggregates greater than 0.25 mm at harvest as influenced by different plant population densities of groundnut	102
20	Mean weight diameter (mm) at harvest as influenced by different plant population densities of groundnut	105
21	Stability index (per cent) of the root at harvest as influenced by different plant population densities of groundnut	108
22	Structural coefficient (per cent) of the soil at harvest as influenced by different plant population densities of groundnut	110
23	Bulk density (g cm^{-3}) of the soil at harvest as influenced by different plant population densities of groundnut	113
24	Hydraulic conductivity of the soil (cm hr^{-1}) at harvest as influenced by different plant population densities of groundnut	116
25	Total porosity (per cent) of the soil at harvest as influenced by different plant population densities of groundnut	118

LIST OF ILLUSTRATIONS

Fig. No.	Title	Page No.
1	Meteorological data during crop growth period (kharif 88)	26
2	Meteorological data during crop growth period (rabi 88)	27
3	Meteorological data during crop growth period (kharif 89)	28
4	Lay-out plan of the experiment	35
5	Evapotranspiration (cm) as influenced by different plant population densities and reference crop ET by different empirical methods at different growth stages of groundnut	54
6	Crop coefficients (K_c) for groundnut at specific growth stages as influenced by different plant population densities	57
7	Can evaporation (cm) at different growth stages as influenced by different plant population densities	62
8	Daily ET (mm day^{-1}) as influenced by different plant population densities of groundnut	65
9	Soil moisture extraction pattern (per cent) as influenced by different plant population densities of groundnut	68
10	Water use efficiency ($\text{kg pod ha}^{-1} \text{mm}$) as influenced by different plant population densities of groundnut	71
11a	Relationship between crop ET and reference crop ET estimated by different methods (kharif 88)	73
11b	Relationship between crop ET and reference crop ET estimated by different methods (rabi 88)	74
11c	Relationship between crop ET and reference crop Et estimated by different methods (kharif 89)	75
12a	Relationship between crop ET and evaporation from U.S.W.B. class A pan and can evaporimeters (kharif 88)	79
12b	Relationship between crop ET and evaporation from U.S.W.B. class A pan and can evaporimeters (rabi 88)	80

Fig. No.	Title	Page No.
12c	Relationship between crop ET and evaporation from U.S.W.B. class A pan and can evaporimeters (kharif 89)	81
13	Length of main root (cm) of groundnut as influenced by different plant population densities	85
14	Lateral spread of roots (cm) of groundnut as influenced by different plant population densities	88
15	Shoot drymatter (kg/ha) of groundnut as influenced by different plant population densities	91
16	Root drymatter (kg/ha) of groundnut as influenced by different plant population densities	94
17	Pod and Haulm yield (kg/ha) of groundnut as influenced by different plant population densities	97
18	Pod yield-crop evapotranspiration relationship in groundnut	101
19	Percent of aggregates greater than 0.25 mm at harvest as influenced by different plant population densities of groundnut	103
20	Mean weight diameter (mm) at harvest as influenced by different plant population densities	106
21	Stability index (per cent) at harvest as influenced by different plant population densities	109
22	Structural coefficient (per cent) at harvest as influenced by different plant population densities	111
23	Bulk density (g cm^{-3}) at harvest as influenced by different plant population densities	114
24	Hydraulic conductivity (cm hr^{-1}) at harvest as influenced by different plant population densities	117
25	Total porosity (per cent) as influenced by different plant population densities	119

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DECLARATION

I, Mr. M.S.S. NAGARAJU hereby declare that the thesis entitled **EFFECT OF DIFFERENT PLANT POPULATION DENSITIES ON EVAPOTRANSPIRATION, SOIL STRUCTURE AND YIELD OF GROUNDNUT (*Arachis hypogaea* L.)** is a result of the original research carried out by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

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ABSTRACT

A field experiment entitled "Effect of different plant population densities on evapotranspiration, soil structure and yield of groundnut (*Arachis hypogaea* L.)" was conducted during *kharif* 88, *rabi* 88 and *kharif* 89 on Typic Ustropepts at College farm, College of Agriculture, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad. The experiment was laid out in simple randomised block design with five plant population density treatments (5.0, 4.0, 3.33, 2.5 lakh plants ha⁻¹ and no crop) replicated four times. Irrigation was scheduled at 12 days interval during *kharif* 88 and *rabi* 88 whereas in *kharif* 89 no irrigation was given to the crop as the rain fall (695.7 mm) was high and as there was no moisture stress during the crop growth period. Well cleaned 500 ml cans (with and without 6/20 mesh screen) were installed in each plot and can evaporation was recorded in all the three seasons. Reference crop evapotranspiration was computed using Modified Penman, Blaney-Criddle, Hargreaves, Radiation and Pan evaporation for *kharif* 88, *rabi* 88 and *kharif* 89 seasons.

Seasonal crop evapotranspiration increased significantly with increase in plant population density. Crop with a plant population of 5.0 lakh plants ha⁻¹ throughout its growth period utilised water at higher rate and resulted in higher evapotranspiration. Similarly increase in plant population, increased the daily moisture use at different crop growth periods in all the three seasons. Significant correlations were observed between crop ET and reference crop ET estimated by Modified Penman, Blaney-Criddle, Hargreaves and Radiation methods. Highest K_c values were observed in the crop with a plant population density of 5.0 lakh plants ha⁻¹ as compared to lower plant densities.

Significant correlations were observed between crop ET and evaporation from USWB class A pan. Crop ET and evaporation from can evaporimeter having screen of with and without 6/20 mesh significantly correlated. Evaporation from USWB class A pan and can (with and without 6/20 mesh screen) were significantly correlated in all the three seasons.

Increase in plant density increased the extraction of soil moisture from lower strata compared to upper strata and this trend was more clear as the age of crop advanced. Plant population density of 5.0 lakh plants ha⁻¹ was highly efficient in producing pods per unit quantity of water.

Length of main root significantly increased whereas, lateral root spread decreased significantly with increase in plant density. Plant population density of 5.0 lakh plants ha⁻¹ produced maximum drymatter compared to other lower plant densities. Significant increase in pod and haulm yields were observed with

increase in plant population density from 2.5 to 5.0 lakhs ha^{-1} . Plant population of 5.0 lakhs ha^{-1} registered highest pod and haulm yields during all the three seasons. Adoption of plant population density of 5.0 lakh plants ha^{-1} gave maximum net returns and benefit-cost ratio.

Soil structural indices viz., aggregates greater than 0.25 mm, mean weight diameter, stability index and structural coefficient were favourably improved in the crop with a plant density of 5.0 lakh plants ha^{-1} . Bulk density was decreased whereas, hydraulic conductivity and porosity were increased with increase in plant density.

LIST OF ABBREVIATIONS

°C	:	degrees celcius
CD	:	Critical difference
CPE	:	Cumulative pan evaporation
CU	:	Consumptive Use
DAS	:	Days after sowing
dS m ⁻¹	:	deci Siemen per meter
ET	:	evapotranspiration
ET _o	:	Reference crop (grass) evapotranspiration
ET _a	:	Actual evapotranspiration
ET d ⁻¹	:	evapotranspiration per day
FC	:	Field capacity
g	:	gram(s)
ha	:	hectare(s)
K _c	:	Crop coefficient(s)
kg	:	kilogram
kg ha ⁻¹	:	kilogram per hectare
kmph	:	kilometer per hour
mm	:	millimeter
NS	:	Non Significant
S.Ed.	:	Standard error difference
U.S.W.B.	:	United States Weather Bureau
WUE	:	Water use efficiency

INTRODUCTION

INTRODUCTION

CHAPTER I
INTRODUCTION

Groundnut is the most important edible oilseed in India with an area of 8.4 million hectares and production of 8.9 million tonnes. Andhra Pradesh constitutes one of the important states in the country, contributing 28.8 percent of the area and 23.4 percent of country's groundnut production (DOR 1993). However, the productivity of this crop remained almost stagnant for the last few years whereas, the demand for oil is increasing exponentially (Rao, 1988). In view of this, impetus has been placed to increase the area under irrigated conditions during Rabi-summer. Preliminary reports (Mac Gillivray *et al.*, 1981; Kanwar, 1978) have shown that the yields obtained under irrigation were almost twice that of non irrigated crop. This resulted in increase in groundnut area under major and medium irrigation projects and also in non traditional areas due to crop diversification. As the demand for water is mounting and irrigation costs are rapidly increasing world over as well as in India, there is every possibility of encountering water shortage with increasing frequency due to unpredictable monsoon conditions over the years.

The upper limit of crop production is set by the climatic conditions and the genetic potential of the variety grown. The extent to which this limit can reach will always depend on how finely the water supply is in tune with the biological need for water in crop production.

Information on crop water requirements is essential for designing an irrigation project. The design and operation networks must follow the field water requirements as to the quantity and time. Several soil, agronomic and irrigation practices and weather parameters affect crop water requirements. It is not possible to conduct precise field experiments under all these situations to

obtain direct measurement of crop water requirements. As the crop water requirements depend mostly on evapotranspirational demand, estimation of evapotranspiration (ET) or consumptive use (CU) of a crop is of immense use for budgeting water resources. Several models have been proposed to estimate potential evapotranspiration (PET) using climatic data which take into account the soil, crop and other agronomic management practices. The use of empirical formulae for predicting the crop water requirement is considered to be easier and quicker compared to field experimentation (Michael, 1975).

The F.A.O. group of international scientists on crop water requirements (Doorenbos and Pruitt, 1977) have screened 31 of the available prediction methods and finally selected four methods which are widely known as best ones. These methods are Modified Penman, Blaney-Criddle, Radiation and Pan evaporation. Some refinements to these methods were made to suit to the local situations. The reliability and applicability of these methods on groundnut under irrigated conditions in Southern Telangana Zone of Andhra Pradesh needs to be tested.

Several approaches for scheduling irrigation have been used throughout the world. Evaporimetry is one of the valuable tools for assessing water needs of crops. Experiments have confirmed that evaporation from a class A pan (E pan) is a good indicator of crop evapotranspiration (Et) (Reddy *et al.*, 1983). Since use of class A pan by farmers is limited due to its size and bulkiness, workers like Sharma and Dastane (1969), Jain (1975) and Sharma *et al.*, (1975) have advocated the use of simpler evaporimeters for scheduling irrigation. Experiments conducted at Tirupati (India) revealed a high correlation ($r=0.82$) between evapotranspiration in finger millet and evaporation from a Can

(Sreenivasulu *et al.*, 1978). Similar type of information is lacking for groundnut under the agroclimatic conditions of Southern Telangana Zone.

The interaction between soil moisture, root growth and development was known to cause some improvement in the soil physical properties. The longer the ground cover provided by the crop canopy, the most favorable would be in improving the soil physical conditions. Further low plant population densities would encourage weed growth, reduce production per unit area and had less beneficial effects on soil structure (Opera - Nadi and Lal, 1987). Biswas *et al.*, (1967) observed that legumes which play an important role in crop rotations are considered to do so by way of building up and maintaining good soil physical condition. The research work carried out in India on the influence of different plant population densities of groundnut on soil physical properties was found to be very meagre.

Low plant population is one of the principal factors limiting the yield of groundnut which also reduces the response to other management practices such as irrigation and fertilizers. Maximization of yield could be achieved only when plant population exercises optimum pressure on soil nutrients, moisture and light. At low plant population density, there will be little inter-plant competition for growth resources viz., soil nutrients, moisture, space, sunlight and CO₂ and are not fully exploited. In a very dense stand both inter and intra plant competition will be sufficiently severe to reduce all the yield components. A survey conducted in Andhra Pradesh revealed that low plant stand was one of the factors for poor groundnut yields (Reddy and Reddy, 1979). It is difficult to draw a standard conclusion regarding required plant population for groundnut as there was plasticity in population requirement for obtaining maximum yield with regard to soils, seasons, varieties and management practices. Hence, for

maximum yield in a given situation, finding out an optimum plant population is a pre-requisite.

Keeping this in view, the present study entitled "Effect of different plant population densities on evapotranspiration, soil structure and yield of groundnut (*Arachis hypogaea* L.) was under taken with the objectives.

- i. To find out the evapotranspiration under different plant population densities of groundnut by soil moisture depletion.
- ii. To compute reference crop evapotranspiration by different empirical methods and its relationship with evapotranspiration by soil moisture depletion method.
- iii. To study Can evaporation under different plant population densities and its relationship with evapotranspiration in groundnut.
- iv. To study the effect of different plant population densities of groundnut on soil structure.
- v. To find out the effect of different plant population densities on yield of irrigated groundnut in relation to evapotranspiration of the crop.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Accurate crop water requirement data are essential in modern irrigated agriculture. An appraisal of economic returns from irrigation and the proper design and operation of irrigation depend to a large extent on the reliability of the available data on evapotranspiration estimates or actual water used by crops. In addition, the interaction between soil moisture, root growth and development of crop affect the physical properties of soil. The effect of different plant population densities of groundnut on evapotranspiration rates, soil structure and on growth and development of groundnut needs to be explored.

From the literature available, the effect of different plant population densities of groundnut on evapotranspiration rates, soil structure and on growth and development of groundnut, relevant to the present study are reviewed and presented hereunder.

2.1 COMPARISON OF MODELS FOR EVAPOTRANSPIRATION ESTIMATION

Kadam *et al.*, (1978) computed reference crop evapotranspiration data using Modified Penman, Radiation, Blaney-Criddle and Pan evaporation methods in three different crop seasons. They recorded more of ET_0 values during summer and pre-monsoon months and less in winter months. Comparison between different methods in predicting reference evapotranspiration values revealed that Modified Penman method predicted higher values than the other methods during south west monsoon season.

Rao *et al.*, (1983) tested four empirical formulae, Blaney-Criddle, Pan evaporation, Modified Penman and Radiation methods for estimating water requirements of groundnut under semi-arid conditions of Tirupati and reported

that the predicted crop water requirements ranged from 434.3 mm with Blaney-Criddle, 469.1 mm with Pan evaporation, 504.7 with Modified Penman method to 510.4 mm with Radiation method.

Reddy *et al.*, (1984) reported that the water requirements of groundnut ranged from 298.2 to 442.1 mm and were higher (442.1 mm) with Modified Penman method followed by Radiation (360.0 mm), Pan evaporation (332.3 mm) and Blaney-Criddle method (298.2 mm). The high water requirements predicted with Modified Penman method compared to the other three prediction methods was attributed to the fact that it takes into account almost all the weather parameters influencing crop water requirements.

Chhabda *et al.*, (1986) compared Modified Penman and Hargreaves methods in computation of reference crop evapotranspiration and observed that the annual fortnightly mean ratios for kharif and rabi were 1.11 and 1.04 respectively. The correlation coefficients between ET_0 by Modified Penman and Hargreaves method have been found to be highly significant and the r values for kharif and rabi were 0.42** and 0.66** respectively. Thus, they indicated that the Hargreaves method to estimate ET_0 in command area of Nira irrigation project in Maharashtra, can suitably be used wherever adequate data on the weather parameters as required for Modified Penman method are not available.

Palaskar *et al.*, (1987) compared the Pan evaporation and Modified Penman methods for the estimation of reference crop evapotranspiration. They observed that on an average the ratio of an estimate by the Pan evaporation to the estimate by Modified Penman method was 0.9. The correlation coefficient between ET_0 by Pan evaporation and Modified Penman methods has been found to be highly significant ($r = 0.88^{**}$). Linear regression was also fitted to

predict ET_0 values by Pan evaporation method ($Y = 0.8828 + 0.9099 x$). They also compared the Pan evaporation and Modified Penman methods for the estimation of consumptive use of water by groundnut and reported the consumptive use of rainfed groundnut using Pan Evaporation method as 409 mm, compared to 471 mm with Modified Penman method. The ratio of consumptive use by Pan evaporation to consumptive use by Modified Penman was reported to be 0.87.

Sharma and Sharma (1988) determined reference crop evapotranspiration at Pusa using climatological data employing the Blaney-Criddle formula, Penman and Modified Penman methods. The annual ET_0 estimated by Radiation and Modified Penman methods were 171 and 126 mm higher respectively, and by Blaney-Criddle formula 32 mm lower than that estimated by Penman method. When estimated on a monthly basis, values given by Blaney-Criddle formula were within 11 per cent of those of Penman method.

Reddy (1988) computed water requirements of groundnut based on four prediction formulae viz; Blaney-Criddle, Radiation, Pan evaporation and Modified Penman methods for Anantapur region of Andhra Pradesh. He reported that evapotranspiration values ranged from 281.5 mm to 433.6 mm for the four prediction methods. Highest crop water requirements was recorded with Modified Penman method (433.6 mm) and the lowest with Blaney-Criddle (281.5 mm). Radiation and Pan Evaporation methods recorded 393.7 mm and 328.6 mm respectively.

Mandal *et al.*, (1991) compared Penman and Hargreaves ET_0 under different climatic conditions in India and reported that the ET_0 obtained with the two methods were closely related ($r = 0.72$) under semi-arid conditions.

Mohan and Prasad (1991) compared different models for evapotranspiration estimates. Penman method was selected as reference and regression equations were developed to correct the Radiation and Blaney-Criddle methods. Radiation method exhibited high correlation with Penman for Bellary station. For Chikmagalur both Radiation and Blaney-Criddle methods exhibited good correlation with Penman method. The year to year variation of estimates by any method is negligibly small.

2.2 CORRELATION STUDIES BETWEEN EVAPORATION AND EVAPOTRANSPIRATION FROM CROPS

Several workers have correlated Pan evaporation values with evapotranspiration values from crops. Various types of evaporimeters such as Bellani Plates and large diameter pans have been used in these studies. Both types of evaporation devices have limitations of their own. The large pans are difficult to maintain. Subsequently, research has been oriented by replacing large pans with small containers for correlating evaporation to evapotranspiration from crops (Sharma and Dastane, 1969).

Goldberg *et al.*, (1967) related water consumption of peanuts to U.S.W.B. class A pan evaporation and observed that the relation between consumptive use and evaporation is not constant but changed during the course of the growing season and a regression equation ($ET = 0.85E_0 - 175$) has been developed between cumulative evaporation and cumulative evapotranspiration. The average ET/E_0 ratio during the period after 50 per cent ground coverage was worked out to be 0.85.

Sharma and Dastane (1969) assessed evapotranspiration with Can evaporimeters having diameter and depth of 10.3 and 14.3 cm respectively and observed that the evapotranspiration values in wheat were well correlated with

evaporation from the Cans, the U.S.W.B. class A pan and reference evapotranspiration computed by Thornthwaite formula and workedout regressions of ET with evaporation from Cans ($ET = 16.849 + 0.2797 E_{Can}$) and the U.S.W.B. class A pan ($ET = 10.1098 + 0.4218 E_o$).

Sharma *et al.*, (1975) used Can evaporimeters having inner diameter and depth of 10.3 and 14.3 cm respectively and related Can evaporation to evapotranspiration (ET) from Berseem and wheat under adequate moisture supply at IARI, New Delhi and observed that the periodical values of ET were correlated significantly with evaporation from small Cans (E_{can}) having screens of 6/20 mesh size and placed at crop level height.

Sreenivasulu *et al.*, (1978) established relationship between evapotranspiration in finger millet with evaporation from U.S.W.B. Pan, Sunken Screen Pan and Can evaporimeters having inner diameter and depth of 10.4 and 14.1 cm respectively with a cover of 1/2 X 26 wire mesh. The results indicated that significant positive correlation existed between evapotranspiration and evaporation from U.S.W.B. pan evaporation ($r = 0.810^*$), evapotranspiration and Can evaporation ($r = 0.820^*$) and evaporation from Can evaporimeter and evaporation from open pan ($r = 0.850^*$).

Tosso and Tondreau (1978) found that the relationship between evapotranspiration of sunflower crop and pan evaporation (E_v) was $ET = -6.3 + 1.79E_v$ ($r = 0.90$).

Reddy *et al.*, (1981) observed significant correlation between evapotranspiration from finger millet and evaporation from Can, sunken screen pan and open pan evaporimeter for three different moisture regimes. The results indicated that the evaporimeters had significant correlation with

evapotranspiration from finger millet. With the help of regression equation, ET_0 values were predicted based on evaporimeters and are generally comparable with the observed values with all evaporimeters. Since the observed values were close to regression line with regard to evaporation from pan evaporimeter kept at crop level, it can be used more precisely for scheduling irrigations to the crop than the sunken screen pan and open pan evaporimeters.

Studies on scheduling irrigation to groundnut using a Can evaporimeter having inner diameter and depth of 10.3 and 14.3 cm respectively revealed a high positive correlation ($r = 0.98$) between evaporation from both U.S.W.B. class A pan and Can evaporimeter as well as a close association ($r = 0.99$) between crop ET and evaporation from the Can evaporimeter (Reddy, 1984).

Biswas (1992) reported that the ratio of evapotranspiration to pan evaporation varied from crop to crop and also during different growth stages of the same crop. Ratio of cumulative evapotranspiration (ET) to pan evaporation (E_{pan}) varied from 0.58 to 0.99.

2.3 EVAPOTRANSPIRATION IN GROUNDNUT

Sinha and Kalra (1992) working on soil moisture use by crop plants observed that the water use by crop plants is the key factor in crop production and that precise information about it is very essential for proper irrigation scheduling to get optimum yields.

Evapotranspiration of groundnut crop varied widely depending on soil, season, variety and other cultural practices (Reddy 1988). Sivakumar and Sarma (1985) also observed that the total water use by groundnut could be

altered by agronomic practices irrespective of the rainfall or number of irrigations.

Studies on water requirement of groundnut, conducted in Israel, revealed that the total amount of water required for groundnut ranged from 60 to 70 cm on light soils and from 50 to 60 cm on heavy soils (Mantell and Golden, 1964).

Two year study on water requirement of groundnut at Kanpur on loamy soils by Mehrotra *et al.*, (1968) revealed that consumptive use was 55cm for spanish bunch variety, T-32. Optimum water requirement of spanish bunch (TMV 2) groundnut grown on sandy soils of Bhavanisagar was 606 mm (Mohan, 1970).

At Garikapadu Andhra Pradesh, spanish bunch (TMV 2) groundnut required 59.3cm of water in 1968 and 66.6cm in 1969 during Rabi season on red sandy loam soil. At Amaravati in Andhra Pradesh, the same variety needed 42.7cm of water on black clay loam soil (Reddy, 1973).

Experiments conducted on sandy clay loam soils at Bhavanisagar indicated that total water requirement of spanish bunch groundnut was 57.5 cm, whereas on medium black clay loam soil of Hyderabad, the same variety needed 52.1 cm (AICRPWMSS, 1973).

Cheema *et al.*, (1977) conducted experiments on groundnut grown on loamy sand soil of Ludhiana during wet season of 1972 and 1973 and reported the consumptive water use as 57.0 cm.

Babu *et al.*, (1977) from Tirupati reported the consumptive use of spanish bunch groundnut as 450 mm when irrigations were scheduled once in 10 days.

Rasve *et al.*, (1983) reported that application of 540 mm of water in irrigations with ten day interval was most beneficial for higher yield of groundnut during summer season.

Reddy *et al.*, (1980) worked on evapotranspiration and water use efficiency of different crops on sandy loam soils and reported that the consumptive use of groundnut as 56 cm.

2.3.1 Crop Coefficients

Doorenbos and Pruitt (1977) defined crop coefficient (K_c) as "the ratio between crop evapotranspiration (ET_{crop}) and the reference crop evapotranspiration (ET_0) when crop is grown in large field under optimum growing conditions". This approach permits the use of FAO-24 version of Blaney-Criddle, Radiation, Modified Penman and adjusted Pan evaporation methods for estimating ET_0 .

Doorenbos and Pruitt (1977) presented crop coefficients for a great variety of crops. They divided the crop growth period into four stages viz., initial, crop development, midseason and late season. They then illustrated the method of constructing crop coefficient curve for the four growth stages.

Crop Coefficients (K_c) for groundnut under semi-arid conditions of Tirupati were found to be 0.92, 0.77, 0.74 and 0.77 at initial, crop development, mid and late stages respectively based on Modified Penman method. The corresponding values when Radiation method was used for estimating ET_0

in place of Modified Penman method for the four stages were 0.84, 0.75, 0.73 and 0.79 respectively (Reddy *et al.*, 1983) while for Bapatla region of Andhra Pradesh, having coastal climate, the Kc values for groundnut in the four stages were 0.51, 0.76, 1.00 and 0.78 respectively with Radiation method and 0.45, 0.74, 1.00 and 0.79 respectively with Modified Penman method (Reddy *et al.*, 1984).

2.3.2 Effect of different plant population densities of groundnut on evapotranspiration

Manipulation of ground cover by altering plant spacing provides a means of adjusting the evaporation from a crop to match the supply of water and thereby to avoid loss of yield caused by shortage of water during reproductive growth (Simmonds and Williams, 1989).

Van Bavel *et al.*, (1968) reported that crop rooting characteristics (lateral and vertical expansion of roots, root density, root effectiveness) and soil hydraulic properties were the important factors in determining the availability and uptake of water by the crop plants. Dakshinamurthi *et al.*, (1973) found that any practice that increases drymatter production will lead to increased efficiency in water use.

Bhan and Misra (1970) reported that groundnut variety AK 12-24 with a spacing of 30 x 25 cm, which produced more roots, gave higher cumulative evapotranspiration (375 mm) as compared to 60 x 25 cm spacing (362 mm) which recorded lower root weight.

Bhan (1973) studied the water relations of groundnut in relation to variety, spacing and soil fertility under arid conditions and observed that a

spacing of 30 cm between the rows depleted the available moisture more thoroughly and rapidly, as compared to row spacings of 45 cm and 60 cm.

Azam Ali *et al.*, (1984) observed that greater root proliferation to deeper depths may be a response to the greater inter-plant competition for water in denser plant stands which leads to increased water extraction from deeper layers in the profile.

Erickson *et al.*, (1986) studied the initial evaporative demands for differential stomatal action in peanut grown in narrow and wide row spacings and observed that on the days with high-evaporative demand, stomata on plants in wide rows tended to close less than those on plants with narrow rows.

Opara-Nadi and Lal (1987) reported that a complete ground cover under the highest plant population minimised the evaporation losses and increased the soil moisture content. The total soil water depletion was significantly higher for the higher plant population than for the lower plant populations. They also further reported significant differences in soil water flux and water uptake from different soil horizons among various plant population densities of the crop. The total water loss was found to be highest with the highest plant population density,

Simmonds and Williams (1989) worked on population, water use and growth of groundnut maintained on stored water and reported that transpiration increased with increasing plant densities and the evaporation from the soil surface was only a small component of seasonal water balance in dense stands and was little affected by plant density. They also reported that denser stands extracted more water from deeper layers in the profile, whereas plants in widely spaced rows preferentially extracted water from near the row.

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Azam - Ali *et al.*, (1989) studied the relationships between the production of shoot and root drymatter to transpired water and intercepted radiation in groundnut and observed that the accumulated transpiration increased linearly with intercepted radiation at $0.37 \text{ Kg water MJ}^{-1}$ in the sparser stands. With denser spacing, the initial slope of the relation at 0.28 Kg MJ^{-1} decreased later in the season because of much larger soil water deficits encountered in the denser stands than in the sparser stands.

Simmonds and Azam Ali (1989) reported that when soil water content decreased below a threshold value, the ratio of transpiration rate to fraction of incident radiation (T/f) and canopy conductance to fraction of incident radiation (gc/f), decreased because of increased stomatal resistance. They also observed earlier stomatal closure in response to soil water stress in denser stands, partly because of more rapid depletion of soil water. The sparser stands, which had a relatively large root : shoot ratio, had a greater capacity to keep stomata open as the soil water deficit increased.

Rao (1990) conducted experiments during Rabi 1985- 86 and reported that each higher level of plant population increased the consumptive use at all the stages of crop growth and this was attributed to higher root net at higher plant density.

Wright and Bell (1992) reported that plant population influenced both the temporal and spatial pattern of water use. High water use prior to early pod filling in high density crops was associated with more rapid leaf area development.

2.4 EFFECT OF DIFFERENT PLANT POPULATION DENSITIES OF GROUNDNUT ON ROOT AND SHOOT GROWTH AND YIELD

2.4.1 GROWTH CHARACTERS

2.4.1.1 Root length

Seshadri *et al.*, (1958) studied the root development under different plant population densities in groundnut and reported a marked improvement in development of root system due to increased spacing.

The length of the main root increased with increase in plant population density at different stages of plant growth of soybean (Misra and Singh, 1968). They also reported that root spread decreased as the plant population density increased due to crowding of roots at high plant population density, which allowed little lateral development.

Bhan and Misra (1970) reported that root length in groundnut tended to improve appreciably with an increase in the spacing between the plants. They also observed that root growth increased markedly when spacing was increased from 30 x 25cm to 45 x 25cm and further increase in spacing to 60 x 25cm brought only very little increase in root growth.

Rao *et al.*, (1989) measured the growth of roots in stands of groundnut grown at a number of populations and reported that the total length of roots per unit land area increased with population density.

2.4.1.2 Root weight

Mehta (1985) reported that high plant population increased the root weight of peas in sandy loam soil. He also observed that increase in plant population decreased the root weight of plants at low moisture content but increased the same at high moisture content.

Rao *et al.*, (1989) reported that total root weight per plant increased with increasing plant population density. Further, they found that the proportion of root weight to total plant weight increased in the densest population stand as compared to the widely spaced population. Denser stands produced greater proportion of roots at deeper depths.

2.4.1.3 Shoot Weight

Bhan and Misra (1972) reported that the number of functional leaves and dry weight of the plant tended to increase with an increase in spacing from 30 x 10 cm to 45 x 10 cm and 60 x 10 cm.

Vegetative and reproductive development of four virginia type varieties of peanuts differing in plant size were tested by Cahaner and Ashri (1974). These showed that increased stand density led to increased vegetative growth per unit area.

Mehta (1985) found that increased root weight at high plant population density increased the shoot weight also because of more number of plants per unit area, enhanced uptake of moisture and increased nutrient uptake.

Rao *et al.*, (1989) reported that total drymatter per unit land area increased with population although the weight per plant was less in denser stands.

Rao (1990) reported decreased dry matter accumulation per plant in groundnut crop at different stages of plant growth with reduced row spacing. It was least in plants grown at a spacing of 20 x 10 cm.

2.4.2 Pod and Haulm Yields

Based on the results of a trial conducted at Agricultural Research Station, Bhavanisagar, Kumaraswamy *et al.*, (1963) recommended a spacing of 22.5 x 10cm for irrigated bunch groundnut.

Cox and Reid (1965) reported that an increase in plant population by reducing the row width, increased the yield of groundnut by increasing the number of plants per foot of row.

Rao (1973) recommended a spacing of 15 x 15 cm for bunch groundnut for sandy loam soils of Cuddapah district in Andhra Pradesh.

Reddy (1979) conducted field experiments on sandy loam soils of Tirupati with bunch groundnut (TMV 2) and reported that plant height, number of flowers per unit area and haulm yield were increased with increase in plant population.

Experiments conducted both under irrigated and rainfed conditions with various populations for three years using the peanut cultivar Argentina indicated that 25 X 10 cm spacing gave the highest pod yield. (Choy *et al.*, 1982).

The pod and haulm yields of groundnut under rainfed conditions in Maharashtra were significantly higher at row spacing of 30 cm than at 37.5 cm with a uniform intra row plant spacing of 15 cm (Chavan and Kalra, 1983). Reddy *et al.*, (1983) reported 30 x 15 cm as optimum spacing for rainfed virginia runner groundnut.

Kalra *et al.*, (1984) conducted a field experiment during rabi (hot weather) seasons of 1978-79, 1979-80 and 1980-81 at trial- cum-demonstration farm, Raigad, Maharashtra to examine the performance of improved varieties of

groundnut under various levels of plant population. They found that closer spacing of 30 x 15 cm gave significantly higher dry pod yield than 45 x 15 cm and 30 x 30 cm spacing.

Experiments were conducted at Regional Research Station, Dharwad to study the response of three groundnut cultivars (M 13, TG 1 and DH 3-30) to six spacings (40 x 10, 40 x 15, 40 x 20, 30 x 10, 30 x 15, 30 x 20cm). The results indicated that all the varieties responded well upto narrow spacing of 30 x 10cm (Agasimani *et al.*, 1984).

Experiment conducted with groundnut varieties under three inter and intra-row spacings at Ranchi during 1979-82 by Ahmed *et al.*, (1986) revealed that closer inter-row spacing of 20 or 30 and 10cm intra-row spacing were significantly superior to wider spacing.

Deshpande *et al.*, (1986) studied the performance of groundnut under different geometries and noted that maximum pod yield was realised at 40cm row width and yield decreased with wider row spacings. The yield reduction at 50 and 60cm row to row spacing in comparison with 40cm was 6.6 per cent and 13.2 per cent respectively.

Kvien and Bergmark (1987) observed that increased population increased interplant competition for light which resulted in more plant height and per cent drymatter partitioned to the stem.

Thorat and Patil (1987) reported that 30 x 14cm spacing gave the highest pod yield of groundnut compared to 45 x 15 cm and 30 x 10 cm spacing.

Agasimani *et al.*, (1989) found that bunch type groundnut (Cv. Dh - 8) gave the highest average yield at 20 x 15 cm and was on par with 20 x 10 cm spacing and the yields were lowest at 10 x 5 cm or 40 x 20 cm spacings.

Reddy and Giri (1989) reported that low plant density of 1.5 lakh plants ha⁻¹ significantly increased the drymatter accumulation, LAI, number and weight of pods/plant over higher (2.21 lakh) plant density. They further stated that higher productivity per plant in low plant density failed to compensate the reduced number of plants per unit area when compared to higher plant densities.

Rao (1990) reported that row spacing influenced pod and haulm yields of groundnut to an appreciable level. The maximum pod and haulm yields were obtained by adopting a spacing of 20 x 10 cm and was significantly superior to the row spacings of 30 x 10 and 40 x 10 cm.

2.5 YIELD WATER RELATION

It has been established that potential crop yield is a combined function of crop genetics and the environment under which it grows. More explicitly, the crop yield response to different plant population densities is depended on the integrated behaviour of soil water-crop-environment interrelations.

2.5.1 Crop yield response to seasonal evapotranspiration

The earliest work of Dewit (1958) has shown that a linear relationship existed between drymatter yield (Y) and the ratio of transpiration (T) to free water evaporation (E₀) for arid and semi arid regions.

$$Y = M (T/E_{Pan})$$

in which, M represents the coefficient reflecting the crop characteristics and availability of water. He opined that the same relationship will not hold good for humid regions and hence he suggested a modified form as follows

$$Y/Y_p = T/T_p$$

where Y_p is potential yield when transpiration is equal to potential transpiration, T_p . T_p is that transpiration which occurs when soil water does not limit transpiration.

The linear relationship between crop yield and ET was reported by several workers (Stewart *et al.*, 1976, Hanks, (1974) Doorenbos and Kassam, 1979). Singh *et al.*, (1987) studied linear, quadratic, third degree polynomial, square root and power functions for wheat and concluded that the linear function may be considered appropriate and practically more useful considering its simplicity. They proposed the following model:

$$Y = a + b [(1 - (1 - ET_a/ET_m)^2)]$$

2.6 SOIL PHYSICAL PROPERTIES AND CROP GROWTH

The ability of soil to sustain a crop is dependent not only on the inherent availability of nutrients but also on the soil physical conditions essential for efficient use of nutrients and water by plants. Hence, it is essential to maintain the soil in good physical condition for optimum growth and yield of crops.

Soil productivity can be determined by its structure, which influences water, air and heat regimes in the field (Hillel, 1971). Soil structure influenced soil air, soil water and soil temperature relations and thus the plant growth

(Taylor and Ashcroft, 1972). Looseness and friability of the surface soil facilitate peg penetration, while physical factors of soil surrounding the developing pod affects its proper development (Shanmugam, 1983).

Combined effect of reduced bulk density, improved soil moisture content and retention, aeration and soil structure results in better growth of crop (Kumar, 1987).

2.6.1 Soil Structure

Cook (1962) reported that the role of a legume in crop rotation is not simply that nitrogen is added to the soil but also improved soil structure by the organisms that decompose the leguminous organic matter.

Kiselev (1955) reported that all agricultural crops were able to improve soil structure during their development but structure formation was greatest under legumes and perennial grasses.

Berseem, a winter fodder legume, improved the structural status of sandy loam soil and the structure was built up with the advancement of crop growth (Biswas *et al.*, 1967).

Rao (1970) reported that the improvement in soil structure resulted in an increase in porosity and decrease in bulk density there by increasing the water holding capacity. Reddy and Dakshinamurthi (1971) reported that better root growth was one of the most important factors for improving the soil structure.

2.6.1.1 Soil aggregation

Soil aggregation refers to the cementing or binding together of several soil particles into secondary units. Water stable aggregates are of special importance for high water infiltration, good soil structure and good plant growth. Donahue *et al.*, (1977) reported that the direct influence of plants on soil aggregation was manifested through exudates from roots, leaves, stems and leachates from weathering and decaying plant materials which bound soil particles together. Shankaranarayana and Mehta (1987) reported that crop rotations having legumes gave better aggregation compared with maize-wheat rotations. They also reported that the stability of aggregates increased in the sub soil layers due to the inclusion of legumes in crop rotations.

Opara-Nadi and Lal (1987) reported that the interaction between soil moisture, root growth and development was known to cause some improvement in the soil physical properties. The longer the ground cover provided by the crop canopy, the more favourable would be its affect in improving the soil physical conditions.

2.6.2 Bulk density

Hill and Sumner (1967) reported that increase in bulk density resulted in decrease in total porosity, increase in total number of soil pores, their relative volume and decrease in the total number of large pores and their relative volume. Juo and Lal (1977) reported that with increasing amounts of crop residues, soil bulk density decreased.

2.6.3 Hydraulic conductivity

Juo and Lal (1977) reported that hydraulic conductivity has greater affect with high plant population density and this was found to be due to

differences in the rooting pattern of the crops studied. Reddy *et al.*, (1978) reported that the higher rates of hydraulic conductivity at compacted minimum bulk density, a sensitive index of soil structure observed under 50 and 100 kg potash treatments might be attributed to the better root growth of the crops which would have improved the structure of the rhizosphere soil.

Bhatia and Srivastava (1982) reported that hydraulic conductivity was found to be the highest in the soil under grass cover and lowest in uncultivated soil.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field experiments on groundnut were conducted during Kharif 1988, Rabi 1988-89 and Kharif 1989 to study the "Effect of different plant population densities on evapotranspiration, soil structure and yield of groundnut (*Arachis hypogaea* L.)". Details of the experimental materials used and methodologies followed during the investigations are given below in this chapter.

3.1 EXPERIMENTAL SITE

The present experiments were conducted at the College Farm, College of Agriculture, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad. The experimental site was located at an altitude of 542.6 m above mean sea level on 17° 19' North Latitude and 78° 23' East Longitude.

3.2 WEATHER DURING CROP GROWTH PERIOD

Data on weather parameters recorded at meteorological observatory of the College Farm during crop growth period are presented in Appendices 1, 2 and 3 and depicted in Fig. 1, 2 and 3.

3.2.1 Kharif 1988

The weekly mean maximum temperature during crop growth period ranged from 25.7°C to 32.4°C with an average of 29.6°C. The weekly mean minimum temperature ranged from 11.4°C to 22.7°C with an average of 16.4°C. The weekly mean maximum relative humidity ranged from 68.0 to 93.0 per cent with an average of 81.2 per cent, whereas weekly mean minimum relative humidity ranged from 27 to 71 per cent with an average of 46.7 per cent. The weekly mean sunshine hours ranged from 3.3 to 10.4 with an

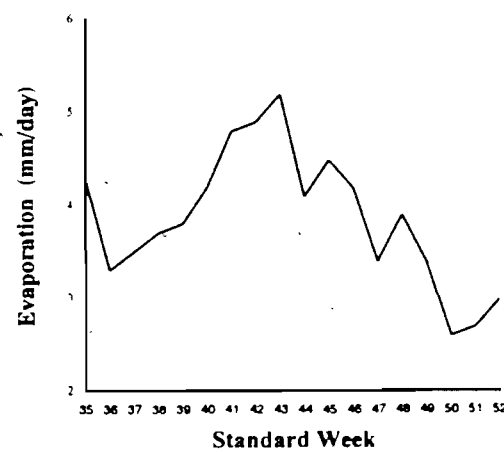
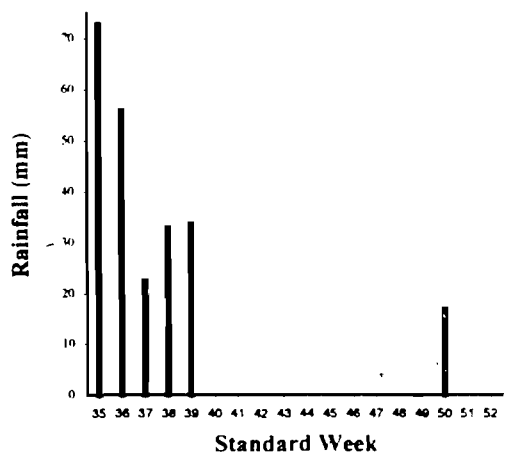
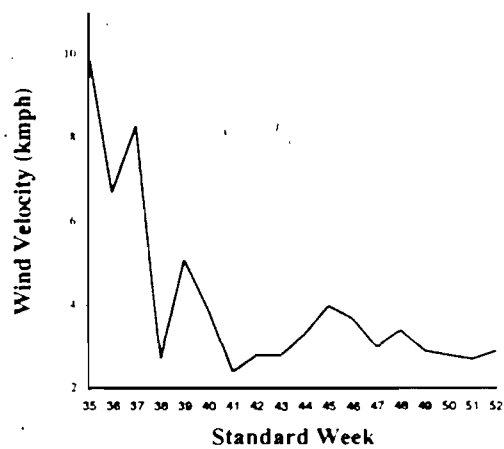
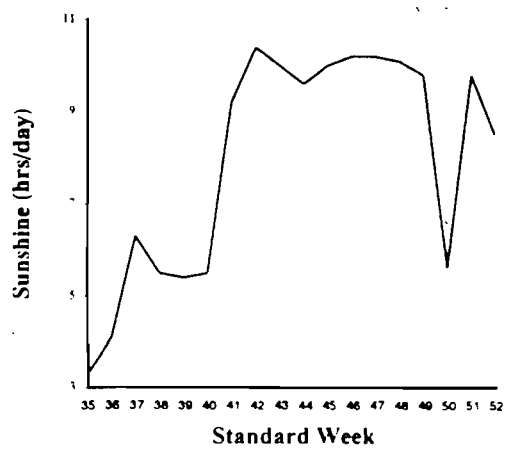
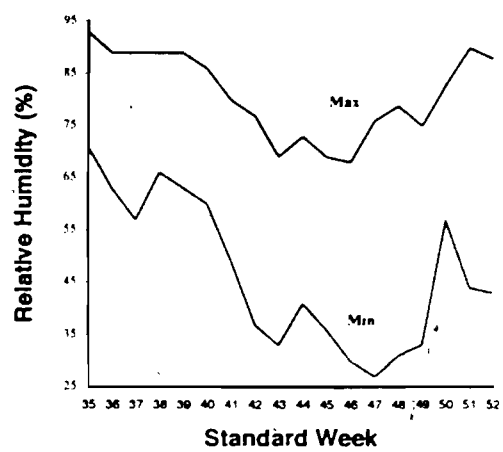
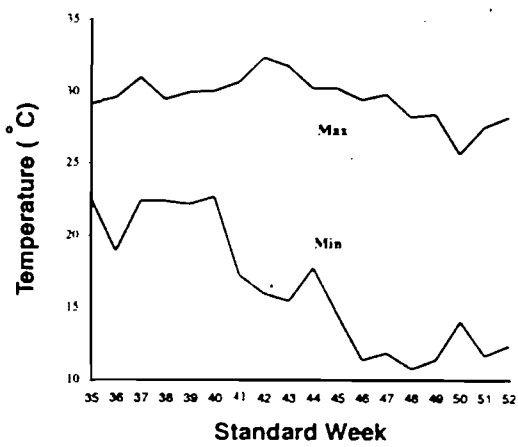


Fig 1 : Meteorological data during the crop growth period (Weekly means) : Kharif 88

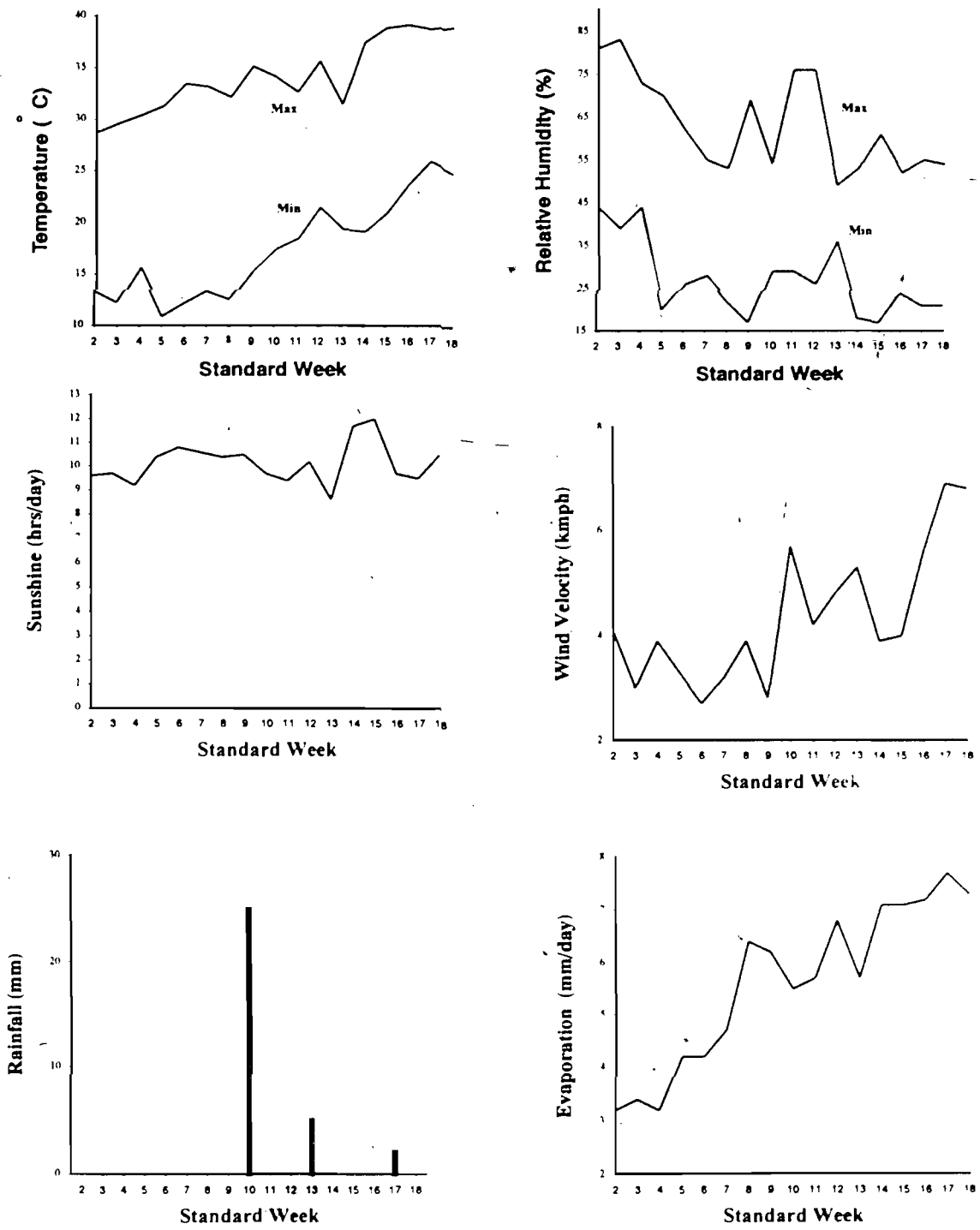


Fig 2 : Meteorological data during the crop growth period (Weekly means) : Rabi 88-89

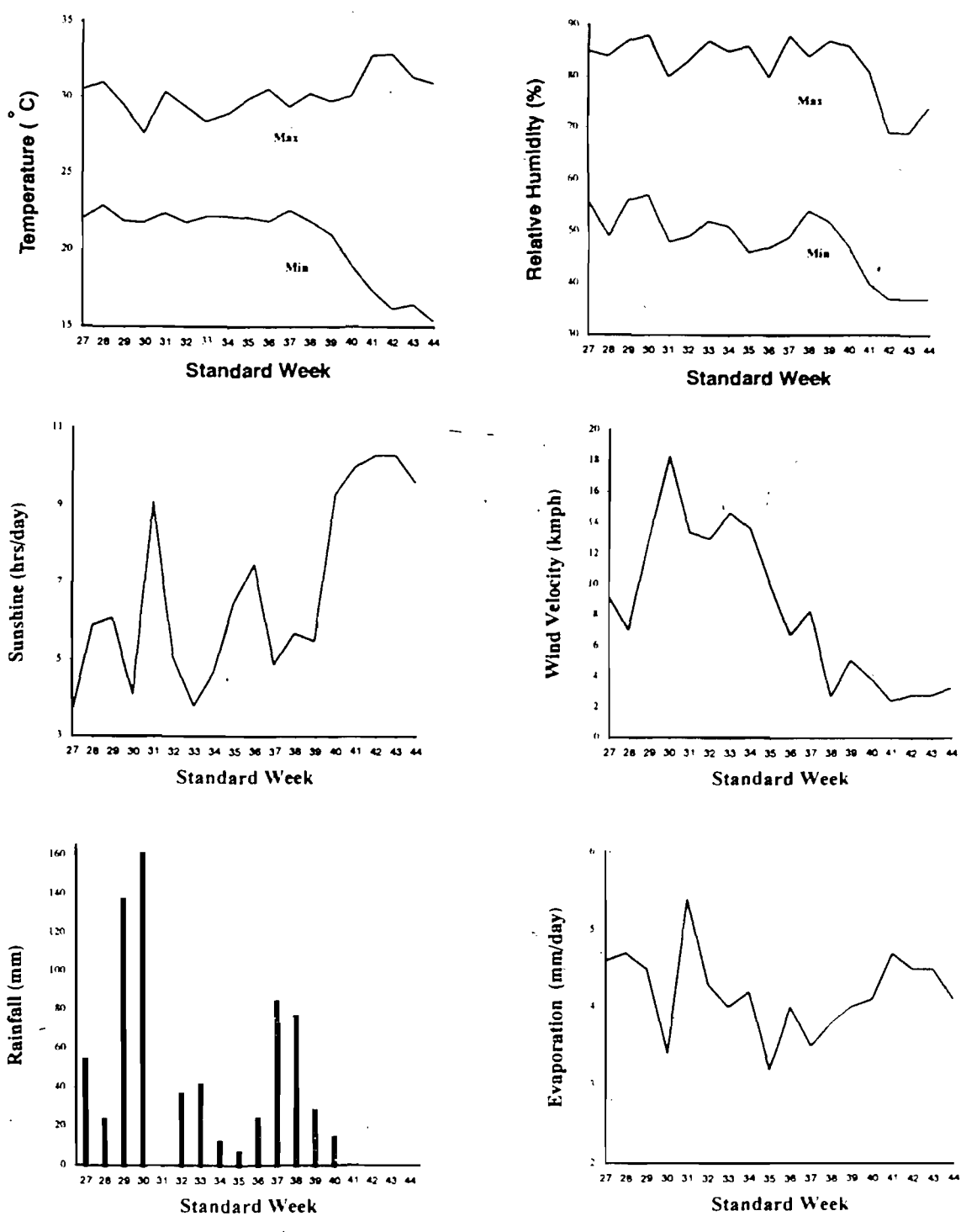


Fig 3 : Meteorological data during the crop growth period (Weekly means) : Kharif 89

average of 8 hours day⁻¹. The weekly mean wind velocity ranged from 2.4 to 10.1 kmph with an average of 4.1 kmph. A total rainfall of 234.4 mm was received in 16 rainy days. The weekly mean evaporation rate (mm day⁻¹) ranged from 2.6 to 5.2 with an average of 3.9

3.2.2 Rabi 1988-89

The weekly mean maximum temperature during crop growth period ranged from 28.7°C to 39.2°C with an average of 34.2°C. The weekly mean minimum temperature ranged from 10.9°C to 26.0°C with an average of 17.5°C. The weekly mean maximum relative humidity ranged from 49 to 83 per cent with an average of 63 per cent, whereas weekly mean minimum relative humidity ranged from 17 to 44 per cent with an average of 27 per cent. The weekly mean sunshine hours ranged from 8.6 to 12.0 with an average of 10.1 hours day⁻¹. The weekly mean wind velocity ranged from 2.7 to 6.9 kmph with an average of 4.4 kmph. A total rainfall of 32 mm was received in 3 rainy days. The weekly mean evaporation rate (mm day⁻¹) ranged from 3.2 to 7.7 with an average of 5.6.

3.2.3 Kharif 1989

The weekly mean maximum temperature during crop growth period ranged from 27.6°C to 32.9°C with an average of 30.2°C. The weekly mean minimum temperature ranged from 15.4°C to 22.9°C with an average of 20.6°C. The weekly mean maximum relative humidity ranged from 69 to 88 per cent with an average of 82 per cent, whereas the weekly mean minimum relative humidity ranged from 37 to 57 per cent with an average of 48 per cent. The

weekly mean sunshine hours ranged from 3.6 to 10.3 with an average of 6.7 hours day⁻¹. The weekly mean wind velocity ranged from 2.4 to 18.3 kmph with an average of 8.3 kmph. A total rainfall of 695.7 mm was received in 34 rainy days. The weekly mean evaporation rate (mm day⁻¹) ranged from 3.2 to 5.4 with an average of 4.2.

3.3 SOIL CHARACTERISTICS

The soil of the experimental site is a member of loamy, mixed, isohyperthermic family of Typic Ustropepts. The soil was developed on weathered granite-gneiss and occur on very gently sloping land. The soil profile description is given below.

Horizon	Depth(cm)	Description
Ap	0-15	Dark brown (10 YR 4/3 D), dark brown (10YR 3/3 M); Sandy clay loam; fine, weak, subangular blocky; hard, firm, sticky and plastic; many, fine roots; strongly effervescent; moderately alkaline (pH 8.1); clear, smooth boundary
Bw	15-45	Dark brown (10 YR 3/3 M); Sandy clay loam; medium, moderate, subangular blocky; firm, sticky and plastic; common, fine roots; strongly effervescent (pH 8.3); clear, wavy boundary
Cr	45+	Weathered parent material

Soil samples drawn at random from the field prior to sowing of each crop were analysed for physical and chemical properties and the data are presented in Table 1a, 1b and 1c.

3.4 EXPERIMENTAL DETAILS

The details of cultivation practices followed during the experimentation are described below and the calendar of operations are given in the Appendix 4. The experiment consists of five treatments arranged in randomised block design and replicated four times. The field was divided into 20 plots and bunds were formed around each plot using bund former and manual labour. The layout plan is given in Fig.4.

3.4.1 Treatments

A. Plant Population Densities

- T₁ : Plant population density of 5,00,000 plants per hectare with a spacing of 20 X 10 cm.
- T₂ : Plant population density of 4,00,000 plants per hectare with a spacing of 25 X 10 cm.
- T₃ : Plant population density of 3,33,333 plants per hectare with a spacing of 30 X 10 cm.
- T₄ : Plant population density of 2,50,000 plants per hectare with a spacing of 40 X 10 cm.
- T₅ : No Crop.

Table 1a : Physical, Physico-chemical and hydrological properties of the experimental site (Kharif 88)

Properties	Depth (cm)		
	0 - 15	15 - 30	30 - 45
A. Physical Properties			
1. Gravel (%)	10.0	24.0	36.0
Sand (%)	60.6	59.5	60.2
Silt (%)	13.5	9.5	5.5
Clay (%)	25.9	31.0	34.3
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam
2. Bulk density (g cm^{-3})	1.58	1.60	1.69
3. Hydraulic conductivity (cm hr^{-1})	5.40	3.82	3.60
4. Total porosity (%)	43.25	39.00	30.50
5. Aggregate Analysis			
i. Aggregates greater than 0.25 mm	44.00	43.00	36.55
ii. Mean weight diameter (mm)	1.63	1.53	1.50
iii. Stability index (%)	20.00	18.90	19.20
iv. Structural coefficient (%)	44.00	41.20	38.20
B. Physico-Chemical properties			
1. pH	8.1	8.3	8.2
2. EC (dS m^{-1})	0.13	0.20	0.22
3. CEC ($\text{cmol (p}^+) \text{ kg}^{-1}$)	34.5	37.6	40.4
4. CaCO_3 (%)	7.4	6.6	6.1
C. Hydrological properties			
1. Field capacity (%)	15.8	16.7	17.0
2. Wilting point (%)	7.9	8.7	9.0
3. Available moisture (%)	7.9	8.0	8.0

ble 1b : Physical, Physico-chemical and hydrological properties of the experimental site (Rabi 88)

Properties	Depth (cm)		
	0 - 15	15 - 30	30 - 45
Physical Properties			
1. Gravel (%)	12.0	22.5	34.0
Sand (%)	61.5	59.0	61.0
Silt (%)	14.0	10.2	6.0
Clay (%)	24.5	30.8	33.0
Textural class	Sandy clay-loam	Sandy clay loam	Sandy clay loam
2. Bulk density (g cm^{-3})	1.60	1.62	1.67
3. Hydraulic conductivity (cm hr^{-1})	5.40	3.83	2.75
4. Total porosity (%)	43.50	39.00	32.00
5. Aggregate Analysis			
i. Aggregates greater than 0.25 mm	45.50	41.55	34.00
ii. Mean weight diameter (mm)	1.60	1.49	1.40
iii. Stability index (%)	19.00	18.95	17.50
iv. Structural coefficient (%)	44.00	41.25	39.00
Physico-Chemical properties			
1. pH	8.0	8.2	8.2
2. EC (dS m^{-1})	0.14	0.21	0.24
3. CEC ($\text{cmol (p}^+) \text{ kg}^{-1}$)	39.4	40.6	42.8
4. CaCO_3 (%)	7.2	6.4	6.0
Hydrological properties			
1. Field capacity (%)	15.6	16.5	17.5
2. Wilting point (%)	7.7	8.7	9.2
3. Available moisture (%)	7.9	7.8	8.3

Table 1c : Physical, Physico-chemical and hydrological properties of the experimental site (Kharif 89)

Properties	Depth (cm)		
	0 - 15	15 - 30	30 - 45
A. Physical Properties			
1. Gravel (%)	9.0	25.0	33.0
Sand (%)	61.0	61.2	60.4
Silt (%)	14.4	9.9	5.8
Clay (%)	24.6	28.9	33.8
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam
2. Bulk density (g cm^{-3})	1.57	1.60	1.67
3. Hydraulic conductivity (cm hr^{-1})	5.90	4.18	3.57
4. Total porosity (%)	44.00	39.70	33.52
5. Aggregate Analysis			
i. Aggregates greater than 0.25 mm	47.00	42.55	36.80
ii. Mean weight diameter (mm)	1.70	1.56	1.51
iii. Stability index (%)	21.00	20.10	20.10
iv. Structural coefficient (%)	45.00	42.10	39.30
B. Physico-Chemical properties			
1. pH	8.1	8.2	8.2
2. EC (dS m^{-1})	0.12	0.18	0.20
3. CEC ($\text{cmol (p}^+) \text{ kg}^{-1}$)	33.2	36.4	38.5
4. CaCO_3 (%)	7.0	6.5	6.1
C. Hydrological properties			
1. Field capacity (%)	15.5	16.8	17.2
2. Wilting point (%)	7.7	8.5	9.0
3. Available moisture (%)	7.8	8.3	8.2

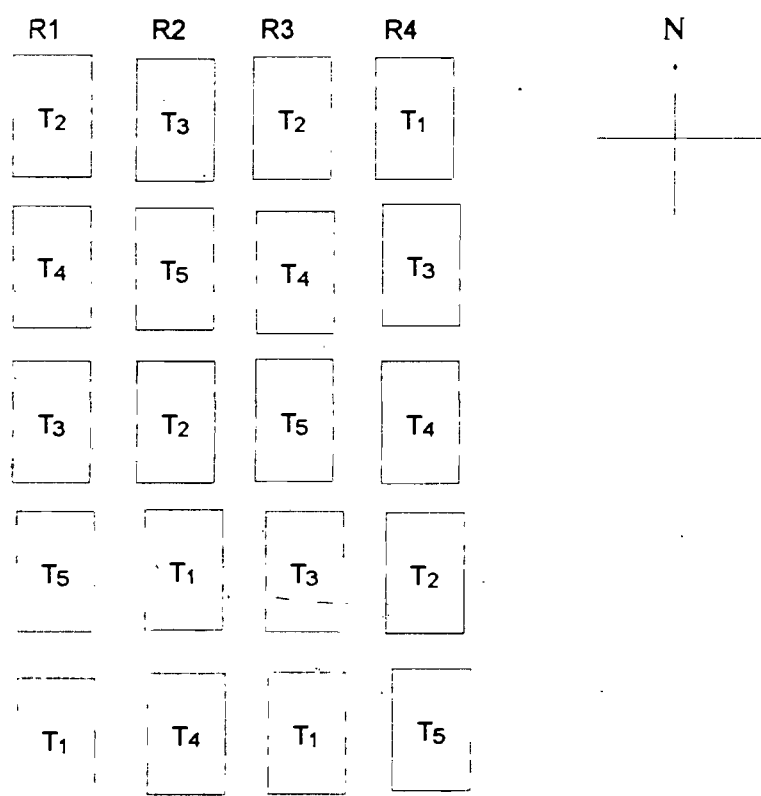


Fig. 4 Lay out plan of the experiment

Treatments:

- T₁ : Plant population density of 5,00,000 plants per hectare with a spacing of 20 x 10 cm
- T₂ : Plant population density of 4,00,000 plants per hectare with a spacing of 25 x 10 cm
- T₃ : Plant population density of 3,33,333 plants per hectare with a spacing of 30 x 10 cm
- T₄ : Plant population density of 2,50,000 plants per hectare with a spacing of 40 x 10 cm
- T₅ : No crop
- Replications : Four
- Gross plot size : 4.5 x 3.5 m
- Net plot size : 4 x 3 m
- Crop : Groundnut
- Variety : JL. 24

B. Open Can evaporimeters of 500 ml capacity covered with 6/20 mesh were installed in each plot.

3.4.2 Crop and variety

Groundnut (JL 24) was used in the study.

3.5 DETAILS OF FIELD OPERATIONS

Various field operations carried out prior to and during experimentation are detailed in Appendix 4.

3.5.1 Preparatory Tillage

The experimental field was prepared thoroughly by working with tractor drawn disc plough followed by disc harrow and levelling. Bunds were raised around each plot and were compacted in order to confine the irrigation water within the plot. The plots (4 x 3 m) were levelled within properly for uniform spread of irrigation water.

3.5.2 Fertilizer application

Fertilizers were applied to supply 20,80 and 40 Kg of N, P₂O₅ and K₂O ha⁻¹ through urea, superphosphate and muriate of potash respectively. Half the dose of N and entire quantities of P and K fertilizers were applied as basal at the time of sowing and the remaining half of N was applied 40 days after sowing. Gypsum was applied @ 500 kg ha⁻¹ at the time of sowing. The fertilizers were applied by placement method 5 cm away from seed row at a depth of 5 cm.

3.5.3 Seeds and Sowing

Bold and healthy pods were selected for seed purpose. After shelling, bold kernels were selected and treated with Dithane M-45 at a rate of 3g kg⁻¹ of seed to control seed borne diseases. The seeds were hand dibbled in

the soil at a depth of 5 cm keeping the spacings of 20 x 10 cm, 25 X 10 cm, 30 x 10 cm and 40 x 10 cm. The seeds sown were covered with soil immediately by manual labour. Gap filling was done eight days after sowing to maintain the required plant stand in all the treatments specified above.

3.5.4 Irrigation

In Kharif 1988, a total rainfall of 144.6 mm was received from the date of sowing to 26 days after sowing. Subsequently irrigations were scheduled at 15 days interval considering soil moisture depletion from 0-45 cm soil depth in each treatment. During Rabi, 1988 irrigation was given immediately after sowing to all the treatments (5 cm) to ensure good germination. Another common irrigation of 5 cm depth was given on 8th day after sowing for crop establishment and to facilitate gap filled seeds to germinate. A total rainfall of 32 mm received during this season. During Kharif, 1989 no irrigation was given to the crop as the rainfall (695.7 mm) was high and as there was no moisture stress during the crop growth period. Measured quantity of water was applied at each of irrigation by using pigmy water current meter. The quantity of water applied at each irrigation was calculated by using the formula:

$$(i) \text{ Depth of water(cm)} = \frac{\text{moisture depleted X depth of soil (45 cm) to be brought to F.C. X B.D. (g/cc)}}{100}$$

$$(ii) \text{ Total quantity of water(m}^3\text{)} = \text{Plot size(m}^2\text{) X depth of water(m)}$$

3.5.5 Interculture and plant protection operations

Hand weeding was done twice after sowing. As a prophylactic measure, endosulfan (0.07%) was sprayed at the rate of 2ml/litre at 50 days after sowing to control sucking pests.

3.5.6 Harvesting

The crop was considered mature when more than 70 per cent of the pods of randomly selected plants showed dark streaks inside the shell. The plants in the net plots were harvested and stripped.

3.6 EXPERIMENTAL OBSERVATIONS RECORDED

For recording the observations, five plants were selected from 3rd row of each plot and labelled.

3.6.1 Studies on root and shoot growth

Five plants were excavated very carefully by digging around the plant and the depth of vertical and lateral root penetration were recorded in each treatment. The plant roots were cleaned with water by placing the roots in 0.1 mm sieve and then the shoot was separated from the root. The plant samples were dried in oven at 75°C for two days and the dry weight of the shoot and root were taken separately. Plant samples collected at 30, 60 days after sowing and at harvest were used for estimating the dry weights of roots and shoots.

3.6.2 Pod Yield

Pods from the net plot area were sun dried till a constant weight was obtained. The pod yields were recorded and expressed in kg ha^{-1} .

3.6.3 Haulm Yield

Haulm yield obtained from the net plot area was sun dried to constant weight and the weight was expressed in kg ha^{-1} .

3.7 COMPUTATION OF EVAPOTRANSPIRATION

The following four formulae were used for computing evapotranspiration.

3.7.1 Modified Penman Method

This is the most widely used method basically proposed by Penman (1948) and slightly modified by Doorenbos and Pruitt (1977) and was used for estimating the reference crop (grass) evapotranspiration. This method accounts well the aerodynamic and thermodynamic properties of the atmosphere. The climatic data required are (i) mean temperature (T in $^{\circ}\text{C}$) (ii) mean relative humidity (RH in per cent) (iii) Total wind run (U in km day^{-1} at 2 m height from ground level). Reference crop evapotranspiration was calculated as per the procedure outlined by Doorenbos and Pruitt (1977) in mm day^{-1} as

$$ET_0 = C[W \times R_n + (1-W) \times f(U) \times (e_a - e_d)]$$

where

$$ET_0 = \text{Reference crop evapotranspiration, mm day}^{-1}$$

$$W = \text{Temperature and elevation related weighting factor}$$

$$R_n = \text{Net radiation} = R_{ns} - R_{nl}$$

$$R_{ns} = \text{The net incoming short wave solar radiation}$$

$$R_{ns} = R_s (1 - \alpha)$$

$$R_s = (0.25 + 0.5 n/N) R_a$$

$$R_a = \text{Extraterrestrial radiation expressed in equivalent evaporation in mm day}^{-1}$$

$$\alpha = \text{Reflection coefficient of evaporating surface (0.25)}$$

$$R_{nl} = \text{The net long wave radiation}$$

$$R_{nl} = f(t) \cdot f(e_d) \cdot f(n/N)$$

$$n/N = \text{Ratio between actual and possible hours of bright sunshine}$$

- $f(t)$ = Function of temperature
 $f(ed)$ = Function of actual vapour pressure
 $f(n/N)$ = Function of sunshine duration
 ea = Saturation vapour pressure in millibars at the mean air temperature °C.
 ed = Mean actual vapour pressure of the air in millibars.
 ed = $ea \cdot \frac{RH \text{ Mean}}{100}$
 RH = Relative humidity
 $f(U)$ = Wind related function.
 $f(U)$ = $0.27 \left(1 + \frac{U}{100} \right)$
 U = 24 hour wind run in Kilometers per day at 2 m height.
 $1-W$ = A temperature and elevation related weighing factor.
 C = Adjustment factor to compensate for the effect of day and night weather conditions. The Penman equation assumes medium to high solar radiation, maximum relative humidity and a moderate day time wind with about twice the velocity of the night time wind.

The empirical input data which was not actually measured was read directly from the tables given in FAO-24 (Doorenbos and Pruitt, 1977).

3.7.2 Radiation Method

The climatic data required in the radiation method are mean temperature (T in °C) and mean sunshine hours (n in hd^{-1}). Estimated value of mean

relative humidity (RH in per cent) and mean day time wind speed (U day in m sec⁻¹ at 2 m height) are also needed.

Reference crop evapotranspiration in mm d⁻¹ was calculated by the following formula (Doorenbos and Pruitt, 1977).

$$ET_0 = C(W \cdot R_s)$$

where

$$ET_0 = \text{Evapotranspiration, mm day}^{-1}$$

$$C = \text{Adjustment factor for mean humidity and day time wind conditions.}$$

$$W = \text{Temperature related weighing factor}$$

$$R_s = \text{The average daily solar radiation}$$

$$= (0.25 + 0.5 n/N) R_a$$

$$R_a = \text{Extraterrestrial radiation expressed in equivalent evaporation in mm day}^{-1}$$

$$n/N = \text{Ratio between actual and possible hours of bright sunshine.}$$

3.7.3 Blaney - Criddle Formula

The original Blaney-criddle equation developed in 1950 involves the calculation of consumptive use factor (f) from mean temperature (T) and percentage (P) of total annual day light hours occurring during the period being considered. An empirically determined consumptive use crop coefficient (k) is then applied to establish the consumptive water requirement (cu) or $cu = k \cdot f = k(P \cdot T / 100)$ with T in °F. The effect of climate on crop water requirement is,

however, insufficiently defined by temperature and day length. Crop water requirement will vary widely between climates having similar values of T and P. Consequently the consumptive use crop coefficient (k) will need to vary not only with the crop but also with climatic conditions.

$$ET_0 = C [p (0.46 T + 8.1)]$$

where

ET_0 = Reference crop Evapotranspiration, mm day⁻¹

T = Mean daily temperature in °C.

p = Mean daily percentage of total annual day time hours, obtained for a given month and latitude (FAO - 24)

C = Adjustment factor, which depends upon minimum relative humidity, sunshine hours and day time wind estimates (FAO - 24)

3.7.4 Hargreaves formula

Hargreaves (1985) presented a method for determining ET_0 which requires only maximum and minimum temperature data. The equation was derived using the Hargreaves radiation equation and empirically developed relationships for solar radiation as a function of extra-terrestrial solar radiation as well as maximum and minimum temperature differences. The equation is

$$ET_0 = 0.0022 R_a (TD)^{0.5} (17.8 + T^{\circ}C)$$

ET_0 = Reference crop evapotranspiration, mm day⁻¹

TD = Temperature difference

$$= (T_{\max} - T_{\min})^{\circ}C$$

$$T = \text{Mean Temperature} = \frac{(T_{\text{max}} + T_{\text{min}})^{\circ}\text{C}}{2}$$

Ra = Extra - terrestrial radiation in equivalent evaporation in mm day⁻¹ which is a function of latitude and time of a year (FAO - 24)

3.7.5 Pan Evaporation Method

Because of simplicity, evaporation pans are widely used. The most common type is U.S.W.B. Class A pan. Evaporation from a Pan (Epan) represents the power of the atmosphere to extract water from the pan. Despite major differences in the energy balance and aerodynamics of pan and vegetative surfaces, strong correlations have been usually found between pan evaporation and reference crop evapotranspiration. This enforced their continued usage over the years (Doorenbos and Pruitt, 1977).

3.8 CAN EVAPORATION

Well cleaned 500 ml capacity small cans, having inner diameter 10.2 cm and depth of 11 cm were used. A pointer of 9.0 cm long was bent from the tip at right angle at a distance of one cm from the tip and was attached to the rim of the Can leaving the tip 1.5 cm below the rim. Screen of desired mesh size (6/20) was fitted as a lid to the Can evaporimeter. A set of two Cans (open and 6/20 mesh) were placed in each treatment. Can heights were adjusted by erecting a brick structure commensurate with crop height.

Evaporation readings were taken daily. At the start of the experiment, water level in each Can evaporimeter was adjusted to the tip of the pointer. On the day evaporation was recorded, water was added to bring the water level to the original level and the volume (ml) was converted into depth (mm) of water.

3.9 SOIL MOISTURE STUDIES

Soil moisture was worked out by taking the soil samples from 0- 15, 15-30 and 30-45 cm depths at weekly intervals from each treatment during the crop growth period. Tube auger was used for collecting soil samples from different depths. The total moisture depleted (cm) from the root zone depth (0-45 cm) was calculated using the following equation. Percent moisture depleted was converted into depth of soil water.

$$d_i = (F_{c_i} - P_{w_i}) \cdot p_{b_i} \cdot D_i$$

where

d_i = depth of water depleted from the 'i'th soil layer (cm)

f_{c_i} = field capacity of the soil of the 'i'th layer (per cent)

p_{w_i} = per cent of water present in the 'i'th layer of the soil at the time of sampling.

p_{b_i} = bulk density of the soil of the 'i'th layer (g/cm^3)

D_i = depth of 'i'th layer of the soil (cm) i.e., 0-15, 15-30 and 30-45 cm from which moisture was determined (cm).

After this total moisture depleted (SMD_t) from the root zone depth (0-45 cm) was calculated using the expression

$$SMD_t = SMD_1 + SMD_2 + SMD_3$$

where

SMD_t = Soil moisture depleted from 0-45 cm

SMD_1 = Soil moisture depleted from 0-15 cm

SMD_2 = Soil moisture depleted from 15-30 cm

SMD₃ = Soil moisture depleted from 30-45 cm

3.9.1 Cumulative Crop Evapotranspiration

The soil moisture depletion method was employed to determine the evapotranspiration (ET) of crop. The soil was levelled and the ground water table was very deep and as a result it did not influence the soil moisture fluctuations within the root zone. The study involved measurement of soil moisture from three depths, 0- 15, 15-30 and 30-45 cm, just before and one day after each irrigation. Such soil moisture measurement data facilitated the estimation of crop evapotranspiration by the following relationship (Michael *et al.*, 1977).

$$\text{Crop ET} = \sum_{i=1}^n \frac{(M1_i - M2_i)}{100} \cdot A_i + D_i$$

where

ET = Crop Evapotranspiration from the effective root zone depth within one irrigation cycle in cm

n = number of irrigation cycles during the crop life period

M1_i = Soil moisture percentage by weight 24 hours after 'n' th irrigation

M2_i = Soil moisture percentage by weight just before 'n'th irrigation in the ith layer

A_i = Apparent specific gravity or bulk density of ith layer

D_i = Depth of ith layer of the soil (cm) i.e., 0-15, 15-30 and 30-45 cm

= represents summation

Seasonal consumptive use was calculated by summing up the consumptive values.

3.9.2 Daily Evapotranspiration Rate (mm day^{-1})

Daily evapotranspiration rate was calculated based on the moisture use of the crop between the irrigations.

$$\text{Daily ET rate} = \frac{u}{n}$$

where

u = ET during irrigation interval (mm)

n = Number of days of the irrigation interval

The following stages and duration were considered for groundnut crop under the agroclimatic conditions of Hyderabad for the evapotranspiration studies (Table 2). Either numerically denoted stage/actual stage or duration was used in the subsequent chapter wherever it was appropriate.

Table 2 : Groundnut crop growth stages and their duration.

Stage	Phenological Stage	Stage as per FAO,33	Duration DAS
I.	Establishment	Initial	0-15
II.	Vegetative and Flowering	Crop development	16-35
III.	Maximum flowering, pegging and beginning of pod initiation	Mid season	36-65
IV.	Pod initiation to pod development	Late season	66-95
V.	Pod development to Maturity	Harvest	96-116

3.9.3 Crop Coefficients

Doorenbos and Pruitt (1977) defined crop coefficient (K_c) as ratio between crop evapotranspiration (ET_a) and the reference crop evapotranspiration (ET_o) when crop is grown in large fields under optimum conditions. The actual evapotranspiration (ET_a) was estimated gravimetrically by soil sampling while the ET_o was estimated by Modified Penman method. Thus, the K_c values were calculated as follows

$$K_c = \frac{ET_a}{ET_o}$$

Similarly, the K_c based on the ET_o estimated by different methods besides Penman method were also worked out.

3.9.4 Water Use Efficiency

The crop water use efficiency was computed for different plant population densities of groundnut based on the cumulative evapotranspiration of the crop in the season.

Crop water use efficiency in $Kg\ ha^{-1}\ mm$ of water was calculated using the following equation.

$$WUE = \frac{Y}{ET}$$

Where

WUE = Crop water use efficiency

Y = Yield in $Kg\ ha^{-1}$

ET = Cumulative evapotranspiration during the crop growth period (mm).

4.0 ECONOMICS

4.0.1 Gross returns (Rs. ha⁻¹)

Monetary value of the produce from each treatments was obtained considering the prevailing market price of groundnut

4.0.2 Net returns (Rs. ha⁻¹)

Value of produce - cost of production (Rs. ha⁻¹)

4.0.3 Benefit - cost ratio (Rs./Rupee investment)

$$\frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of production (Rs. ha}^{-1}\text{)}}$$

4.1 SOIL PHYSICAL PARAMETERS

Before commencing preparatory cultivation, soil samples were collected from the experimental plots from 0-15, 15-30 and 30-45 cm depths and were used for the determination of physical properties, pH, EC and O.C.

Core soil samples were collected at the time of sowing and harvest of the crop, in each treatment from 0-15, 15-30 and 30-45 cm depths, per cent aggregates greater than 0.2 mm (Degree of aggregation), mean weight diameter, stability index and structural coefficient were estimated as per the procedures given below.

4.1.1 Bulk density

The bulk density of the soil was determined using core sampler as per the procedure given by Dakshinamurthi and Gupta (1967). Undisturbed core samples were collected with 5 cm height and 5 cm diameter brass rings by mechanically pushing the core sampler. The cores were taken in duplicate. The core sampler was driven into the soil ensuring no compaction of soil. Oven

dry weight of the sample was then determined. The bulk density of the soil was calculated by using the formula:

$$\text{Bulk density} = \frac{\text{Weight of oven dry soil}}{\text{Volume of core used}}$$

4.1.2 Hydraulic Conductivity

Undisturbed soil core samples for hydraulic conductivity were collected by using 5 cm diameter and 15 cm length brass rings. Constant head method was followed as per the procedure outlined by Black *et al.*, 1973.

4.1.3 Total Porosity

Total porosity was determined as per the procedure given by Dakshinamurti and Gupta (1967).

4.1.4 Aggregate analysis

Undisturbed soil core samples collected at the time of harvest stage of the crop were used for the estimation of degree of aggregation and mean weight diameter as per the procedure of Yoder (1937). Stability index and structural coefficient were determined as per the procedure given by Dakshinamurti and Gupta (1967). The following equations were used for the computation:

$$\text{i) Degree of Aggregation} = \frac{\text{Weight of the aggregates greater than 0.20 mm}}{\text{Weight of the soil sample taken}} \times 100$$

$$\text{ii) M.W.D} = \text{Mean Weight Diameter (mm)}$$

$$\text{M.W.D} = \frac{\sum_{i=1}^n \bar{x}_i w_i}{\sum_{i=1}^n w_i}$$

where

$$\bar{x}_i = \text{Mean diameter of each size fraction}$$

w_i = Proportion of the total sample occurring in the corresponding size fraction

n = Number of size fractions

iii) Stability index = $D - S$

iv) Structural Coefficient = $\frac{D - S}{D} \times 100$

where

D = Amount of silt and clay after complete soil dispersion (mechanical analysis)

S = Amount of silt and clay after simple water dispersion.

4.1.5 Particle size distribution

Particle size distribution (Mechanical composition) of the soil was determined by the Bouyoucos hydrometer method as described by Bouyoucos (1962). Based on particle size distribution, textural classification was done using textural diagram of U.S.D.A. Hand Book 60.

4.2 SOIL CHEMICAL ANALYSIS

4.2.1 Soil Reaction (pH)

The pH of the soil was estimated in 1 : 2.5 soil water suspension using a systronix pH meter (model 335) as per procedure described by Jackson (1967).

4.2.2 Electrical Conductivity (EC)

The electrical conductivity was measured in a 1 : 2.5 soil water suspension using an electrical conductivity meter (Elico Model EM 88) as per the method given by Richards *et al.*, (1954).

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4.2.3 Organic Carbon

Organic Carbon content of the soil was estimated by Walkley and Black rapid wet digestion method (1934) as described by Piper (1950).

4.3 STATISTICAL ANALYSIS

Data were analysed through analysis of variance as suggested by Snedecor and Cochran (1967). Statistical significance was tested by F test at 0.05 level of probability. Critical differences were worked out for testing the significance. Simple correlation and regression were worked out between different attributing characters using the formulae given by Snedecor and Cochran (1967).

RESULTS

CHAPTER IV

RESULTS

Results obtained and data collected from the field experiment entitled "Effect of different plant population densities on evapotranspiration, soil structure and yield of groundnut (*Arachis hypogaea* L.) " during kharif 1988, rabi 1988 and kharif 1989 are furnished in this chapter through Tables and elaborated through figures wherever necessary.

4.1 WATER USE STUDIES (ET)

4.1.1 Evapotranspiration

Data pertaining to stage wise and cumulative ET (estimated by soil moisture depletion) of groundnut crop, as influenced by different plant population densities, are given in Table 3 and illustrated in Fig. 5.

Perusal of data indicate that the amount of water evapotranspired was relatively less at initial stages of crop growth (2.84 to 3.28 cm during kharif 88; 2.75 to 3.31 cm during rabi 88; and 2.34 to 3.12 cm during kharif 89) and increasing with advancement of crop age and reached a peak (15.54 to 19.75 cm during kharif 88, 16.49 to 20.94 cm during rabi 88 and 15.50 to 17.09 cm during kharif 89) between 36-65 DAS (3rd stage, maximal flowering to pod initiation). Thereafter, the consumptive use was reduced gradually between 66-95 DAS (4th stage, pod development) with a sudden drop (5.56 to 6.91 cm during kharif 88, 8.41 to 8.96 cm during rabi 88 and 5.30 to 6.78 cm during kharif 89) between 96 to 116 DAS (fifth stage, end of pod development and maturity).

Successive increments of plant population increased the consumptive use at all the stages of crop growth and during all the seasons.

Table 3 : Crop and reference evapotranspiration (cm) at different growth stages as influenced by different plant population densities of groundnut

Treatments	S ₁ (0-15 DAS)			S ₂ (16-35) DAS			S ₃ (36-65 DAS)			S ₄ (68-95 DAS)			S ₅ (96-116 DAS)			Seasonal			
	Kharif	Rabi	88	Kharif	Rabi	88	Kharif	Rabi	88	Kharif	Rabi	88	Kharif	Rabi	88	Kharif	Rabi	88	
	88	88	89	88	88	89	88	88	89	88	88	89	88	88	89	88	88	89	
T ₁	3.28	3.31	3.12	6.66	7.71	6.56	19.75	20.94	17.09	18.00	18.18	15.55	6.91	8.96	6.78	54.6	59.1	49.1	
T ₂	2.96	3.18	3.04	6.15	7.39	6.00	17.80	19.08	16.50	18.30	18.43	15.50	6.89	8.92	5.76	52.1	58.0	46.8	
T ₃	2.95	3.00	2.35	5.98	7.00	5.10	16.96	18.00	15.64	17.45	17.50	14.58	5.96	8.50	5.33	49.3	54.0	43.0	
T ₄	2.84	2.75	2.34	5.92	5.95	4.91	15.54	16.49	15.50	16.34	16.20	13.95	5.56	8.41	5.30	46.2	50.8	42.0	
S.E.D. _±	0.04	0.06	0.04	0.10	0.07	0.08	0.12	0.17	0.15	0.08	0.10	0.03	0.04	0.03	0.05	0.65	1.23	0.45	
C.D.(0.05)	0.09	0.14	0.08	0.23	0.16	0.18	0.28	0.39	0.33	0.19	0.22	0.07	0.09	0.06	0.11	1.48	2.79	1.02	
Reference ET by																			
Modified Penman	5.18	9.32	6.34	6.62	12.73	10.59	14.52	19.56	15.40	15.76	19.36	15.00	9.44	14.66	12.48	51.52	75.63	59.81	
Blaney-Criddle	7.02	7.75	7.02	8.95	10.21	9.41	15.53	15.74	14.30	15.10	16.32	15.94	10.89	11.40	11.40	57.49	61.42	58.11	
Hargreaves	3.49	3.99	4.53	3.97	8.24	6.05	9.89	13.16	13.69	9.30	12.78	12.79	3.00	8.81	12.16	29.65	46.98	49.22	
Radiation	7.58	11.72	6.11	9.72	16.65	8.91	21.63	23.35	13.23	22.43	22.06	17.87	14.27	13.26	17.58	68.05	87.04	63.70	
Pan evaporation	4.17	5.01	6.06	7.63	8.61	8.28	14.43	21.97	11.33	12.02	20.51	11.10	6.01	11.50	9.74	44.26	67.60	46.51	

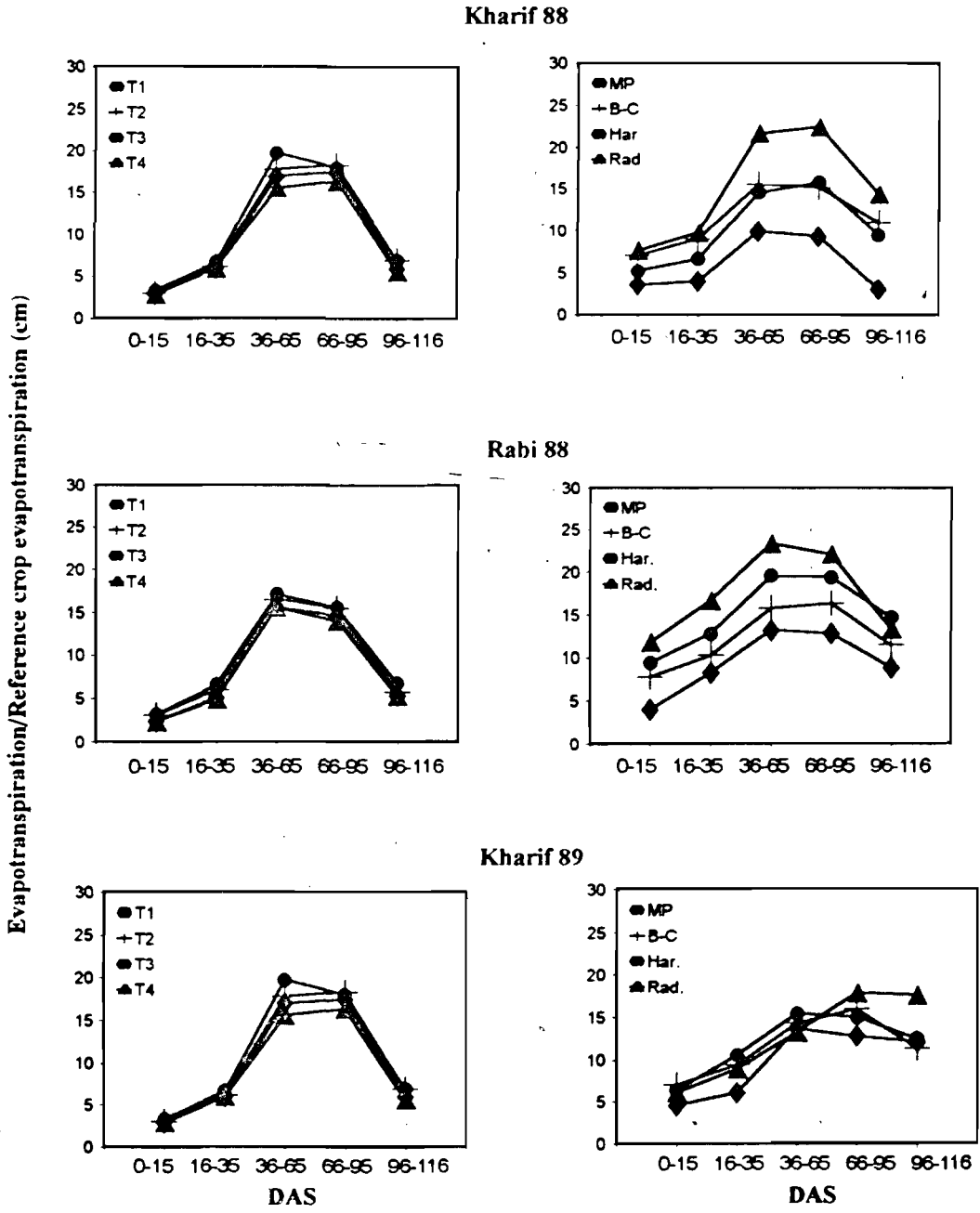


Fig. 5 : Evapotranspiration (cm) as influenced by different plant population densities and reference crop ET by different empirical methods at different growth stages of groundnut

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Amount of water evapotranspired (seasonal ET) was highest (54.6, 59.1 and 49.1 cm) during kharif 88, rabi 88 and kharif 89 respectively) with the plant population density of 5.0 lakh plants ha⁻¹ (T₁). On the other hand, it was the lowest (46.2, 50.8 and 42.0 cm during kharif 88, rabi 88 and kharif 89 respectively) with the population density of 2.5 lakh plants ha⁻¹ (T₄). The reduction in seasonal ET was 4.58, 9.71 and 15.38 per cent with population density of 4.00, 3.33 and 2.5 lakhs ha⁻¹ as compared to 5 lakhs ha⁻¹ during kharif 88. The corresponding reduction in ET values were 1.86, 8.63 and 14.04 per cent for rabi 88 and 4.68, 12.42 and 14.46 per cent for kharif 89. The seasonal crop ET was more during rabi 88 compared to kharif 88 and kharif 89.

The reference crop evapotranspiration, calculated at different growth phases by Modified Penman, Blaney-Criddle, Hargreaves, Radiation and Pan evaporation methods showed similar trends as that of actual evapotranspiration estimated by soil moisture depletion. Highest values were obtained with Radiation method in all the three seasons followed by Modified Penman method. The lowest reference crop evapotranspiration values were observed with Hargreaves method during kharif 88 and rabi 88, whereas during kharif 89, Pan evaporation method recorded the lowest.

4.1.2 Crop coefficients (K_c)

Crop coefficients of groundnut under 5.0 lakh plants ha⁻¹ calculated on the basis of Modified Penman method are presented in table 4 and illustrated in fig. 6

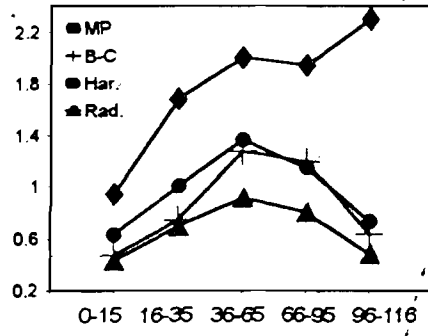
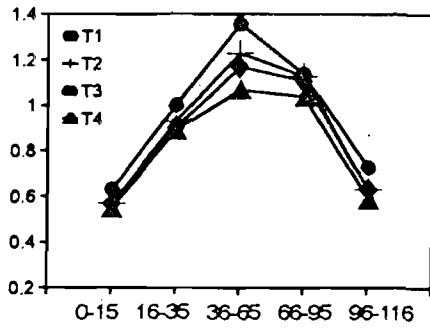
These data indicate that K_c values of groundnut, in general, were low during the initial crop growth period (S₁). With advancement of crop age,

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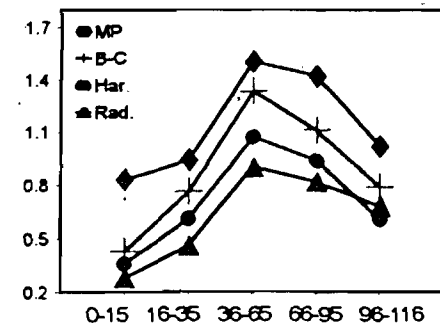
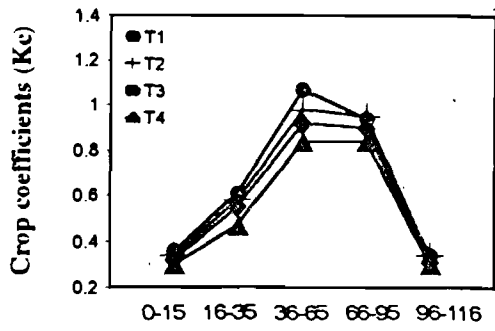
Table 4: Crop coefficients (K_c) for groundnut at specific growth stages as influenced by different plant population densities

Treatments	S ₁ (0-15 DAS)			S ₂ (16-35 DAS)			S ₃ (36-65 DAS)			S ₄ (66-95 DAS)			S ₅ (96-110 DAS)			Seasonal		
	Kharif 88	Rabi 88	Kharif 89	Kharif 88	Rabi 88	Kharif 89	Rabi 88	Kharif 88	Rabi 88	Kharif 89	Rabi 88	Kharif 88	Rabi 88	Kharif 89	Rabi 88	Kharif 88	Rabi 88	Kharif 89
T ₁	0.63	0.36	0.49	1.00	0.61	0.62	1.36	1.07	1.11	1.14	0.94	1.04	0.73	0.34	0.54	1.06	0.78	0.82
T ₂	0.57	0.34	0.48	0.93	0.58	0.57	1.23	0.98	1.07	1.16	0.95	1.03	0.63	0.34	0.46	1.01	0.77	0.78
T ₃	0.57	0.32	0.37	0.90	0.55	0.48	1.17	0.92	1.02	1.11	0.90	0.97	0.63	0.31	0.43	0.96	0.71	0.72
T ₄	0.55	0.30	0.36	0.89	0.47	0.46	1.07	0.84	1.01	1.04	0.84	0.93	0.59	0.30	0.43	0.90	0.67	0.70
Reference ET by																		
Modified Penman	0.63	0.36	0.49	1.00	0.61	0.62	1.36	1.07	1.11	1.14	0.94	1.04	0.73	0.61	0.54	1.06	0.78	0.82
Blaney-criddle	0.47	0.43	0.44	0.74	0.76	0.70	1.27	1.33	1.20	1.19	1.11	0.98	0.63	0.79	0.59	0.95	0.96	0.85
Hargreaves	0.94	0.83	0.69	1.68	0.94	1.08	2.00	1.50	1.25	1.94	1.42	1.22	2.30	1.02	0.56	1.84	1.26	1.00
Radiation	0.43	0.28	0.51	0.69	0.46	0.74	0.91	0.90	1.29	0.80	0.82	0.87	0.48	0.68	0.38	0.68	0.68	0.77
Pan evaporation	0.79	0.66	0.52	0.87	0.90	0.79	1.37	0.95	1.51	1.50	0.89	1.40	1.15	0.78	0.70	1.23	0.87	1.06

Kharif 88



Rabi 88



Kharif 89

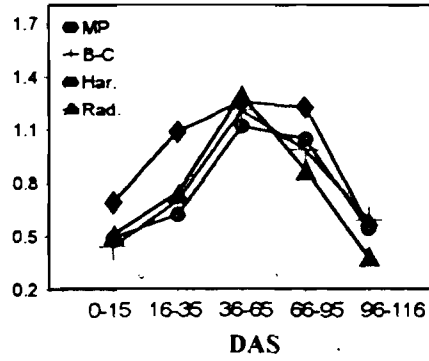
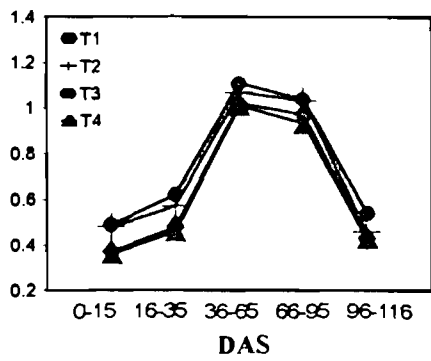


Fig. 6 : Crop coefficients (Kc) for groundnut at specific growth stages as influenced by different plant population densities

coefficients increased gradually upto vegetative stage (16-35 DAS) and then suddenly increased during maximum flowering to pod initiation stage (36-65 DAS). The coefficients decreased during pod initiation to pod development period (66-95 DAS) with a steep fall at the final stage (96-116 DAS) of crop growth. In general, highest K_c values were observed in the crop with a plant population density of 5.0 lakh plants ha^{-1} (T₁) as compared to lower plant densities.

Similar trend was observed at different growth stages of the crop, when K_c values were calculated on the basis of Blaney- Criddle, Hargreaves, Radiation and Pan evaporation methods for 5.0 lakh population. K_c values determined by Hargreaves and Pan evaporation method were relatively higher as compared to those of Blaney-Criddle method followed by Modified Penman method. Radiation method under estimated the K_c values.

4.1.3 Can evaporation

Can evaporation data collected from Can evaporimeters placed in all the treatments are given in table 5a, 5b and 5c and illustrated in fig. 7.

The data indicate that the amount of water evaporated from open Cans was relatively less at initial stages of crop growth (6.83, 11.36 and 5.37 cm during kharif 88, rabi 88 and kharif 89 respectively) and showed an increasing trend with advancement of crop age and reached a peak (17.82 to 25.87 cm during kharif 88 and 18.05 to 19.58 cm during kharif 89) between 36 and 65 DAS (3rd stage, maximal flowering to pod initiation) and 25.19 to 30.15 cm during rabi 88 between 66 and 95 DAS (4th stage, pod development) with a drop (9.93 to 12.57 cm during kharif 88, 15.83 to 26.22 cm during rabi 88 and

Table 5a: Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (Kharif 88)

Treatments	S ₁ (0-15 DAS)		S ₂ (16-35 DAS)		S ₃ (36-65 DAS)		S ₄ (66-95 DAS)		S ₅ (96-116 DAS)		Seasonal	
	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh
T ₁	6.83	5.20	9.17	6.16	17.82	14.19	17.63	12.39	10.57	8.11	62.02	46.05
T ₂	6.83	5.20	9.19	6.63	18.37	14.00	17.37	13.00	10.71	7.91	62.58	57.22
T ₃	6.83	5.20	8.96	6.83	20.45	16.80	16.79	12.43	9.93	7.40	63.01	49.53
T ₄	6.83	5.20	10.25	7.11	19.85	14.77	18.79	12.83	10.82	8.30	66.65	49.07
T ₅	6.83	5.20	10.45	7.38	25.87	19.56	23.07	14.43	12.57	8.94	79.33	56.58
S.E.d±	—	—	0.06	0.07	0.35	0.24	0.51	0.20	0.12	0.05	0.69	0.54
C.D(0.05)	—	—	0.12	0.14	0.76	0.53	1.11	0.45	0.25	0.11	1.49	1.17

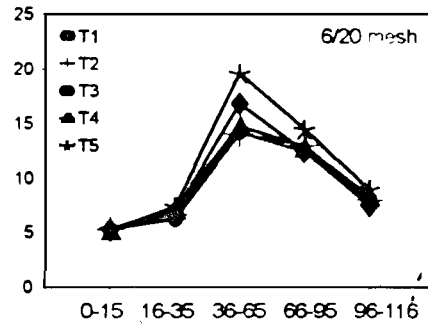
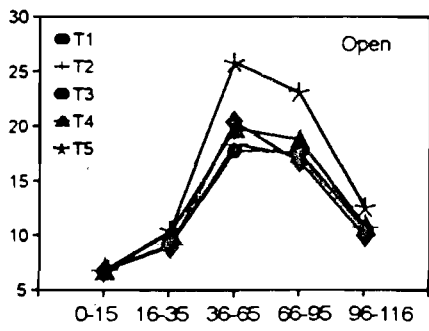
Table 5b: Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (Rabi 88)

Treatments	S ₁ (0-15 DAS)		S ₂ (16-35 DAS)		S ₃ (36-65 DAS)		S ₄ (66-95 DAS)		S ₅ (96-116 DAS)		Seasonal	
	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh
T ₁	11.36	8.03	17.68	13.10	23.81	17.22	25.53	17.03	15.83	11.46	94.21	66.84
T ₂	11.36	8.03	18.33	13.11	24.87	17.53	25.59	18.86	18.43	13.44	98.58	70.97
T ₃	11.36	8.03	17.78	13.26	23.75	18.65	25.19	19.19	20.15	14.84	98.23	73.97
T ₄	11.36	8.03	17.70	12.74	23.25	17.52	27.82	19.76	21.25	15.87	101.38	73.92
T ₅	11.36	8.03	18.40	13.55	26.55	19.21	30.15	20.86	26.22	18.22	112.68	79.87
S.E.d.±	—	—	0.42	0.15	0.25	0.13	0.15	0.13	0.13	0.13	1.41	1.10
C.D.(0.05)	—	—	0.09	0.07	0.55	0.27	0.32	0.28	0.28	0.29	3.08	2.40

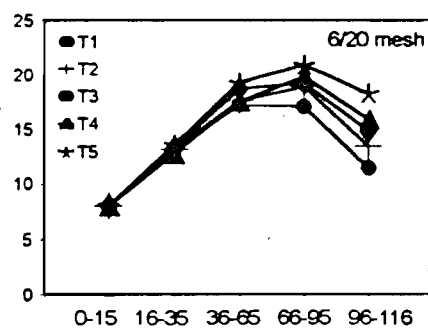
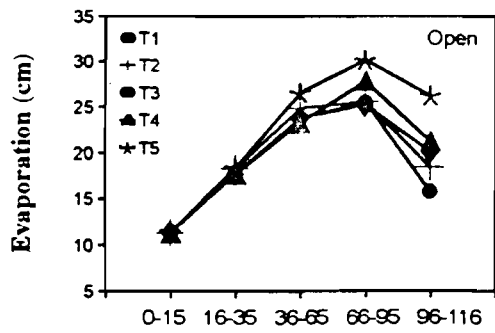
Table 5c: Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut (Kharif 89)

Treatments	S ₁ (0-15 DAS)		S ₂ (16-35 DAS)		S ₃ (36-65 DAS)		S ₄ (66-95 DAS)		S ₅ (96-116 DAS)		Seasonal	
	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh	Open	6/20 mesh
T ₁	5.37	5.20	11.34	9.54	18.05	16.87	16.68	15.04	10.66	8.07	61.50	54.72
T ₂	5.37	5.20	11.40	9.72	18.64	17.02	17.34	15.44	10.68	9.25	63.43	56.63
T ₃	5.37	5.20	11.80	9.90	18.83	17.64	17.99	15.25	12.47	10.17	66.46	58.16
T ₄	5.37	5.20	11.44	9.94	18.90	18.06	18.50	15.86	13.15	11.36	67.36	60.42
T ₅	5.37	5.20	11.85	9.20	19.58	18.68	18.61	16.88	14.06	12.05	69.47	62.01
S.E.D.±	—	—	0.10	0.08	0.07	0.12	0.11	0.19	0.08	0.09	0.96	0.66
C.D.(0.05)	—	—	0.22	0.18	0.15	0.25	0.25	0.42	0.17	0.20	2.09	1.44

Kharif 88



Rabi 88



Kharif 89

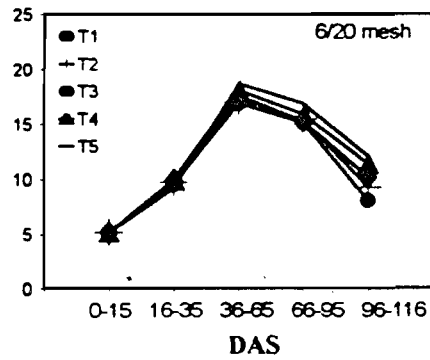
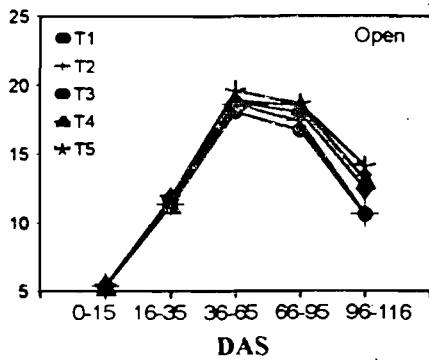


Fig. 7: Can evaporation (cm) at different growth stages as influenced by different plant population densities of groundnut

10.06 to 14.06 cm during kharif 89) between 96 and 116 DAS (fifth stage, end of pod development and maturity).

Similarly, the amount of water evaporated from the Cans with 6/20 mesh screen was relatively less at initial stages of crop growth (5.20, 8.03 and 5.20 cm during kharif 88, rabi 88 and kharif 89 respectively) and showed an increasing trend with advancement of crop age and reached a peak of 14.00 to 19.56 cm during kharif 88; and 16.87 to 18.68 cm during kharif 89) between 36 and 65 DAS (3rd stage, maximal flowering to pod initiation) and from 25.19 to 30.15 cm during rabi 88 between 66 and 95 DAS (4th stage, pod development) with a drop (7.40 to 8.94 cm during kharif 88, 11.46 to 18.22 cm during rabi 88 and 8.07 to 12.05 cm during kharif 89) between 96 and 116 DAS (fifth stage, end of pod development and maturity).

Successive increase of plant population decreased evaporation from Cans at all the stages of crop growth during all the three seasons studied.

Evaporation from Cans fitted with 6/20 mesh screen were lower than those from open Cans in all the treatments at all the stages of crop growth and season.

Cumulative evaporation from both 6/20 mesh covered and open Cans was more during rabi 88 compared to kharif 88 and kharif 89.

4.1.4 Daily Evapotranspiration ($ET\ d^{-1}$)

Data on daily moisture use, calculated based on soil moisture depletion at different crop growth periods, are presented in table 6 and depicted in fig. 8. Increase in plant population density increased the daily moisture use at different crop growth periods in all the three seasons.

Table 6 : Daily ET (mm day⁻¹) of groundnut crop at different growth stages as influenced by different plant population densities

Treatments	S ₁ (0-15 DAS)		S ₂ (16-35 DAS)		S ₃ (36-65 DAS)		S ₄ (66-95 DAS)		S ₅ (96-116 DAS)	
	Kharif 88	Rabi 88	Kharif 88	Rabi 88	Kharif 88	Rabi 88	Kharif 88	Rabi 88	Kharif 88	Rabi 88
T ₁	2.19	2.21	3.33	3.86	6.58	6.98	6.00	6.06	3.29	4.27
T ₂	1.97	2.12	3.08	3.70	5.93	6.36	6.10	6.14	3.28	4.25
T ₃	1.97	2.00	2.99	3.50	5.65	6.00	5.82	5.83	2.83	4.05
T ₄	1.89	1.83	2.96	2.98	5.18	5.50	5.45	5.40	2.65	4.01
Mean	2.01	2.04	3.09	3.51	5.84	6.21	5.84	5.86	3.01	4.15

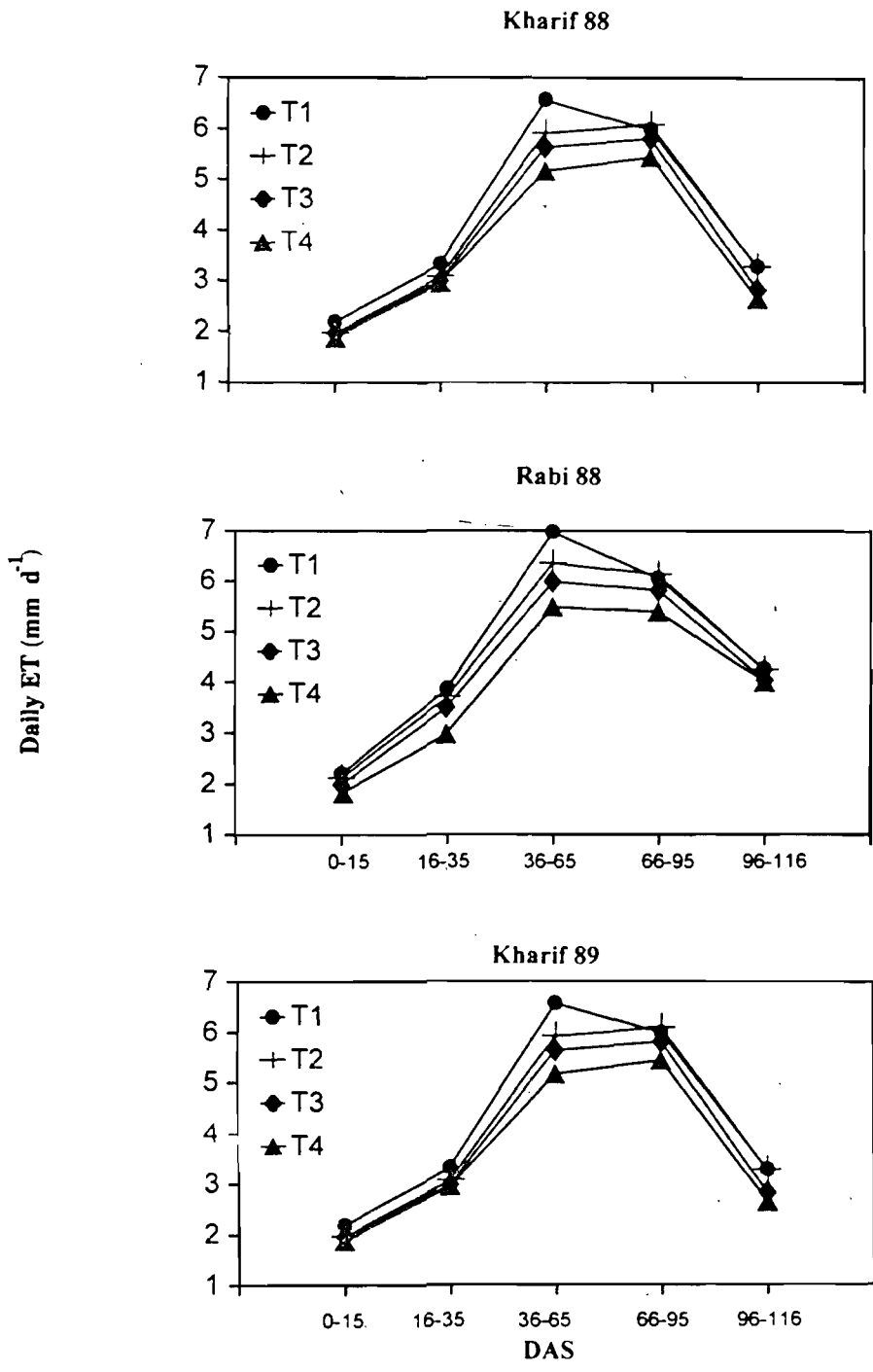


Fig. 8: Daily ET (mm d^{-1}) of groundnut at different growth stages as influenced by different plant population densities

The daily crop ET values were less at initial stages of crop growth (1.89 to 2.19 mm during kharif 88, 1.83 to 2.21 mm during rabi 88; and 1.56 to 2.08 mm during kharif 89) and showed an ascending trend with advancement of crop age and reached a peak (5.18 to 6.58 mm during kharif 88, 5.50 to 6.98 mm during rabi 88 and 5.17 to 5.70 mm during kharif 89) between 36 and 65 DAS (3rd stage, maximal flowering to pod initiation). Thereafter, rate of water use decreased gradually between 66 and 95 DAS (4th stage, pod development) with a sudden drop (2.65 to 3.29 mm during kharif 88, 4.01 to 4.27 mm during rabi 88 and 2.52 to 3.23 mm during kharif 89) between 96 and 116 DAS (fifth stage, end of pod development and maturity).

4.1.5 Soil moisture extraction pattern (per cent)

Soil moisture extracted from different layers of soil (per cent to total soil moisture depleted) during different stages of crop growth period, as influenced by different plant population densities, is presented in table 7 and illustrated in fig. 9.

Perusal of the data indicate that the soil moisture extraction was relatively more from 0-15 cm soil depth, while it decreased with increase in soil depth from 15-30 and 30-45 cm irrespective of plant population density. Further, the per cent of total moisture extracted from the top two layers put together was 71.0 to 80.6 in kharif 88, 71.4 to 80.5 in rabi 88 and 72.8 to 82.3 in kharif 89 while, the remaining was from the 30-45 cm soil depth. On the other hand, extraction of moisture from the top 0-15 cm soil depth decreased as the age of the crop increased, while extraction from the lower strata increased.

Table 7: Influence of different plant population densities on soil moisture extraction (%) pattern in groundnut

Treatments	S ₂ (16-35 DAS)				S ₃ (36-65 DAS)				S ₄ (66-95 DAS)				S ₅ (96-118 DAS)				Mean	
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T ₁	45.0	34.6	20.4	43.6	33.8	22.6	40.3	32.8	26.9	39.0	32.0	29.0	42.0	33.3	24.7			
T ₂	45.3	33.8	20.9	44.0	34.4	21.6	41.7	33.5	24.8	39.2	31.8	29.0	42.6	33.4	24.0			
T ₃	45.5	34.4	20.1	44.4	34.7	20.9	42.6	33.2	24.2	39.5	32.0	28.5	43.0	33.6	23.4			
T ₄	45.9	34.7	19.4	45.0	35.2	19.8	43.3	32.3	24.4	40.0	32.6	27.4	43.6	33.6	22.8			
Kharif 88																		
T ₁	45.3	34.3	20.4	42.5	32.9	24.6	41.6	32.2	26.2	39.6	31.8	28.6	42.2	32.8	25.0			
T ₂	45.6	34.4	20.0	43.0	33.5	23.5	41.9	32.6	25.5	39.9	32.2	27.9	42.6	33.2	24.2			
T ₃	45.9	34.6	19.5	43.3	33.9	22.8	42.2	33.2	24.6	40.3	32.5	27.2	42.9	33.6	23.5			
T ₄	46.2	34.9	18.9	43.6	34.6	21.8	42.6	33.6	23.8	40.6	32.8	26.6	43.2	34.0	22.8			
Kharif 89																		
T ₁	46.1	35.7	18.2	44.7	34.9	20.4	41.4	33.6	25.0	40.1	32.7	27.2	43.1	34.2	22.7			
T ₂	46.5	35.2	18.3	45.1	35.5	19.4	42.6	34.4	23.0	40.4	32.5	27.1	43.6	34.4	22.0			
T ₃	46.7	35.0	18.3	45.6	35.9	18.5	43.4	34.0	22.6	40.8	32.4	26.8	44.1	34.3	21.6			
T ₄	47.2	34.9	17.9	46.2	36.1	17.7	44.2	33.8	22.0	41.1	32.3	26.6	44.7	34.3	21.0			

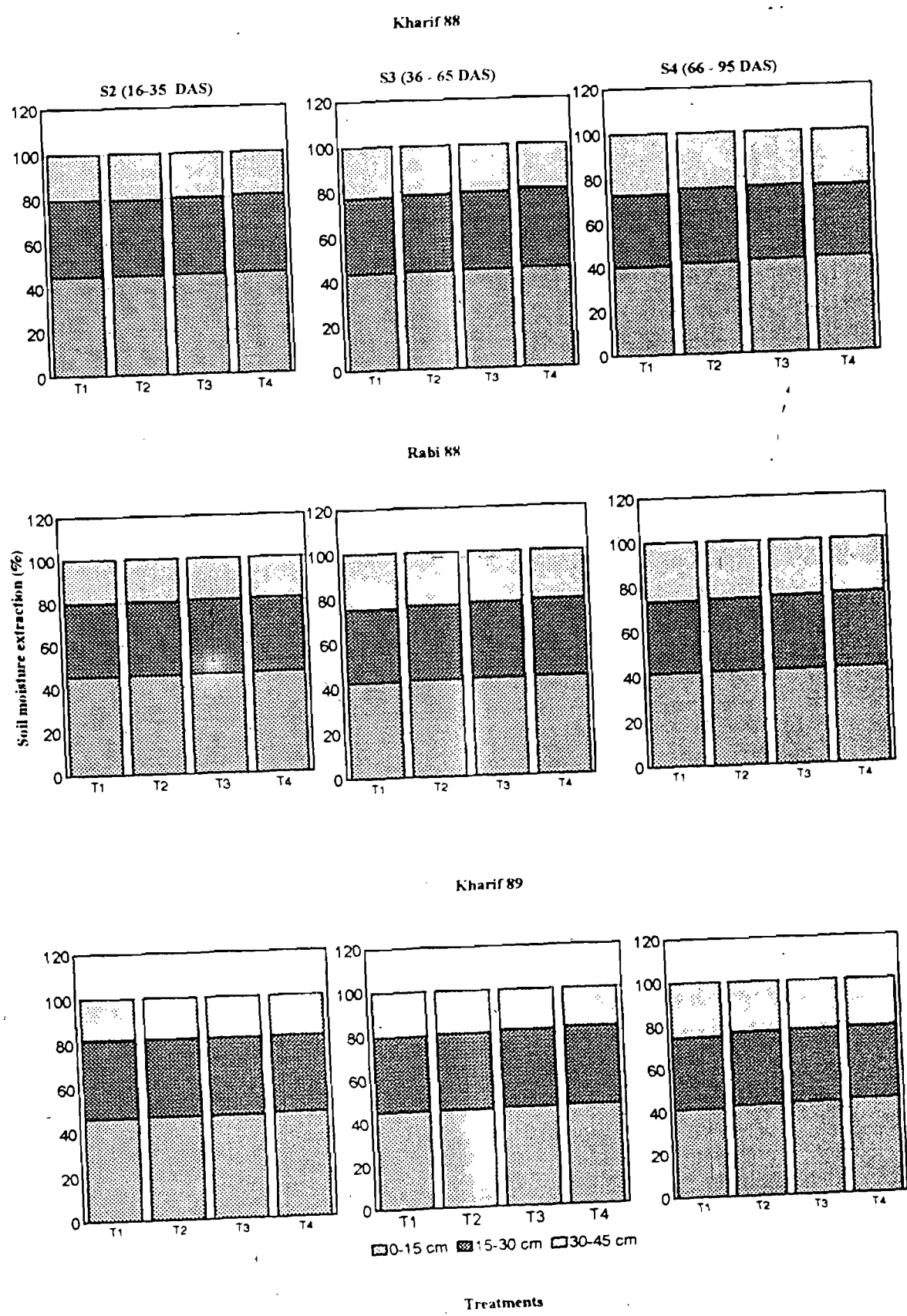


Fig. 9 : Soil moisture extraction (%) at different depths and growth stages as influenced by different plant population densities

Increase in plant density increased the extraction of soil moisture from lower strata compared to upper strata and their trend was more clear as the age of the crop increased in all the three seasons.

4.1.6 Crop water use efficiency (Kg pod ha⁻¹ mm)

Crop water use efficiency, in terms of kg pods ha⁻¹ mm of water utilized by groundnut crop, as influenced by different plant population densities, is presented in Table 8 and illustrated in fig. 10.

Data indicate that plant population density of 5 lakh plants ha⁻¹ was highly efficient in producing pods per unit quantity of water (5.495, 6.240 and 6.253 kg mm⁻¹ during kharif 88, rabi 88 and kharif 89 respectively) while plant population density of 2.5 lakh plants ha⁻¹ proved to be least efficient (3.818, 4.661 and 5.810 kg mm⁻¹ during kharif 88, rabi 88 and kharif 89 respectively).

Reduction in WUE with successive decrease in plant population densities at T₂, T₃ and T₄ was 5.09, 11.7 and 30.5 per cent respectively during kharif 88; 6.5, 12.9 and 25.3 per cent respectively during rabi 88; and 7.1, 5.9 and 7.1 per cent respectively during kharif 89 to that of T₁ with a plant population density of 5.0 lakh plants ha⁻¹.

4.1.7 Relationship between crop ET and reference crop ET

Relationship between crop (5.0 lakh plants ha⁻¹) ET, estimated by soil moisture depletion and reference crop evapotranspiration estimated by different methods is presented in Table 9 and depicted in fig. 11a, 11b and 11c.

The relationship between crop ET and reference ET was adequately described by a linear model $Y=a + bX$. The R^2 varied between 0.9256 and 0.9520 during kharif 88, 0.9146 and 0.9585 during rabi 88; and between 0.3456

Table 8 : Water use efficiency of groundnut (kg pod ha⁻¹ mm) as influenced by different population densities

Treatments	Water use efficiency (kg pods ha ⁻¹ mm)		
	Kharif 88	Rabi 88	Kharif 89
T1	5.495	6.240	6.253
T2	5.221	5.835	5.812
T3	4.852	5.437	5.884
T4	3.818	4.661	5.810
Mean	4.847	5.543	5.940

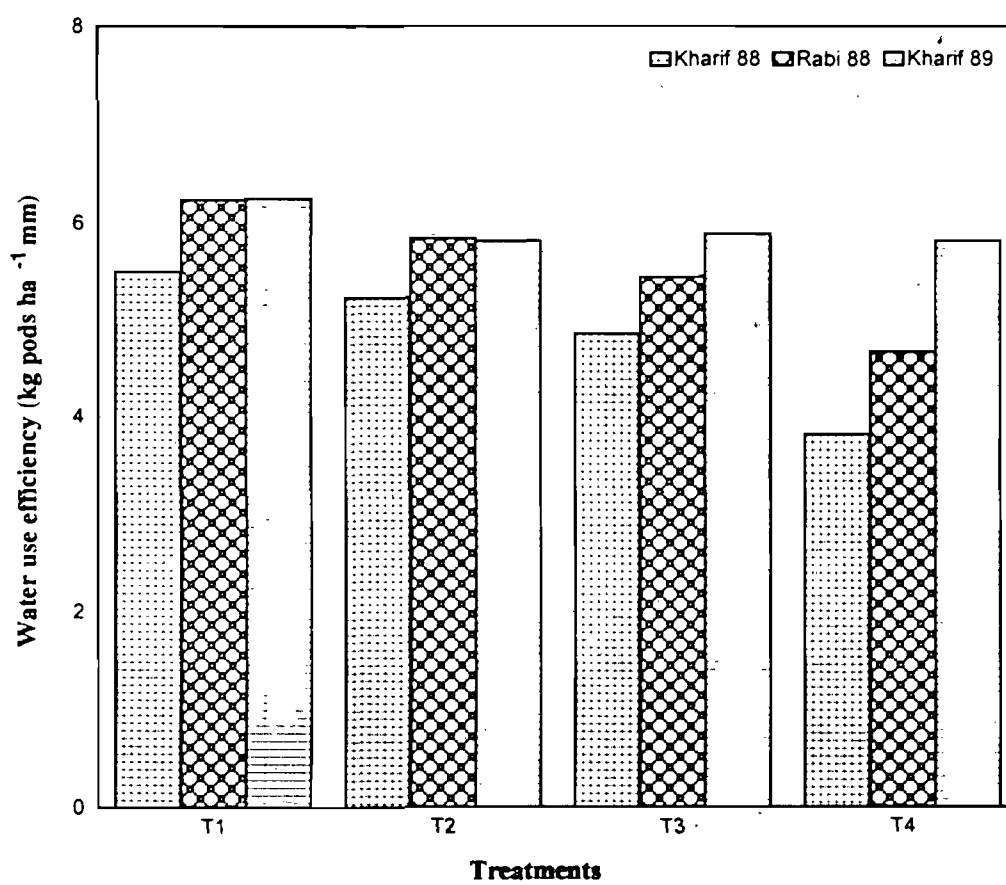


Fig. 10 : Water use efficiency of groundnut (kg pods ha⁻¹ mm) as influenced by different plant population densities

Table 9 : Empirical estimates for the relationship between crop evapotranspiration and reference crop evapotranspiration

Relationship	Regression constants, coefficients and test statistics		
	a	b	R ²
Kharif 88			
Crop ET-Reference ET by Modified Penman	-4.76838 ±2.77399	1.52255 ±0.24926	0.9256**
Crop ET-Reference ET by Blaney-Criddle	-11.32184 ±3.00409	1.93441 ±0.25084	0.9520**
Crop ET-Reference ET by Hargreaves	-1.81866 ±1.89878	2.14827 ±0.28545	0.9497**
Crop ET-Reference ET by Radiation	-5.09310 ±2.79298	1.05865 ±0.17147	0.9270**
Rabi 88			
Crop ET-Reference ET by Modified Penman	-13.23294 ±6.36955	1.65628 ±0.40756	0.9585**
Crop ET-Reference ET by Blaney-Criddle	-12.53771 ±5.52813	1.98288 ±0.43477	0.9580**
Crop ET-Reference ET by Hargreaves	-6.17985 ±4.85472	1.91569 ±0.48647	0.9381**
Crop ET-Reference ET by Radiation	-12.1035 ±2.52847	1.37428 ±0.14037	0.9146**
Kharif 89			
Crop ET-Reference ET by Modified Penman	-8.28828 ±4.82499	1.51382 ±0.38874	0.8348*
Crop ET-Reference ET by Blaney-Criddle	-8.80883 ±4.10655	1.60289 ±0.34058	0.8807*
Crop ET-Reference ET by Hargreaves	-1.99440 ±4.96361	1.20016 ±0.47071	0.6842
Crop ET-Reference ET by Radiation	1.00469 ±7.45675	0.69194 ±0.54967	0.3456

*Significant at P=0.05

**Significant at P=0.01

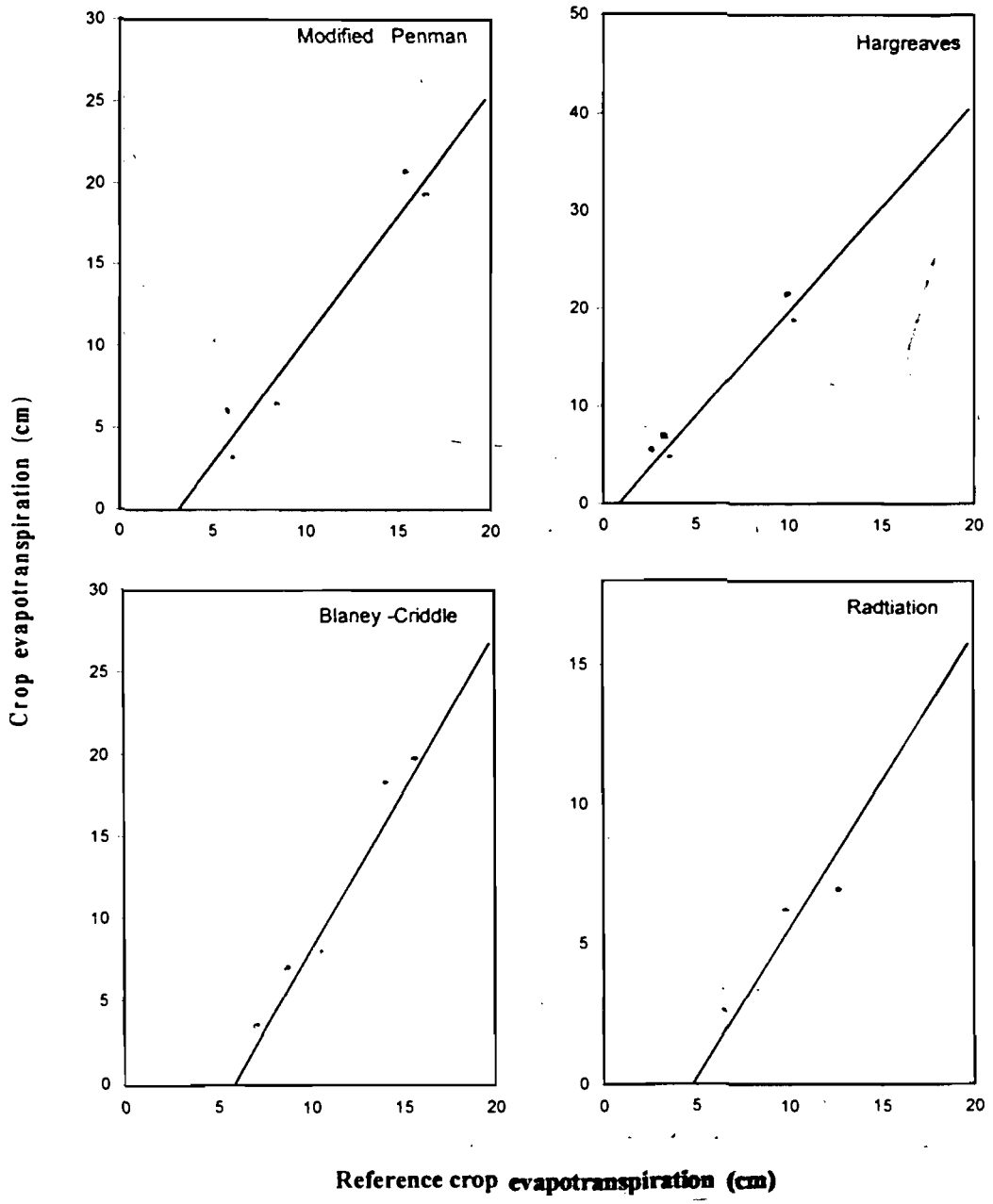


Fig. 11a : Relationship between crop evapotranspiration and reference crop evapotranspiration estimated by different methods (Kharif 88)

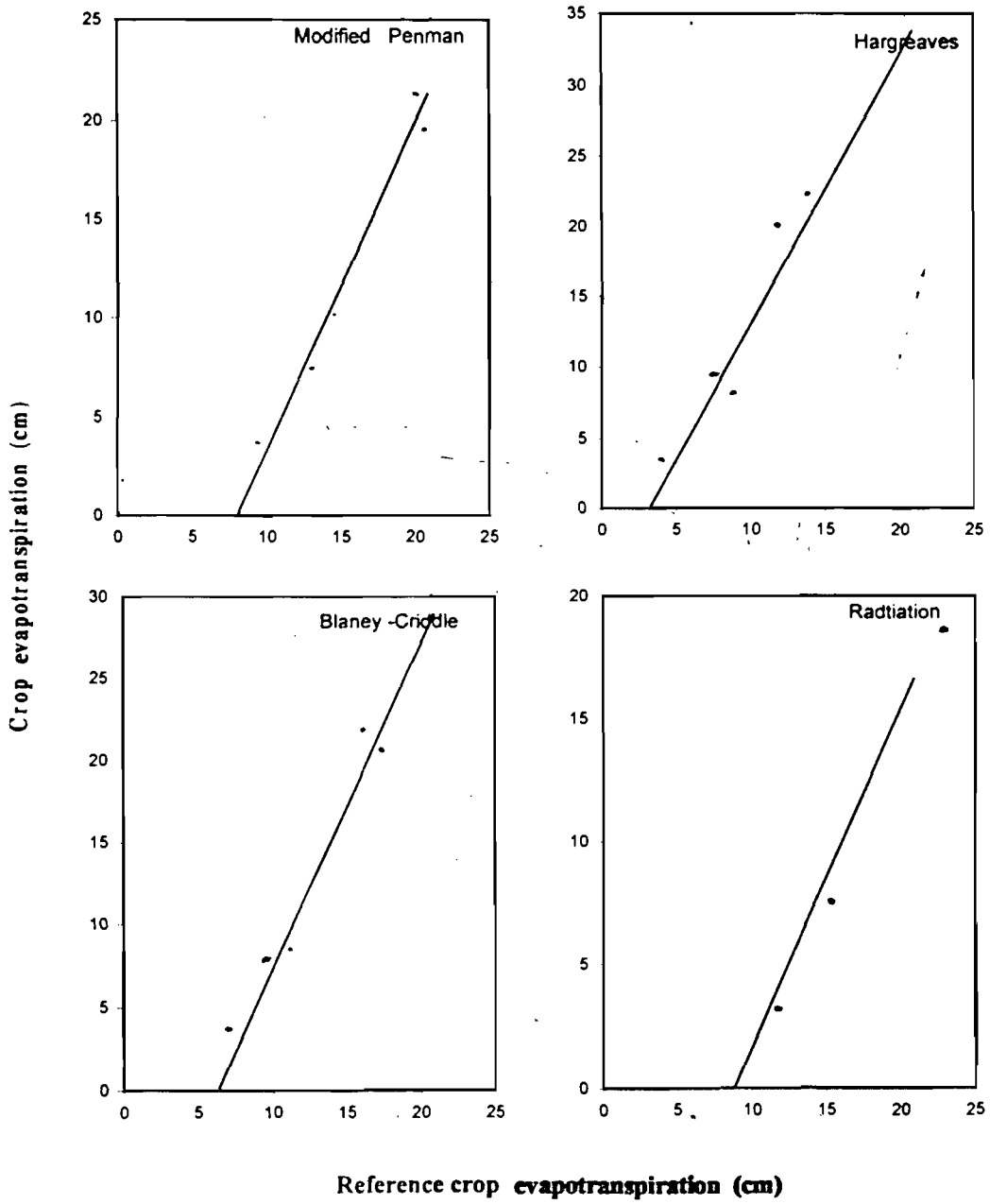


Fig. 11b : Relationship between crop evapotranspiration and reference crop evapotranspiration estimated by different methods (Rabi 88)

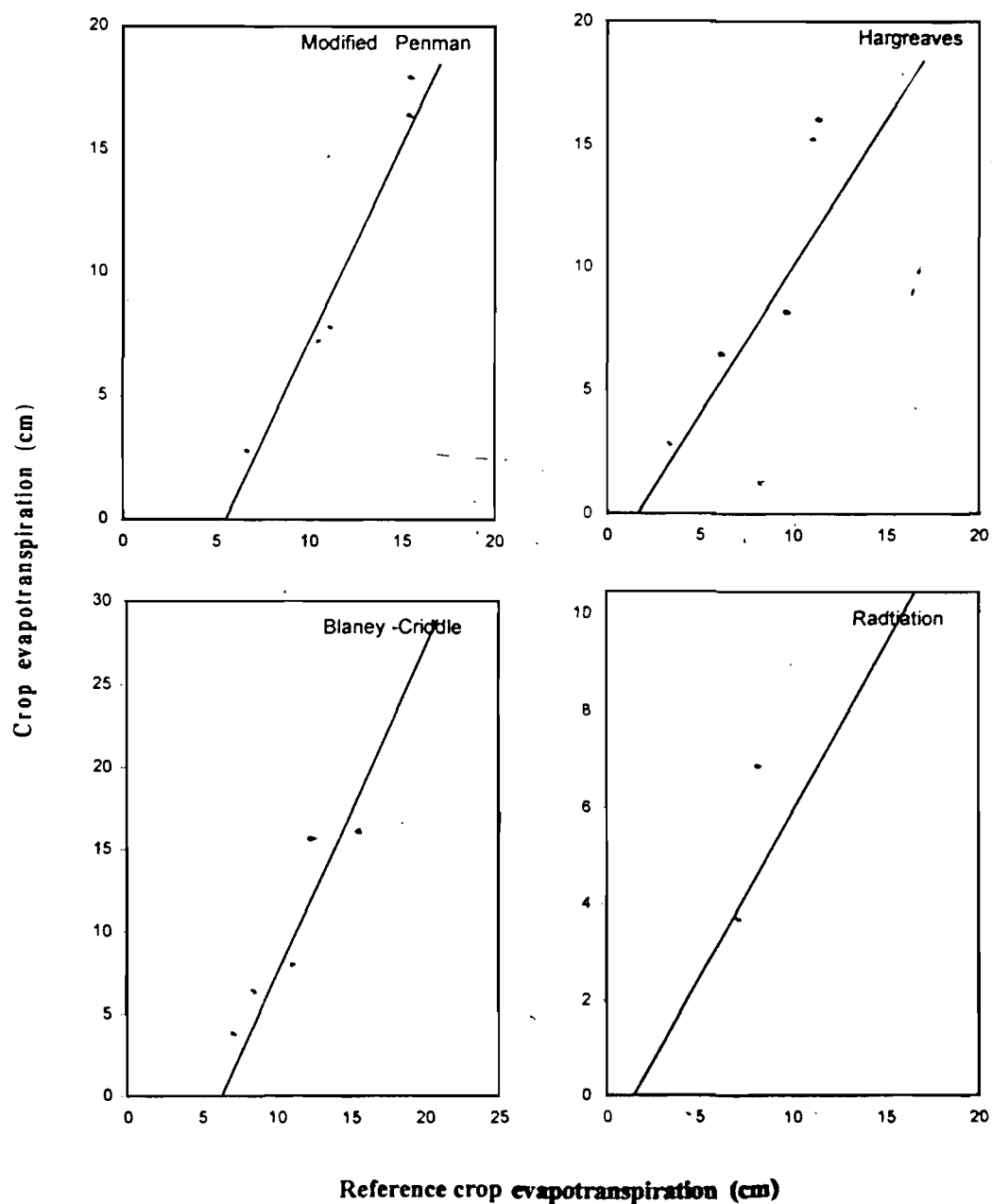


Fig. 11c : Relationship between crop evapotranspiration and reference crop evapotranspiration estimated by different methods (Kharif 89)

and 0.8807 during kharif 89. The variance ratio for testing R^2 were highly significant ($P=0.01$) during kharif 88, rabi 88 and significant ($P=0.05$) during kharif 89 except between crop ET and reference ET by Hargreaves and Radiation methods. The linear coefficients (b_i) in all the equations were positive and significant, indicating that crop ET increased linearly with an increase in reference ET. However, the magnitude of b coefficients varied to and almost unity (1.05865) with Radiation method as compared to Modified Penman (1.67869), Blaney-Criddle (2.04659) and Hargreaves (1.95517) method during kharif 88. During rabi 88, it varied from 1.37428 to 1.98288 with Radiation and Blaney-Criddle methods as compared to Hargreaves (1.91569) and Modified Penman methods (1.65628). In kharif 89, it varied from 0.69194 to 1.60289 with Radiation and Blaney-Criddle methods compared to Hargreaves (1.20016) and Modified Penman methods (1.51382).

4.1.8 Relationship between crop ET and evaporation from U.S.W.B. class

A pan

Data pertaining to the relationship between crop evapotranspiration, estimated by soil moisture depletion under 5.0 lakh plants ha^{-1} and evaporation from U.S.W.B. class A pan is presented in Table 10 and depicted in fig. 12a, 12b and 12c.

The R^2 varied from 0.8278 to 0.9901. Higher R^2 values were observed in rabi 88 than kharif 88 and kharif 89. The variance ratio for testing R^2 were highly significant ($P=0.01$) during kharif 88 and rabi 88 and significant ($P=0.05$) during kharif 89. These show that there is good agreement between crop ET and evaporation from U.S.W.B. class A pan. The linear coefficients (b_i) in all the seasons were positive and significant indicating that crop ET

increased linearly with an increase in evaporation from U.S.W.B. class A pan. However, the magnitude of b coefficients varied, and these worked out to 1.70778, 0.99559 and 2.55430 for kharif 88, rabi 88 and kharif 89 respectively.

4.1.9 Relationship between crop ET and evaporation from Can evaporimeters.

Data on the relationship between crop evapotranspiration under 5.0 lakh plants ha^{-1} by soil moisture depletion method and evaporation from Can evaporimeters are presented in table 10 and illustrated through fig. 12a, 12b and 12c.

The relationship between crop ET and evaporation from Can evaporimeters was described by a linear model. The R^2 varied from 0.9646 to 0.9863 for kharif 88, 0.9056 to 0.9119 for rabi 88; and from 0.9510 to 0.9788 for kharif 89 with open Can evaporation and evaporation from Can evaporimeters having screen size of 6/20 mesh. In general, higher R^2 values were found with Can evaporimeters having screen size of 6/20 mesh size compared to open Can evaporimeters in all the three seasons. The variance ratio for testing R^2 were highly significant ($P=0.01$) in all the three seasons showing that there is good agreement between crop ET and evaporation from open Can evaporimeter having screen size of 6/20 mesh. The linear coefficients (b_i) in all the equations were positive and highly significant indicating that crop ET increased linearly with an increase in evaporation from open Can and Can evaporimeters having screen size of 6/20 mesh. However, the magnitude of b coefficients varied from 1.46293 to 1.86209 in kharif 88, 1.21424 to 1.82625 in rabi 88; and from 1.16062 to 1.25037 in kharif 89 with evaporation from open Can and Can evaporimeter having screen size of 6/20 mesh.

Table 10 : **Empirical estimates for the relationship between crop evapotranspiration and evaporation from U.S.W.B. class A pan and cans**

Relationship	Regression constants, coefficients and test statistics		
	a	b	R ²
Kharif 88			
Crop ET-Evaporation from U.S.W.B. class A pan	-4.19726 ±1.94030	1.70778 ±0.20132	0.9600**
Crop ET-Evaporation from open can	-7.22618 ±1.39203	1.46293 ±0.10548	0.9646**
Crop ET-Can evaporation with 6/20 mesh screen	-6.22981 ±1.97778	1.86209 ±0.20068	0.9863**
Rabi 88			
Crop ET-Evaporation from U.S.W.B. class A pan	-16.40416 ±2.71266	0.99559 ±0.18006	0.9901**
Crop ET-Evaporation from open can	-11.05817 ±4.96106	1.2142 ±0.25376	0.9056**
Crop ET-Can evaporation with 6/20 mesh screen	-12.59330 ±5.26292	1.82625 ±0.38102	0.9119**
Kharif 89			
Crop ET-Evaporation from U.S.W.B. class A pan	-13.94008 ±6.38891	2.55430 ±0.67216	0.8278*
Crop ET-Evaporation from open can	-4.45556 ±1.99847	1.16062 ±0.15215	0.9510**
Crop ET-Can evaporation with 6/20 mesh screen	-4.86439 ±1.24533	1.25037 ±1.24424	0.9788**

* Significant at P=0.05
** Significant at P=0.01

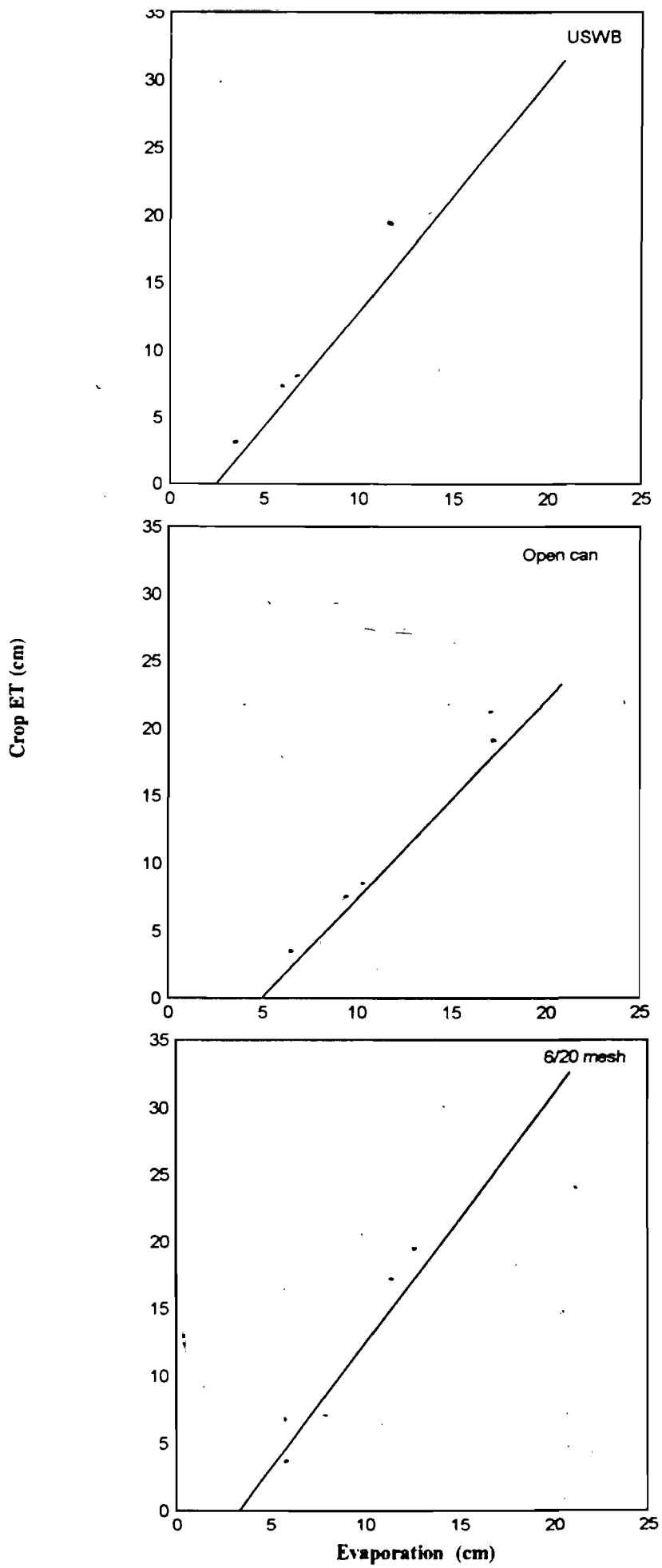


Fig. 12a : Relationship between crop ET and evaporation from USWB class A pan and can evaporimeters (kharif 88)

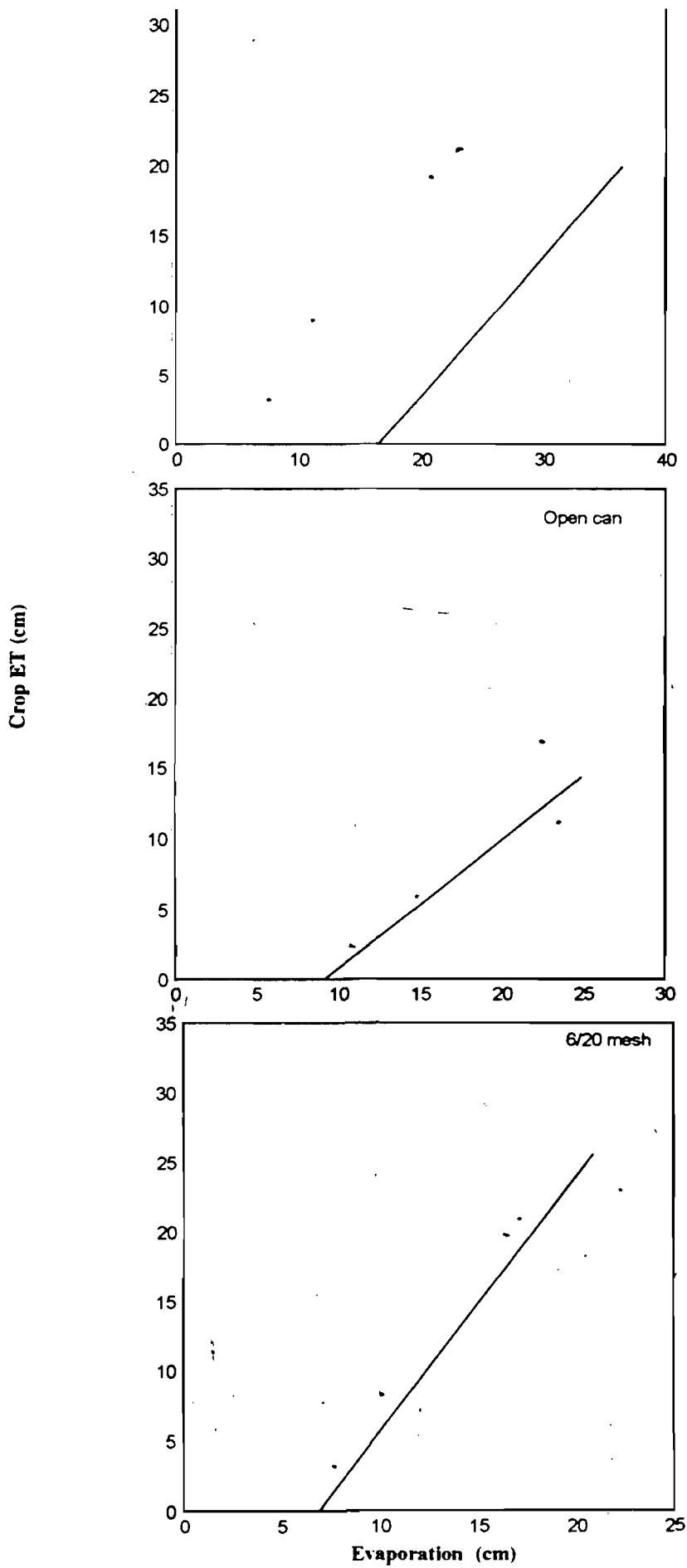


Fig. 12b : Relationship between crop ET and evaporation from USWB class A pan and can evaporimeters (rabi 88)

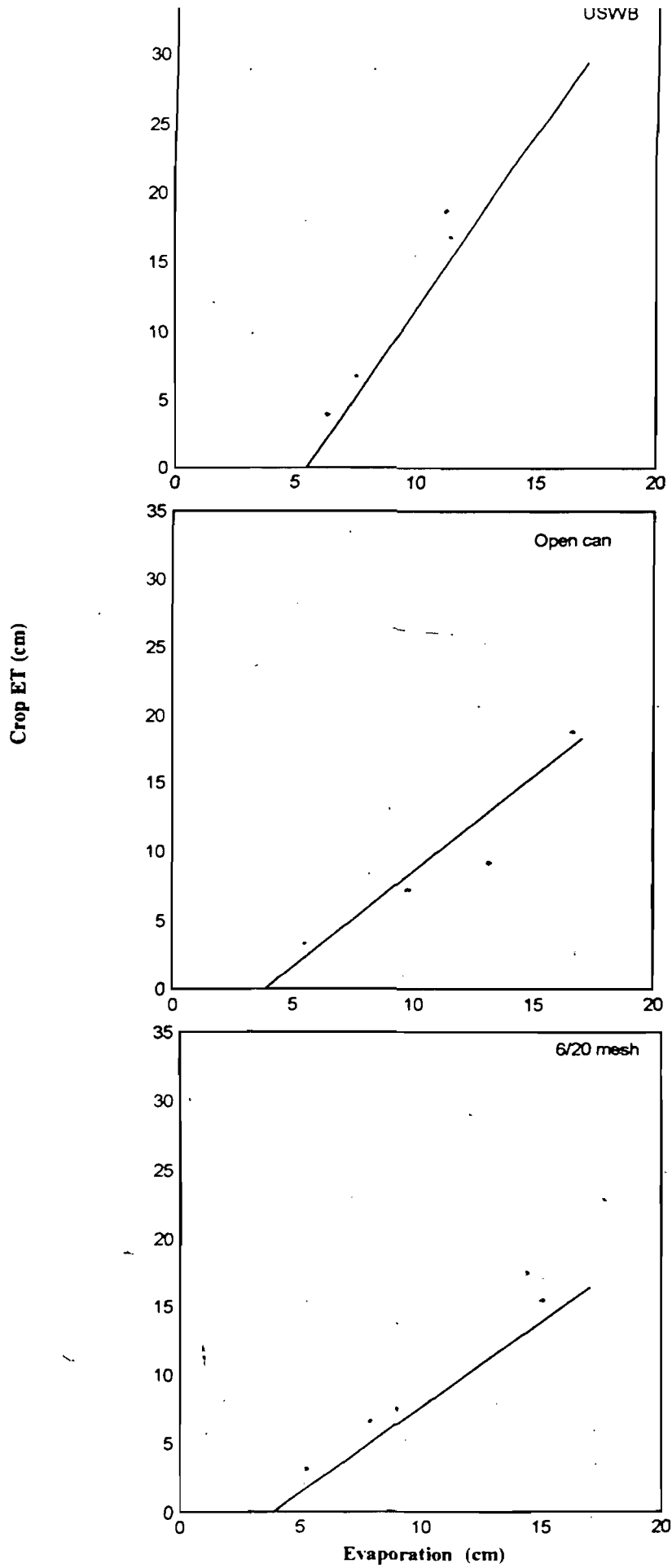


Fig. 12c: Relationship between crop ET and evaporation from USWB class A pan and can evaporimeters (Iharif 89)

4.1.10 Relationship between evaporation from U.S.W.B. class A pan and evaporimeters

Data on the relationship between evaporation from U.S.W.B. class A and Can evaporimeters under 5.0 lakh plants ha^{-1} are presented in table 11.

R^2 values between U.S.W.B. class A pan and open Can ranged from 0.8987 to 0.9123 and 0.8027 to 0.9020 between U.S.W.B. class A pan and Can evaporimeter with 6/20 mesh for all the three seasons studied. The R^2 values were found to be positive and significant.

4.2 GROWTH CHARACTERS AND YIELD

4.2.1 Growth Characters

4.2.1.1 Length of main root

Data on the length of main root at different growth stages, as influenced by plant population densities of groundnut, are presented in table 12 and depicted in fig.13.

Plant population densities influenced the length of main root significantly at all the stages of crop growth. In general, increase in plant density has significantly increased the length of main root at all the growth stages. Crop sown with a narrow spacing of 20 cm (T_1) with a plant population density of 5.0 lakh plants ha^{-1} , registered a maximum length of main root 19.85, 27.08 and 35.80 cm at 30, 60 days after sowing, and at harvest respectively in kharif 88; 20.00, 27.30 and 36.00 cm in rabi 88 and 19.60, 26.80 and 35.90 cm in kharif 89 at the respective stages. With normal recommended population of 3.33 lakh plants ha^{-1} (T_3), the mean main root length was 18.80, 25.18 and 33.65 cm at 30, 60 days after sowing and harvest in kharif 88; 19.60, 25.90 and 34.20 cm in rabi 88 and 18.50, 25.10 and 33.40 in kharif 89 at the respective stages.

Table 11 : Empirical estimates for the relationship between evaporation from U.S.W.B. class Pan and can evaporimeters

Relationship	Regression constants, coefficients and test statistics		
	a	b	R ²
	Kharif 88		
U.S.W.B. class A pan - open can	2.4082 ±1.9486	1.1292 ±0.2022	0.9123**
U.S.W.B. class A pan - can with 6/20 mesh	1.4743 ±1.6032	0.8739 ±0.1663	0.9020**
	Rabi 88		
U.S.W.B. class A pan - open can	8.7916 ±2.1709	0.7434 ±0.1441	0.8987**
U.S.W.B. class A pan - can with 6/20 mesh	6.7116 ±1.5392	0.4923 ±0.1022	0.8856**
	Kharif 89		
U.S.W.B. class A pan - open can	-8.1725 ±4.020	2.2138 ±0.4429	0.9013**
U.S.W.B. class A pan - can with 6/20 mesh	-7.6580 ±5.4407	1.9997 ±0.5724	0.8027*

**Significant at $P=0.01$

*Significant at $P=0.05$

Table 12: Length of main root (cm) of groundnut as influenced by different plant population densities

Treatments	30 DAS	60 DAS	Harvest
Kharif 88			
T ₁	19.85	27.08	35.80
T ₂	19.35	26.00	34.55
T ₃	18.80	25.18	33.65
T ₄	18.50	24.90	33.00
S.Ed.±	0.05	0.13	0.10
C.D.(0.05)	0.11	0.30	0.23
Rabi 88			
T ₁	20.00	27.30	36.00
T ₂	19.50	26.40	34.80
T ₃	19.60	25.90	34.20
T ₄	19.50	25.60	33.90
S.Ed.±	0.18	0.11	0.17
C.D.(0.05)	0.04	0.25	0.39
Kharif 89			
T ₁	19.60	26.80	35.90
T ₂	19.00	25.70	34.60
T ₃	18.50	25.10	33.40
T ₄	18.20	24.70	32.70
S.Ed.±	0.12	0.13	0.14
C.D.(0.05)	0.28	0.29	0.32

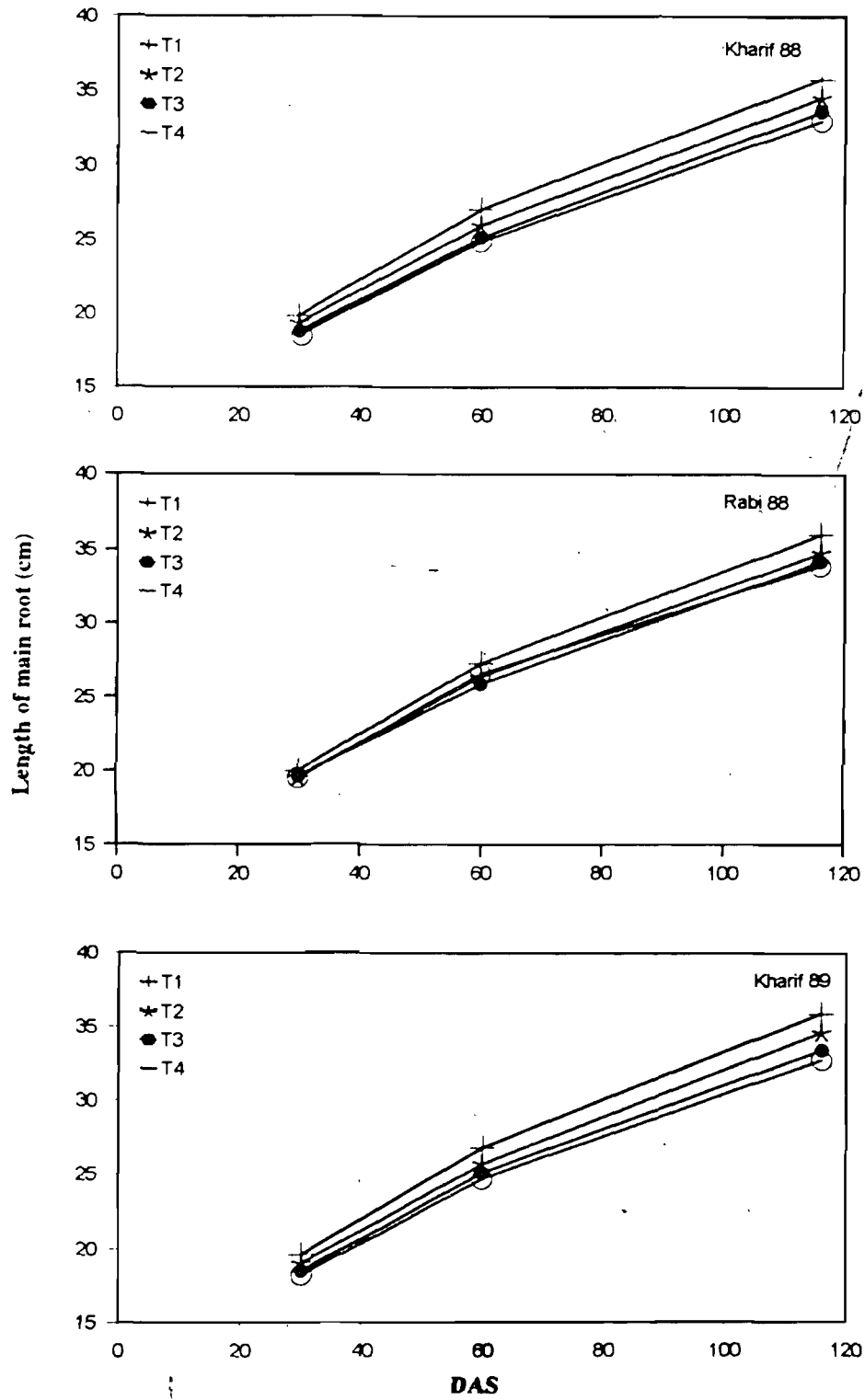


Fig. 13: Length of main root (cm) of groundnut as influenced by different plant population densities

The length of main root in the crop sown with wider row spacing of 40 cm (T₄) with a plant population density of 2.5 lakh plants ha⁻¹ resulted in lower main root length of 18.50, 24.90 and 33.00 cm at 30, 60 days after sowing and harvest respectively in kharif 88; 19.50, 25.60 and 33.90 cm in rabi 88 and 18.20, 24.70 and 32.70 cm in kharif 89 at respective stages of sampling which were found to be lower as compared to normal recommended population of 3.33 lakhs ha⁻¹.

4.2.1.2 Root lateral spread

Data on root lateral spread at different growth stages as influenced by different plant population densities of groundnut are presented in table 13 and illustrated in fig. 14.

In general, each successive increase in plant density significantly reduced the lateral root spread at all the growth stages and in all the three seasons studied. Crop sown with a narrow row spacing of 20 cm (T₁) (plant population density of 5.0 lakh plants ha⁻¹) resulted in lower lateral spread of 10.25, 16.45 and 25.90 cm at 30, 60 DAS and harvest respectively in kharif 88; 10.50, 16.80 and 26.00 cm in rabi 88 and 10.00, 16.30 and 25.60 cm in kharif 89 at respective stages compared to the normal recommended population of 3.33 lakhs ha⁻¹ (T₃) which registered 10.98, 17.40 and 27.20 cm at 30, 60 DAS and harvest in kharif 88; 11.30, 17.60 and 27.30 cm in rabi 88 and 10.80, 17.10 and 27.30 cm in kharif 89 at the respective stages.

Crop sown with a wider row spacing of 40 cm (T₄) corresponding to a plant population density of 2.5 lakh plants ha⁻¹, resulted higher lateral root spread of 11.65, 18.20 and 28.30 cm at 30, 60 DAS and at harvest respectively in kharif 88; 11.90, 18.30 and 28.50 cm in rabi 88; and 11.50, 17.90 and 28.30

Table 13: Lateral spread of roots (cm) of groundnut as influenced by different plant population densities.

Treatments	30 DAS	60 DAS	Harvest
Kharif 88			
T ₁	10.25	16.45	25.90
T ₂	10.58	16.80	26.50
T ₃	10.98	17.40	27.20
T ₄	11.65	18.20	28.30
S.Ed.±	0.14	0.10	0.08
C.D.(0.05)	0.31	0.22	0.19
Rabi 88			
T ₁	10.50	16.80	26.00
T ₂	10.80	17.10	26.50
T ₃	11.30	17.60	27.30
T ₄	11.90	18.30	28.50
S.Ed.±	0.13	0.11	0.15
C.D.(0.05)	0.29	0.26	0.37
Kharif 89			
T ₁	10.00	16.30	25.60
T ₂	10.30	16.60	26.30
T ₃	10.80	17.10	27.20
T ₄	11.50	17.90	28.30
S.Ed.±	0.10	0.14	0.21
C.D.(0.05)	0.24	0.32	0.48

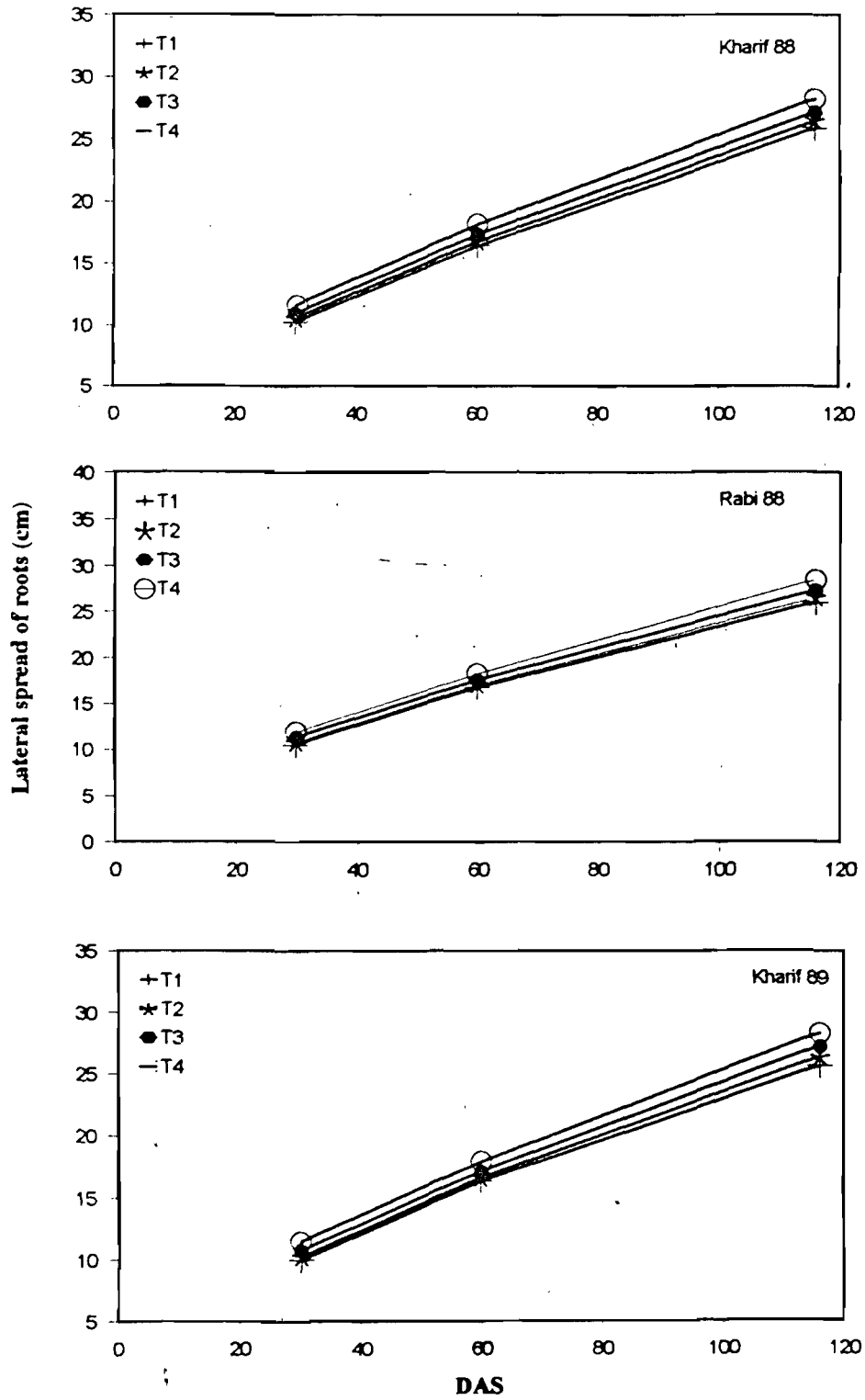


Fig. 14 : Lateral spread of roots (cm) of groundnut as influenced by different plant population densities

cm in kharif 89 at the respective stages which were found to be higher than those with normal recommended population of 3.33 lakhs ha^{-1} .

4.2.2 Dry matter accumulation (kg ha^{-1})

4.2.2.1 Shoot dry matter

Data on shoot dry matter (kg ha^{-1}) at 30, 60 days after sowing and harvest, as influenced by different plant population densities are presented in Table 14 and depicted in fig. 15.

Shoot dry matter increased as the crop growth advanced. Plants grown with a narrow row spacing of 20 cm (T_1) corresponding to a plant population density of 5.0 lakh plants ha^{-1} accumulated maximum shoot dry matter of 1460, 5600 and 7737 kg ha^{-1} at 30, 60 days after sowing and harvest respectively in kharif 88; 1475, 5700 and 7937 kg ha^{-1} in rabi 88; and 1450, 5500 and 7650 kg ha^{-1} in kharif 89 at the respective stages compared to the normal recommended population of 3.33 lakhs ha^{-1} (T_3), which resulted in 1020, 4566 and 6100 kg ha^{-1} at 30, 60 days after sowing and harvest respectively in kharif 88; 1026, 4600 and 6133 kg ha^{-1} in rabi 88; and 1013, 4454 and 6066 kg ha^{-1} in kharif 89 at the respective stages.

Shoot dry matter of the crop with wider row spacing of 40 cm (T_4) corresponding to a plant population of 2.5 lakh plants ha^{-1} , produced relatively less dry matter of 795, 3750 and 5000 kg ha^{-1} at 30, 60 days after sowing and harvest respectively in kharif 88; 800, 3800 and 6133 kg ha^{-1} in rabi 88 and 792, 3725 and 4950 kg ha^{-1} in kharif 89 at the respective stages as compared to that with normal spacing. The increase in shoot dry matter (kg ha^{-1}) with increase in plant population density was found to be significant at 30, 60 days after sowing and at harvest during all the three seasons studied.

Table 14 : Shoot dry matter (kg ha^{-1}) as influenced by different plant population densities of groundnut

Treatments	30 DAS	60 DAS	Harvest
Kharif 88			
T ₁	1460	5600	7737
T ₂	1192	5000	6720
T ₃	1020	4566	6100
T ₄	795	3750	5000
S.Ed.±	3.5	46.3	41.5
C.D.(0.05)	8.0	104.8	93.8
Rabi 88			
T ₁	1475	5700	7937
T ₂	1196	5000	6680
T ₃	1026	4600	6133
T ₄	800	3800	5075
S.Ed.±	3.2	56.5	128.9
C.D.(0.05)	7.2	127.8	291.6
Kharif 89			
T ₁	1450	5500	7650
T ₂	1184	4840	6680
T ₃	1013	4454	6066
T ₄	792	3725	4950
S.Ed.±	4.2	82.4	44.3
C.D.(0.05)	9.5	186.4	100.1

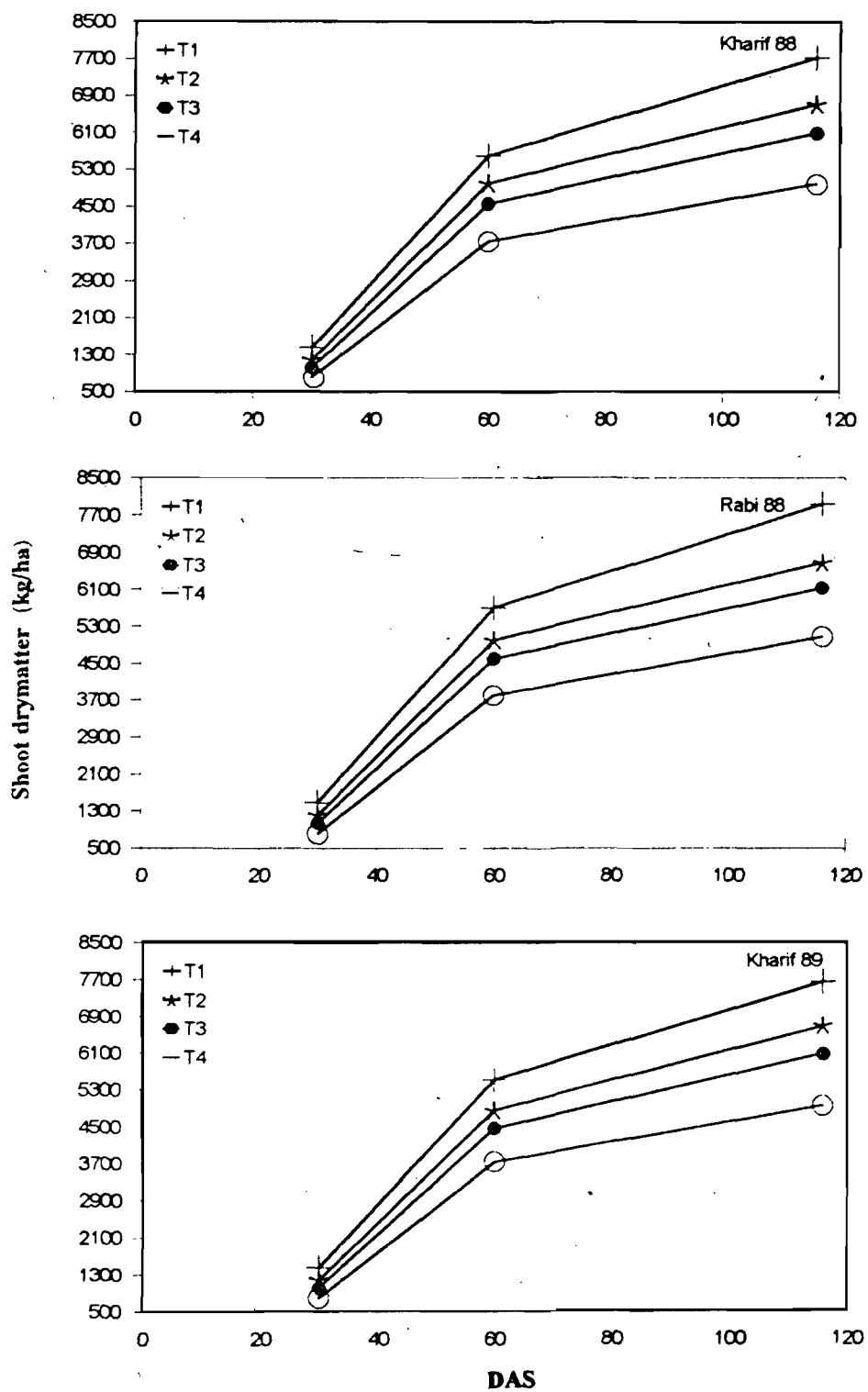


Fig. 15: Shoot drymatter (kg/ha) of groundnut as influenced by different plant population densities

4.2.2.2 Root dry matter

Data on root dry matter (kg ha^{-1}) at 30, 60 days after sowing and at harvest, as influenced by different plant population densities are presented in Table 15 and illustrated in fig. 16. Root dry matter increased as the crop growth advanced. Plants grown with a narrow row spacing of 20 cm (T_1) with a plant population density of 5.0 lakh plants ha^{-1} produced maximum dry matter of 155, 445 and 780 kg at 30, 60 days after sowing and at harvest respectively in kharif 88; 160, 450 and 785 kg in rabi 88; and 155, 435 and 775 kg in kharif 89 at the respective stages as compared to the normal recommended population of 3.33 lakh plants ha^{-1} (T_3), which produced 106, 353 and 573 kg at 30, 60 days after sowing and at harvest respectively in kharif 88; 110, 356 and 580 kg in rabi 88; and 106, 346 and 566 kg in kharif 89 at the respective stages.

Crop sown with wider row spacing of 40 cm (T_4) with a plant population density of 2.5 lakh plants ha^{-1} produced lower root dry matter of 82, 299 and 457 kg ha^{-1} at 30, 60 days after sowing and at harvest respectively in kharif 88; 85, 302 and 462 kg ha^{-1} in rabi 88; and 85, 295 and 452 kg ha^{-1} in kharif 89 at the respective stages, which were relatively low as compared to the normal recommended practice (T_3). The root dry matter significantly increased with increase in plant population density at all the three stages of sampling and in all the seasons.

4.2.3 Pod and Haulm Yield (kg ha^{-1})

4.2.3.1 Pod Yield

Data on pod yield (kg ha^{-1}), as influenced by different plant population densities, are presented in Table 16 and depicted in fig. 17.

Plant population densities significantly influenced pod yield in all the three seasons. Pod yield varied from 1764 to 3000 kg ha^{-1} in kharif 88, 2368

Table 15: Root dry matter (kg ha⁻¹) as influenced by different plant population densities of groundnut

Treatments	30 DAS	60 DAS	Harvest
Kharif 88			
T ₁	155	445	780
T ₂	124	384	652
T ₃	106	353	573
T ₄	82	299	457
S.Ed.±	3.7	3.1	3.1
C.D.(0.05)	8.4	7.1	6.9
Rabi 88			
T ₁	160	450	785
T ₂	128	392	660
T ₃	110	356	580
T ₄	85	302	462
S.Ed.±	2.1	6.9	2.4
C.D.(0.05)	4.7	15.5	5.4
Kharif 89			
T ₁	155	435	775
T ₂	124	372	644
T ₃	106	346	566
T ₄	85	295	452
S.Ed.±	2.2	3.0	3.2
C.D.(0.05)	5.0	6.9	7.2

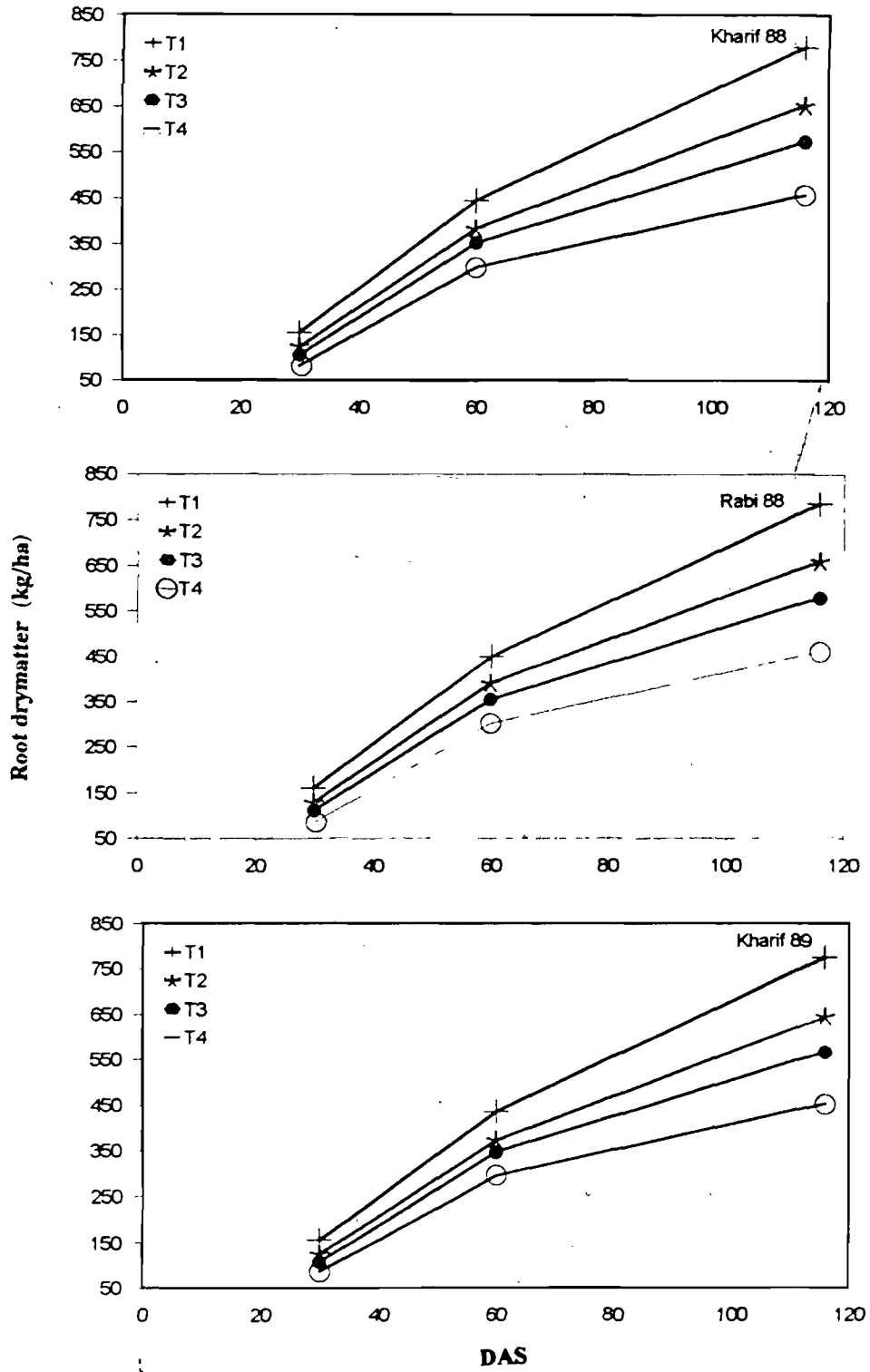


Fig. 16 : Root drymatter (kg/ha) of groundnut as influenced by different plant population densities

to 3688 kg ha⁻¹ in rabi 88 and 2440 to 3070 kg ha⁻¹ in kharif 89. Maximum pod yield of 3000, 3688 and 3070 kg ha⁻¹ was obtained in kharif 88, rabi 88 and kharif 89 respectively by adopting the plant population density of 5.0 lakh plants ha⁻¹. This treatment was significantly superior to all other population densities studied during the three seasons. With increase in population density from 2.5 to 5.0 lakhs ha⁻¹, there was significant increase in pod yield in all the three seasons.

4.2.3.2 Haulm Yield

Data on Haulm yield (kg ha⁻¹) are presented in table 16 and illustrated in fig. 17. These data indicate that plant population densities have significant effect on haulm yield.

It varied from 3186 to 4816 kg ha⁻¹ in kharif 88; 3416 to 5912 kg ha⁻¹ in rabi 88; and 4140 to 5010 kg ha⁻¹ in kharif 89. Maximum haulm yield of 4816, 5912 and 5010 kg ha⁻¹ was obtained in kharif 88, rabi 88 and kharif 89 respectively by adopting the plant population density of 5.0 lakh plants ha⁻¹ (T₁). Lowest haulm yield was recorded with a population density of 2.5 lakhs ha⁻¹ in all the seasons. There was significant increase in haulm yield with every successive increase in plant population density from 2.5 to 5.0 lakh plants ha⁻¹. The Haulm yield was relatively more in rabi season compared to kharif season.

4.3 ECONOMICS

Data on gross, net returns and benefit-cost ratio presented in table 17. Groundnut with a plant population density of 5.0 lakh plants ha⁻¹ gave highest gross and net returns and the lowest gross and net returns were obtained with a plant population density of 2.5 lakh plants ha⁻¹ in all the three seasons studied. Similarly adoption of plant population density of 5.0 lakh plants ha⁻¹

Table 16 : Pod and Haulm yields (kg ha^{-1}) of groundnut as influenced by different plant population densities.

Treatments	Kharif 88		Rabi 88		Kharif 89	
	Pod	Haulm	Pod	Haulm	Pod	Haulm
T ₁	3000	4816	3688	5912	3070	5010
T ₂	2720	4536	3384	5488	2720	4620
T ₃	2392	3842	2936	4832	2530	4330
T ₄	1764	3186	2368	3416	2440	4140
S.Ed.±	55	46	33	55	34	35
C.D.(0.05)	124	103	75	125	77	78

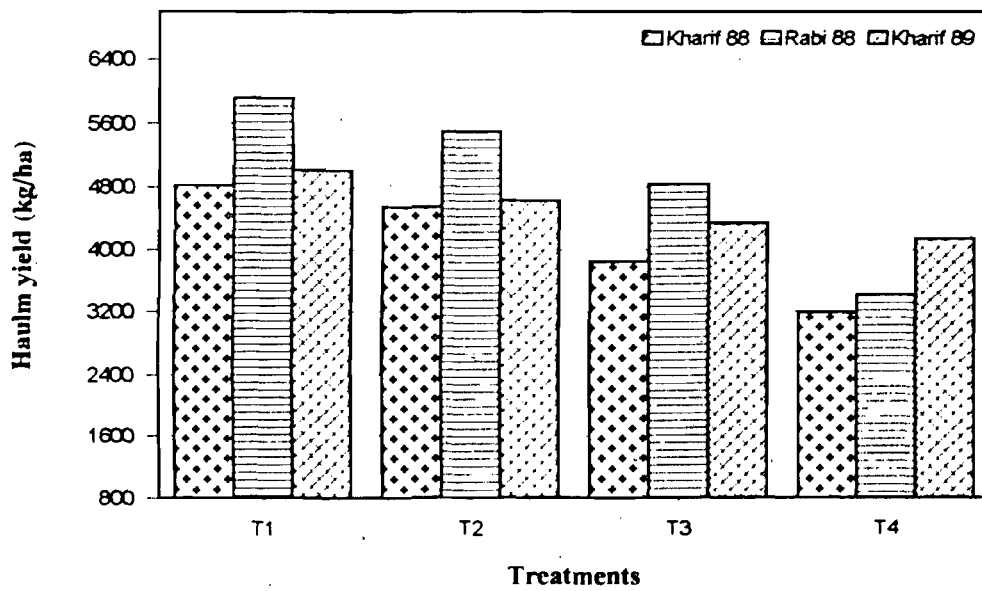
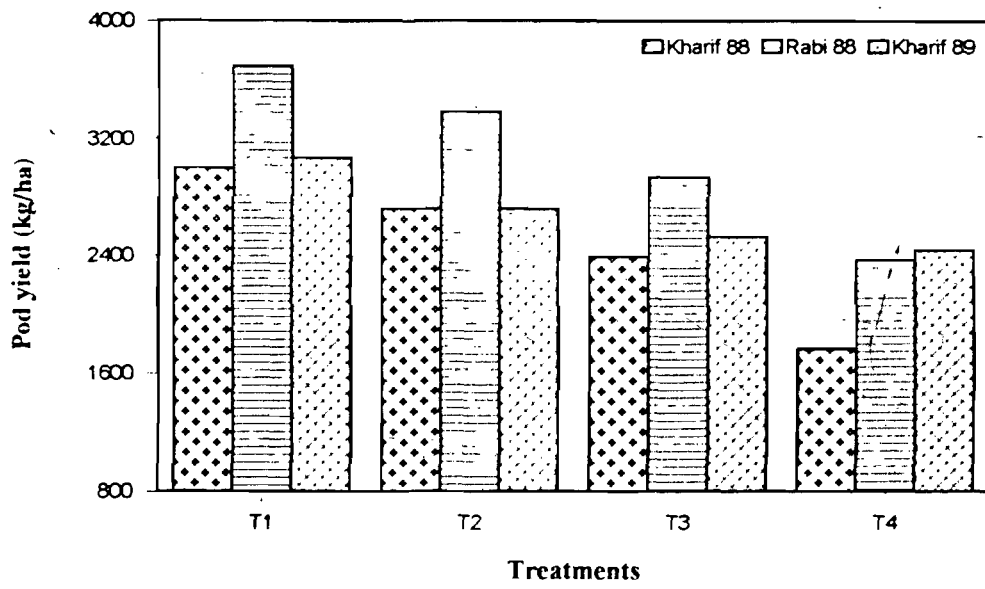


Fig. 17 : Pod and Haulm yields (kg/ha) of groundnut as influenced by different plant population densities

Table 17: Gross, net returns and benefit-cost ratio as influenced by different plant population densities of groundnut

Treatments	Gross returns (Rs./ha)			Net returns (Rs./ha)			Benefit-cost ratio (Rs./Rupee investment)		
	Kharif 88	Rabi 88	Kharif 89	Kharif 88	Rabi 88	Kharif 89	Kharif 88	Rabi 88	Kharif 89
T ₁	14663	17778	14817	10503	13818	10857	3.65	4.49	3.74
T ₂	13147	16326	13164	9502	12681	9519	3.61	4.48	3.61
T ₃	11532	14178	12251	8102	10748	8821	3.36	4.13	3.57
T ₄	8575	11338	11808	5465	8228	8698	2.76	3.65	3.80
Mean	11979	14905	13010	8393	11369	9474	3.35	4.19	3.68

gave maximum benefit-cost ratio of 3.64, 4.49 and 3.74 rupees rupee⁻¹ investment in kharif 88, rabi 88 and kharif 89 respectively). The benefit cost ratio was however least (2.76, 3.65 and 3.80 rupee rupee⁻¹ investment in kharif 88, rabi 88 and kharif 89 respectively) under a plant population density of 2.5 lakh plants ha⁻¹.

4.4 Pod yield - Crop evapotranspiration relationship

The pod yield was correlated with seasonal evapotranspiration and regression equation was worked out. The relationship was found to be linear (Table 18 and fig. 18).

The R² values for all the three seasons ranged from 0.9382 to 0.9848. The R² values were positive and highly significant (P=0.01). The magnitude of b coefficients was 145.1413, 149.5516 and 81.6501 for kharif 88, rabi 88 and kharif 89 respectively. The intercept was negative in all the three seasons.

4.5 PHYSICAL PROPERTIES OF THE SOIL

4.5.1 Soil structural Indices

4.5.1.1 Per cent aggregates greater than 0.25 mm

Soil structural indices are expressed in terms of per cent aggregates greater than 0.25 mm, mean weight diameter, stability index and structural coefficient. Data on per cent aggregates greater than 0.25 mm as influenced by different plant population densities of groundnut are presented in Table 19 and depicted graphically in Fig. 19.

Different plant population densities significantly influenced the per cent aggregates greater than 0.25 mm in the 0-15, 15-30 and 30-45 cm depth. Higher per cent aggregate values were observed with plant population density of 5.0 lakh plants ha⁻¹ (T₁) than with a plant population density of 2.5 lakh plants ha⁻¹ (T₄). When the plant density was 5.0 lakhs ha⁻¹, the mean per cent

Table 18: Empirical estimates for the relationship between pod yield and crop evapotranspiration in groundnut.

Season	Regression constants, coefficients and test statistics		
	a	b	R ²
Kharif 88	-4867.8906	145.1413	0.9761**
Rabi 88	-5202.3771	149.5516	0.9848**
Kharif 89	-1002.6235	81.6501	0.9382**

** Significant at $P=0.01$

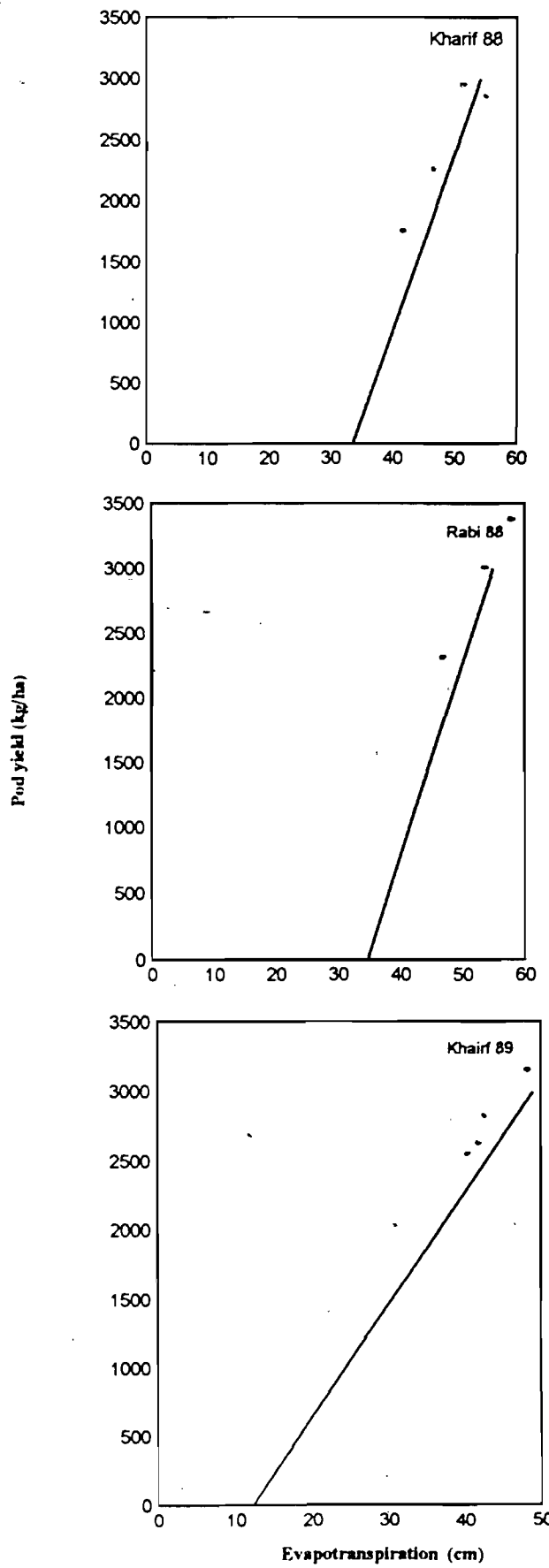


Fig. 18 : Pod yield - crop evapotranspiration relationship in groundnut

Table 19 : Per cent aggregates greater than 0.25 mm at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	47.45	44.39	37.15	43.00
T ₂	46.25	43.97	36.98	42.40
T ₃	46.24	43.65	36.74	42.21
T ₄	45.95	43.48	36.68	42.04
S.Ed. ±	0.15	0.07	0.15	
C.D.(0.05)	0.35	0.16	0.34	
Rabi 88				
T ₁	47.69	42.88	35.39	41.99
T ₂	46.98	42.16	34.85	41.33
T ₃	46.35	42.00	34.48	40.94
T ₄	46.10	41.89	34.16	40.72
S.Ed. ±	0.07	0.07	0.04	
C.D.(0.05)	0.17	0.15	0.09	
Kharif 89				
T ₁	48.95	44.68	37.84	43.82
T ₂	48.46	43.95	37.29	43.23
T ₃	48.22	43.27	37.00	42.83
T ₄	47.99	42.69	36.88	42.52
S.Ed. ±	0.06	0.09	0.07	
C.D.(0.05)	0.14	0.20	0.15	

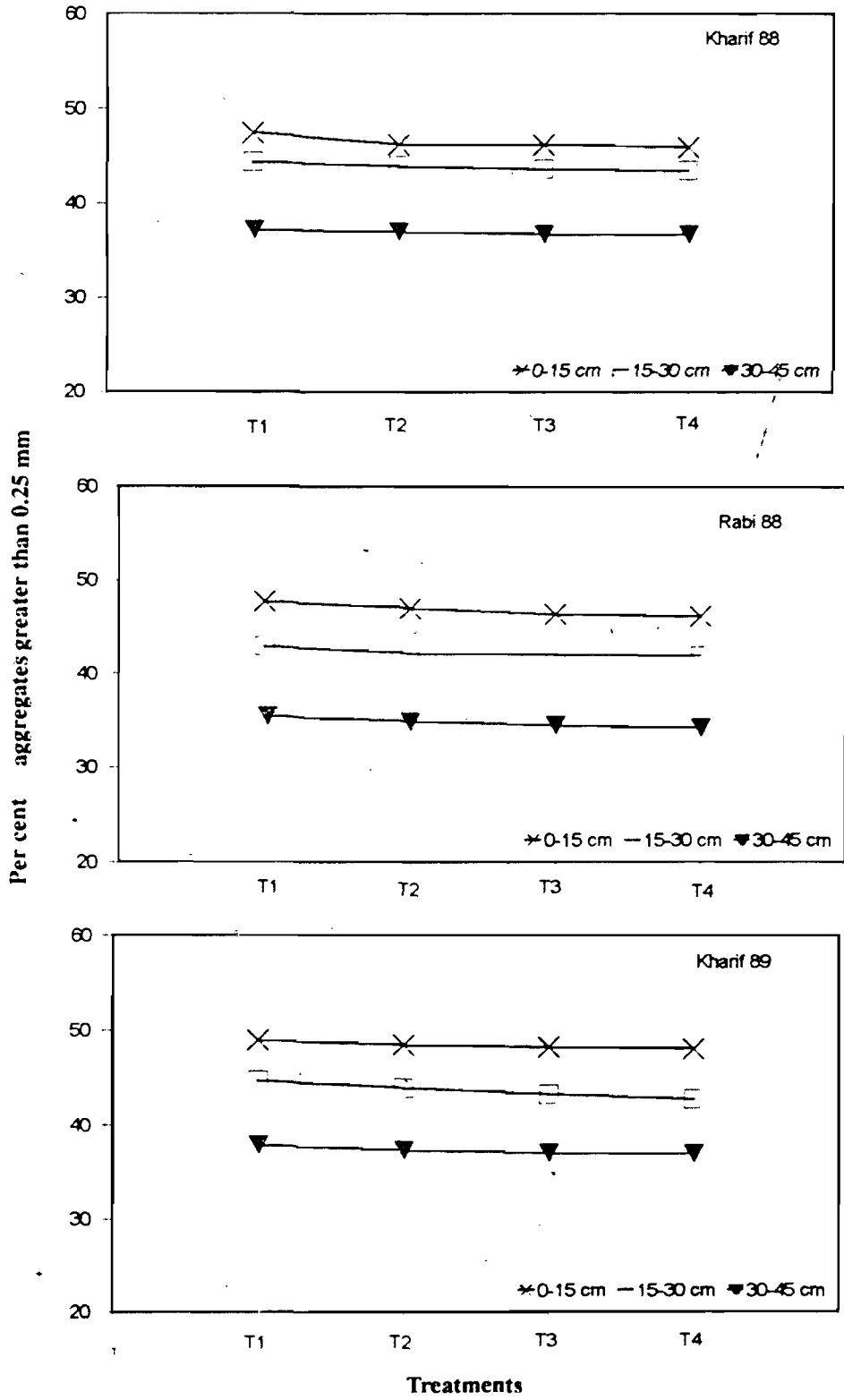


Fig. 19 : : Per cent aggregates greater than 0.25 mm at harvest as influenced by different plant population densities of groundnut

aggregates (greater than 0.25 mm) values were 43.00, 41.99 and 43.82 per cent in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice (T₃) which recorded 42.21, 40.94 and 42.83 per cent in kharif 88, rabi 88 and kharif 89 respectively with a plant population density of 3.33 lakh plants ha⁻¹.

Lower per cent aggregate values of 42.04, 40.72 and 42.52 per cent in kharif 88, rabi 88 and kharif 89 respectively were obtained when groundnut was grown with population of 2.5 lakh plant ha⁻¹. The increase in per cent aggregates greater than 0.25 mm with increase in plant population was found to be significant at different depths in all the three seasons.

4.5.1.2 Mean weight diameter (mm)

The data on mean weight diameter as influenced by different plant population densities of groundnut are presented in Table 20 and illustrated through Fig. 20.

Plant population densities significantly influenced the mean weight diameter in the three sampling depths upto 45 cm. Mean weight diameter values were higher with plant population density of 5 lakh plants ha⁻¹ (T₁) as compared to lower plant population of 2.5 lakh plants ha⁻¹ (T₄). When the plant density was 5.0 lakhs ha⁻¹, the mean weight diameter values were 1.76, 1.68 and 1.77 mm in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice of 3.33 lakh plants ha⁻¹ (T₃) which recorded 1.65, 1.58 and 1.63 mm in kharif 88, rabi 88 and kharif 89 respectively.

Mean weight diameter values were lower (1.56, 1.53 and 1.60 mm in kharif 88, rabi 88 and kharif 89 respectively) when groundnut was grown with

Table 20 : Mean weight diameter (mm) at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	1.85	1.75	1.67	1.76
T ₂	1.81	1.70	1.63	1.71
T ₃	1.74	1.62	1.60	1.65
T ₄	1.64	1.53	1.50	1.56
S.Ed. ±	0.01	0.01	0.01	
C.D.(0.05)	0.02	0.03	0.02	
Rabi 88				
T ₁	1.79	1.66	1.58	1.68
T ₂	1.73	1.61	1.54	1.63
T ₃	1.68	1.58	1.49	1.58
T ₄	1.65	1.51	1.43	1.53
S.Ed. ±	0.01	0.01	0.01	
C.D.(0.05)	0.03	0.02	0.03	
Kharif 89				
T ₁	1.89	1.79	1.63	1.74
T ₂	1.82	1.71	1.58	1.70
T ₃	1.78	1.66	1.54	1.66
T ₄	1.72	1.57	1.51	1.60
S.Ed. ±	0.02	0.01	0.01	
C.D.(0.05)	0.04	0.03	0.03	

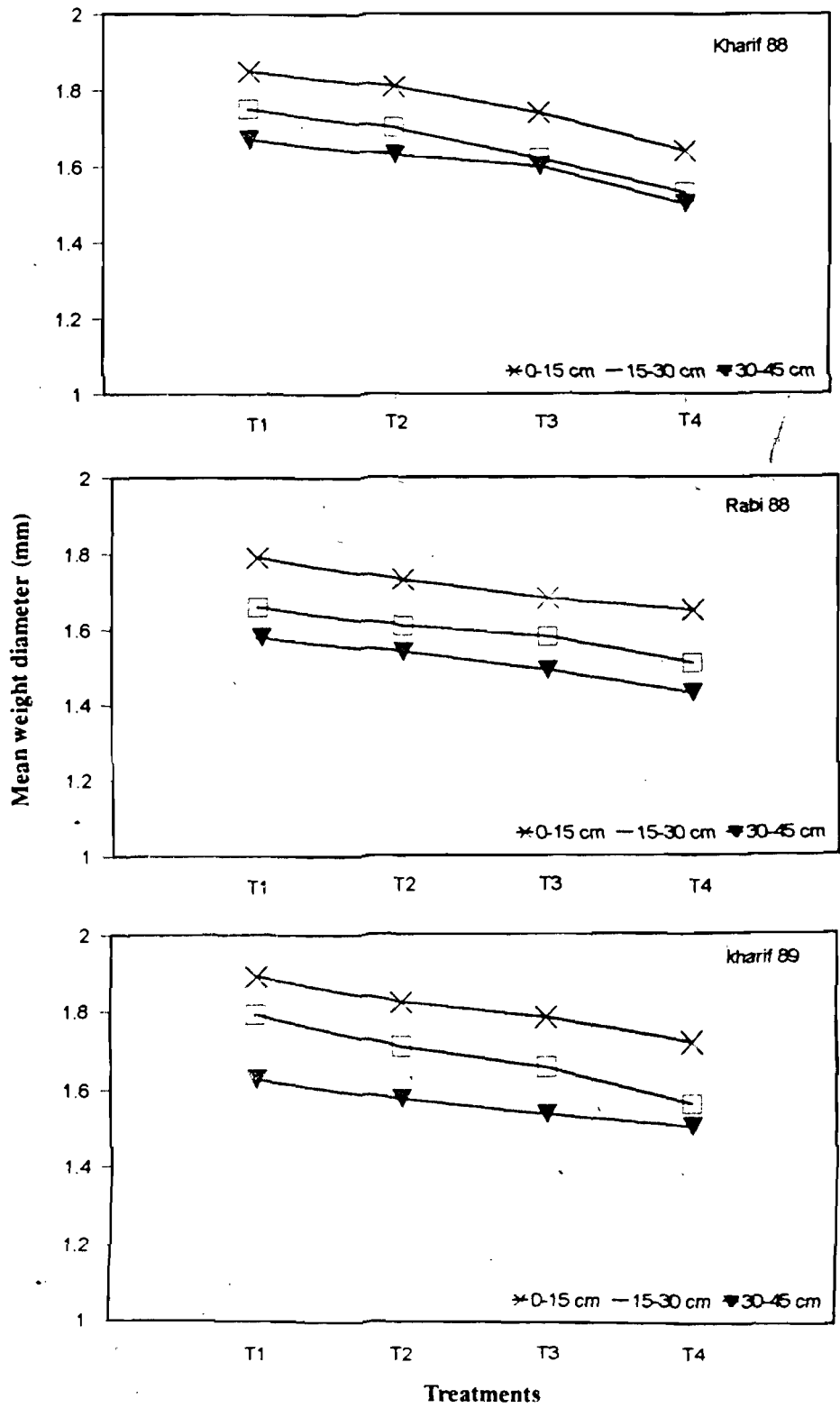


Fig. 20 : Mean weight diameter (mm) at harvest as influenced by different plant population densities of groundnut

population of 2.5 lakh plants ha^{-1} . Increase in mean weight diameter with increase in plant population was found to be significant at different depths in all the three seasons.

4.5.1.3 Stability index (per cent)

Data on stability index, as influenced by different plant population densities of groundnut are presented in table 21 and depicted through Fig. 21.

Stability index of soil in the 0-15, 15-30 and 30-45 cm soil depths was significantly influenced by different plant population densities. Stability index values were higher with plant population density of 5.0 lakh plants ha^{-1} (T₁) than with a plant population density of 2.5 lakh plants (T₄). When the plant density was 5.0 lakhs ha^{-1} , mean stability index values were 23.87, 22.51 and 24.72 per cent in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice (T₃) which recorded 20.49, 19.62 and 21.56 per cent in the respective seasons with a plant population density of 3.33 lakh plants ha^{-1} .

Lower stability index values of 19.46, 18.84 and 20.44 per cent in kharif 88, rabi 88 and kharif 89 respectively were obtained when groundnut was grown with a population of 2.5 lakh plants ha^{-1} . The increase in stability index of the soil with increase in plant population was found to be significant at different depths in all the three seasons.

4.5.1.4 Structural coefficient (per cent)

The data on structural coefficient as influenced by different plant population densities of groundnut, are presented in table 22 and illustrated through fig. 22.

Table 21 : Stability index (per cent) of the soil at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	25.88	23.98	21.75	23.87
T ₂	23.56	21.65	20.36	21.86
T ₃	21.20	20.28	20.00	20.49
T ₄	20.07	19.06	19.25	19.46
S.Ed. ±	0.07	0.09	0.09	
C.D.(0.05)	0.15	0.21	0.21	
Rabi 88				
T ₁	23.89	22.45	21.18	22.51
T ₂	20.88	20.92	19.54	20.45
T ₃	20.05	19.95	18.86	19.62
T ₄	19.58	19.18	17.75	18.84
S.Ed. ±	0.09	0.12	0.08	
C.D.(0.05)	0.21	0.26	0.18	
Kharif 89				
T ₁	26.65	24.85	22.65	24.72
T ₂	24.45	22.76	21.46	22.89
T ₃	22.30	21.34	21.05	21.56
T ₄	21.09	20.12	20.10	20.44
S.Ed. ±	0.10	0.06	0.29	
C.D.(0.05)	0.22	0.13	0.66	

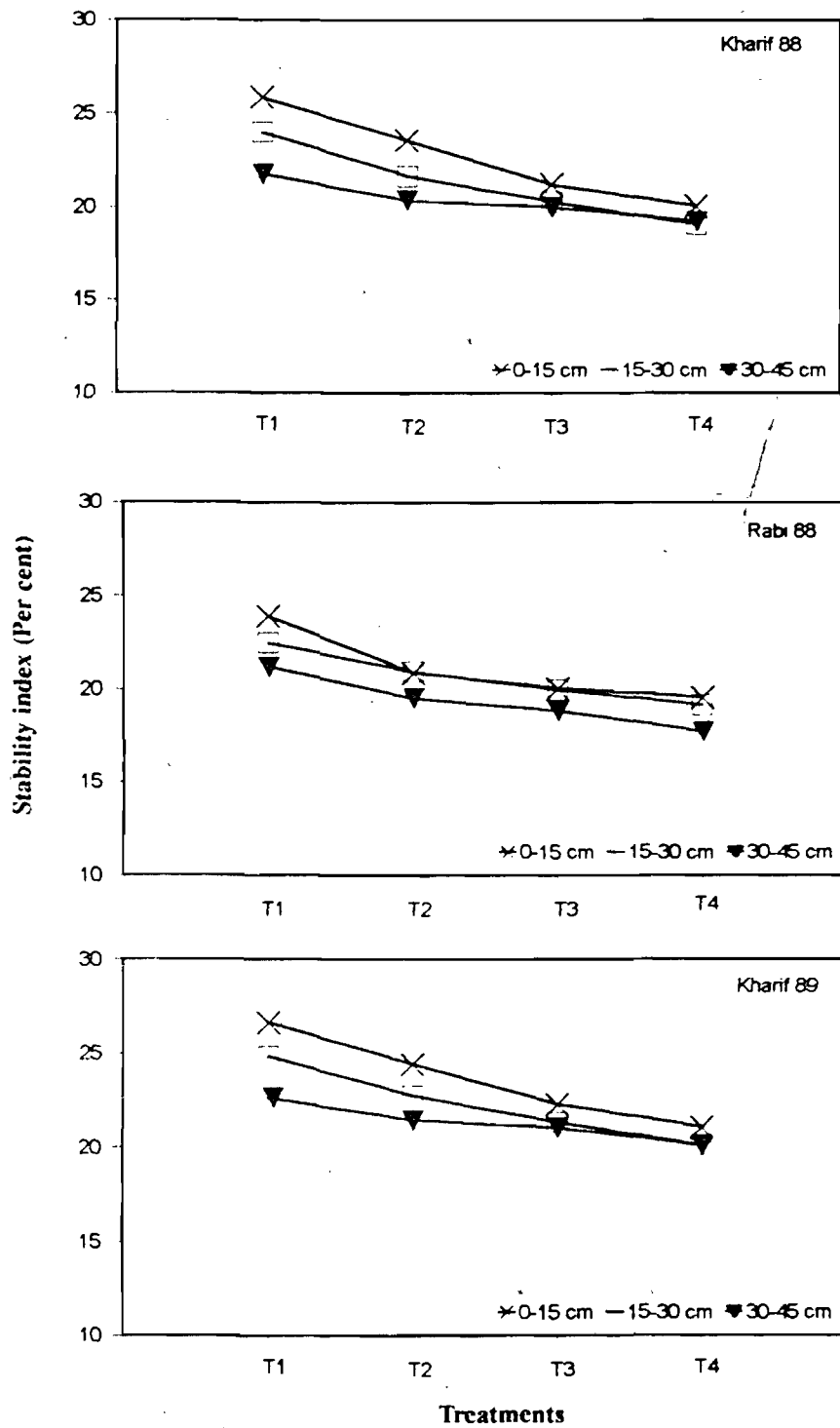


Fig. 21: Stability index (per cent) at harvest as influenced by different plant population densities

Table 22: Structural coefficient (per cent) of the soil at harvest as influenced by different plant population densities of groundnut -

Treatments	Depth (cm)			
	0 - 15	15 - 30	30 - 45	Mean
Kharif 88				
T ₁	47.88	44.73	41.27	44.63
T ₂	46.57	42.37	40.46	43.13
T ₃	45.25	41.98	39.55	42.26
T ₄	44.45	41.25	38.25	41.32
S.Ed.±	0.25	0.05	0.29	
C.D.(0.05)	0.56	0.12	0.65	
Rabi 88				
T ₁	47.52	44.46	41.50	44.49
T ₂	46.34	43.24	40.45	43.34
T ₃	45.55	42.26	39.66	42.49
T ₄	44.94	41.55	39.35	40.94
S.Ed.±	0.15	0.10	0.01	
C.D.(0.05)	0.34	0.22	0.23	
Kharif 89				
T ₁	48.75	45.66	42.35	45.59
T ₂	47.60	43.45	41.25	44.10
T ₃	46.35	42.88	40.20	43.14
T ₄	45.50	42.34	39.33	42.39
S.Ed.±	0.08	0.17	0.12	
C.D.(0.05)	0.17	0.38	0.28	

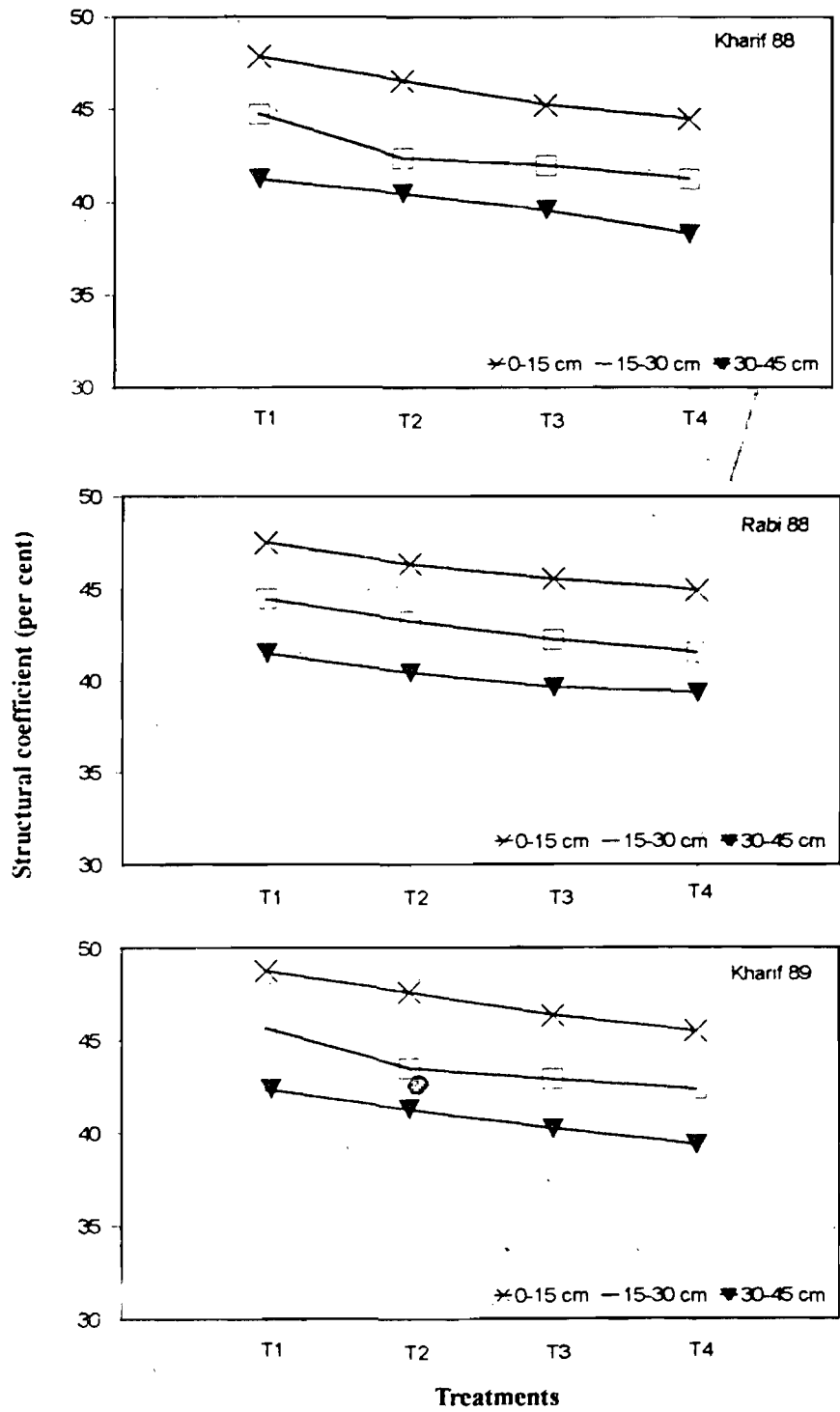


Fig. 22 : Structural coefficient (per cent) at harvest as influenced by different plant population densities

Different plant population densities significantly influenced the structural coefficient of soil in the 0-15, 15-30 and 30-45 cm depths. Higher structural coefficient values were observed with plant population density of 5.0 lakh plants ha^{-1} (T₁) than with a plant population density of 2.5 lakh plants (T₄). When the plant density was 5.0 lakhs ha^{-1} , the mean structural coefficient values were 44.63, 44.49 and 45.59 per cent in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice of T₃ which recorded 42.26, 42.49 and 43.14 per cent in the respective seasons with a plant population density of 3.33 lakh plants ha^{-1} .

Lower structural coefficient values of 41.32, 40.94 and 42.39 per cent in kharif 88, rabi 88 and kharif 89 respectively were obtained when groundnut was grown with population of 2.5 lakh plants ha^{-1} . The increase in structural coefficient values of the soil with increase in plant population was found to be significant at different depths during all the three seasons.

4.5.1.5 Bulk density (g cm^{-3})

Data on soil bulk density as influenced by different plant population densities of groundnut are presented in Table 23 and illustrated in fig. 23. From these data, it could be noticed that plant population densities significantly influenced the soil bulk density in the 0-15 cm layer. The effect of higher plant population density was less in the deeper layers. Bulk density was relatively higher with plant population of 5.0 plants ha^{-1} as compared to that of 2.5 lakh plants ha^{-1} . When the plant density was 5.0 lakhs ha^{-1} (T₁), the mean bulk density values were 1.57, 1.60 and 1.58 g cm^{-3} in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice of 3.33 lakh plants ha^{-1} (T₃), which recorded 1.60, 1.62 and 1.60 g cm^{-3} in kharif 88, rabi 88 and kharif 89 respectively.

Table 23: Bulk density (g cm^{-3}) of the soil at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	1.50	1.53	1.67	1.57
T ₂	1.53	1.55	1.68	1.59
T ₃	1.56	1.56	1.68	1.60
T ₄	1.58	1.58	1.69	1.62
S.Ed.±	0.02	0.02	0.03	
C.D.(0.05)	0.05	NS	NS	
Rabi 88				
T ₁	1.55	1.59	1.66	1.60
T ₂	1.57	1.59	1.66	1.61
T ₃	1.58	1.60	1.67	1.62
T ₄	1.59	1.60	1.67	1.62
S.Ed.±	0.01	0.01	0.01	
C.D.(0.05)	0.01	NS	NS	
Kharif 89				
T ₁	1.53	1.56	1.65	1.58
T ₂	1.55	1.58	1.66	1.60
T ₃	1.55	1.59	1.66	1.60
T ₄	1.56	1.59	1.67	1.61
S.Ed.±	0.01	0.01	0.03	
C.D.(0.05)	0.01	0.01	NS	

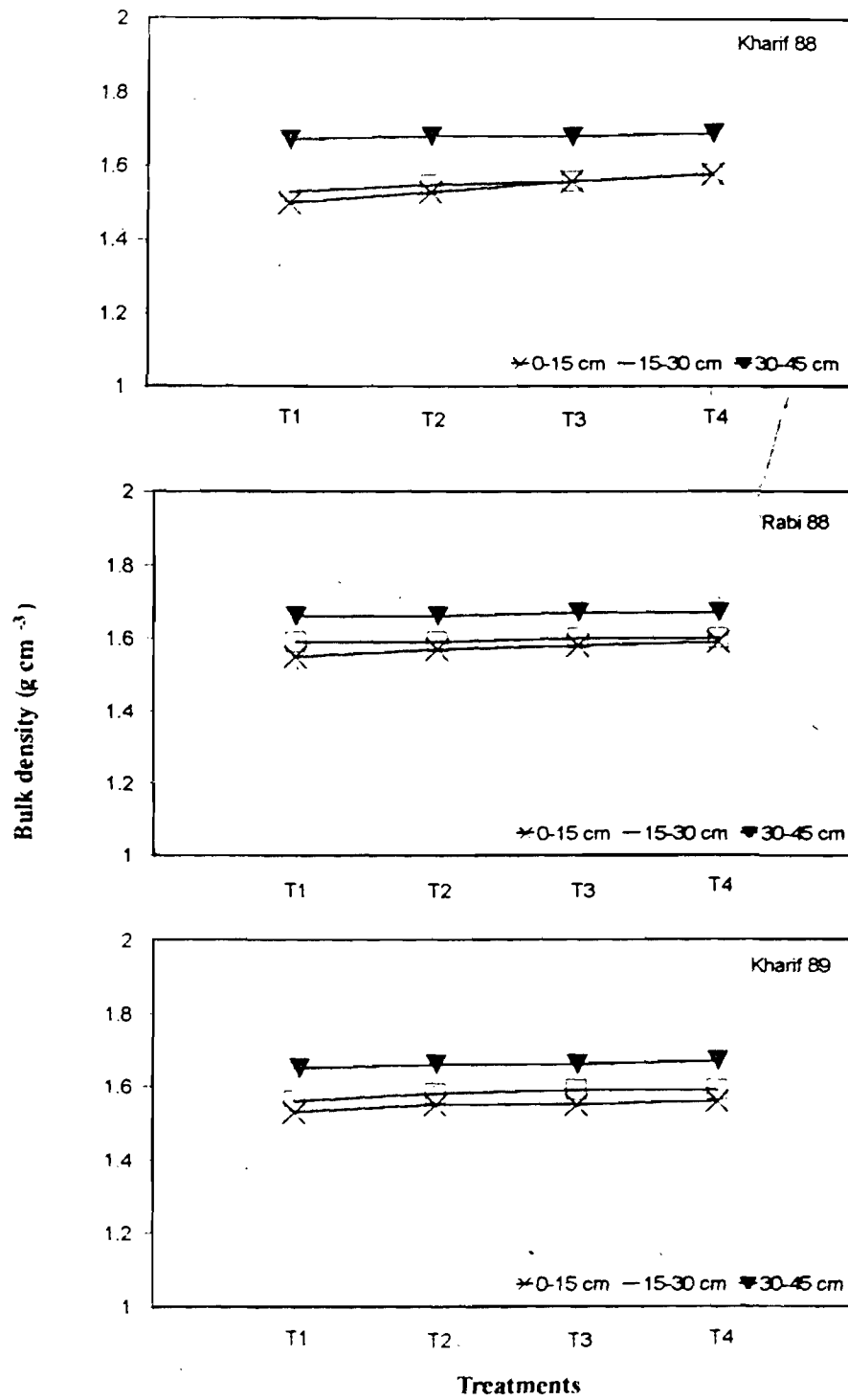


Fig. 23: Bulk density (g cm³) at harvest as influenced by different plant population densities

Higher soil bulk density values of 1.62, 1.62 and 1.61 g cm⁻³ in kharif 88, rabi 88 and kharif 89 seasons respectively were noticed when groundnut was grown with a population of 2.5 lakh plants ha⁻¹. The decrease in bulk density with increase in plant population was found to be significant in the surface layers but the effect was non-significant in lower layers except at 15-30 cm depth in kharif 89.

4.5.1.6 Hydraulic Conductivity (cm hr⁻¹)

Data on hydraulic conductivity as influenced by different plant population densities of groundnut are presented in table 24 and illustrated in fig.24. It could be noticed from these data that different plant population densities significantly influenced the hydraulic conductivity upto 45 cm depth. Higher hydraulic conductivity values were observed with plant population density of 5.0 lakh plants ha⁻¹ (T₁) as compared to that of 2.5 lakh plants ha⁻¹ (T₄). When the plant density was 5 lakhs ha⁻¹, the mean hydraulic conductivity values were 4.90, 4.45 and 4.94 cm hr⁻¹ in kharif 88, rabi 88 and kharif 89 respectively compared to the normal practice (T₃) which recorded 4.57, 4.16 and 4.71 cm hr⁻¹ in kharif 88, rabi 88 and kharif 89 respectively.

Lower hydraulic conductivity values of 4.43, 4.03 and 4.60 cm hr⁻¹ in kharif 88, rabi 88 and kharif 89 respectively were obtained when groundnut was grown with a population of 2.5 lakh plants ha⁻¹. The increase in hydraulic conductivity with increase in plant population was found to be significant in all the three seasons.

4.5.1.7 Total Porosity (per cent)

The data on total porosity as influenced by different plant population densities are presented in table 25 and depicted in fig. 25.

Table 24: Hydraulic conductivity of the soil (cm hr^{-1}) at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	6.05	4.72	3.94	4.90
T ₂	5.84	4.56	3.86	4.75
T ₃	5.67	4.24	3.79	4.57
T ₄	5.55	3.99	3.75	4.43
S.Ed.±	0.04	0.03	0.02	
C.D.(0.05)	0.08	0.06	0.05	
Rabi 88				
T ₁	5.92	4.18	3.26	4.45
T ₂	5.84	4.06	2.96	4.29
T ₃	5.60	4.00	2.88	4.16
T ₄	5.48	3.86	2.75	4.03
S.Ed.±	0.02	0.02	0.02	
C.D.(0.05)	0.04	0.05	0.04	
Kharif 89				
T ₁	6.31	4.75	3.77	4.94
T ₂	6.28	4.54	3.70	4.84
T ₃	6.14	4.37	3.62	4.71
T ₄	6.00	4.22	3.58	4.60
S.Ed.±	0.02	0.01	0.15	
C.D.(0.05)	0.04	0.03	0.04	

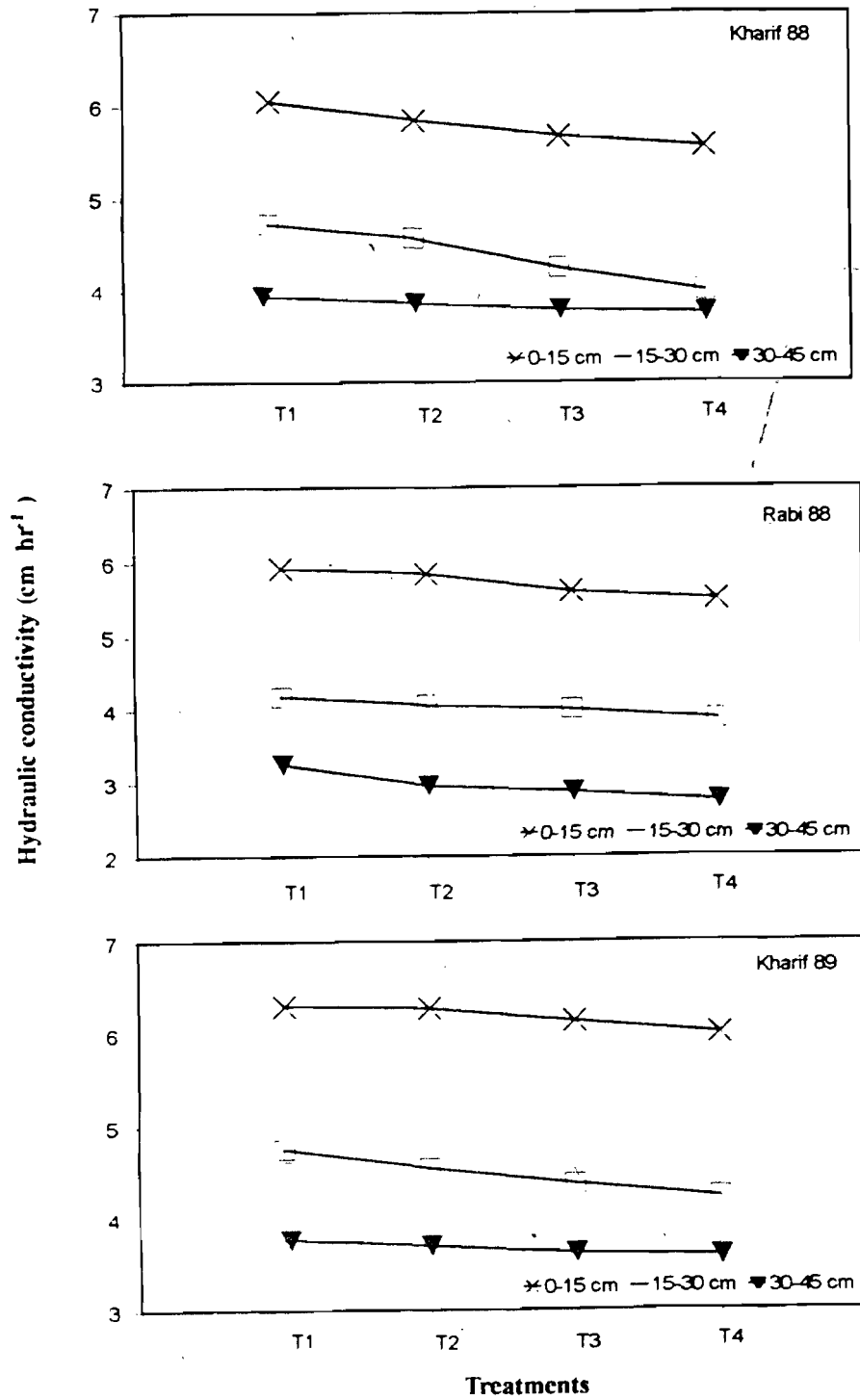


Fig. 24 : Hydraulic conductivity (cm hr⁻¹) at harvest as influenced by different plant population densities

Table 25: Total porosity (per cent) of the soil at harvest as influenced by different plant population densities of groundnut

Treatments	Depth (cm)			Mean
	0 - 15	15 - 30	30 - 45	
Kharif 88				
T ₁	46.36	41.54	33.45	40.45
T ₂	45.58	40.70	32.88	39.72
T ₃	44.76	39.98	32.36	39.03
T ₄	44.24	39.64	31.92	38.60
S.Ed.±	0.07	0.07	0.07	
C.D.(0.05)	0.15	0.17	0.15	
Rabi 88				
T ₁	46.14	42.00	33.13	40.42
T ₂	45.56	41.36	32.55	39.82
T ₃	45.68	40.96	32.36	39.67
T ₄	44.97	39.70	32.20	38.96
S.Ed.±	0.07	0.07	0.07	
C.D.(0.05)	0.16	0.17	0.17	
Kharif 89				
T ₁	46.98	41.72	34.20	40.97
T ₂	45.76	40.98	33.95	40.23
T ₃	45.25	40.62	33.66	39.84
T ₄	44.40	39.75	33.54	39.23
S.Ed.±	0.09	0.07	0.08	
C.D.(0.05)	0.20	0.15	0.18	

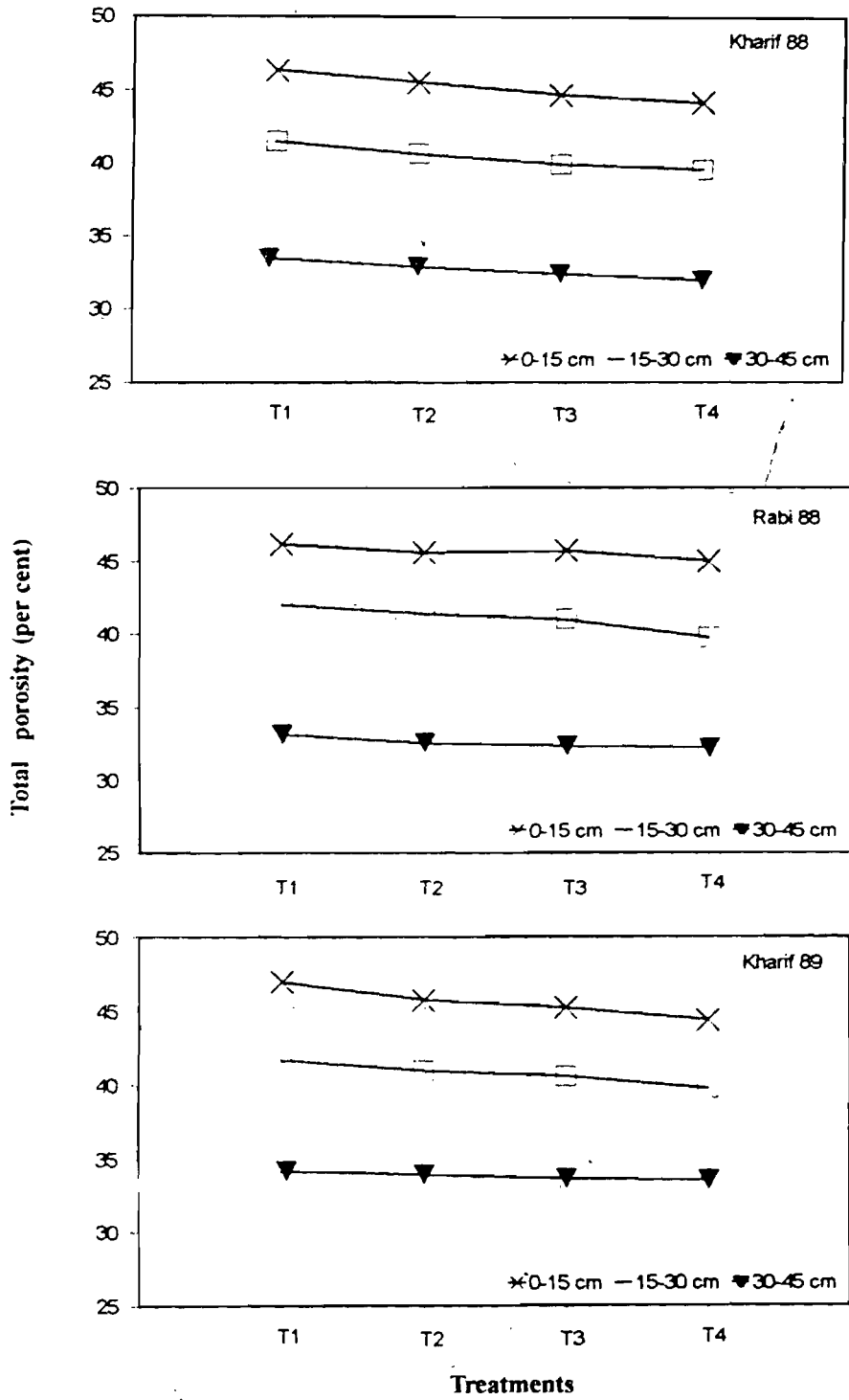


Fig. 25: Total porosity (per cent) as influenced by different plant population densities

Total porosity of soil in the 0-15, 15-30 and 30-45 cm depths was significantly influenced by different plant population densities. Higher porosity was observed with a plant population density of 5.0 lakh plants ha^{-1} as compared to that of 2.5 lakh plants ha^{-1} in all the three seasons. When the plant density was 5.0 lakhs ha^{-1} , the mean total porosity values were 40.45, 40.42 and 40.97 per cent in kharif 88, rabi 88^{and} kharif 89 respectively compared to the normal practice (T₃), which recorded 39.03, 39.67 and 39.84 per cent respectively.

Lower total porosity values of 38.60, 38.96 and 39.23 per cent in kharif 88, rabi 88 and kharif 89 seasons respectively were noticed when groundnut was grown with a population of 2.5 lakh plants ha^{-1} .

DISCUSSION

CHAPTER IV

DISCUSSION

The results obtained have been discussed in this chapter in the light of the literature available. For convenience the discussion has been made under the following heads.

5.1 Effect of different plant population densities of groundnut on evapotranspiration and water use efficiency.

Daily water use rate ($ET\ d^{-1}$) and K_c values of groundnut increased progressively with crop age in all the three seasons (Fig. 6). Peak evapotranspiration, water use and K_c values coincided with higher rate of dry matter accumulation during the period from 36 to 95 DAS (Tab. 14). Slightly lower values were recorded during maturity period (96 to 116 DAS) in all the three seasons due to leaf senescence and reduced root activity (Reddy, 1988; Reddy, 1991).

Consumptive use of water increased significantly with increase in plant population density. Crop with a plant population density of 5.0 lakh plants ha^{-1} throughout its growth period utilized water at higher rate and resulted in higher evapotranspiration (54.6, 59.1 and 49.1 cm during kharif 88, rabi 88 and kharif 89 respectively). The increase in consumptive use of water with the increase in plant density might be due to higher leaf area displayed per unit land area (Rao, 1990). Greater root proliferation at depths (Tab. 12) may be a response to the greater inter-plant competition for water in denser plant stands which leads to increased water extraction from deeper layers in the profile (Azam-Ali *et al.*, 1984). These results are in good agreement with the findings of Bhan and Misra (1970), Bhan (1973), Simmonds and Williams (1989) and Azam-Ali *et al.*, (1989).

The relationship between crop ET and reference crop ET (Fig. 11a, 11b 11c) was linear indicating that crop ET was dependent upon climatic parameters (Palaskar *et al.*, 1987). Further the K_c values at different crop growth stages between the actual based on reference ET estimated by different empirical methods (Modified Penman, Blaney-Criddle, Hargreaves and Radiation) corroborate well with the K_c values presented in F.A.O. - 33 (Doorenbos and Kassam, 1979) suggest that any of these crop coefficients can be satisfactorily used particularly when the data input is a limitation for estimation of reference ET (Tab. 4).

Significant correlations were observed between crop ET and reference crop ET estimated by Modified Penman, Blaney-Criddle, Hargreaves, Radiation and Pan evaporation during all the three seasons studied. Higher Correlations were obtained with Blaney- Criddle (R^2 0.9520) followed by Hargreaves (R^2 0.9497), Radiation (R^2 0.9270) and Modified Penman (R^2 0.9256) during kharif 88; Modified Penman (R^2 0.9585) followed by Blaney-Criddle (R^2 0.9580), Hargreaves (R^2 0.9381) and Radiation (R^2 0.9146) during rabi 88 and Blaney-Criddle (R^2 0.8807) followed by Modified Penman (R^2 0.8348) during kharif 89. These suggest that any of the empirical methods in their order can reliably be used for estimating reference crop evapotranspiration in Southern Telangana Zone. Among the methods, Modified Penman method is the most reliable as it accounts for all the environmental variables affecting crop evapotranspiration. However, the data input requirement of various methods for estimating reference ET may pose a limitation for prediction of crop water requirements (Crop ET_a). This problem may be solved in two ways. One is that the data on pan evaporation, as it significantly correlated with crop ET (R^2 0.9600, 0.9901 and 0.8278 during kharif 88, rabi 88 and kharif 89 respectively)

is available in almost all the places. Hence, under limited climatic data availability situations, the E_{pan} values which integrate the effect of all climatic factors into a single entity can reliably be used for estimation of crop ET (Rao, 1989).

Further, the data input for Hargreaves method is only temperature which can be easily collected in command areas. Number of meteorological observatories can be located in command areas of irrigation projects to record only minimum and maximum temperature with minimum cost, rather than depending on a full-fledged meteorological observatory (Chhabda *et al.*, 1986).

Values of evapotranspiration from groundnut having a plant population density of 5.0 lakh plants ha^{-1} were significantly correlated with evaporation from open Can (R^2 0.9646, 0.9056 and 0.9510 during kharif 88, rabi 88 and kharif 89 respectively) and Can evaporimeter having screen size of 6/20 mesh (R^2 0.9863, 0.9119 and 0.9788 for kharif 88, rabi 88 and kharif 89 respectively) in all the three seasons. The regression equations developed showed the relationship between evapotranspiration in groundnut having a plant population density of 5.0 lakh plants ha^{-1} and evaporation from open Can and Can evaporimeter having screen size of 6/20 mesh (Tab. 11). Sharma and Dastane (1969) established similar relationships in wheat. Higher R^2 values between crop ET and evaporation from Can evaporimeter having screen size of 6/20 mesh compared to that of open Can indicate that the later may be preferred in evapotranspiration estimates under the agro climatic condition of Southern Telangana Zone. Significant correlation between U.S.W.B. class A pan and Can evaporimeters (both open and 6/20 mesh screen) (Tab. 10) indicate that the former can be replaced with small cans can effectively be used for evapotranspiration studies and scheduling irrigation in groundnut in this

agroclimatic zone. Sharma *et al.*, (1975), Sreenivasulu *et al.*, 1978, Reddy *et al.*, (1988) and Reddy (1981) advocated the use of simpler evaporimeters for scheduling irrigation.

Groundnut crop with lower plant population density of 2.5.0 lakh plants ha^{-1} extracted higher percent of moisture from 0-15 cm soil depth (Tab. 7). As the plant population density increased from 2.5 to 5.0 lakh plants ha^{-1} , the competition among the plants increased and this extracted more moisture from the deeper layers. Greater root proliferation at depths for water may be a response to the greater plant competition which leads to increased extraction from deeper layers in the profile (Azam-Ali, 1984).

The dense root system in groundnut with a plant population density of 5.0 lakh plants ha^{-1} was responsive to crop water use efficiency in terms of pod yield (Tab. 8). It is therefore clear that a plant population density of 5.0 lakh plants ha^{-1} is better than the normal practice of 3.33 lakh plants ha^{-1} in utilizing the water more efficiently.

Pod yield increased linearly with the increase in evapotranspiration (Fig. 18). This response was seen due to adoption of different plant population density treatments which differed significantly in extracting water from the soil. The linear function between pod yield and seasonal evapotranspiration performed well during all the seasons as evident from the total variation (R^2 0.9382 to 0.9848). The negative intercept during all the three seasons suggested that certain amount of water needs to be expended even at zero level of pod yield. Similar linear relationship was reported by several workers for many crops (Hanks *et al.*, 1969 Samis, 1981; Hanks 1974 and Singh *et al.*, 1987).

5.2 Effect of different plant population densities on growth and yield of groundnut

Increase in plant density from 2.5 to 5.0 lakh plants ha^{-1} significantly increased the length of main root at all the growth stages in all the three seasons studied (Fig.13). This might be ascribed to the crowding of the lateral roots due to severe competition and allowed more vertical penetration of the main root. Similar results were reported by Misra and Singh (1968) and Azam-Ali (1984). Each successive increase in plant density significantly reduced the root lateral spread at all the growth stages and in all the three seasons (Tab. 13). This might be attributed to less availability of space for light, moisture and nutrients under high competitive environment in high plant density which allowed less root lateral spread compared to lower plant density.

Both root and shoot dry matter increased significantly with increase in plant population density at all the growth stages in all the three seasons (Tab. 14 and 15). Dry matter accumulation seems to have been more influenced by number of plants per unit area.

The data presented in Table 16 indicated that pod and haulm yields increased with increase in plant population from 2.5 to 5.0 lakh plants ha^{-1} . Regulating the plant density to an optimum level is essential to exploit the yield potential by allowing the inter and intra row spacing competitiveness without detriment to the total out put.

The crop with a population density of 5.0 lakh plants ha^{-1} resulted in significantly higher pod and haulm yield than the crop with 4.00, 3.33 and 2.50 lakh plants ha^{-1} in all the three seasons. At low plant population, there will be no competition at the time of germination, vegetative period and at flowering. Under this situation, large size pods are possible. With increasing population,

though the individual pod size is decreased to certain extent, it is over compensated by the increased number of plants per unit area, thereby resulting in higher yields. Physiologically higher yields can be obtained when source and sink are well balanced. These results are in good agreement with the findings of Rao (1990) and Ramulu (1992).

5.3 Economics

Economic considerations in any package of recommendation should be set on a priority basis. The present investigation indicated higher pod yield, net profit and benefit-cost ratio with the population density of 5.0 lakh plants ha^{-1} as compared to other lower levels under assured irrigation irrespective of the seasons.

5.4 Effect of different plant population densities on structural indices in rizhosphere.

The results recorded in Table 19, 20, 21 and 22 indicated that soil structural indices viz., aggregates greater than 0.25 mm, mean weight diameter, structural coefficient and stability index were increased in all the three seasons due to high plant population density (5.0 lakh plants ha^{-1}) of groundnut. Aggregates greater than 0.25 mm were increased by 2.28, 3.12 and 3.06 per cent in kharif 88, rabi 88 and kharif 89 respectively by maintaining the plant population densities of 5.0 lakh plants ha^{-1} compared to the lower plant population density of 2.5.0 lakh plants ha^{-1} . This might be due to the fact that increased plant population density, increased the root net per unit area. More number of roots per unit area cause more pressure and compress the primary and secondary soil particles into compound particles. Similarly rapid removal of water from the soil mass by the extensive root system under high population causes dehydration and shrinkage of soil with the formation of surface fracture

(Ghildyal and Tripathi, 1987). The roots are known to secrete organic cementing substances which help in the aggregate formation. The root secretions are directly related to the roots per unit volume. So due to more roots per unit area, more secretions might have been produced under high plant population density resulting in improved soil structure. Kiselev (1955) opined that all agricultural crops improve the soil structure during their development. The results of the present study were supported by the reports of Biswas *et al.*, (1967), Donahue *et al.*, (1977) and Opara-Nadi and Lal (1987).

Bulk density of the soil (Table 23) decreased with increasing plant population density of groundnut. Highest bulk density values were observed with 2.5.0 lakh plants ha^{-1} and the crop with 5.0 lakh plants ha^{-1} recorded the lowest values. In kharif 88, when the plant population increased from 2.5 to 5.0 lakh plants ha^{-1} , the bulk density decreased by 0.05 g cm^{-3} . The corresponding values were 0.02 and 0.03 g cm^{-3} for rabi 88 and kharif 89 respectively. Loosening of the soil by development of more number of roots per unit area, better soil aggregation might have resulted in lower bulk densities under high plant population density. The results are fairly in agreement with those reported by Juo and Lal (1977) and Opara-nadi and Lal (1987).

Hydraulic conductivity of soil was significantly decreased with an increase in plant population density of groundnut. The Hydraulic conductivity increased by 10.61 per cent with plant population density of 5.0 lakh plants ha^{-1} over the value of 4.43 cm hr^{-1} recorded with 2.5 lakh plants ha^{-1} in kharif 88. The corresponding values were 10.42 and 7.39 per cent in rabi 88 and kharif 89 respectively (Table 24). The increase in hydraulic conductivity with increase in plant population density might be attributed to improved soil

aggregation, reduced bulk density with increase in root net per unit area. Dakshinamurthi (1972) observed that hydraulic conductivity correlated significantly with stability index and structural coefficient of soils.

Total porosity of the soil which is derived factor, was increased with increasing plant population densities of groundnut in all the three seasons (Table 25). Lower values were observed with 2.5 lakh plants ha^{-1} and the plots with 5.0 lakh plants ha^{-1} recorded the highest values. In kharif 88, the increase in total porosity with the increase in plant population density from 2.5 to 5.0 lakh plants ha^{-1} was 4.79 per cent. The corresponding values were 3.75 and 4.44 per cent for rabi 88 and kharif 89 respectively. The increase in total porosity with the increase in plant population might be attributed to increased aggregation and decreased bulk density.

From the above discussion of results, the following conclusions can be drawn.

Different plant population densities of groundnut under irrigation have significant effect not only on the evapotranspiration of the crop, pod yield and benefit-cost ratio but also on the structure of the soil in the rhizosphere. Soil structural indices were favourably improved in the crop with a population density of 5.0 lakh plants ha^{-1} as compared to the lower levels.

The relationship between crop ET estimated by soil moisture depletion and reference crop ET computed by Modified Penman, Blaney-Criddle, Hargreaves, Radiation and Pan evaporation methods showed a positive correlation suggesting that any of these methods can be useful for estimating reference ET in Southern Telangana Zone of Andhra Pradesh. Evapotranspiration from groundnut was significantly correlated with evaporation

from Can evaporimeters. The can evaporimeters can be used for scheduling of irrigation for groundnut. Groundnut (JL. 24) with a plant population of 5.0 plants ha⁻¹ gave maximum net returns, benefit-cost ratio and higher water use efficiency. Therefore, under assured irrigation, adoption of population density of 5.0 plants ha⁻¹ seems to be more beneficial on sandy loam soils of Southern Telangana Zone.

SUMMARY

CHAPTER VI

SUMMARY

A field experiment entitled "Effect of different plant population densities on evapotranspiration, soil structure and yield of groundnut (*Arachis hypogaea* L.)" was conducted during kharif 88, rabi 88 and kharif 89 on Typic Ustropepts at College farm, College of Agriculture, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad. The experiment was laid out in simple randomised block design with five plant population density treatments (5.0, 4.0, 3.33, 2.5 and no crop, replicated four times. Irrigation was scheduled at 12 days interval during kharif 88 and rabi 88 where as in kharif 89 no irrigation was given to the crop as the rain fall (695.7) was high and as there was no moisture stress during the crop growth period. Well cleaned 500 ml small cans (open and 6/20 mesh screen) were installed in each plot density and evaporation readings were recorded in all the three seasons. Reference crop evapotranspiration was computed by using Modified Penman, Blaney-Criddle, Hargreaves, Radiation and Pan evaporation for kharif 88, rabi 88 and kharif 89 seasons. Following is the summary of the results and conclusions drawn :

1. Consumptive use of water increased significantly with increase in plant population density. Groundnut at a plant population density of 5.0 lakh plants ha^{-1} utilized water at higher rate throughout its growth period and resulted in higher evapotranspiration.
2. Significant correlations were observed between crop ET and reference crop ET estimated by Modified Penman, Blaney-Criddle, Hargreaves and Radiation methods during all the three seasons.
3. Significant correlations were observed between crop ET and evaporation from USWB class A pan during all the three seasons.
4. Highest K_c values were observed in the crop at a plant population density of 5.0 lakh plants (T_1) as compared to other plant densities.
5. Crop ET and evaporation from open Can and Can evaporimeter having screen size 6/20 mesh, were significantly correlated with each other. R^2 values

were higher with Can evaporimeters having screen size of 6/20 mesh compared to Can evaporimeter with no mesh cover in all the three seasons.

6. Evaporation from USWB class A pan and Can (with and without 6/20 mesh screen) evaporimeters were significantly correlated in all the three seasons.

7. Increase in plant population density increased the daily moisture use at different crop growth periods in all the three seasons.

8. Soil moisture extraction was relatively more from 0-15 cm soil depth, and it decreased with Can increase in soil depth from 15-30 to 30-45 cm irrespective of plant population density. Increase in plant density increased the extraction of soil moisture from lower strata as compared to upper strata and this trend was more clear as the age of the crop advanced in all the three seasons.

9. Plant population density of 5.0 lakh plants ha^{-1} was highly efficient in producing pods per unit quantity of water during all the three seasons.

10. Increase in plant density significantly increased the length of main root at all the growth stages.

11. Successive increments in plant density significantly reduced the lateral root spread at all the growth stages in all the three seasons studied.

12. Plants grown with a narrow row spacing of 20 x 10 cm (T_1) corresponding to a plant population density of 5.0 lakh plants ha^{-1} , accumulated maximum shoot drymatter compared to the normal recommended population of 3.33 lakh plants ha^{-1} corresponding to a spacing of 30 x 10 cm.

13. Plant population density of 5.0 lakh plants ha^{-1} produced maximum dry matter compared to other lower plant densities.

14. There was significant increase in pod and haulm yield, with increase in plant population density from 2.5 to 5.0 lakhs ha^{-1} . Plant population of 5.0 lakhs ha^{-1} resulted in highest pod and haulm yields during all the three seasons.

15. Adoption of plant population density of 5.0 lakh plants ha^{-1} gave maximum net returns and benefit cost ratio in all the three seasons.
16. Pod yield was significantly correlated with seasonal evapotranspiration in all the three seasons.
17. Soil structural indices viz., aggregates greater than 0.25 mm, mean weight diameter, stability index and structural coefficient were favourably improved in the crop with higher plant population density (5.0 lakh plants ha^{-1}).
18. Bulk density was decreased with an increase in plant population from 2.5 to 5.0 lakh plants ha^{-1} .
19. Hydraulic conductivity and porosity were improved with increase in plant density from 2.5 to 5.0 plants ha^{-1} in all the three seasons.

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* *Original not seen*

APPENDICES

APPENDIX - 1

Meteorological data during crop growth period (Weekly means) kharif 1988

Standard Week	Date	Temperature (°C)		Relative Humidity (%)		Sunshine (hrs/day)	Wind Velocity (kmph)	Rainfall		Evaporation (mm/day)
		Max.	Min.	Max.	Min.			Days	Amount (mm)	
35	27/08/88 to 02/09/88	29.2	22.6	93	71	3.3	10.1	5	72.8	4.3
36	03/09/88 to 09/09/88	29.6	18.9	89	63	4.1	6.7	3	55.8	3.3
37	10/09/88 to 16/09/88	31.0	22.4	89	57	6.3	8.3	2	22.4	3.5
38	17/09/88 to 23/09/88	29.5	22.4	89	66	5.5	2.7	2	32.8	3.7
39	24/09/88 to 30/09/88	30.0	22.2	89	63	5.4	5.1	3	33.6	3.8
40	01/10/88 to 07/10/88	30.1	22.7	86	60	5.5	3.9	0	0.0	4.2
41	08/10/88 to 14/10/88	30.7	17.3	80	49	9.2	2.4	0	0.0	4.8
42	15/10/88 to 21/10/88	32.4	16.0	77	37	10.4	2.8	0	0.0	4.9
43	22/10/88 to 28/10/88	31.8	15.5	69	33	10.0	2.8	0	0.0	5.2
44	29/10/88 to 04/11/88	30.3	17.8	73	41	9.6	3.3	0	0.0	4.1
45	05/11/88 to 11/11/88	30.3	14.5	69	36	10.0	4.0	0	0.0	4.5
46	12/11/88 to 18/11/88	29.5	11.4	68	30	10.2	3.7	0	0.0	4.2
47	19/11/88 to 25/11/88	29.9	11.9	76	27	10.2	3.0	0	0.0	3.4
48	26/11/88 to 02/12/88	28.3	10.8	79	31	10.1	3.4	0	0.0	3.9
49	03/12/88 to 09/12/88	28.5	11.4	75	33	9.8	2.9	0	0.0	3.4
50	10/12/88 to 16/12/88	25.7	11.1	83	57	5.6	2.8	1	17.0	2.6
51	17/12/88 to 23/12/88	27.6	11.7	90	44	9.8	2.7	0	0.0	2.7
52	24/12/88 to 31/12/88	28.3	12.4	88	43	8.5	2.9	0	0.0	3.0

APPENDIX - 2

Meteorological data during the crop growth period (weekly means) rabl 1988-89

Standard Week	Date	Temperature (°C)		Relative Humidity (%)		Sunshine (hrs/day)	Wind Velocity (kmph)	Rainfall		Evaporation (mm/day)
		Max.	Min.	Max.	Min.			Days	Amount (mm)	
2	08/01/89 to 14/01/89	28.7	13.4	81	44	9.6	4.1	0	0.0	3.2
3	15/01/89 to 21/01/89	29.6	12.3	83	39	9.7	3.0	0	0.0	3.4
4	22/01/89 to 28/01/89	30.4	15.7	73	44	9.2	3.9	0	0.0	3.2
5	29/01/89 to 04/02/89	31.3	10.9	70	20	10.4	3.3	0	0.0	4.2
6	05/02/89 to 11/02/89	33.5	12.2	62	26	10.8	2.7	0	0.0	4.2
7	12/02/89 to 18/02/89	33.2	13.4	55	28	10.6	3.2	0	0.0	4.7
8	19/02/89 to 25/02/89	32.2	12.6	53	22	10.4	3.9	0	0.0	6.4
9	26/02/89 to 04/03/89	35.2	15.4	69	17	10.5	2.8	0	0.0	6.2
10	05/03/89 to 11/03/89	34.2	17.5	54	29	9.7	5.7	1	25.0	5.5
11	12/03/89 to 18/03/89	32.7	18.5	76	29	9.4	4.2	0	0.0	5.7
12	19/03/89 to 25/03/89	35.7	21.5	76	26	10.2	4.8	0	0.0	6.8
13	26/03/89 to 01/04/89	31.5	19.4	49	36	8.6	5.3	1	5.0	5.7
14	02/04/89 to 08/04/89	37.5	19.2	53	18	11.7	3.9	0	0.0	7.1
15	09/04/89 to 15/04/89	38.9	21.0	61	17	12.0	4.0	0	0.0	7.1
16	16/04/89 to 22/04/89	39.2	23.8	52	24	9.7	5.6	0	0.0	7.2
17	23/04/89 to 29/04/89	38.8	26.0	55	21	9.5	6.9	1	2.0	7.7
18	30/04/89 to 06/05/89	39.1	24.9	54	21	10.5	6.8	0	0.0	7.3

APPENDIX - 3

meteorological data during the crop growth period (weekly means) kharif 1989

Standard Week	Date	Temperature (°C)		Relative Humidity (%)		Shunshine (hrs/day)	Wind Velocity (kmph)	Rainfall		Evaporation (mm/day)
		Max.	Min.	Max.	Min.			Days	Amount (mm)	
27	02/07/89 to 08/07/89	30.5	22.0	85	56	3.6	9.3	3	53.8	4.6
28	09/07/89 to 15/07/89	31.0	22.9	84	49	5.9	7.0	2	23.0	4.7
29	16/07/89 to 22/07/89	29.5	21.9	87	56	6.1	13.0	3	137.0	4.5
30	23/07/89 to 29/07/89	27.6	21.8	88	57	4.1	18.3	3	160.7	3.4
31	30/07/89 to 05/08/89	30.4	22.4	80	48	9.1	13.4	0	0.0	5.4
32	06/08/89 to 12/08/89	29.4	21.8	83	49	5.1	13.0	2	36.4	4.3
33	13/08/89 to 19/08/89	28.4	22.2	87	52	3.8	14.7	4	41.2	4.0
34	20/08/89 to 26/08/89	28.9	22.2	85	51	4.7	13.7	2	11.5	4.2
35	27/08/89 to 02/09/89	29.9	22.1	86	46	6.5	10.1	2	6.4	3.2
36	03/09/89 to 09/09/89	30.6	21.9	80	47	7.5	6.7	4	23.7	4.0
37	10/09/89 to 16/09/89	29.4	22.6	88	49	4.9	8.3	4	84.0	3.5
38	17/09/89 to 23/09/89	30.3	21.9	84	54	5.7	2.7	2	76.2	3.8
39	24/09/89 to 30/09/89	29.8	21.0	87	52	5.5	5.1	2	28.0	4.0
40	01/10/89 to 07/10/89	30.1	19.0	86	47	9.3	3.9	1	13.8	4.1
41	08/10/89 to 14/10/89	32.8	17.4	81	40	10.0	2.4	0	0.0	4.7
42	15/10/89 to 21/10/89	32.9	16.2	69	37	10.3	2.8	0	0.0	4.5
43	22/10/89 to 28/10/89	31.4	16.5	69	37	10.3	2.8	0	0.0	4.5
44	29/10/89 to 04/11/89	31.0	15.4	74	37	9.6	3.3	0	0.0	4.1

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APPENDIX - 4

Seasonal irrigation water (mm) applied to groundnut

Treatment	Kharif 88	Rabi 88
T ₁	577	626
T ₂	553	609
T ₃	522	572
T ₄	493	536

