# OPTIMIZATION OF SAFFLOWER PRODUCTION THROUGH LAND LAYOUT AND DEPTH OF IRRIGATION

*By*



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B.Sc. Hon.(Agri)



## DISSERTATION

Submitted to
the Marathwada Agricultural University
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IN

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**COLLEGE OF AGRICULTURE, PARBHANI**
MARATHWADA AGRICULTURAL UNIVERSITY
PARBHANI - 431 402 (M.S.) INDIA

**2006**

Affectionately dedicated

to my beloved

parents

# CANDIDATE'S DECLARATION

*I, hereby declare that this Dissertation*
*or part thereof, has not been*
*previously submitted by*
*me for a degree of*
*any University.*

Place : PARBHANI

Date : 30 / 05 /2006.

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This is to certify that **VIJENDRA KUMAR MEENA** has satisfactorily prosecuted his course of research for a period of not less than four semesters and that the dissertation entitled "**OPTIMIZATION OF SAFFLOWER PRODUCTION THROUGH LAND LAYOUT AND DEPTH OF IRRIGATION**" submitted by him is the result of original research work and is of sufficiently high standard to warrant it's presentation to the examination for the degree of **MASTER OF SCIENCE** (Agriculture) in **AGRONOMY**.

I also certify that, the dissertation or part thereof has not been previously submitted by him for a degree of any university.

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# CERTIFICATE – II

This is to certify that the dissertation entitled **"OPTIMIZATION OF SAFFLOWER PRODUCTION THROUGH LAND LAYOUT AND DEPTH OF IRRIGATION"** submitted by **VIJENDRA KUMAR MEENA** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** (Agriculture) in the subject of **AGRONOMY** has been approved by the Student's Advisory Committee after oral examination in collaboration with the External Examiner.

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Place : Parbhani

Date 30/05/2006

(Vijendra Kumar Meena)

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# ABBREVIATIONS

| | |
|---|---|
| @ | At the rate |
| °C | Degree Celsius |
| C.D. | Critical difference |
| cm | Centimeter(s) |
| CU | Consumptive use |
| Cv. | Crop varieties or Cultivars |
| dm.sq. | Decimeter square |
| DAS | Days after sowing |
| *et al* | And others |
| Fig. | Figure |
| g | Gram(s) |
| ha | Hectare |
| hrs. | Hours |
| i.e. | That is |
| kg | Kilogram(s) |
| l | litres |
| Max. | Maximum |
| Met. | Meteorological |
| mg | milligram(s) |
| Min. | Minimum |
| mm | Millimeter(s) |
| m | Meter (s) |
| MW | Meteorological week |
| N | North |
| No. | Number |
| NS | Non-significant |
| % | Per cent |
| / | Per |
| q | Quintal(s) |
| RDF | Recommended dose of fertilizer |
| Rs. | Rupees |
| SE | Standard error |
| SSP | Single Super Phosphate |
| Sq | Square |
| t | Tonnes |
| viz. | Namely |
| WUE | Water use efficiency |

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# Introduction

Chapter I

# INTRODUCTION

India is among the largest oil economy in the world with 21 per cent of the world's area but accounts for less than 10 per cent of world's production to meet the need of about 16 per cent of the world's population. Oilseeds form the second largest agriculture commodity after cereals sharing 13 per cent of country's gross cropped area and accounting for nearly 6 per cent of gross national product and 10 per cent of the value of all agriculture commodities.

The oilseeds scenario of India has undergone drastic change in recent years due to various incentives and institutional support given by the Government for the development of this sector, following constitution of Technology Mission on Oilseeds (TMO) between 1985-1986 and 1996-1997, the area under oilseeds increased from 19.02 to 26.81 m ha, production increased from 10.83 to 24.96 m tonnes, productivity increased from 570 to 931 Kg/ha and the level of self sufficiency increased from 69 to 87 per cent. Despite such impressive achievement in the oilseed sector, the import of edible oil during 1996-1997 was nearly 1.95 m tonnes and costing Rs. 789 crores.

This seems to be tremendous pent up demand for edible oils which are turning into effective demand with increasing purchasing power. There is an urgent need to step up oilseed production on sustainable basis to meet the needs of increasing population and expanding demands. However, with chances on area expansion being limited, increase in oilseeds production have to come primarily from land saving technologies, protective irrigation, highlighting a combination of high yielding plant types, standard agronomic practices and balance plant nutrition attained through integrated supply system (Hegde,1999).

Safflower (*Carthamus tinctorius* L.) is an important *rabi* oilseed crop of Maharashtra, apart from it's superior adaptability to scanty moisture conditions. It produces oil rich in polyunsaturated fatty acids (Linoleic acid 78%), which play an important role in reducing the blood cholesterol level for centuries. It has been under cultivation in India either for it's colored florets and much valued oil.

The crop possesses deep and efficient root system and hence utilizes the soil moisture efficiently. The crop being spiny, does not require protection from the stray cattle and birds. The oil content of whole seed ranges from 28 to 32%. The oil is also used for various industrial purposes. A number of products could be developed from safflower such as carthamin pigments. This could be used as a food additive for making herbal type of tea and extracting protein and amino acids.

The crop is cultivated to an extent of 1.05 million ha with a production of 0.8 million tonnes in the world. India has the legitimate pride of being the largest producer of safflower in the world, grown on an area of 5.4 lakh ha. with production of 4.7 lakh tonnes. Maharashtra and Karnataka are the two most important safflower growing states accounting 73 and 22 per cent of acreage and 68 and 30 per cent of production, respectively. Out of total area contributed by Maharashtra state, Marathwada contributes about 40 to 45 per cent of the acreage in safflower.

The yield of safflower can be doubled with only 2-3 protective irrigations, requires low input cost technology and high benefit cost ratio. There is a tremendous scope for expansion of area and number of conventional dry land crops like wheat, chickpea, linseed and mustard can be profitably replaced by sole crop of safflower in all potential areas of its cultivation in Jayakwadi and Purna commands. Despite three fold increase in the production of this crop in two decades, the present productivity of about 500 Kg/ha is still very low as compared to the demonstrated production potential. FLD data indicated that due to irrigation, yield of safflower was increased from 50 to 100 per cent over rainfed control.

About 90 per cent of the oilseed cultivation in India is under rainfed, uncertain and abnormal weather conditions. Irregular rains, moisture stress at critical growth stages and faulty method of irrigation largely affect the final seed yield. Poor crop management under input starved conditions and growing of crop in rainfed conditions are the main reasons for low yield of safflower.

Introduction of safflower in Jayakwadi and Purna command area help to stabilize the yield of crop by scheduling the irrigation. Generally, farmers are in hesitation about proper time, quantity and method of irrigation. Scheduling of one or two irrigation at critical growth stage of the crop increases the yield. Wheat crop requires 5-6 irrigations under irrigated conditions for getting optimum yields, whereas safflower needs only 2-3 irrigations. Therefore, the area under wheat crop can be easily replaced by 2-3 times thereby increasing the in area of safflower with the same irrigation potential. As safflower is a salt tolerant crop, hence suitable for command areas of Jayakwadi and Purna. It has wider range of elasticity both in rainfed as well as under irrigated conditions due to its deep root system, xerophytic characters, thorniness and waxy coating of leaves, thus reducing the moisture use. As compared to other *rabi* crops, the cost of cultivation is low, it has highest B: C ratio with minimum irrigations. This will result in increase in productivity of safflower and helps to sustain the production in command areas.

Productivity of safflower needs to be increased, as this is a cash crop of medium and small holding farmers. It is hypothesised that this problem can be solved by introducing safflower in command areas with 2-3 protective irrigations. This will reflect in achieving the self sufficiency to some extent in oilseeds production of Maharashtra in general and Marathwada in particular. Farmers are using old method of irrigation i.e. flooding due to which wilting of plant occurs. The losses due to safflower wilt is more than 40%. To overcome this problem, modification in the land layout for scheduling of irrigation is the only one solution besides this growing of wilt tolerant variety should be preferred. The information on land layout, methods of scheduling of irrigation and depth of irrigation required is meagre. Hence, there is urgent need to know land layout for irrigation scheduling and depth of irrigation so as to make safflower cultivation a successful proposition under Jayakwadi and Purna command areas of vertisols and salt prone areas.

In view of this, experiment entitled "Optimization of safflower production through land layout and depth of irrigation" was formulated and conducted at Agricultural College Farm, Marathwada Agricultural University, Parbhani during *rabi* season of 2004-2005 with the following objectives.

1. To study the effect of land layout on growth and yield of safflower.
2. To find out optimum water requirement of safflower.
3. To find out suitable land layout and depth of irrigation for Vertisol.

# Review of Literature

Chapter-II

# REVIEW OF LITERATURE

The research work carried out in the past on the aspects under study is reviewed in brief.

## 2.1 Effect of land layout on safflower

Leonard and French (1969) reported that consumptive use associated with maximum yield of seeds was more than 107 cm of water at Arizona. The peak water use was more than 1.3 cm per day. They further observed that safflower can withdraw water from the below 180 cm soil depth.

Suryanarayana (1975) conducted an experiment at Bangalore with three irrigation intervals at 40, 60 and 80 mm cumulative evaporation with three depth of 100, 75 and 50 per cent. He found that the average consumptive use was about 45 cm and it decreased with increase in irrigation water applied to each irrigation depth and at all intervals. He further observed that application of 50 per cent irrigation water after 60 mm cumulative evaporation gave the highest water use efficiency.

Raghu and Sharma (1978) at Jabalpur recorder the consumptive use values under 0, 1, 2, 3, 4 and 5 irrigation frequencies and the values were 119, 170, 213, 255, 281 and 300 cm, respectively. The water use efficiency decreased with increased water supply. The water use efficiency was 18 kg/ha/mm when irrigation was applied at branching stage as against 13.2, 15.1 and 14.3 obtained under one irrigation given at early leaf stage, flowering and grain formation stage respectively.

Singh and Singh (1979) observed at Kota that the consumptive use increase with increase in levels of moisture regime. Maximum consumptive use (53.6 cm) was under six irrigation treatment (60% ASM) under 40 % ASM and 20 % ASM, consumptive use decreased to 60 and 24 per cent, respectively over control.

Rajput *et al.* (1981a) at Karnal found that water productive efficiency per unit of applied water was the highest in number of irrigation treatment. The productive efficiency declined with an increase in the frequency of irrigation. The decline was less when irrigation was given at flowering stage.

Kampen (1982) conducted experiment on Vertisols and reported that the broad bed and furrow system has been fund very useful in improving drainage on Vertisols.

Rasve *et al.* (1983) conducted a field experiment at Marathwada Agricultural University, Parbhani and reported that summer groundnut (TG 17) grown on ridges and furrow layout produced maximum and significantly more dry pod and haulm yield per hectare and shelling percentage than flat bed.

Samdi and Sepaskhah (1984) reported that fixed alternate furrow irrigation decreased dry bean yields as compared with ordinary furrow irrigation and this could be attributed to smaller amount of water being.

applied leading to moisture stress especially at reproduction stage of growth.

Khistaria *et al.* (1986) compared different methods of scheduling life saving irrigation to *kharif* groundnut during moisture stress period and reported that potential production and profit can be secured by using flood method of life saving irrigation in comparison with every furrow and alternate furrow irrigation. Further reported that the higher pod yield with flood method of irrigation assigned to higher number of pods and pod weight per plant.

Nalawade and More (1993) observed in a experiment with three land configuration as broad bed and furrow 1.5 m width with 4 row (BBF) narrow bed and furrow 0.75 m width with two rows (BBF) and flat bed without furrow 1.5 m width with 4 row (FBWF) of groundnut indicated that BBF (1330 kg/ha) and NBF (1250 kg/ha) produced significantly highest pod yield of groundnut over flat bed system (1108 kg/ha) but were on per with each other BBF caused 20 per cent increase on pod yield over control due to favourable soil physical environment.

Karle *et al.* (1995) conducted a field experiment on medium black soil by adopting ridges and furrow for *rabi* crop (Gram, safflower, sorghum) and showed that the moisture use and moisture use efficiency were improved better in ridges and furrow than flat beds in all the crops. The increased infiltration rate moisture used and moisture use efficiency reflected in higher yield of crop gram (607 kg/ha), safflower (650 kg/ha) and sorghum ( 928 kg/ha) in ridges and furrow than in flat bed (529, 511 and 655 kg/ha, respectively).

Karle *et al.* (1995) carried out an experiment on medium black soil in *kharif* season at 1992 and revealed that opening furrow of 20 cm depth after three lines of green gram (BM 4) gave significantly higher grain yield (542 kg/ha) over flat bed (458 kg/ha).

Jadhav and Pawar (1999) studied the effect of crop spacing and land configuration on seed yield of gram, at Rahuri. The average productivity of crop was 2.94 t/ha, 2.48 and 2.88 t/ha with 30 x 10, 45x 10 and 45 x 6.67 cm spacing, respectively. The crop planted on ridges and furrow (2.87 t/ha) recorded higher yield that flat bed (2.67 t/ha) by 7.5 per cent.

Oza *et al.* (1996 a) conducted the field experiment at Water Management Research Project, MAU, Parbhani and NARP, Aurangabad during *rabi* season of 1990-91 and 1992-93 and reported that seed yield of safflower with irrigation in furrow (60 x 15 cm) and skip row furrow (45 x 20 cm) were on par and recorded significantly more yield than irrigation in alternate furrow (45 x 20 cm) and paired planting ( 60 + 30 x15 cm) . The later two methods were at par with treatment of irrigation furrow (45 x20 cm) in flat bed. However, irrigating safflower in skip furrow method resulted in 35 per cent saving of irrigation water besides providing high water use efficiency.

Shelke et al. (1998) reported that the experiment conducted on vertisol in alternate to skipped row furrow layout, gave 23 per cent higher seed yield of safflower, 32 per cent saving in irrigation water and increase in WUE by 34 per cent over former method of irrigation.

Bharambe *et al.*(1999) reported that safflower yield was higher in flat bed than furrow irrigation method. Safflower irrigated in alternate furrow or skip row furrow resulted in a 33 % saving of irrigation water.

Shelke *et al.* (2002) reported that application of irrigation to safflower through different land layout was beneficial over no irrigation treatment. Further it was noticed that irrigating safflower either alternate furrow (45 cm x20 cm) or in skipped furrow (spacing is 45x20 cm but one row after every two rows is skipped and opening furrow in skipped row) gave seed yield at par with irrigating each furrow (45x20cm) and indicating thereby saving of about 30 per cent of water due to skipped row furrows.

## 2.2 Effect of irrigation on yield

Mahapatra and Singh (1975) studied the irrigation requirement Of safflower at IARI, New Delhi and concluded that crop responded favourable to different levels of irrigation at all location. They observed that seed yield increased consistently from control i.e. 19.8 q/ha to 34.8 q/ha, when 4 irrigation's were applied at 4-6 leaf stage, branching, flowering and seed development stage.

Suryanarayana (1975) reported that application of 50 mm irrigation water after 60 mm CPE gave highest seed and oil yields.He also found that highest consumptive use of water for high economic returns was about 450 mm and the internal between irrigation was about 15 days.

Raghu and Sharma (1978) revealed that the seed yield of safflower was 1.35 t/ha without irrigation and 1.93 to 1.94 t/ha with irrigations applied at branching or seed formation stage. It is also observed that the yields were further increased with 2-3 irrigations.

Yazdi-Samadi and Zafar-Ali (1980) reported that one irrigation at sowing or 2-3 irrigation after sowing gave similar yields in safflower.

Yusuf *et al.* (1981) observed that irrigation applied at rosette stage was more helpful to enhance plant height than at other stage. One irrigation at rosette stage produced significantly more branches per plant than unirrigated control. However, three and four irrigations significantly increased number of branches and capsules per plant over one and two irrigation. The percentage increase over control was in the order of 29, 44, 58 and 76 under one, two, three and four irrigations, respectively. One irrigation given at rosette stage produced 29 and 17 per cent higher seed yield as compared to one irrigation applied at seed development and flowering stage. One irrigation at rosette stage was as good as two irrigations applied either at branching and seed development or at rosette and seed development stage.

Umrani (1983) reported that the application of one irrigation at 30 to 35 and 55 to 60 days after sowing increased the growth of safflower and yield by 26 and 34 per cent over control (no irrigation), respectively. Application of three irrigations one at presowing, branching and 50 per cent flowering was found better under optimum irrigation resource condition. Under irrigation constraint, two irrigations i.e. one at presowing and other at branching would be sufficient for better yield. If only one irrigation is available it should be applied at branching stage only.

Magar (1984) reported that three irrigations each at presowing, branching and 50 per cent flowering to safflower was found better under optimum irrigation resource conditions. Under irrigation constraint, two irrigations one at presowing and other at branching would be sufficient for better yield. If only one irrigation is available it should be applied at branching stage only.

Pisal (1985) reported that application of two irrigations one at rosette and other at 50 per cent flowering, with 75 kg N/ha give highest seed yield, spread, number of primary and secondary branches, dry matter, number of capitula per plant and number of seeds per capitulum, respectively.

The water requirement of safflower has been reported to very from 300-350 mm depending upon the 900 climatic condition under which the crop is grown. Though safflower is a crop of dry farming areas, it has been found to have excellent potential under irrigated farming also (Sondge, *et al.*, 1985).

Chordia and Gaur (1986) revealed that seed yield of safflower was significantly affected by irrigation levels. Application of one irrigation at preflowering and seed filling, two irrigations at flowering and seed filling stages produced higher seed yield by 21.7, 18.2 and 30.6 per cent, respectively over no irrigation.

Zaman (1989) reported that safflower gave average seed yield of 0.59 – 0.65, 0.76 – 0.87 and 1.08 – 1.14 t/ha with 1, 2 and 3 irrigation, respectively compared with 0.50 – 0.54 under rainfed conditions variety A 300 gave the highest yield of 1.81 – 1.90 t/ha.

Zaman and Das (1990) reported that the application of 1, 2 or 3 irrigation to safflower gave seed yields of 1.70, 1.78 and 1.84 t/ha, respectively as compared to 1.29 t/ha under rainfed conditions.

Zaman and Das (1991) studied the effect of 1 irrigation at flowering, 2 irrigation at branching and flowering, 3 irrigation at branching, flowering and seed development stage or no irrigation and reported that seed yield increased from 0.56 t/ha(no irrigation) to 0.86 to 1.38 t/ha with increase in frequency of irrigation.

Bhalerao *et al.* (1993) reported that fourteen irrigation treatments (Cv. Bhima) were applied including a rainfed control and different combination of irrigation at rosette, branching, flowering and seed development stages. Irrigation at first 2 growth stages also gave a good yield and increase of 61.4 % compared with control. While single irrigation at rosette or branching stage gave increase in yield of about 35 %.

Bansal and Katara (1993) reported that safflower given irrigation treatment of no irrigation, 1 irrigation at branching, 1 irrigation at flowering, 2 irrigation at branching + flowering, 2 irrigation at branching + seed filling, 3 irrigation at branching + flowering + seed filling, capitulum/ plant, seed/ capitulum, 1000 seed weight, seed yield, stover yield and oil content were all greatest with irrigation at branching + flowering + seed filling.

Patel and Patel (1993) reported that when safflower cv. Bhima was irrigated during rapid vegetative growth at flowering or seed formation stage or various combination of these growth stages. The highest seed yield of 1.65 t/ha was obtained from irrigation at all 3 stages. The critical growth stage for irrigation were flowering and seed formation.

Katara and Bansal ( 1995) reported seed yield was highest with 3 irrigations i.e. 2.6 t/ha over control. Other irrigation treatments i.e. branching (Br), flowering (FI), branching + flowering, branching + seed filling or at 3 growth stages.

Gajendra Giri and Giri (1995) reported that safflower cv. JSI 7 was not irrigated or irrigated at rosette termination (Rt), flowering (FI) or Rt+FI. The seed yield was highest (2.60 t/ha) with 2 irrigations.

Ved Singh *et al* (1995) reported that irrigation at all growth stages produced the highest mean seed yield of 1.85 t/ha, which was not significantly different from the yields obtained with irrigating at rosette + flowering (1.79 t) or seed formation stages.

Patil and Sabale (1997) reported that application of two irrigations at 35 and 70 days after sowing along with 50 kg N/ha produced the highest safflower seed yield of 2.43 t/ha in 1988-89 and 2.31 in 1989-90.

Chatol et al. (1998) reported that safflower yield increased with increasing irrigation and irrigation at later stages of development. Safflower yield was greatest with 3 irrigations at rosette, branching and seeds development stages.

Zaman and Chaudhari (1998) reported that application of three irrigations of 75 mm depth each applied at branching, flowering and seed development stages gave the highest seed yield of 1666 kg/ha.

Sharma et al.(2001) reported that safflower was irrigated at early stage i.e. 30 DAS, one late irrigation at 90 DAS and two irrigation each at 30 and 90 DAS. The highest yield of safflower was obtained at 30 and 90 days after sowing.

## 2.3 Effect of irrigation on oil content

Leonard and French (1969) conducted an experiment safflower at Arizona Agricultural Experimental Station, USA. The irrigation were given when 60 or 72 per cent moisture from the top 120 cm of soil was depleted. In irrigation treatment when 3 to 6 irrigation were given. Oil content in seed was 39 per cent, which was significantly less when more ( 7 to 9) irrigation were given. The oil content increased to 41.3 per cent with increased number of irrigation.

Abd-Muishani (1972) reported that yield of oil per hectare was increased with the irrigation application.

Singh and Yusuf (1981) found that seed oil content had a quadratic relationship with moisture supply but was independent of row spacing.

Wakil *et al.* (1987) reported that oil content increased with increasing frequency of irrigation. Oil content was greater when irrigation continued until maturity.

Ibrahim *et al.* (1991) reported that seed oil content was highest with irrigated at 40 % ASMD.

2.4 Irrigation requirement of safflower

Suryanarayana (1975) reported that average consumptive use of Water for high economic returns was about 450 mm and the interval between irrigation was about 15 days.

Abel (1976) found that seed yield was significantly lower when irrigation was with held until plants had used 90 per cent of available water than when soil water depletion was limited to 60 to 70 per cent.

Raghu and Sharma (1978) reported that safflower responded significantly to irrigation. Only one irrigation at branching stage gave 41.5 per cent higher yield over no irrigation.

Rajput *et al.* (1981 a) reported that one irrigation at flowering stage increased the seed yield significantly. Two irrigation at flowering and milk stage produced as much seed yield as 3 irrigations at branching flowering and milk stage. The water reproductive efficiency declined with an increase in the frequency of irrigation.

Yusuf *et al.* (1981 a) reported that seed yields of safflower grown with 1, 2, 3 and 4 irrigations were 29, 44, 58, 76 per cent higher respectively than without irrigation. Water use efficiency was highest with one irrigation at rosette stage.

Rawson and Turner (1983) reported that in single irrigation treatment, the highest yield was resulted from water application 3 weeks before anthesis over 5, 7, 9 and 11 weeks after sowing. The better yield were associated primarily with the presence of more live leaf area during early seed filling.

Mahey *et al.* (1989) reported that a presowing irrigation 5 or 10 cm water gave average safflower seed yields of 1.13 and 1.26/ha, respectively. The seed yield with 1 or 2 post sowing irrigation were 1.28, and 1.39 t/ha, respectively.

Patel and Patel (1996) reported that safflower was irrigated at irrigation water : cumulative pan evaporation ( IW:CPE) ratio of 0.2, 0.4, 0.6 or 0.8. Seed yield was highest with an IW:CPE ratio of 0.6.

# Material and Methods

Chapter III

# MATERIALS AND METHODS

The details of the materials used and methods adopted during the course of the investigation are given in this chapter under appropriate heads.

## 3.1 Experimental site and soil

The experiment was conducted in plot No. B-21 during *rabi* season of 2004-2005 at College farm, MAU, Parbhani. The topography of the experimental plot was fairly levelled. The soil was medium dark gray in colour and about 100 cm deep. The soil sample were taken from 0 to 30 cm depth, (Three sample from each replication) covering experimental area and their composite representative soil samples were prepared by International pipette method (Piper, 1966), available nitrogen by Alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Metavenadate method (Olsen *et al.*, 1954), available potassium by Flame Photometer (Black, 1965) soil pH by Glass electrode pH meter and organic carbon by Walkey and Black's rapid titration method. The data obtained are presented in Table 1.

**Table 1 Mechanical and chemical composition of composite soil sample of experimental field**

| Sr. No | Particulars | Value |
|---|---|---|
| **A.** | **Mechanical analysis** | |
| 1. | Coarse sand (per cent) | 6.25 |
| 2. | Fine sand (per cent) | 13.55 |
| 3. | Silt (per cent) | 22.15 |
| 4. | Clay (per cent) | 56.87 |
| **B.** | **Chemical analysis** | |
| 1. | Available nitrogen (kg/ha) | 113.10 |
| 2. | Available phosphorous (kg/ha) | 20.24 |
| 3. | Available potassium (kg/ha) | 512.30 |
| 4. | Soil pH | 8.24 |

## 3.2 Climate and weather

Parbhani is situated at 409 m altitude, 19°16' North latitude and 76°47' East longitude and has a sub-tropical climate. The average annual precipitation is 900 mm with 70 rainy days. The precipitation is assured for *kharif* crops. The mean daily maximum temperature varies from 30.5°C in December to 43.1°C in May. The month of July, August and September were humid and moisture index was positive, winter was cool with moisture index oscillating to deficit side and rest of the period was dry. Parbhani is grouped under assured rainfall zone. The weather data recorded at Agriculture Meteorological Observatory, M.A.U., Parbhani during the period of experimentation are given in Table 2 and depicted in Fig. 1.

**Table 2 Weekly Weather data for the year 2004-05 at Parbhani**

| MW | Rain-fall (mm) | Rainy days (no.) | Temperature °C | | Humidity % | | EVP (mm) | BSS (hours) per day | Wind speed (kmph) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Max | Min | AM | PM | | | |
| 47 | 0 | 0 | 30.8 | 11.8 | 88 | 37 | 3.9 | 10.7 | 2.5 |
| 48 | 0 | 0 | 29.8 | 10.1 | 81 | 32 | 4.3 | 10.5 | 2.8 |
| 49 | 0 | 0 | 29.3 | 8.5 | 80 | 31 | 4.8 | 10.7 | 3.3 |
| 50 | 0 | 0 | 29.7 | 8.0 | 78 | 34 | 3.9 | 10.2 | 2.5 |
| 51 | 0 | 0 | 30.2 | 9.2 | 78 | 30 | 3.7 | 10.5 | 2.1 |
| 52 | 0 | 0 | 29.7 | 12.5 | 69 | 36 | 4.0 | 9.6 | 3.0 |
| 1 | 0.0 | 0 | 30.1 | 14 | 75 | 37 | 4.0 | 8.6 | 2.7 |
| 2 | 0.0 | 0 | 30.2 | 9.1 | 75 | 31 | 4.2 | 10.6 | 2.8 |
| 3 | 0.0 | 0 | 28.9 | 9.2 | 74 | 26 | 4.3 | 10.3 | 3.4 |
| 4 | 10.0 | 1 | 30.4 | 15.4 | 67 | 41 | 4.6 | 9.2 | 3.8 |
| 5 | 11.0 | 1 | 26.2 | 12.8 | 77 | 52 | 3.9 | 7.6 | 4.6 |
| 6 | 0.0 | 0 | 33.3 | 14.7 | 74 | 25 | 5.4 | 10.9 | 3.5 |
| 7 | 0.0 | 0 | 36.4 | 12.2 | 66 | 24 | 6.8 | 11.1 | 3.4 |
| 8 | 0.0 | 0 | 33.1 | 13.9 | 64.4 | 28 | 6.6 | 10.8 | 4.0 |
| 9 | 2.4 | 0 | 35.6 | 17.0 | 70.4 | 43 | 6.9 | 8.6 | 4.0 |

The temperature data revealed that thermal conditions of crop environment during crop life were within physiological cardinal limits. In general temperature range was fluctuating from 26.2°C to 36.4°C and

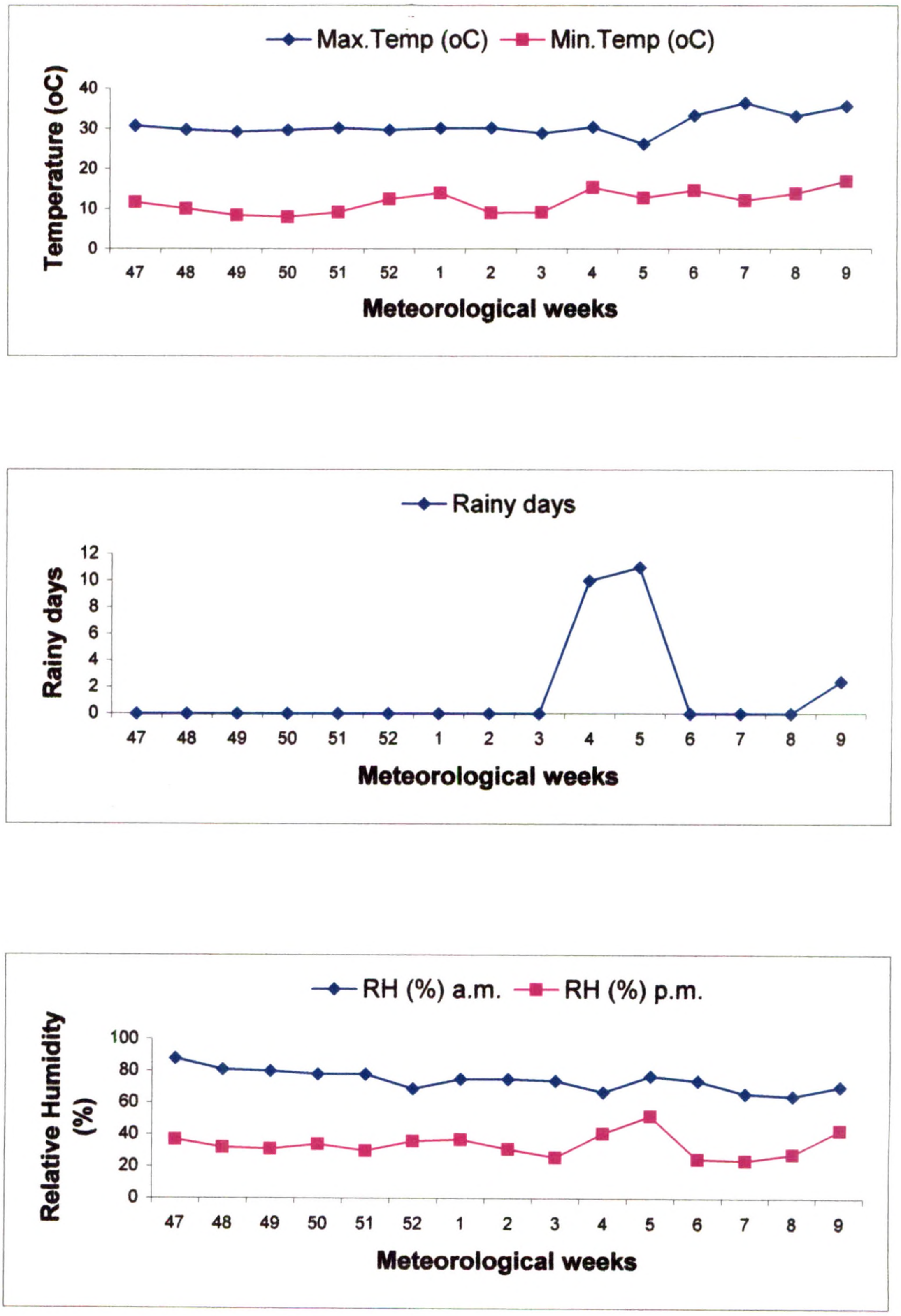



**Fig.1 Weather data recorded at Agricultural Meteorology Observatory, Parbhani during crop season 2004-2005**

minimum temperature fluctuating from 8°C to 17°C. The mean relative humidity was decreased progressively with increase in crop life. As regards the bright sunshine hours, it was fluctuating from 7.6 hrs/day to 11.1 hrs/day. The total precipitation received during crop period was only 21.00 mm with two rainy days.

The weekly mean evaporation varied from 3.7 mm/day to 6.9 mm/day. The mean evaporation per day was recorded with United State Weather Bureau (USWB) Class A Pan Evaporimeter. As regards wind velocity, it was varied from 2.1 km/hr to 4.6 km/hr.

### 3.3 Previous cropping pattern

The cropping programme followed on the experimental plot for last three years of the investigation is given in Table 3.

**Table 3 Previous cropping history of the experimental field**

| Sr. No. | Year | *Kharif* | *Rabi* | Summer |
|---|---|---|---|---|
| 1. | 2001-2002 | Greengram | Castor | Fallow |
| 2. | 2002-2003 | Greengram | French bean | Fallow |
| 3. | 2003-2004 | Greengram | French bean | Fallow |
| 4. | 2004-2005 | Soybean | Present experiment | --- |

The residual effect of previous cropping was practically uniform on the crop grown during investigation.

## 3.4 Experimental details

The present experiment was laid out in split plot design with four replications, comprising nine treatments of land layout and depth of irrigation.

**A) Main plot (Land layout)**

$L_1$ Ridges and furrow method at 60 cm x 15 cm.

$L_2$ Skip row method at 45-90 cm x 13.33 cm.

$L_3$ Paired row planting at 30-60 cm x 20 cm.

**B) Sub plot (Depth of irrigation in mm)**

$D_1$ 40

$D_2$ 50

$D_3$ 60

**Additional treatment**

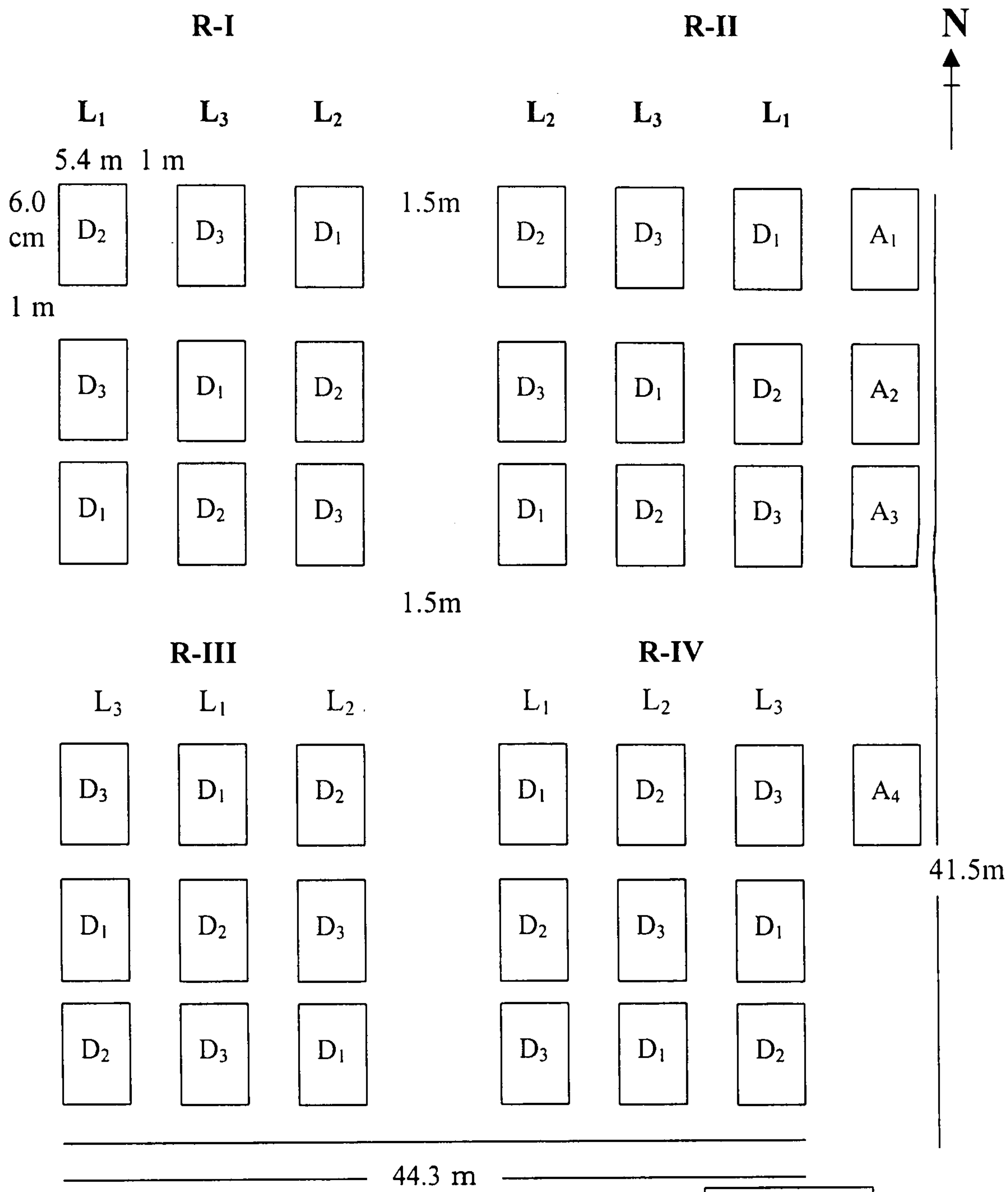
Flat bed (normal planting at 45 x 20 cm) irrigation scheduled at 60 mm depth.

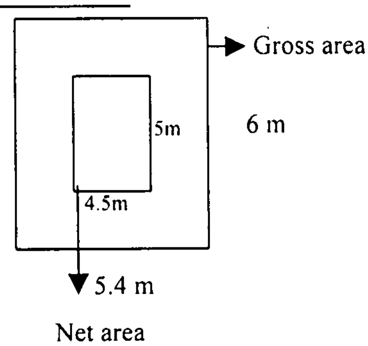
| | | |
|---|---|---|
| Plot size | : | Gross 5.4 m x 6.0 m |
| | | Net 4.5 m x 5.0 m |
| Fertilizer dose | : | 60:40:0 kg NPK/ha. |
| Variety | : | PBNS-12 |
| Method of sowing | : | Dibbling |
| Seed rate | : | 12 kg/ha |

### 3.4.1 Layout

Experimental field was laid out in split plot design after preparatory cultivation. It consisted of four replications with nine experimental units. The gross and net plot size were 5.4 m x 6.0 m and 4.5 m x 5.0 m, respectively. Land layout and depth of irrigation treatment were randomly allotted to blocks in each replication. The distance between two plots was 1.0 m and in between two replications was 1.5 m. Irrigations were applied to safflower in Ridge and furrow (60 cm x 15 cm), Skip row furrow (45-90 cm x 13.33 cm) method and Paired row planting (30-60 cm x 20 cm).

In skip row method/furrows were opened at 30 days after sowing. One row after every two crop rows was skipped and a furrow was opened in between skipped row. In paired row planting, every two crop rows were combined and a furrow was opened for giving irrigation. The plan of layout in *rabi* season of 2004-2005 is given in Fig. 2.



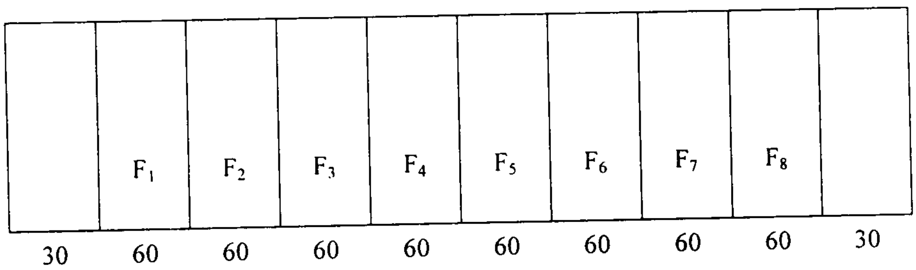

**Plot size**
Gross : 5.4m x 6.0m
Net : 4.5m x 5.4m

**Fig. 2 Plan of layout**

**$L_1$ Ridges and furrow method at 60 cm x 15 cm (9 lines)**

40 plant

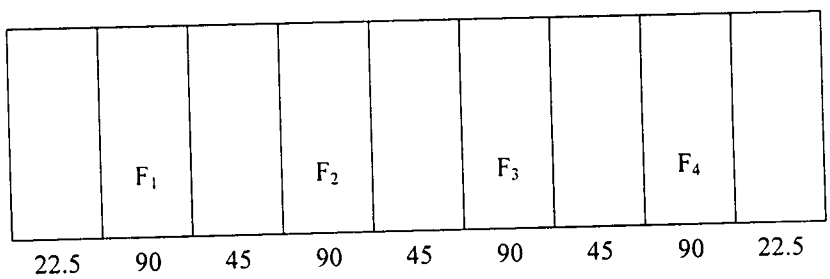
(Total plant 360)




**$L_2$ Skip row method at 45 - 90 cm x 13.33 cm (8 lines)**

45 plant

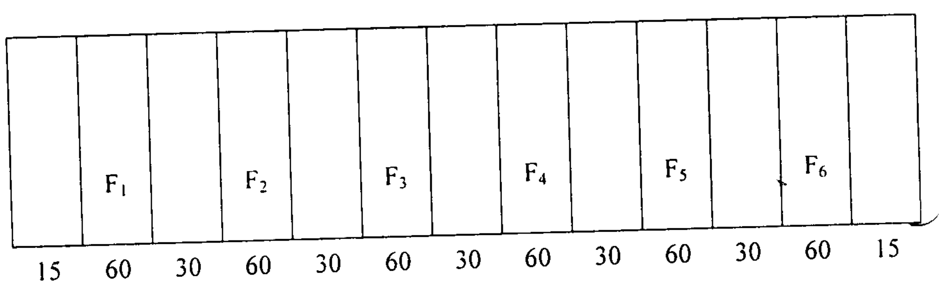
(Total plant 360)




**$L_3$ Paired row planting at 30 - 60 cm x 20 cm (12 lines)**

30 plant

(Total plant 360)



## 3.5 Cultivation

The details of cultural and other operations carried out in the experimental plot during the period of experimentation were presented in Table 4.

### 3.5.1 Preparatory tillage

The land was ploughed 20 cm deep with tractor plough immediately after the harvest of soybean crop. It was subsequently harrowed thrice with a blade harrow to achieve a loose and friable seed bed. The stubbles of previous crop were collected before the last harrowing and burned.

### 3.5.2 Fertilizer application

The complete dose of phosphorus (40 kg $P_2O_5$/ha) along with half dose of nitrogen (30 kg N/ha) as per recommendations was applied and placed 5 cm deep in line and to the side of crop row but prior to sowing uniformly in each plot. The remaining half dose of 30 kg N/ha was applied at 30 days after sowing. The fertilizer used were 20:20:0, urea (46 per cent N), single super phosphate (16 per cent $P_2O_5$).

### 3.5.3 Seed and sowing

Spiny safflower viz., PBNS-12 was selected for the present investigation. Seed were sown by hand dibbling as per spacing in each plot. Basal dose of fertilizer was side dressed before sowing. The varietal characters are given below.

| Sr. No. | Particulars | PBNS-12 |
|---|---|---|
| 1. | Growth habit | Normal |
| 2. | Stem colour | Yellow |
| 3. | Nature of plant | Spiny |
| 4. | Leaf colour | Dark green |
| 5. | Flower colour | Yellow, orange red |
| 6. | Seed size | Bold |
| 7. | 100 seed weight | 5 to 5.5 |
| 8. | Duration | 125-128 |
| 9. | Oil content (%) | 29-30 |

**Table 4 Schedule of cultural operations**

| Sr. No. | Operation | Frequ-ency | Dates |
|---|---|---|---|
| 1 | Ploughing | 1 | 20.10.04 |
| 2 | Harrowing | 3 | 25.10.04, 30.10.04 and 8.11.04 |
| 3 | Cleaning | 2 | 10.11.04 and 13.11.04 |
| 4 | Experimental Layout | 1 | 15.11.04 |
| 5. | Basal fertilizer application | 1 | At sowing |
| 6. | Sowing | 1 | 17.11.04 |
| 7 | Gap filling | 1 | 28.11.04 |
| 8. | Thinning | 1 | 10.12.04 |
| 9. | Top dressing | 1 | 22.12.04 |
| 10. | Weeding | 2 | 8.12.04 and 27.12.04 |
| 11. | Hoeing | 1 | 10.12.04 |
| 12. | Spraying | 4 | 7.12.04, 25.12.04, 4.1.05 and 14.1.04 |
| 13. | Irrigation | 3 | 22.12.04, 17.1.05 and 7.2.05 |
| 14. | Harvesting | 1 | 20.3.05 |
| 15. | Threshing and weighing | 1 | 27.3.05 |

### 3.5.4 Gap filling and thinning

After emergence of the crops, gaps in the field were filled by dibbling 2-3 seeds per hill. In order to keep single vigorous growing plant at each hill, thinning was carried out by uprooting the extra and disease affected plants.

### 3.5.5 Irrigation application

The irrigations were given with the help of water meter and scheduled as per treatment and considering the critical growth stages of crop. One common pre soaking irrigation was applied to all treatments including control for good germination and proper establishment of the crop. The details of irrigation schedule is given below.

| Sr.No. | Critical growth stage | Crop age (DAS) | Actual irrigation schedule (DAS) |
|---|---|---|---|
| 1. | Rosette | 30-35 | 35 |
| 2. | Branching | 55-60 | 60 |
| 3. | Flowering | 75-80 | 80 |

DAS – Days after sowing

The quantity of water applied to each plot/irrigation was calculated as under.

Quantity of water (litre) applied = Plot area $m^2$ x depth of irrigation (mm)

D1 5.4 x 6.0 x 40 mm = 1296 litre

D2 5.4 x 6.0 x 50 mm = 1620 litre

D3 5.4 x 6.0 x 60 mm = 1944 litre

### 3.5.6 Crop protection

In order to control the aphids and capsule borer, spraying of endosulfan 35 EC @ 17 ml and dimethoate 30 EC @ 10 ml in 10 litres of water was undertaken. For protecting the crop from alternaria, Dithane M-45 @ 25 g /10 lit of water was sprayed.

### 3.5.7 Inter cultivation

Intercultural operations i.e. hoeing by hand hoe and two hand weedings were carried out so as to keep the weeds under control and proper aeration to the soil. The schedule of various cultural operations are given in Table 5.

### 3.5.8 Harvesting and threshing

At maturity, the crop plants in each net plot were cut at ground level with the help of sickle. The plotwise harvested plants were collected and sundried for 3-4 days. After drying, threshing and winnowing were done. Weight of biological, seed and straw yield were recorded separately for each net plot.

### 3.5.9 Method of irrigation

Irrigation was applied to different plots as per treatments. The water meter was fitted to hose pipe for measuring the discharge of irrigation water directly in the plot and it was shifted from plot to plot at each irrigation.

### 3.6 Emergence count and final plant stand

Emergence count was taken 15 days after sowing (DAS) wherein, all the emerged plants were counted. Final plant stand from each net plot was recorded at harvest. The per cent of plant count were then transformed in arcsine values for statistical analysis.

### 3.7 Biometric observations

Observations on biometric plant characters are indicators of crop growth viz., height of main shoot, number of leaves, leaf area, number of branches per plant were recorded at various growth stages with an interval of 15 days from 30 days onwards after sowing upto harvest.

Observations on yield attributes viz., number of capitula per plant were recorded at 60, 75, 90, 105 DAS and at harvest, weight of capitula per plant, number of seeds per capitula, number of seed per plant, weight of seed per plant, 1000 seed weight (g) and volume weight were recorded at harvest of the crop. Particulars of the observations are given in Table 5.

**Table 5 Particulars of biometric observations recorded with frequency**

| Sr. No. | Particulars | Frequency | Crop age in days. |
|---|---|---|---|
| **A.** | **Pre-harvest studies** | | |
| 1 | Emergence count | 1 | 15 |
| 2 | Plant height in cm | 7 | 30, 45, 60, 75, 90, 105 and at harvest |
| 3 | Number of branches/ plant | 6 | 45, 60, 75, 90, 105 and at harvest |
| 4 | Number of functional leaves/ plant | 7 | 30, 45, 60, 75, 90, 105 and at harvest |
| 5 | Leaf area/plant (sq.m.) | 7 | 30, 45, 60, 75, 90, 105 and at harvest |
| 6 | No. of capitula/plant | 5 | 60, 75, 90, 105 and at harvest |
| 7 | Total dry matter/plant | 7 | 30, 45, 60, 75, 90, 105 and at harvest |
| 8 | Days to first flower opening | 1 | |
| 9 | Days to 50% flowering | 1 | |
| 10. | Soil moisture study | 3 | Before and after each irrigation |
| **B.** | **Post harvest studies** | | |
| 1 | No. of capitula/plant | 1 | At harvest. |
| 2 | Wt. of capitula/plant (g) | 1 | At harvest. |
| 3 | No. of seeds/capitulum | 1 | At harvest. |
| 4 | Wt. of seeds/plant (g) | 1 | At harvest. |
| 5 | Seed yield/plot (kg) | 1 | At harvest. |
| 6 | Biological yield/plot (kg) | 1 | At harvest. |
| 7 | Harvest index (%) | 1 | At harvest. |
| 8 | Volume weight (g) | 1 | At harvest. |
| 9 | 1000 seed weight (g) | 1 | At harvest. |
| 10 | Oil content (%) | 1 | At harvest. |
| 11 | Final plant stand | 1 | At harvest. |

### 3.7.1 Sampling techniques

Five plants were selected at random from each net plot and labelled with wax coated paper labels. Biometric observations were recorded on these labelled plants. These plants were separately harvested at maturity for assessing their yield and yield attributes.

### 3.7.2 Height of plant

The height of main shoot of each plant was recorded from ground level to the base of apical bud with an interval of 15 days.

### 3.7.3 Number of branches per plant

The total number of branches per plant were counted (both primary and secondary) and recorded on labelled plants at 45, 60, 90, 105 DAS and at harvest.

### 3.7.4 Number of functional leaves

Progressive number of functional leaves per plant were counted from 30 days of selected plants at various stages of crop growth.

### 3.7.5 Leaf area ($dm^2$)

Leaves of the plant uprooted for dry matter studies were clipped, grouped into 3 grades viz., big, medium and small. The gradewise leaves were counted and their frequency was recorded. The representative sample of these grades was observed for linear measurement of maximum length and breadth Leaf area was calculated by using formula for each grade.

$$A = \sum_{i=1} L \times B \times K \times N$$

Where,

| | | |
|---|---|---|
| A | = | Leaf area ($dm^2$) under particular group |
| L | = | Length of leaf |
| B | = | Breadth of leaf |
| K | = | Leaf area constant as 0.87 (Singh *et al.,* 1970) |
| N | = | Number of leaves under particular group |

### 3.7.6 Dry matter per plant (g/plant)

The weight of dry matter per plant is an index of overall plant growth. Hence one representative plant from each net plot with an interval of 15 days was carefully uprooted. The root and leaves were removed and the plants were air dried for 3-4 days and subsequently oven dried at 70°C for 48 hours and their dry weight excluding roots were recorded.

### 3.7.7 Days to first flowering

Number of days required for first flowering was recorded from each net plot.

### 3.7.8 Days to 50 per cent flowering

Number of days required to 50 per cent flowering was recorded from each net plot.

## 3.8 Post harvest studies

The plant selected for biometric observations were used for generating data on yield attributes viz., number of capitula/plant, number of seeds/capitulum, weight of capitula/plant, weight of seed/plant, 1000 seed weight and volume weight.

### 3.8.1 Number of capitula per plant

Number of capitula per plant was counted and recorded.

### 3.8.2 Number of seeds/capitulum

All capitula from the observational plants were counted and threshed together. Seeds were separated and total seeds were weighed and mean number of seeds/plant/capitulum was calculated.

### 3.8.3 1000 seed weight (g)

1000 representative seeds were counted from the total produce of net plot and weight was recorded.

### 3.8.4 Volume weight

While calculating the volume weight, the seeds from net plots were taken and measured in measuring cylinders upto 1 lit mark and 1 lit measured seeds were weighed.

## 3.9 Growth analysis

Data on growth characters namely height, dry matter and leaf area per plant were further subjected for the computation of different growth functions viz. AGR, RGR and LAI. Data on these growth functions were not statistically analyzed and the inferences were drawn on the basis of mean values.

### 3.9.1 Absolute Growth Rate (AGR)

Absolute Growth Rate (AGR) of two variables viz. plant height (cm) and total dry matter (g) per plant was worked out with the formula given by Richards (1969).

$$\text{Absolute Growth Rate (AGR) (Height)} = \frac{H_2 - H_1}{t_2 - t_1} \quad \text{(cm/day)}$$

$$\text{Absolute Growth Rate (AGR) (Total dry matter)} = \frac{W_2 - W_1}{t_2 - t_1} \quad \text{(g/day)}$$

Where, $H_2$ and $H_1$ as well as $W_2$ and $W_1$ are the heights and weights of dry matter per plant at $t_2$ and $t_1$ times, respectively.

### 3.9.2 Relative Growth Rate (RGR)

This parameter indicates rate of growth per unit of dry matter. It is expressed as 'g' of dry matter produced by a 'g' of existing dry matter in a day. The incorporation of dry matter into the substance of a plant is measured by Relative Growth Rate (RGR) and is expressed mathematically as per Fisher (1921).

$$\text{Relative Growth Rate (RGR)} = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{t_2 - t_1} \quad \text{(g/g/day)}$$

Where,

$\text{Log}_e$ = natural logarithm to the base 'e' (e = 2.3026)

$W_1$ and $W_2$ are the weights of dry matter in g/plant at time $t_1$ and $t_2$, respectively.

### 3.9.3 Leaf area index (LAI)

Leaf area index is the measure of crop growth per unit area, since the crop yield to be expressed/unit of ground area, instead of per plant. The leaf area existing on unit ground was proposed by Watson (1952) as the ratio of leaf area to ground area occupied by the crop plant. It is calculated by the following formula.

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Ground area per plant } (dm^2)}$$

## 3.10 Yield (kg/ha)

### 3.10.1 Yield of seed/plant (g)

Total weight of seeds was obtained by threshing all capitula from the observational plant and divided by number of observational plants i.e. 5 to get average seed yield in g/plant.

### 3.10.2 Seed yield (kg/ha)

The plants from each net plot were threshed and seeds were cleaned. The seed obtained in each net plot were weighed after sufficient sundrying and converted on hectare basis.

### 3.10.3 Biological yield (kg/ha)

Biological yield was calculated by summation of straw yield and seed yield per plot and expressed as kg/ha.

### 3.10.4 Harvest index (HI)

The harvest index was worked out by the formula given by Donald and Hambin (1976) as :

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}}$$

### 3.10.5 Oil content (%) in seed and oil yield

About 25 g clean seeds from each net plot were taken and oil content in per cent was calculated. Oil yield was calculated by multiplying oil content and seed yield.

### 3.10.6 Soil moisture studies

Soil moisture studies were started right from sowing and continued upto harvesting of crop. Access tube were fixed in each treatment of one replication and the soil moisture contents in each plot placed in the specified replication were determined 24 hours before and 48 hours after each irrigation by Neutron probe moisture gauge from 0-30, 30-45, 45-60 cm depth layers.

The final moisture content at each irrigation was determined by comparing the neutron scatter counts with standardized calibration curve of experimental site.

### 3.10.7 Consumptive use of water

The field consumptive use of water by safflower (mm) was computed by the formula

$$CU = \sum_{i=1}^{n} E_0 + \sum_{j=1}^{n} Vi$$

where,

CU = seasonal consumptive use of water in mm

Eo = evaporation from the pan evaporimeter for the period between irrigation and sampling after irrigation in mm.

n = number of time interval

$$Vi = \sum_{i=1}^{n} \frac{M_1 i - M_2 i}{100} \times ASi \times Di\ GWC + ERF$$

Where,

| | | |
|---|---|---|
| N | = | number of soil layer in the root zone |
| $M_{1i}$ | = | moisture (per cent) on oven dry weight basis at first sampling in ith layer (per cent) |
| $M_{2i}$ | = | moisture on oven dry weight basis at second sampling in ith layer (per cent) |
| $As_i$ | = | Apparent specific gravity at ith layer |
| $D_i$ | = | Depth of soil in the ith layer (mm) |
| GWC | = | Ground water contribution (mm) |
| ERF | = | Effective rainfall (mm) |
| $V_1$ | = | water used during the interval between the first and the second irrigation |

### 3.10.8 Water use efficiency

Water use efficiency i.e. kg of seed yield produced for mm of applied water per hectare in each treatment was worked out by the formula.

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

Where,

WUE = Water use efficiency (kg of seed yield per ha mm)

Y = Seed yield of safflower in kg/ha

CU = Total seasonal consumptive use of water (mm)

### 3.11 Statistical analysis and interpretation of data

The data on various growth and yield attributes were tabulated and subjected to statistical analysis as per the methods given in the book 'Statistical Methods for Agricultural Workers' by Panse and Sukhatme (1967).

### 3.12 Economics

Gross returns were calculated as per the prevailing market prices for seed yield. The cost of cultivation for seed yield was separately worked out. The net returns were calculated by excluding the treatmentwise cost of cultivation from gross returns. B:C ratio was calculated by dividing gross returns with respective cost of cultivation.

# Experimental Findings

Chapter IV

# EXPERIMENTAL FINDINGS

The summarized data, statistical parameters and results are presented in this chapter.

## 4.1 Emergence count and final plant stand

Data on per cent emergence count and arcsine values of mean number of plants per net plot on establishment of crop and its final plant stand available at harvest are presented in Table 6.

Data presented in Table 6 indicates that crop establishment and its final plant stand was not significantly influenced by different treatments. Similarly, final plant stand at harvest was also apparently uniform indicating that variations obtained in the different parameters under study were the real effects of treatments.

## 4.2 Growth attributes

### 4.2.1 Plant height

The data on mean plant height (cm) of safflower as recorded at various growth stages of crop were presented in Table 7 and depicted in Fig.3.

The mean plant height increased upto harvest, the rate of increase in plant height was gradual and steady upto 30 days, fast between 45 to 60 days and increased with increasing rate upto 90 days and there

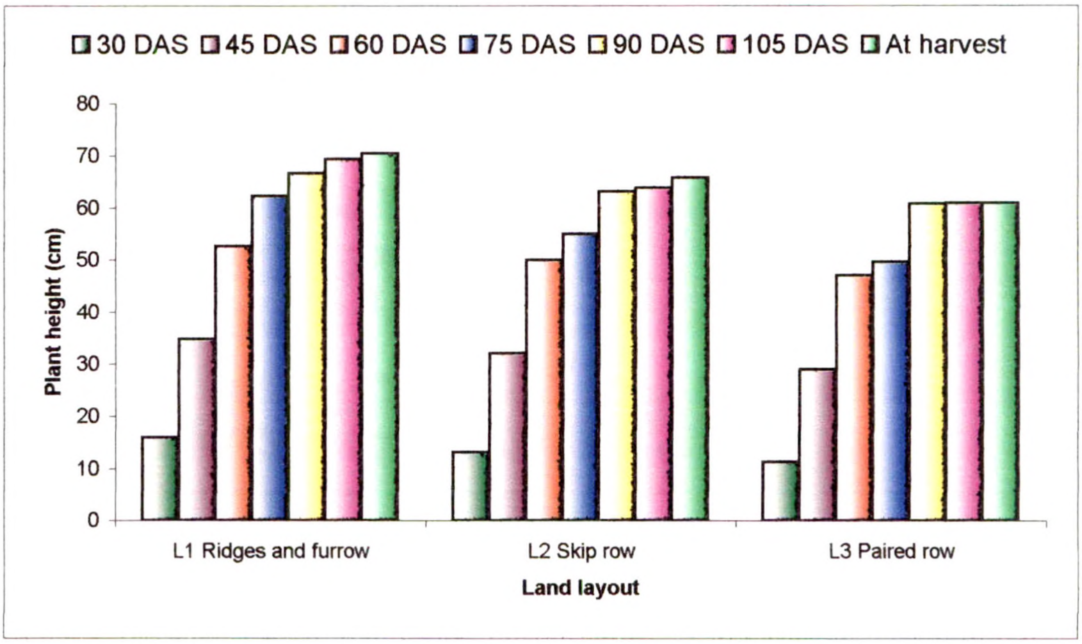
**Table 6 Emergence and final plant stand of safflower as influenced by irrigation schedules**

| Treatments | Emergence count | Final plant stand |
|---|---|---|
| **Land layout** | | |
| $L_1$ - Ridges and furrow | 95 (67.19) | 85 (58.58) |
| $L_2$ - Skip row furrow method | 93 (66.40) | 84 (58.39) |
| $L_3$ - Paired row planting | 92 (66.37) | 84 (58.33) |
| SE $\pm$ | 0.44 | 0.46 |
| CD at 5% | NS | NS |
| **Depth of irrigation (mm)** | | |
| $D_1$ – 40 | 91 (66.19) | 83 (58.29) |
| $D_2$ - 50 | 92 (66.41) | 84 (58.50) |
| $D_3$ - 60 | 97 (67.36) | 85 (58.50) |
| SE $\pm$ | 0.44 | 0.77 |
| CD at 5% | NS | NS |
| **Interaction** | | |
| SE $\pm$ | 0.77 | 1.34 |
| CD at 5% | NS | NS |
| **General mean** | 93 (66.65) | 84 (63.12) |
| **Additional treatment** | 92 (66.37) | 84 (58.33) |

Figures in parenthesis are arcsine values for emergence count and final plant stand.

**Table 7 Mean plant height (cm) as influenced by different treatments at various stages**

| Treatments | Days after sowing 30 | 45 | 60 | 75 | 90 | 105 | At harvest |
|---|---|---|---|---|---|---|---|
| **Land layout** | | | | | | | |
| $L_1$ - Ridges and furrow | 15.96 | 34.77 | 52.74 | 62.28 | 66.75 | 69.49 | 70.55 |
| $L_2$ - Skip row furrow method | 13.18 | 32.13 | 49.97 | 55.09 | 63.22 | 63.88 | 65.90 |
| $L_3$ - Paired row planting | 11.35 | 29.02 | 47.12 | 49.66 | 60.85 | 60.97 | 60.99 |
| SE $\pm$ | 0.10 | 0.16 | 0.55 | 0.21 | 0.58 | 0.46 | 0.46 |
| CD at 5% | 0.31 | 0.48 | 1.65 | 0.64 | 1.74 | 1.39 | 1.39 |
| **Depth of irrigation (mm)** | | | | | | | |
| $D_1$ – 40 | 12.75 | 30.16 | 47.42 | 53.73 | 62.28 | 62.95 | 63.18 |
| $D_2$ – 50 | 13.26 | 31.41 | 50.29 | 55.81 | 63.98 | 64.31 | 65.56 |
| $D_3$ – 60 | 14.47 | 34.35 | 52.12 | 57.33 | 65.22 | 66.41 | 68.70 |
| SE $\pm$ | 0.18 | 0.21 | 0.42 | 0.18 | 0.14 | 0.32 | 0.32 |
| CD at 5% | 0.56 | 0.65 | 1.25 | 0.55 | 0.43 | 0.95 | 0.95 |
| **Interaction** | | | | | | | |
| SE $\pm$ | 0.32 | 0.38 | 0.73 | 0.32 | 0.25 | 0.55 | 0.55 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 13.49 | 31.97 | 49.94 | 55.65 | 63.71 | 64.66 | 65.81 |
| **Additional treatment (Flat bed)** | **12.11** | **30.65** | **48.51** | **55.15** | **62.46** | **64.17** | **64.20** |



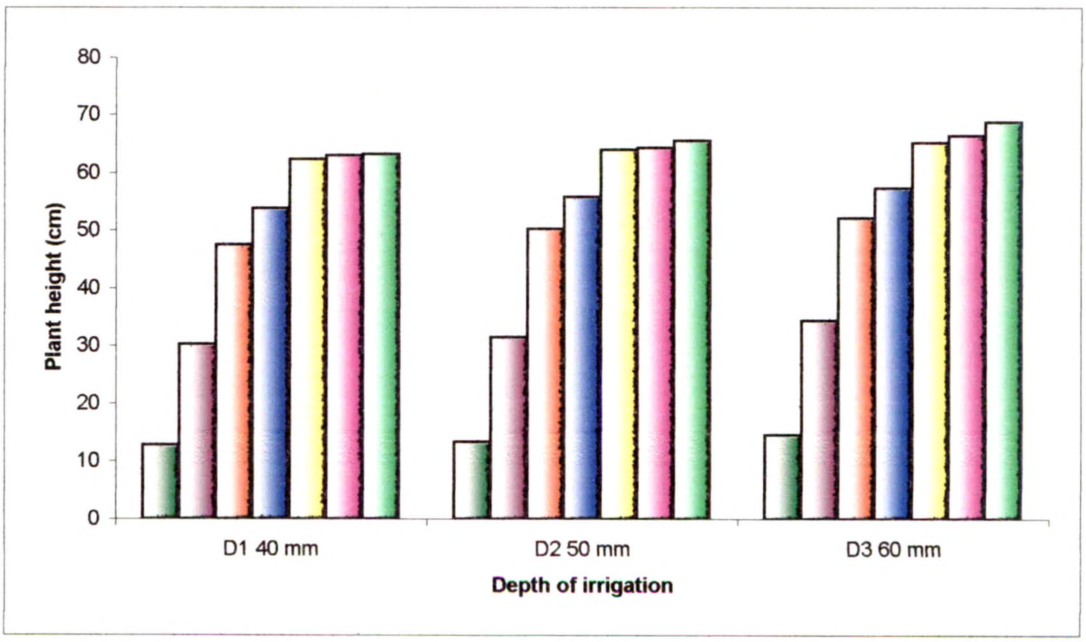




Fig. 3 Mean plant height (cm) of safflower as influenced by different treatment at various crop growth stages

after slightly increased till harvest. The mean plant height recorded at harvest was 65.81 cm.

#### 4.2.1.1 Land layout

The effect of land layout on plant height was found significant at all growth stages (Table 7).

At 30 days, ridges and furrow land layout recorded highest plant height (15.96 cm), which was significantly superior over other land layouts. Minimum plant height was recorded in paired row planting. Similar trends were observed at 45, 60, 75, 90, 105 days and at harvest.

#### 4.2.1.2 Depth of irrigation

The data presented in Table 7 indicated that the plant height was significantly affected by depth of irrigation at all growth stages.

At 30 days, irrigation scheduled at 60 mm depth recorded highest plant height (14.47 cm), which was significantly superior over other depth of irrigation and followed by 50 and 40 mm. Similar results were observed at 45, 60, 75, 90, 105 days after sowing and at harvest.

#### 4.2.1.3 Interaction

The interaction effect of land layout and depth of irrigation on plant height (cm) was found to be non-significant at all the stages of crop growth.

### 4.2.2 Number of primary branches per plant

The data on mean number of primary branches per plant was significantly influenced by different treatments and are presented in Table 8 and depicted in Fig.4.

The number of primary branches increased rapidly during 60 to 90 days after sowing (9.51 to 14.77) and increased with decreasing rate till the harvest. The mean primary branches recorded at harvest were 19.18.

#### 4.2.2.1 Land layout

The effect of land layout on number of primary branches was significant at all growth stages and are presented in Table 8.

At 45 days, the highest number of branches (10.32) was recorded by ridges and furrow method, which was significantly superior over rest of the treatments. Second best land layout was skip row method, which was significantly superior over paired row planting method. Similar trends were recorded at 60, 75, 90, 105 days and at harvest.

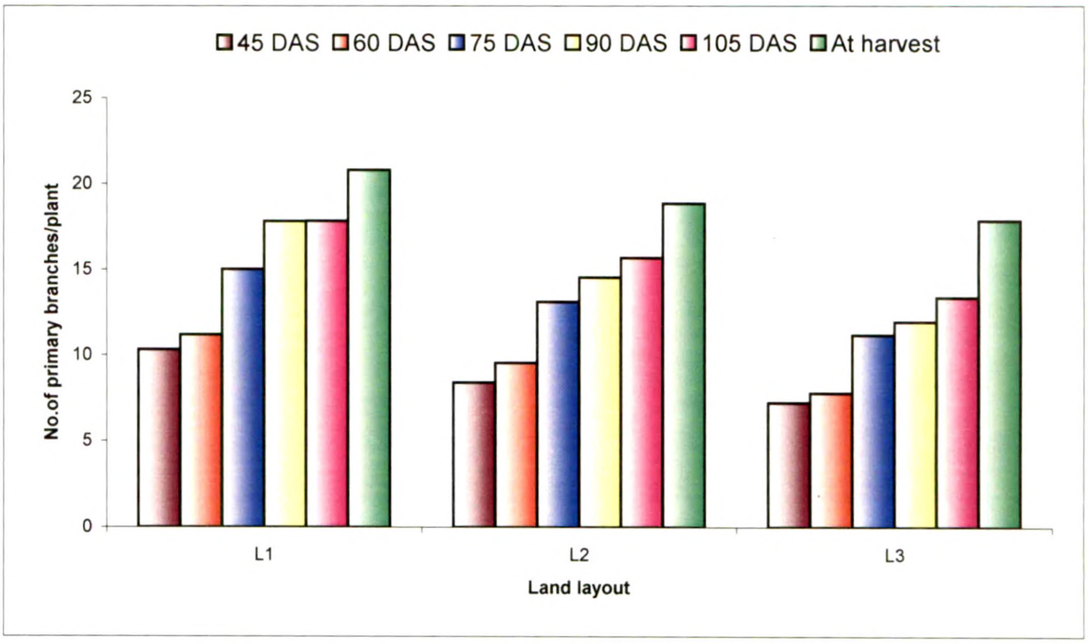
#### 4.2.2.2 Depth of irrigation

The data presented in Table 8 revealed that the effect of depth of irrigation on number of primary branches were significant at all stages of crop growth.

At 45 days, among different irrigation depths, irrigating safflower at 60 mm depth recorded significantly highest number of primary branches (9.53) followed by 50 mm (8.92) and 40 mm depth (7.54). Similar trend was observed at 60, 75, 90, 105 days and at harvest.

**Table 8** **Mean number of primary branches per plant as influenced by different treatments at various stages.**

| Treatments | Days after sowing | | | | | |
|---|---|---|---|---|---|---|
| | **45** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | | |
| $L_1$- Ridges and furrow | 10.32 | 11.18 | 15.01 | 17.83 | 17.85 | 20.81 |
| $L_2$- Skip row furrow method | 8.42 | 9.55 | 13.11 | 14.54 | 15.68 | 18.87 |
| $L_3$- Paired row Planting | 7.26 | 7.82 | 11.18 | 11.96 | 13.39 | 17.87 |
| SE± | 0.19 | 0.19 | 0.20 | 0.35 | 0.39 | 0.07 |
| CD at 5% | 0.56 | 0.58 | 0.61 | 1.04 | 1.61 | 0.20 |
| **Depth of Irrigation (mm)** | | | | | | |
| $D_1$- 40 | 7.54 | 8.70 | 12.34 | 13.89 | 13.92 | 18.14 |
| $D_2$- 50 | 8.92 | 9.51 | 13.07 | 14.74 | 15.65 | 19.18 |
| $D_3$- 60 | 9.53 | 10.35 | 13.90 | 15.69 | 16.92 | 20.23 |
| SE± | 0.14 | 0.17 | 0.18 | 0.19 | 0.27 | 0.12 |
| CD at 5% | 0.42 | 0.52 | 0.54 | 0.57 | 0.82 | 0.36 |
| **Interaction** | | | | | | |
| SE± | 0.24 | 0.30 | 0.30 | 0.30 | 0.47 | 0.21 |
| CD at 5% | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 8.66 | 9.51 | 13.10 | 14.77 | 15.49 | 19.18 |
| **Additional treatment (Flat bed)** | **8.10** | **9.25** | **12.15** | **16.20** | **16.50** | **17.81** |



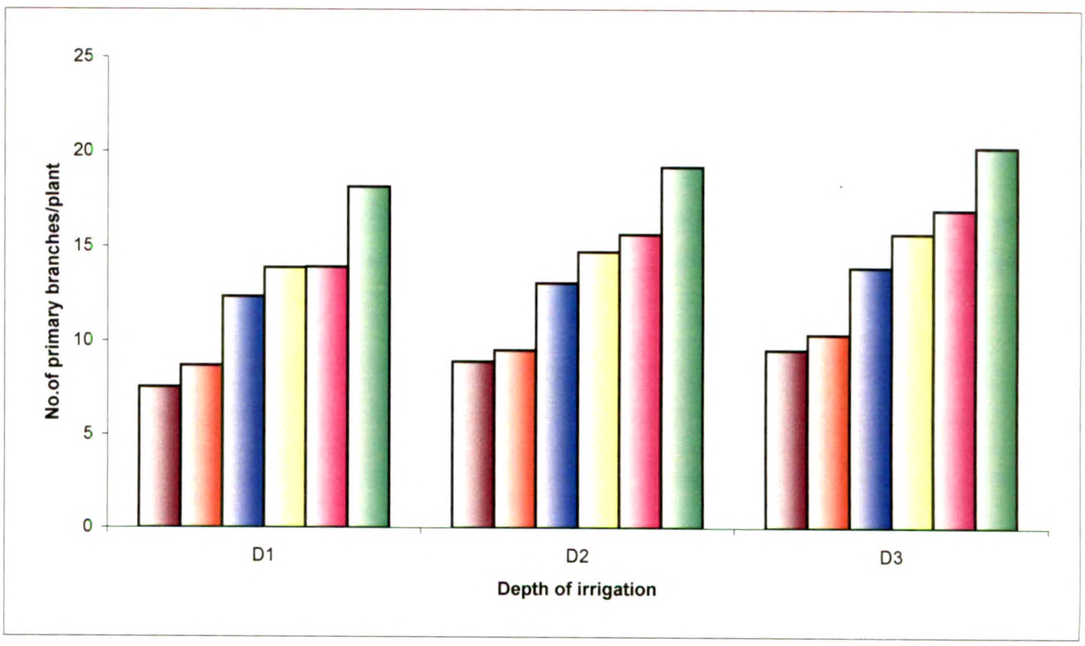




**Fig. 4 Mean number of primary branches per plant as influenced by different treatments at various crop growth stages of safflower**

#### 4.2.2.3 Interaction

The interaction effect of land layout and depth of irrigation on primary branches was not evident.

### 4.2.3 Number of secondary branches per plant

The data in Table 9 indicated that the mean number of secondary branches/plant were significantly affected by different treatments. The number of secondary branches increased rapidly during 60 to 90 days after sowing and then increased slowly upto 105 days. The mean number of secondary branches per plant recorded at harvest were 19.93. The graph of number of secondary branches per plot is depicted in Fig.5.

#### 4.2.3.1 Land layout

The data presented in Table 9 indicated that the effect of land layout on number of secondary branches were significant at all growth stages.

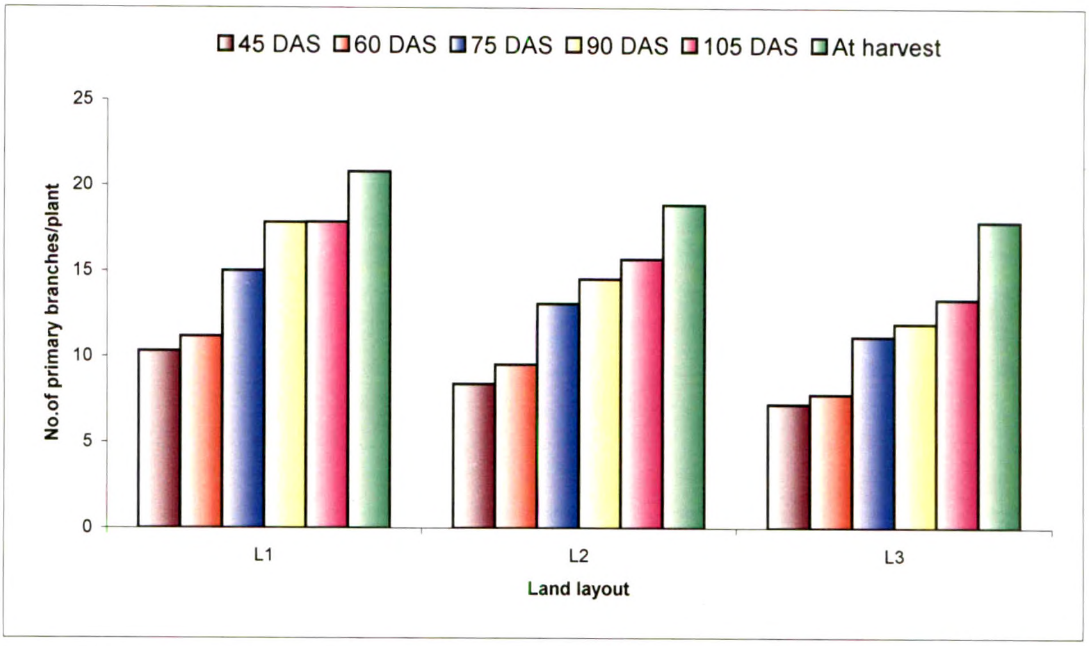
At 60 days, among different land layouts, ridges and furrow produced significantly higher secondary branches (10.81) as compared to other land layouts. The lowest secondary branches were produced in paired row planting method (7.07). Similar trend was observed at 75, 90, 105 days and at harvest.

#### 4.2.3.2 Depth of irrigation

At 60 days, the highest number of secondary branches (9.82) was found in irrigation scheduled at 60 mm depth, which was significantly

**Table 9 Mean number of secondary branches per plant as influenced by different treatments at various stages**

| | Days after sowing | | | | |
|---|---|---|---|---|---|
| **Treatments** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | |
| $L_1$ - Ridges and furrow | 10.81 | 15.02 | 16.33 | 17.37 | 22.63 |
| $L_2$ - Skip row furrow method | 8.98 | 12.70 | 14.38 | 15.68 | 20.81 |
| $L_3$ - Paired row planting | 7.07 | 10.35 | 12.06 | 13.39 | 14.87 |
| SE ± | 0.27 | 0.26 | 0.09 | 0.41 | 0.14 |
| CD at 5% | 0.81 | 0.78 | 0.28 | 1.23 | 0.41 |
| **Depth of irrigation (mm)** | | | | | |
| $D_1$ - 40 | 8.19 | 10.68 | 12.23 | 13.87 | 19.25 |
| $D_2$ - 50 | 8.85 | 12.68 | 14.25 | 15.65 | 20.43 |
| $D_3$ - 60 | 9.82 | 14.71 | 16.30 | 16.92 | 21.64 |
| SE ± | 0.11 | 0.04 | 0.06 | 0.27 | 0.15 |
| CD at 5% | 0.35 | 0.13 | 0.17 | 0.80 | 0.45 |
| **Interaction** | | | | | |
| SE ± | 0.20 | 0.07 | 0.10 | 0.46 | 0.26 |
| CD at 5% | NS | NS | NS | NS | NS |
| **Grand mean** | 8.95 | 12.69 | 14.25 | 15.48 | 19.93 |
| **Additional treatment (Flat bed)** | **8.21** | **12.10** | **14.15** | **15.81** | **19.21** |



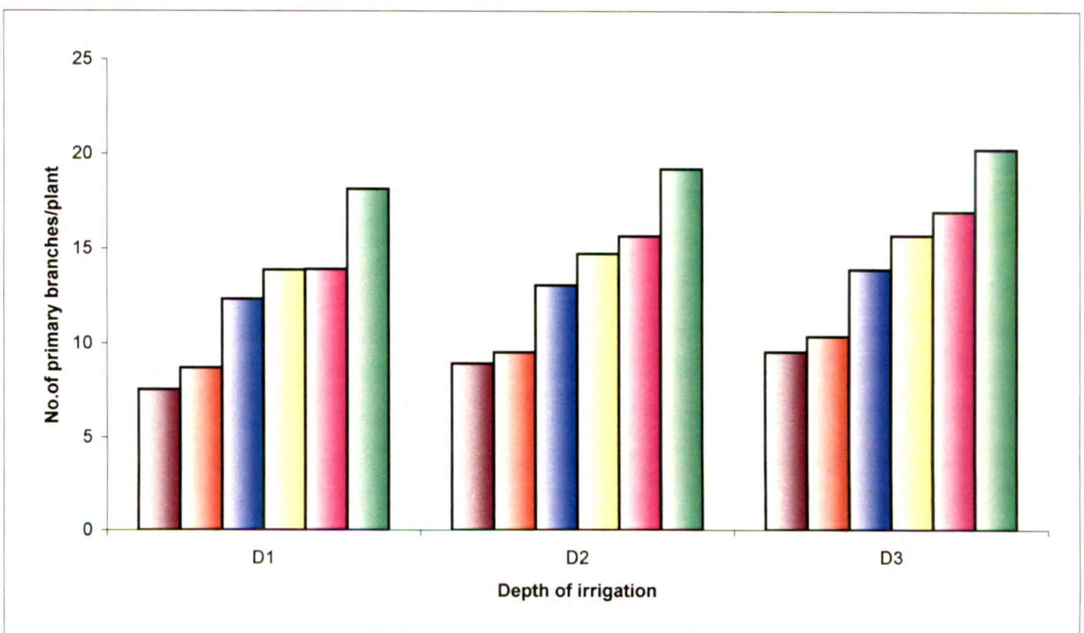




**Fig. 5 Mean number of secondary branches per plant as influenced by different treatments at various crop growth stages of safflower**

superior over all other treatments. The lowest number of secondary branches (8.19) were produced by 40 mm depth of irrigation. Similar results were recorded at 75, 90, 105 days and at harvest (Table 9).

#### 4.2.3.3 Interaction

The interaction effect of land layout and depth of irrigation was not evident.

### 4.2.4 Number of functional leaves

The number of functional leaves of safflower per plant were significantly affected by different treatments and are presented in Table 10 and depicted in Fig.6.

The number of leaves per plant increased upto 90 days after sowing (175.98) and the number decreased relatively at faster rate due to leaf senescence of safflower.

#### 4.2.4.1 Land layout

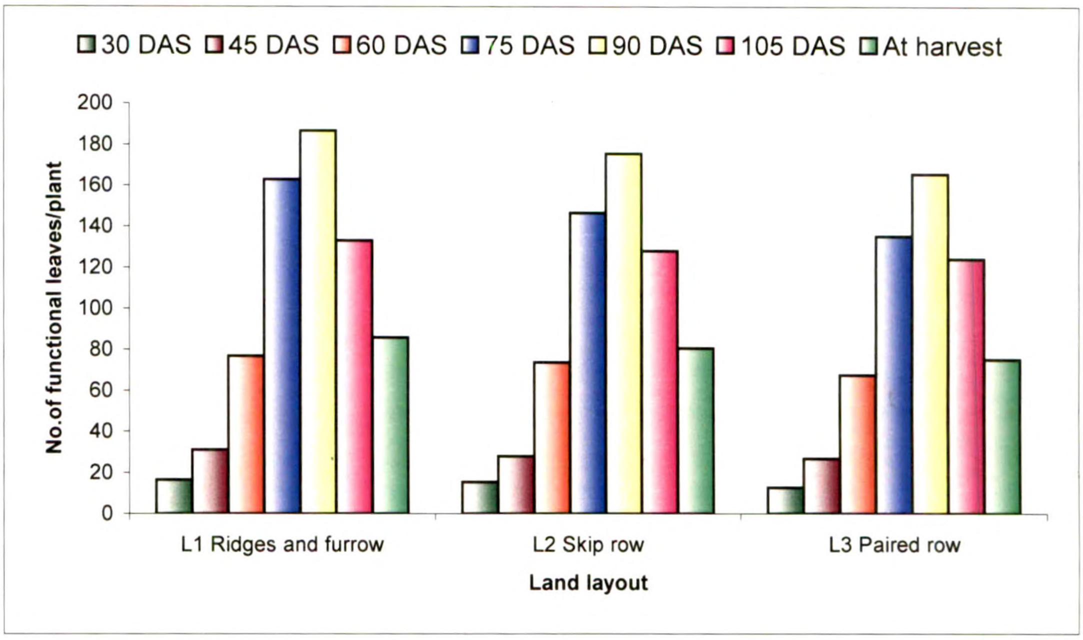
The effect of land layout on number of leaves per plant was found significant at all stages of crop growth.

At 30 days, the maximum number of leaves of safflower were recorded in ridges and furrow method (16.50), which was significantly superior over skip row and paired row planting.

Minimum number of leaves were observed in paired row planting method (12.75).

**Table 10 Mean number of functional leaves per plant as influenced by different treatments at various stages**

| | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatments** | **30** | **45** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | | | |
| $L_1$ - Ridges and furrow | 16.50 | 31.13 | 76.91 | 162.92 | 186.76 | 133.10 | 85.91 |
| $L_2$ - Skip row furrow method | 15.50 | 28.06 | 73.83 | 146.57 | 175.62 | 128.06 | 80.75 |
| $L_3$ - Paired row planting | 12.75 | 26.90 | 67.75 | 135.34 | 165.58 | 124.19 | 75.16 |
| SE $\pm$ | 0.28 | 0.40 | 0.43 | 0.60 | 2.70 | 0.69 | 0.42 |
| CD at 5% | 0.83 | 1.19 | 1.30 | 1.80 | 8.02 | 2.05 | 1.26 |
| **Depth of irrigation (mm)** | | | | | | | |
| $D_1$ - 40 | 13.80 | 24.58 | 69.66 | 145.44 | 168.07 | 123.97 | 77.16 |
| $D_2$ - 50 | 14.82 | 27.20 | 73.41 | 147.14 | 175.70 | 128.36 | 80.50 |
| $D_3$ - 60 | 16.13 | 34.31 | 75.41 | 152.24 | 184.19 | 133.02 | 84.16 |
| SE $\pm$ | 0.19 | 0.41 | 0.50 | 0.86 | 1.88 | 0.58 | 0.49 |
| CD at 5% | 0.58 | 1.22 | 1.49 | 2.55 | 5.60 | 1.74 | 1.47 |
| **Interaction** | | | | | | | |
| SE $\pm$ | 0.34 | 0.71 | 0.87 | 1.49 | 3.27 | 1.01 | 0.86 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 14.91 | 28.69 | 72.82 | 148.27 | 175.98 | 128.45 | 80.68 |
| **Additional treatment (Flat bed)** | **13.20** | **19.87** | **72.50** | **142.56** | **170.25** | **125.17** | **74.25** |



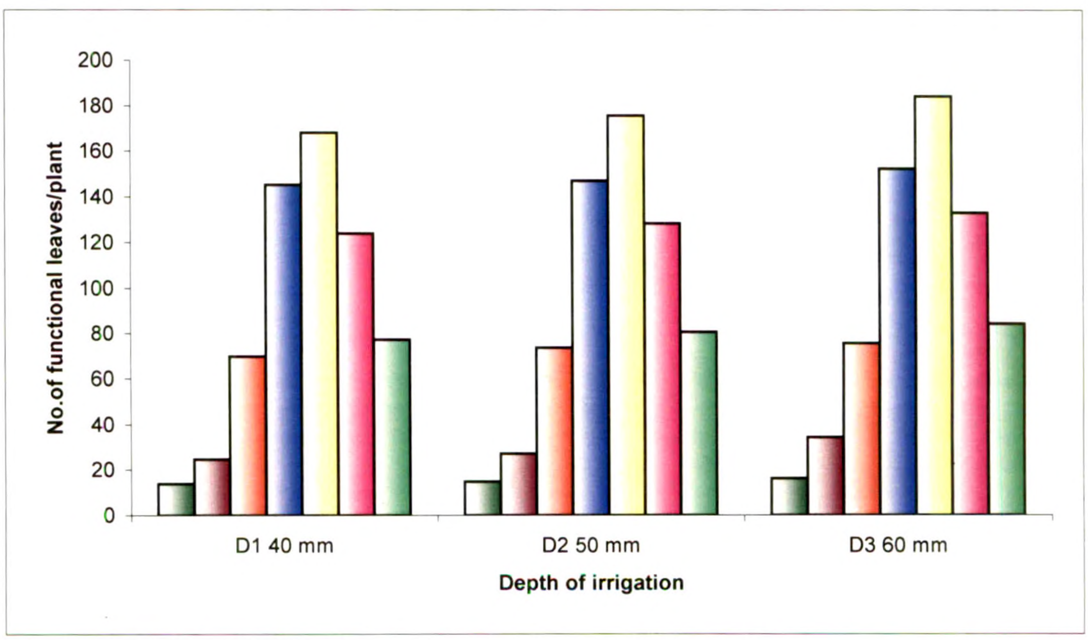




**Fig. 6 Mean number of functional leaves per plant as influenced by different treatments at various crop growth stages of safflower**

Similar type of trend was observed at 45, 60, 75, 90, 105 days after sowing and at harvest.

#### 4.2.4.2 Depth of irrigation

At 30 days, maximum number of leaves (16.13) were recorded at 60 mm depth of irrigation, which was significantly superior over other depth of irrigation. The minimum number of leaves were recorded at 40 mm depth of irrigation (13.80).

Similar results were observed at 45, 60, 75, 90, 105 days and at harvest.

#### 4.2.4.3 Interaction

The interaction effect of land layout and depth of irrigation was not observed.

### 4.2.5 Mean leaf area per plant

Data on mean leaf area of safflower per plant recorded at all stages of crop growth are presented in Table 11.

The mean leaf area ($dm^2$) per plant was increased upto 90 days after sowing and decreased thereafter upto harvest. The rate of increase was very rapid during 45 to 75 days after sowing.

The maximum mean leaf area per plant recorded at 90 days after sowing was 29.78 $dm^2$ and minimum leaf area of 17.60 $dm^2$ was recorded at harvest.

**Table 11** **Mean leaf area ($dm^2$) per plant as influenced by different treatments at various stages.**

| | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatments** | **30** | **45** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 7.37 | 14.67 | 22.95 | 31.04 | 32.56 | 21.12 | 20.07 |
| $L_2$- Skip row Furrow Method | 5.41 | 13.00 | 20.84 | 27.81 | 29.33 | 17.64 | 16.77 |
| $L_3$- Paired row Planting | 4.39 | 9.80 | 18.70 | 25.54 | 27.43 | 16.09 | 14.24 |
| SE± | 0.12 | 0.53 | 0.08 | 0.23 | 0.34 | 0.37 | 0.16 |
| CD at 5% | 0.35 | 1.59 | 0.25 | 0.70 | 1.01 | 1.11 | 0.50 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 3.67 | 7.91 | 18.40 | 26.27 | 27.92 | 16.16 | 14.57 |
| $D_2$- 50 | 5.79 | 12.32 | 21.13 | 28.24 | 29.85 | 17.40 | 17.16 |
| $D_3$- 60 | 7.72 | 17.24 | 22.96 | 29.89 | 31.62 | 21.08 | 21.07 |
| SE± | 0.11 | 0.29 | 0.18 | 0.26 | 0.15 | 0.31 | 0.27 |
| **CD at 5%** | 0.34 | 0.83 | 0.53 | 0.79 | 0.46 | 0.94 | 0.82 |
| **Interaction** | | | | | | | |
| SE± | 0.20 | 0.51 | 0.31 | 0.31 | 0.27 | 0.55 | 0.48 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 5.72 | 12.49 | 20.83 | 28.13 | 29.78 | 18.28 | 17.60 |
| **Additional treatment (Flat bed)** | **5.10** | **11.45** | **17.35** | **25.47** | **29.33** | **16.50** | **14.25** |

#### 4.2.5.1 Land layout

At 30 days, the maximum leaf area per plant of safflower (7.37) was recorded in ridges and furrow method and followed by skip row method and paired row planting (Table 11).

Similar trends were observed at 45, 60, 75, 90, 105 days after sowing and at harvest.

#### 4.2.5.2 Depth of irrigation

The data on mean leaf area per plant of safflower revealed that the effect of depth of irrigation was found to be significant at all growth stages (Table 11).

At 30 days, the mean leaf area per plant (7.72) was found significantly highest in 60 mm depth of irrigation followed by 50 mm and 40 mm. Similar trends were observed at 45, 60, 75, 90, 105 days after sowing and at harvest.

#### 4.2.5.3 Interaction

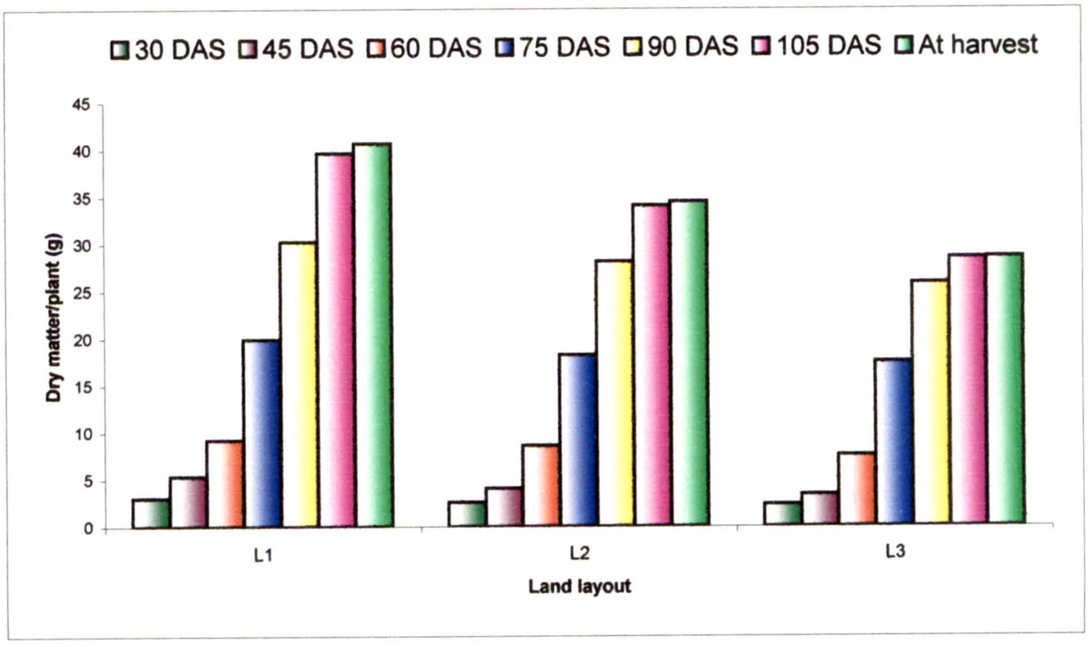
The interaction effect of land layout and depth of irrigation was not observed.

### 4.2.6 Total dry matter per plant (g)

The data on total dry matter of safflower per plant recorded at various stages of crop growth and are presented in Table 12 and depicted in Fig.7.

**Table 12** **Mean total dry matter per plant (g) as influenced by different treatments at various stages.**

| Treatments | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| | **30** | **45** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 3.07 | 5.38 | 9.20 | 19.93 | 30.29 | 39.68 | 40.70 |
| $L_2$- Skip row Furrow Method | 2.61 | 4.07 | 8.59 | 18.21 | 28.13 | 34.04 | 34.45 |
| $L_3$- Paired row Planting | 2.35 | 3.41 | 7.54 | 17.47 | 25.83 | 28.50 | 28.60 |
| SE$\pm$ | 0.05 | 0.09 | 0.11 | 0.19 | 0.37 | 1.33 | 2.00 |
| CD at 5% | 0.17 | 0.27 | 0.34 | 0.56 | 1.12 | 3.95 | 4.00 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 1.91 | 3.61 | 7.48 | 15.27 | 24.98 | 28.44 | 29.55 |
| $D_2$- 50 | 2.69 | 4.36 | 8.36 | 18.59 | 29.70 | 31.71 | 32.85 |
| $D_3$- 60 | 3.43 | 4.89 | 9.54 | 21.76 | 31.56 | 40.14 | 41.35 |
| SE$\pm$ | 0.06 | 0.06 | 0.07 | 0.13 | 0.35 | 0.63 | 0.64 |
| CD at 5% | 0.18 | 0.18 | 0.22 | 0.41 | 1.05 | 1.87 | 1.92 |
| **Interaction** | | | | | | | |
| SE$\pm$ | 0.11 | 0.10 | 0.13 | 0.23 | 0.61 | 1.09 | 1.09 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 2.67 | 4.28 | 8.45 | 18..43 | 28.41 | 33.43 | 34.58 |
| **Additional treatment (Flat bed)** | **2.56** | **3.35** | **8.40** | **17.21** | **25.27** | **30.27** | **30.30** |



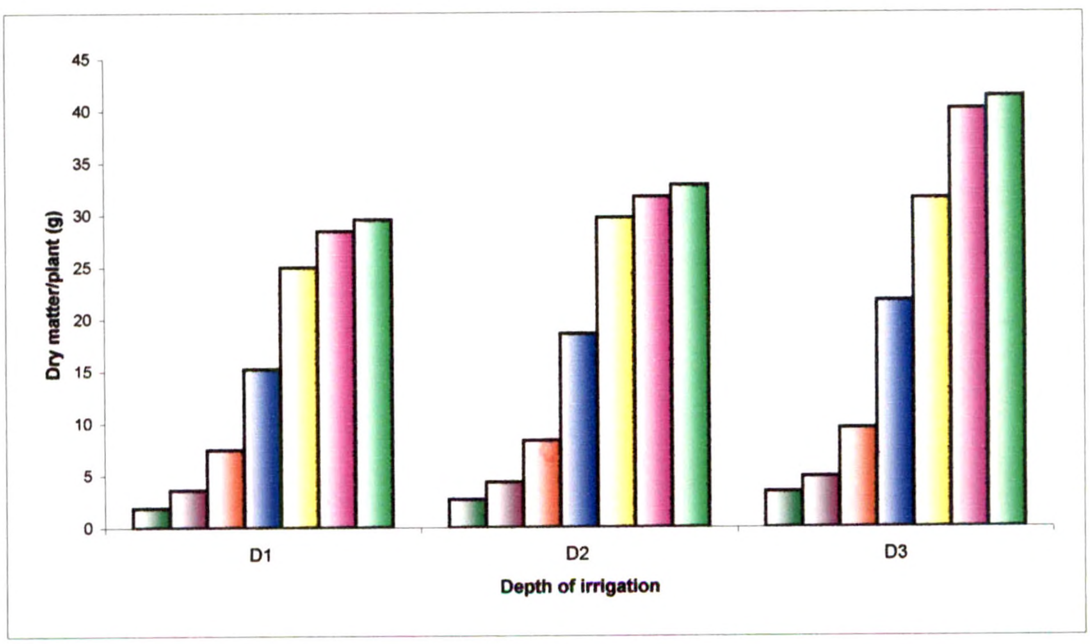




Fig. 7 Mean total dry matter (g) of safflower as influenced by different treatments at various crop growth stages

#### 4.2.6.1 Land layout

The data on total dry matter per plant revealed that the effect of land layout on dry matter per plant of safflower was found to be significant at all stages of crop growth (Table 12).

At 30 days, the maximum dry matter per plant was accumulated in ridges and furrow method (3.07), which was significantly superior over other land layouts. Similar trend was found at 45, 60, 75, 90, 105 days after sowing and at harvest.

#### 4.2.6.2 Depth of irrigation

At 30 days, the maximum dry matter accumulated per plant (3.43) was due to irrigation scheduling to safflower at 60 mm depth, which was significantly superior over 50 and 40 mm depth. The lowest dry matter per plant (1.91) was observed in 40 mm depth of irrigation. Similar type of results were observed at 45, 60, 75, 90, 105 days and at harvest (Table 12).

#### 4.2.6.3 Interaction

The interaction effects were not observed.

### 4.2.7 Number of days for first flower opening

Data on number of days required for first flower opening are presented in Table 13. The data revealed that the average number of days required for first flower opening of safflower was 77.90.

**Table 13** **Mean number of days for first flower opening and 50 % flowering as influenced by different treatments.**

| Treatments | Days to first flower | Days to 50 % Flowering |
|---|---|---|
| **Land layout** | | |
| $L_1$- Ridges and furrow | 80.79 | 90.56 |
| $L_2$- Skip row furrow method | 77.66 | 87.74 |
| $L_3$- Paired row Planting | 75.27 | 86.37 |
| SE± | 0.75 | 0.25 |
| CD at 5% | 2.24 | 0.76 |
| **Depth of Irrigation (mm)** | | |
| $D_1$- 40 | 75.46 | 87.35 |
| $D_2$- 50 | 77.91 | 88.31 |
| $D_3$- 60 | 80.34 | 89.00 |
| SE± | 0.68 | 0.14 |
| CD at 5% | 2.02 | 0.43 |
| **Interaction** | | |
| SE± | 1.18 | 0.25 |
| CD at 5% | NS | NS |
| **Grand mean** | 77.90 | 88.22 |
| **Additional treatment (Flat bed)** | 75.65 | 80.75 |

#### 4.2.7.1 Land layout

The data in Table 13 indicated that the effect of land layout on number of days required for first flower opening of safflower was found significant.

More number of days (80.79) for first of flower opening were required in ridges and furrow and found significantly superior over other method of land layouts. The lowest number of days (75.27) for the first flower opening was observed in paired row planting method.

#### 4.2.7.2 Depth of irrigation

The data presented in Table 13 indicated that the effect of irrigation depth on number of days required for first flower open was found significant. At 60 mm depth of irrigation to safflower, 80.34 days are required for first flower open and found significant over 50 mm and 40 mm depth.

#### 4.2.7.3 Interaction

The interaction effect of land layout and depth of irrigation on first flower open was found to be non-significant.

### 4.2.8 Number of days for 50 per cent flowering

Data on number of days for 50 per cent flowering are presented in Table 13. The average number of days required for 50 per cent flowering was 88.22 days.

#### 4.2.8.1 Land layout

The effect of sowing date on number of days required for 50 per cent flowering was found significant.

Ridges and furrow method required 90.56 days for 50 per cent flowering of safflower than skip row method (87.74) and paired row planting (86.37).

#### 4.2.8.2 Depth of irrigation

Among the different depth of irrigation to safflower, 50% flowering was earlier due to 40 mm depth and it was delayed as the irrigation depths increased.

#### 4.2.8.3 Interaction

The interaction effects were not observed.

## 4.3 Growth attributes

### 4.3.1 Absolute growth rate (plant height)

Mean values of Absolute Growth Rate (AGR) for plant height of safflower in cm/day obtained at various stages of growth are presented in Table 14.

The AGR of height was slow upto 30 days after sowing, very fast during 31 to 60 days, and thereafter it was slow down till harvest of crop. In general, the AGR on plant height was highest with ridges and furrow method than other treatment except between 76-90 days after sowing.

**Table 14** **Mean Absolute Growth Rate (AGR) in height as influenced by different treatments.**

| Treatments | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-30 | 31-45 | 46-60 | 61-75 | 76-90 | 91-105 | 106-At harvest |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 0.53 | 1.26 | 1.19 | 0.63 | 0.29 | 0.18 | 0.07 |
| $L_2$- Skip row Furrow Method | 0.43 | 1.25 | 1.18 | 0.34 | 0.54 | 0.17 | 0.06 |
| $L_3$- Paired row Planting | 0.37 | 1.17 | 1.20 | 0.16 | 0.74 | 0.14 | 0.06 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 0.42 | 1.16 | 1.14 | 0.42 | 0.57 | 0.07 | 0.05 |
| $D_2$- 50 | 0.44 | 1.21 | 1.25 | 0.36 | 0.54 | 0.16 | 0.06 |
| $D_3$- 60 | 0.48 | 1.32 | 1.18 | 0.34 | 0.52 | 0.21 | 0.06 |
| **Grand mean** | 0.44 | 1.22 | 1.19 | 0.37 | 0.53 | 0.13 | 0.06 |

Among the depth of irrigations, the AGR for 60 and 50 mm depth was higher than 40 mm except at 61-75 and 76-90 days.

### 4.3.2 Absolute growth rate (dry matter)

Mean values of Absolute Growth Rate (AGR) for drymatter in g/day obtained at various stages of crop growth are presented in Table 15 and inferences are drawn on mean basis.

The AGR for dry matter was slow upto 30 days after sowing, fast during 31-75 days after sowing, and thereafter it was slow down till harvest of crop.

In general ridges and furrow method recorded higher AGR for drymatter than other treatment except at 46-60 days after sowing.

Among the different depth of irrigation, 60 mm recorded highest AGR values for dry matter than 50 and 40 mm.

### 4.3.3 Relative Growth Rate (RGR)

Mean values of RGR computed in g/g/day for total dry matter accumulation at various stages of safflower are presented in Table 16. The inferences are drawn on mean basis.

The RGR was maximum between 46-60 and 61-75 days and thereafter it was decreased till harvest of the crop.

In general, ridges and furrow method and skip row method recorded the higher RGR values almost in all stages of crop growth.

**Table 15 Mean Absolute Growth Rate (AGR) in drymatter as influenced by different treatments.**

| | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatments** | **0-30** | **31-45** | **46-60** | **61-75** | **76-90** | **91-105** | **106-At harvest** |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 0.10 | 0.15 | 0.25 | 0.71 | 0.69 | 0.62 | 0.06 |
| $L_2$- Skip row Furrow Method | 0.087 | 0.09 | 0.30 | 0.64 | 0.66 | 0.39 | 0.02 |
| $L_3$- Paired row Planting | 0.078 | 0.07 | 0.27 | 0.66 | 0.55 | 0.17 | 0.006 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 0.06 | 0.11 | 0.25 | 0.55 | 0.64 | 0.23 | 0.06 |
| $D_2$- 50 | 0.08 | 0.11 | 0.26 | 0.68 | 0.74 | 0.13 | 0.06 |
| $D_3$- 60 | 0.11 | 0.97 | 0.31 | 0.81 | 0.65 | 0.57 | 0.07 |
| **Grand mean** | 0.08 | 0.23 | 0.27 | 0.67 | 0.65 | 0.35 | 0.04 |

**Table 16 Mean Relative Growth Rate (RGR) of safflower in g/g/day as influenced by different treatments.**

| Treatments | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-30 | 31-45 | 46-60 | 61-75 | 76-90 | 91-105 | 106-At harvest |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 0.03 | 0.03 | 0.03 | 0.05 | 0.07 | 0.01 | 0.001 |
| $L_2$- Skip row Furrow Method | 0.03 | 0.03 | 0.05 | 0.05 | 0.02 | 0.01 | 0.003 |
| $L_3$- Paired row Planting | 0.02 | 0.02 | 0.05 | 0.05 | 0.02 | 0.009 | 0.0006 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 0.02 | 0.04 | 0.04 | 0.04 | 0.03 | 0.009 | 0.002 |
| $D_2$- 50 | 0.03 | 0.03 | 0.04 | 0.05 | 0.03 | 0.06 | 0.002 |
| $D_3$- 60 | 0.04 | 0.02 | 0.04 | 0.05 | 0.02 | 0.01 | 0.001 |
| **Grand mean** | 0.02 | 0.02 | 0.04 | 0.04 | 0.03 | 0.01 | 0.001 |

Among the depth of irrigation, the maximum RGR was recorded at 60 and 50 mm depth of irrigation.

### 4.3.4 Leaf area index

Data on mean leaf area index (LAI) at various stages are presented in Table 17.

The leaf area index was increased upto 90 days and decreased thereafter due to leaf senescence. In general, ridges and furrow method recorded higher values of LAI than skip row method and paired row planting. Among the depth of irrigation 60 mm had higher value of LAI followed by 50 mm and 40 mm.

## 4.4 Yield attributes

### 4.4.1 Number of capitula per plant

The data on mean number of capitula per plant was recorded at various stages of safflower and are presented in Table 18.

The mean for number of capitula per plant revealed that the rate of increase was rapid during 75 to 90 days after sowing. The mean number of capitula recorded at harvest were 23.71.

#### 4.4.1.1 Land layout

At 60 days after sowing, the maximum capitula were recorded in ridges and furrow method (16.33), which was significantly superior over rest of the treatments. The lowest number of capitula was observed in paired row planting method (12.15). Similar trends were observed in 75, 90, 105 days and at harvest (Table 18).

**Table 17** **Mean Leaf Area Index (LAI) of safflower as influenced by different treatments.**

| | Days after sowing | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatments** | **0-30** | **31-45** | **46-60** | **61-75** | **76-90** | **91-105** | **106-At harvest** |
| **Land layout** | | | | | | | |
| $L_1$- Ridges and furrow | 0.81 | 1.63 | 2.55 | 3.44 | 3.61 | 2.34 | 2.31 |
| $L_2$- Skip row Furrow Method | 0.45 | 1.08 | 1.73 | 2.32 | 2.45 | 1.47 | 1.39 |
| $L_3$- Paired row Planting | 0.36 | 0.82 | 1.56 | 2.13 | 2.29 | 1.34 | 1.19 |
| **Depth of Irrigation (mm)** | | | | | | | |
| $D_1$- 40 | 0.33 | 0.72 | 1.67 | 2.39 | 2.54 | 1.47 | 1.32 |
| $D_2$- 50 | 0.52 | 1.12 | 1.92 | 2.57 | 2.72 | 1.58 | 1.56 |
| $D_3$- 60 | 0.70 | 1.56 | 2.09 | 2.72 | 2.88 | 1.94 | 1.92 |
| **Grand mean** | 0.53 | 1.16 | 1.92 | 2.60 | 2.75 | 1.69 | 1.62 |

**Table 18 Mean number of capitula per plant as influenced by different treatments at various stages.**

| | Days after sowing | | | | |
|---|---|---|---|---|---|
| **Treatments** | **60** | **75** | **90** | **105** | **At harvest** |
| **Land layout** | | | | | |
| $L_1$- Ridges and furrow | 16.33 | 18.23 | 23.85 | 25.36 | 25.40 |
| $L_2$- Skip row Furrow Method | 13.71 | 14.62 | 21.66 | 23.27 | 23.30 |
| $L_3$- Paired row Planting | 12.15 | 12.37 | 19.80 | 22.42 | 22.45 |
| SE± | 0.40 | 0.25 | 0.22 | 0.34 | 0.34 |
| CD at 5% | 1.20 | 0.72 | 0.68 | 1.01 | 1.01 |
| **Depth of Irrigation (mm)** | | | | | |
| $D_1$- 40 | 12.49 | 12.93 | 19.93 | 21.74 | 21.80 |
| $D_2$- 50 | 14.03 | 14.37 | 21.66 | 23.67 | 23.69 |
| $D_3$- 60 | 15.68 | 17.91 | 23.73 | 25.63 | 25.65 |
| SE± | 0.36 | 0.27 | 0.29 | 0.31 | 0.32 |
| CD at 5% | 1.08 | 0.82 | 0.86 | 0.92 | 0.96 |
| **Interaction** | | | | | |
| SE± | 0.63 | 0.48 | 0.47 | 0.50 | 0.50 |
| CD at 5% | NS | NS | NS | NS | NS |
| **Grand mean** | 14.06 | 15.07 | 21.77 | 23.68 | 23.71 |
| **Additional treatment (Flat bed)** | **12.75** | **15.00** | **20.48** | **23.6** | **23.65** |

#### 4.4.1.2 Depth of irrigation

The data presented in Table 18 indicated that the effect of depth of irrigation on number of capitula was found significant at all stages of safflower.

At 60 days the highest capitula per plant (15.68) were recorded due to 60 mm depth of irrigation, which was significantly superior over 50 and 40 mm depth. Similar type of results were observed at 75, 90, 105 days after sowing and at harvest.

#### 4.4.1.3 Interaction

The interaction effects were found to be non-significant.

### 4.4.2 Weight of capitula per plant (g)

The data presented on weight of capitula per plant in Table 19 revealed that average weight of capitula per plant was 55.20 g/plant.

#### 4.4.2.1 Land layout

The effect of land layout on weight of capitula per plant was found significant. Ridges and furrow method recorded significantly highest weight of capitula per plant (58.43g) than other land layouts. Minimum weight of capitula were observed in paired row planting method (52.45 g).

#### 4.4.2.2 Depth of irrigation

The depth of irrigation at 60 mm recorded highest weight of capitula/plant (57.14 g) and significantly superior over other treatments.

Table 19 Mean weight of capitula per plant (g), number of seeds per capitula, number of seeds per plant, seed weight per plant (g), 1000 seed weight (g) and volume weight (g) as influenced by various treatments

| Treatments | Weight of capitula / plant (g) | No. of seed/ capitula | No. of seeds/ plant | Seed weight/ plant (g) | 1000 seed weight (g) | Volume weight (g) |
|---|---|---|---|---|---|---|
| **Land layout** | | | | | | |
| $L_1$ - Ridges and furrow | 58.43 | 22.81 | 449.05 | 20.45 | 45.91 | 470.08 |
| $L_2$ - Skip row furrow method | 54.72 | 20.43 | 370.36 | 16.96 | 44.00 | 398.50 |
| $L_3$ - Paired row planting | 52.45 | 18.48 | 342.10 | 13.40 | 41.66 | 325.21 |
| SE $\pm$ | 0.33 | 0.49 | 8.90 | 0.85 | 0.46 | 5.71 |
| CD at 5% | 0.99 | 1.46 | 26.42 | 2.52 | 1.36 | 17.13 |
| **Depth of irrigation (mm)** | | | | | | |
| $D_1$ - 40 | 53.16 | 18.50 | 304.60 | 11.53 | 42.08 | 325.46 |
| $D_2$ - 50 | 55.30 | 20.74 | 359.80 | 14.74 | 43.83 | 395.58 |
| $D_3$ - 60 | 57.14 | 22.48 | 505.10 | 24.55 | 46.66 | 472.75 |
| SE $\pm$ | 0.45 | 0.29 | 10.65 | 0.80 | 0.24 | 4.96 |
| CD at 5% | 1.34 | 0.88 | 32.53 | 2.38 | 0.72 | 14.88 |
| **Interaction** | | | | | | |
| SE $\pm$ | 0.78 | 0.51 | 18.99 | 1.39 | 0.42 | 8.60 |
| CD at 5% | NS | NS | NS | NS | NS | NS |
| **Grand mean** | 55.20 | 20.57 | 388.50 | 16.93 | 43.85 | 397.93 |
| **Additional treatment (Flat bed)** | 65.43 | 20.43 | 450.27 | 22.37 | 53.15 | 350.40 |

#### 4.4.2.3 Interaction

The interaction effect of land layout and depth of irrigation on weight of capitula (g) was found to be non-significant.

### 4.4.3 Number of seeds per capitula

The data on number of seeds per capitula of safflower are presented in Table 19. The average number of seeds per capitula were 20.57.

#### 4.4.3.1 Land layout

Ridges and furrow method of layout recorded highest number of seeds per capitulum (22.81) and significantly superior over other land layout. Significantly lowest number of seeds were observed in paired row planting (18.48).

#### 4.4.3.2 Depth of irrigation

Scheduling of irrigation at 60 mm depth recorded highest number of seeds/capitula (22.48) and followed by 50 and 40 mm depth.

#### 4.4.3.3 Interaction

The interaction effect on number of seed per capitula (g) was found to be non-significant.

### 4.4.4 Number of seeds per plant

The data on number of seeds per plant of safflower are presented in Table 19. The average number of seeds per plant was 388.50.

#### 4.4.4.1 Land layout

The effect of land layout on number of seed per plant was found significant. Ridge and furrow method recorded highest number of seeds per plant (449.05) and was significantly superior over other land layouts. Lowest number of seeds per plant was observed with paired row planting method (342.10).

#### 4.4.4.2 Depth of irrigation

The irrigation scheduling at 60 mm depth recorded highest number of seeds per plant (505.10) and significantly superior over other treatments. The lowest seeds per plant was recorded at 40 mm depth of irrigation (304.60).

#### 4.4.4.3 Interaction

The interaction effect of land layout and depth of irrigation on number of seeds per plant (g) was found to be non-significant.

### 4.4.5 Seed weight per plant (g)

The data presented on seed weight of safflower per plant in revealed that the average seed weight per plant was 16.93 g (Table 19).

#### 4.4.5.1 Land layout

The effect of land layout on seed weight per plant was found significant. Ridges and furrow method recorded highest seed weight per plant (20.45) and significantly superior over other treatments. Lowest seed weight per plant (13.40) was observed with paired row planting method.

#### 4.4.5.2 Depth of irrigation

The effect of depth of irrigation on weight of seed per plant was found significant. Irrigating safflower at 60 mm depth recorded highest seed weight per plant (24.55) and found significantly superior over 50 and 40 mm. The lowest seed weight was recorded in 40 mm depth (11.53).

#### 4.4.5.3 Interaction

The interaction effect of land layout and depth of irrigation on seed weight per plant was found to be non-significant.

### 4.4.6 1000 seed weight (g)

The data on 1000 seed weight are presented in Table 19. The average test weight of safflower was 43.85.

#### 4.4.6.1 Land layout

Ridges and furrow land layout recorded significantly highest test weight (45.91 than other land layouts. It was followed by skip row furrow method (44.00).

#### 4.4.6.2 Depth of irrigation

Test weight of safflower was significantly more due to 60 mm irrigation depth (46.66) than 50 (43.83) and 40 mm (42.08).

#### 4.4.6.3 Interaction

The interaction effect of land layout and depth of irrigation on 1000 seed weight was found to be non-significant.

#### 4.4.7 Volume weight

The data presented on volume weight revealed that the average volume weight was 397.93 (Table 19).

##### 4.4.7.1 Land layout

The volume weight was highest in ridges and furrow method (470.08) and lowest due to paired row planting (325.21).

##### 4.4.7.2 Depth of irrigation

The effect of depth of irrigation on volume weight was found to be significant. Volume weight of safflower was significantly more due to 60 mm irrigation depth (472.75) than 50 and 40 mm.

##### 4.4.7.3 Interaction

The interaction effect of land layout and depth of irrigation on volume weight was found to be non-significant.

### 4.5 Seed yield (kg/ha)

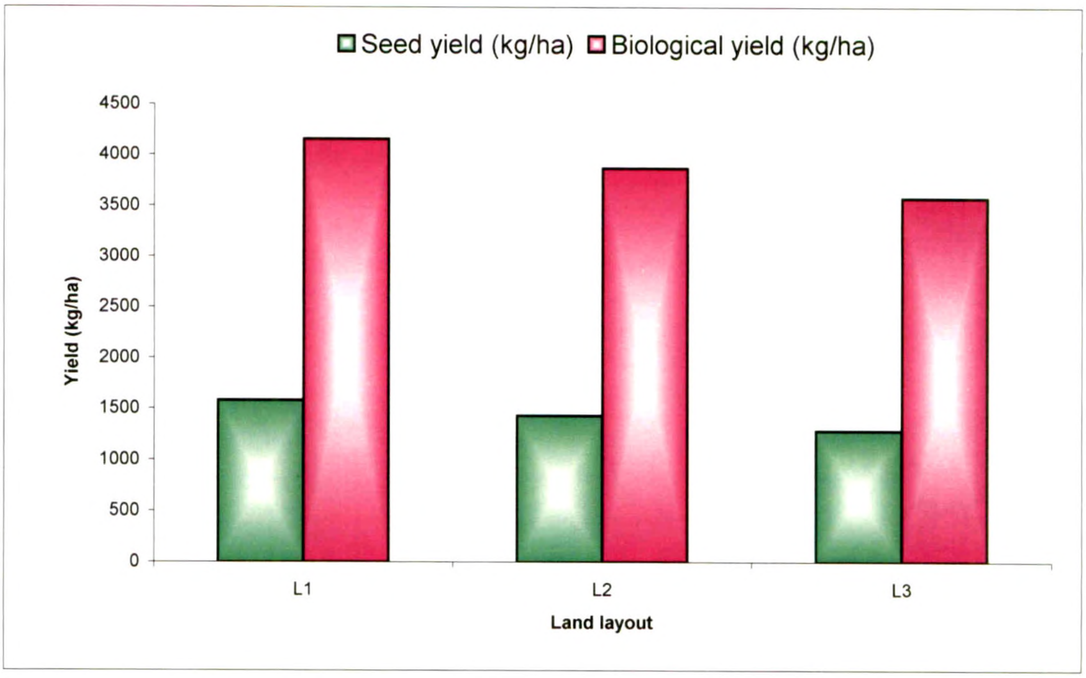
The data presented in Table 20 revealed that average seed yield was 1432.5 kg/ha and depicted in Fig.8.

#### 4.5.1 Land layout

The effect of land layout on seed yield was found to be significant Ridges furrow method recorded significant highest seed yield (1579 kg/ha) over other treatment. Paired row planting method produced significantly lowest seed yield (1287 kg/ha) than skip row method (1430 kg/ha).

**Table 20 Seed yield (kg/ha) and biological yield (kg/ha) of safflower as influenced by land layout and depth of irrigation**

| Treatments | Seed yield (kg/ha) | Biological yield (kg/ha) | Harvest index (%) |
|---|---|---|---|
| **Land layout** | | | |
| $L_1$ - Ridges and furrow | 1579 | 4155 | 38.53 |
| $L_2$ - Skip row furrow method | 1430 | 3868 | 37.24 |
| $L_3$ - Paired row planting | 1287 | 3576 | 35.79 |
| SE ± | 34 | 93 | 0.28 |
| CD at 5% | 103 | 276 | 0.84 |
| **Depth of irrigation (mm)** | | | |
| $D_1$ – 40 | 1317 | 3555 | 36.40 |
| $D_2$ – 50 | 1423 | 3843 | 37.03 |
| $D_3$ – 60 | 1556 | 4201 | 37.99 |
| SE ± | 28 | 76 | 0.20 |
| CD at 5% | 83 | 226 | 0.61 |
| **Interaction** | | | |
| SE ± | 48 | 132 | 0.26 |
| CD at 5% | NS | NS | NS |
| **Grand mean** | **1432.5** | **3067.0** | **37.16** |
| **Additional treatment (Flat bed)** | **1357.9** | **3850.50** | **37.0** |



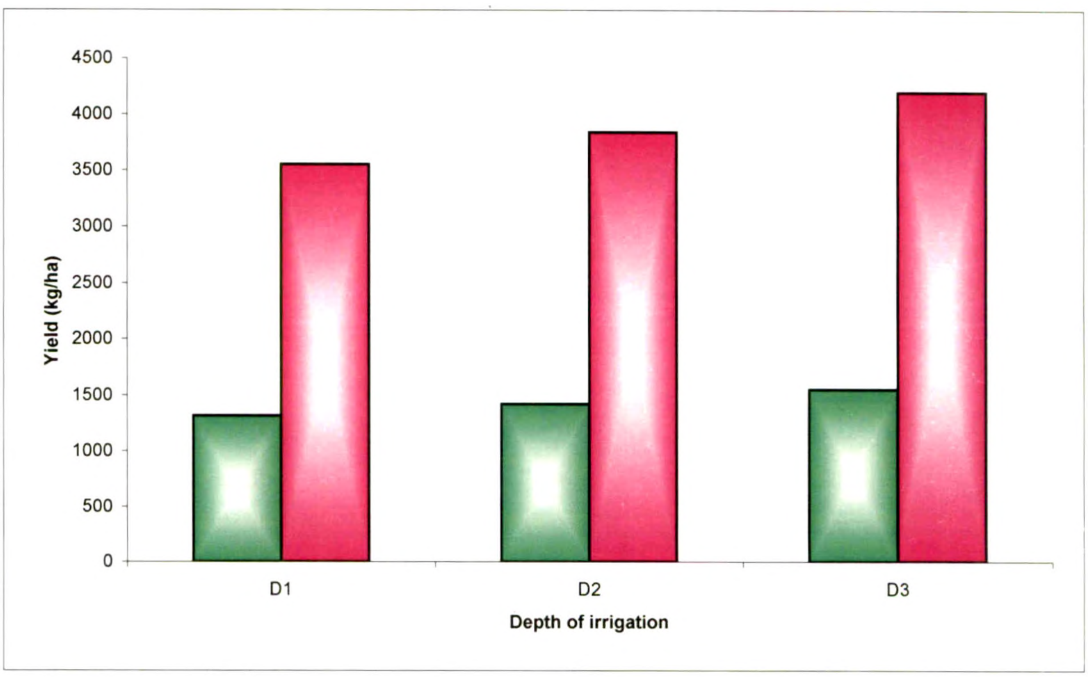




**Fig.8 Mean seed yield (kg/ha) and biological yield (kg/ha) of safflower as influenced by different treatments at various crop growth stages**

### 4.5.2 Depth of irrigation

The effect of depth of irrigation on seed yield/ha was found significant. Irrigating safflower at 60 mm depth recorded highest seed yield (1556 kg/ha) and was found significantly superior over 50 mm (1423 kg/ha) and 40 mm (1317 kg/ha)s.

### 4.5.3 Interaction

The interaction effect of land layout and depth of irrigation on seed yield of safflower was found to be non-significant.

## 4.6 Biological yield

The data presented in Table 20 revealed that average biological yield was 3067 kg/ha.

### 4.6.1 Land layout

The effect of land layout on biological yield was found to be significant. Ridges furrow method of land layout produced highest biological yield 4155 kg/ha over other land layouts. Lowest biological yield was observed in paired row planting method (3576 kg/ha).

### 4.6.2 Depth of irrigation

Irrigating safflower at 60 mm depth was more effective and recorded significantly highest biological yield (4201 kg/ha) and followed by 50 and 40 mm depth.

### 4.6.3 Interaction

The interaction effect of land layout and depth of irrigation on Biological yield (kg) was found to be non- significant.

## 4.7 Harvest index

The data presented in Table 20 revealed that the mean harvest index was found to be 37.16. Ridges and furrow method (38.53) and irrigating safflower at 60 mm depth (37.99) recorded significantly higher harvest index.

## 4.8 Oil content

The data presented in table 21 revealed that the average oil content of safflower was 28.20 per cent and depicted in Fig. 9.

### 4.8.1 Land layout

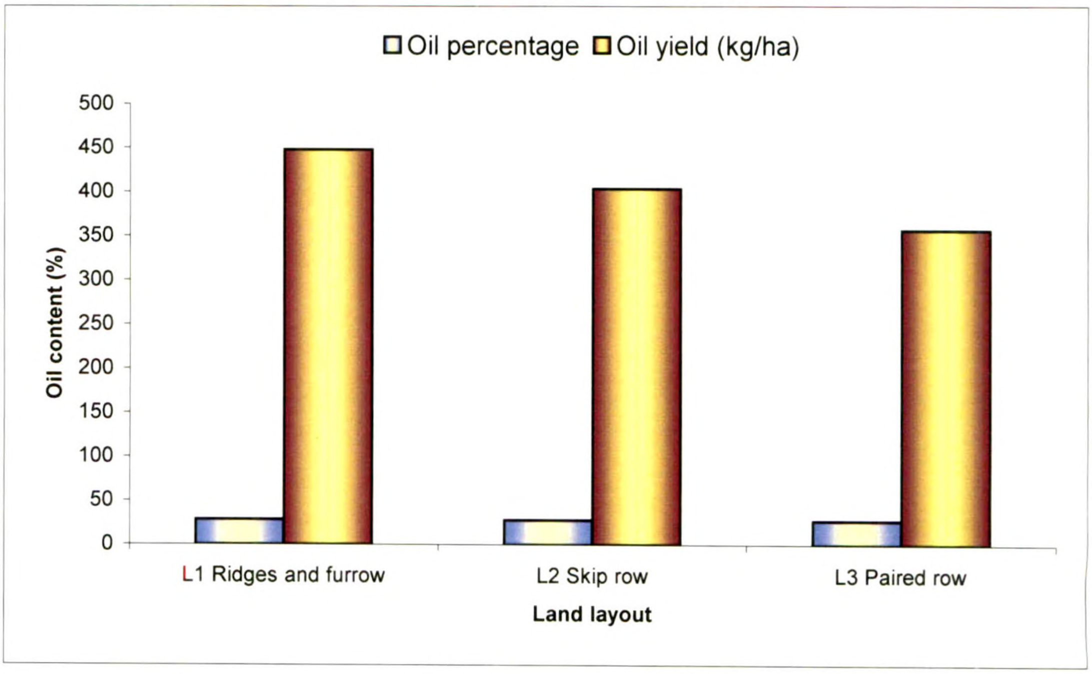
The treatment differences due to various land layout was found to be non significant in influencing the oil content of safflower.

### 4.8.2 Depth of irrigation

The effect of depth of irrigation on oil content was found to be non significant.

**Table 21** **Mean oil content in seed (per cent) as influenced by various different treatments.**

| Treatments | Days to first flower | Days to 50 % Flowering |
|---|---|---|
| **Land layout** | | |
| $L_1$- Ridges and furrow | 28.3 | 447.9 |
| $L_2$- Skip row furrow method | 28.2 | 403.9 |
| $L_3$- Paired row Planting | 27.7 | 357.2 |
| SE± | 0.29 | 6.72 |
| CD at 5% | NS | 20.16 |
| **Depth of Irrigation (mm)** | | |
| $D_1$- 40 | 27.7 | 365.9 |
| $D_2$- 50 | 28.0 | 399.4 |
| $D_3$- 60 | 28.5 | 443.9 |
| SE± | 0.10 | 5.96 |
| CD at 5% | NS | 17.97 |
| **Interaction (LxD)** | | |
| SE± | 0.17 | 8.32 |
| CD at 5% | NS | NS |
| **Grand mean** | 28.06 | 403.06 |
| **Additional treatment (Flat bed)** | 28.20 | 355.3 |



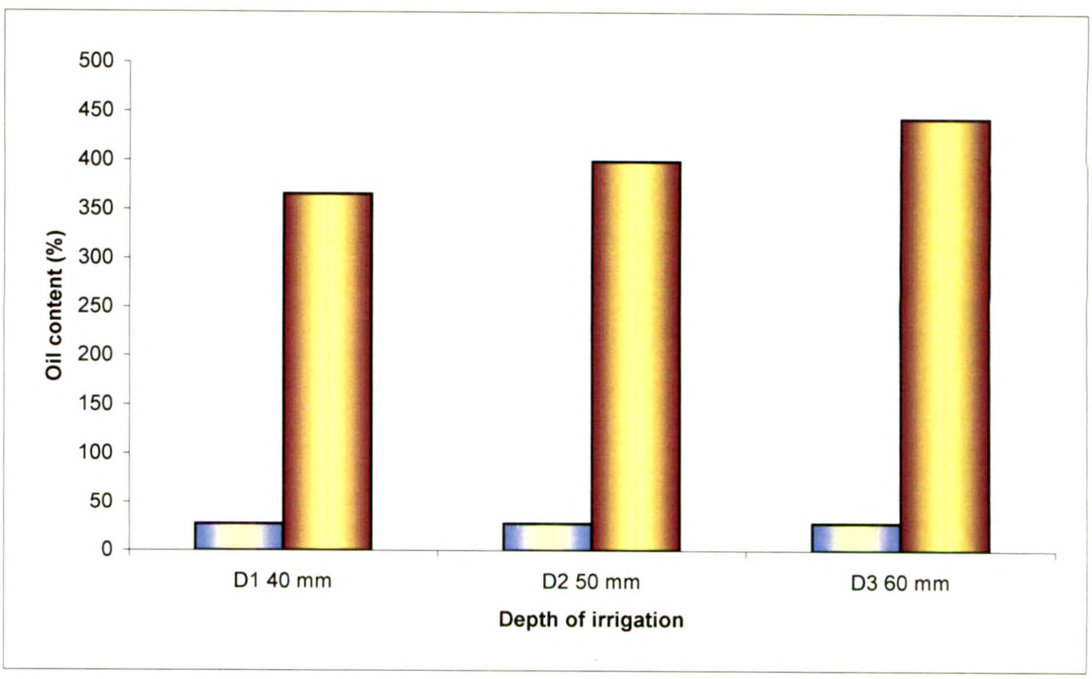




**Fig.9 Mean oil content in seed (per cent) as influenced by various treatments**

### 4.8.3 Interaction

The interaction effect of land layout and depth of irrigation on oil content was found to be non-significant.

## 4.9 Oil yield (kg/ha)

The data presented in Table 21 revealed that average oil yield of safflower was 403.06 kg/ha.

### 4.9.1 Land layout

The effect of land layout on oil yield was found to be significant. Ridges and furrow method of land layout produced highest oil yield (447.9 kg/ha) over other land layouts. Lowest oil yield was observed in paired row planting method (357.2 kg/ha).

### 4.9.2 Depth of irrigation

Irrigation depth at 60 mm recorded higher oil yield and found to be significant over 50 mm and 40 mm.

### 4.9.3 Interaction

The interaction effect of land layout and depth of irrigation on oil yield was found to be non-significant.

## 4.10 Irrigation studies

The total water requirement of safflower was worked out for the season which includes 60 mm water applied as common irrigation to all treatment at the time of sowing. There was no contribution of ground water

water for the growth of crop. Mean seasonal water requirement of safflower was 350-400 mm (Table 22).

The seasonal water requirement of safflower crop showed progressive increase with increase in irrigation frequency. The total water applied was 168.19, 208.19 and 248.19 mm in irrigation schedule 40, 50 and 60 mm respectively.

**Table 22 Total irrigation water applied under different depth of irrigation to safflower**

| Treatment | Irrigation water applied (mm) | Contribution of effective rainfall (mm) | Total water applied (mm) |
|---|---|---|---|
| **Depth of irrigation (mm)** | | | |
| $D_1$ 40 | 160 (3+1=4) | 8.19 | 168.19 |
| $D_2$ 50 | 200 (3+1=4) | 8.19 | 208.19 |
| $D_3$ 60 | 240 (3+1=4) | 8.19 | 248.19 |
| Mean | 200 | 8.19 | 208.19 |

One common irrigation was given for crop establishment.
Figures in parentheses indicates number of irrigations.

In general frequency of depth of ir 'gation increased with increase in depth of irrigation at 40, 50 and 60 mm.

## 4.11 Consumptive use (mm)

The data pertaining to the effect of land layout and depth of irrigation on consumptive use (mm) are presented in Table 23.

### 4.11.1 Land layout

Perusal of data presented in Table 23 revealed that mean consumptive use was highest in ridges and furrow method to the tune of 198.49 mm and lowest in skip row furrow method (143.31 mm). Further it was observed that saving of water to the extent of 33.33 was noticed in skip row furrow as compared to rest of the land layouts.

### 4.11.2 Depth of irrigation

Data pertaining to the effect of depth of irrigation on consumptive use are presented in Table 23. The highest consumptive use was recorded at 60 mm (288.51 mm) and lowest value was recorded in 40 mm depth (150.99 mm).

## 4.12 Water use efficiency (kg/ha/mm)

The data pertaining to water use efficiency of safflower are presented in Table 23.

**Table 23 Consumptive use (mm) and water use efficiency (kg/ha mm) of safflower**

| Treatment | Consumptive (mm) | Water use efficiency (kg/ha mm) |
|---|---|---|
| **Land layout** | | |
| $L_1$ Ridges and furrow | 198.49 | 7.95 |
| $L_2$ Skip row method | 143.31 | 7.39 |
| $L_3$ Paired row planting | 186.31 | 6.90 |
| **Depth of irrigation (mm)** | | |
| $D_1$ 40 | 150.99 | 8.05 |
| $D_2$ 50 | 193.91 | 7.33 |
| $D_3$ 60 | 288.51 | 8.80 |

### 4.12.1 Land Layout

The highest water use efficiency (kg/ha/mm) was observed in Ridges and furrow method (7.95) and followed by skip row furrow (7.39) and paired row planting (6.90).

### 4.12.2 Depth of irrigation

The maximum water use efficiency was observed in 60 mm depth (8.80) and followed by 40 mm (8.05) and 50 mm (7.33).

## 4.13 Water requirement

The water required for irrigating one ha safflower crop by flood method of irrigation is more than 6 lakh/ha and there was significant difference in water requirement by using different depth of irrigation.

The water requirement as per irrigation depth to safflower crop is given below.

| Sr. No | Irrigation depth (mm) | Water required (lakh lit/ha) |
|---|---|---|
| 1. | 40 | 4 |
| 2. | 50 | 5 |
| 3. | 60 | 6 |

By using skip row method of irrigation, 33% water can be saved under scarcity of irrigation water.

## 4.14 Economics

The data pertaining to economics of safflower as influenced by land layout and depth of irrigation are presented in Table 24 and depicted in Fig.10.

**Table 24 Economics of safflower as influenced by different treatments**

| Treatment | Gross returns (Rs/ha) | Net returns (Rs./ha) | B:C ratio |
|---|---|---|---|
| **Land layout** | | | |
| $L_1$ – Ridges and furrow | 23987 | 14611 | 2.56 |
| $L_2$ - Skip row furrow method | 21737 | 12733 | 2.41 |
| $L_3$ – Paired row planting | 19558 | 10371 | 2.13 |
| SE ± | 528 | 528 | 0.027 |
| CD at 5% | 1569 | 1569 | 0.081 |
| **Depth of irrigation (mm)** | | | |
| $D_1$ – 40 | 20006 | 10944 | 2.21 |
| $D_2$ – 50 | 21620 | 12439 | 2.35 |
| $D_3$ - 60 | 23645 | 14332 | 2.54 |
| SE ± | 426 | 426 | 0.030 |
| CD at 5% | 1265 | 1265 | 0.089 |
| **Interaction** | | | |
| SE ± | 738 | 738 | 0.052 |
| CD at 5% | NS | NS | NS |
| **General mean** | 21759 | 12575 | 2.36 |
| **Additional treatment (Flat bed)** | 20532 | 11782 | 2.34 |

* Cost of irrigation (Rs.)
Rs.500 for 40 mm depth = 1296 litre
Rs.625 for 50 mm depth = 1620 litre
Rs. 750 for 60 mm depth = 1944 litre

** Common cost of cultivation Rs.8000; Market rate (Rs.q = 1519)

**Treatmentwise cost of cultivation**

**a) Land layout**
Ridges and furrow method ($L_1$) = 9375/-
Skip row method ($L_2$) = 9000/-
Paired row method ($L_3$) = 9186/-

**b) Depth of irrigation (mm)**
$D_1$ 40 = 9062/-
$D_2$ 50 = 9187/-
$D_3$ 60 = 9312/-

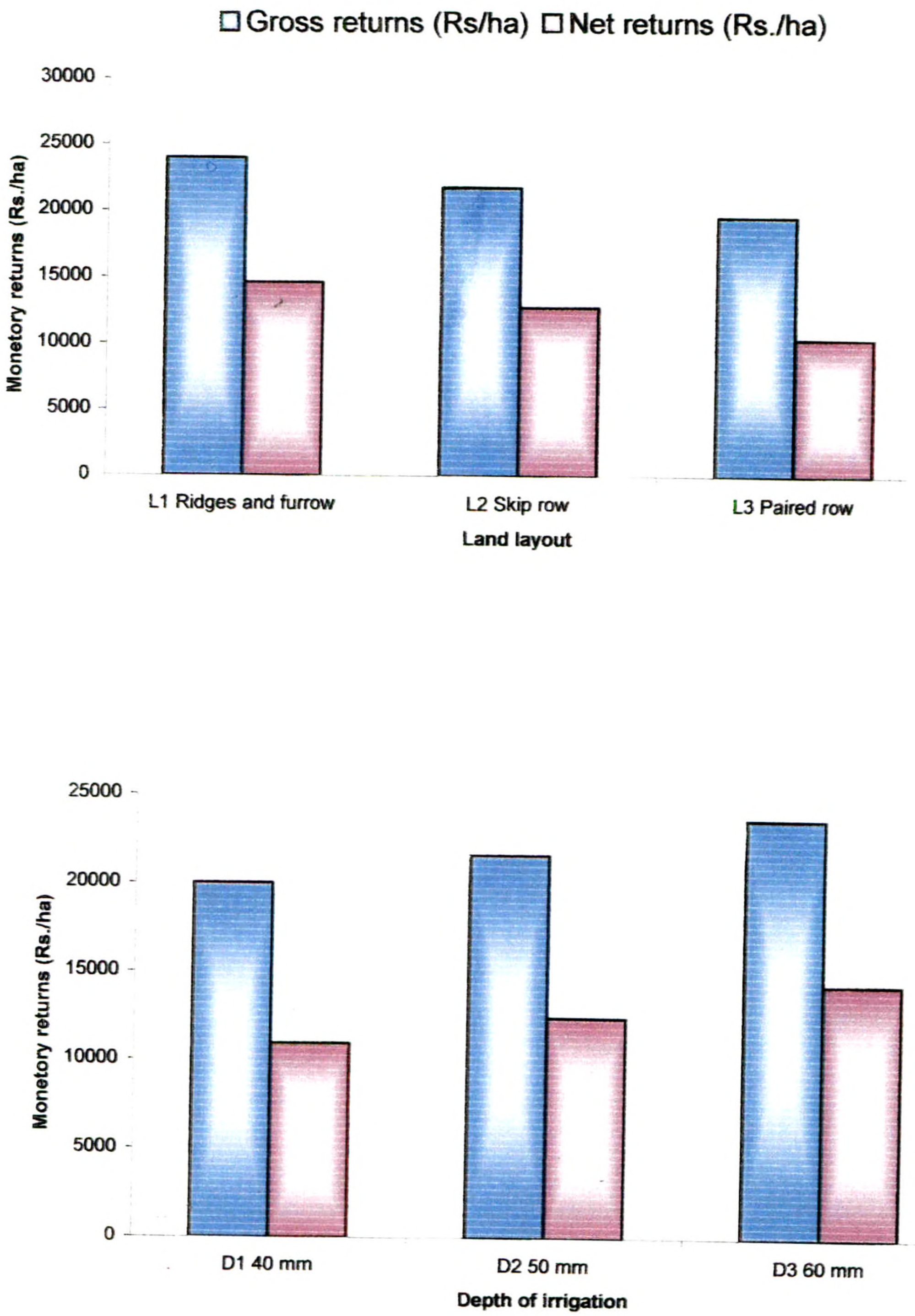



Fig. 10 Economics of safflower as influenced by different treatments

### 4.14.1 Land layout

Adoption of ridges and furrow method of land layout to safflower crop recorded significantly highest gross returns (Rs.23987/ha), net returns (Rs.14611/ha) and B:C ratio of 2.56. It was followed by skip row furrow method of land layout.

### 4.14.2 Depth of irrigation

Among depth of irrigation, scheduling of irrigation at 60 mm depth proved better for producing significantly highest gross returns to the extent of Rs.23645/ha, net returns of Rs.14332/ha and B:C ratio of 2.54 than 50 mm and 40 mm depth.

### 4.14.3 Interaction

Interaction effects on economics of safflower were not observed.

L$_1$ Ridges and furrow method (spacing 60x15 cm)

L$_3$ Paired row planting (spacing 30-60x20 cm)


$L_1$ Ridges and furrow method (spacing 60x15 cm)


$L_2$ Skip row method (spacing 45-90x13.33 cm)


$L_3$ Paired row planting (spacing 30-60x20 cm)

Scheduling of irrigation to experiment

PBNS-12 of flowering stage

# Discussion

**Chapter V**

# DISCUSSION

The results of the present investigation are briefly discussed in this chapter.

**Soil**

The physio-chemical composition of the soil revealed that the soil of experimental plots was clayey in texture, low in nitrogen. medium in phosphorus, rich in potassium and slightly alkaline in reaction.

**Weather**

Weather data (Table 2) indicated that the mean maximum and minimum temperatures ranges from 26.2°C to 36.4°C and 8.0°C to 17.0°C respectively during the crop season. The morning and evening relative humidity ranges from 64.4 to 81% and 24 to 52%, respectively. The total rainfall during the experimental period was only 21 mm with two rainy days. The climatic conditions were in general favourable for growth of the safflower except rainfall.

**General growth**

The growth of the crop in general could be understood if series of physiological process involved are seen critically at various stages (Table 25). The growth and yield attributes recorded at different growth phase showed that safflower can be divided into three growth phases viz.

**Table 25 An extract of growth parameters per plant recorded at various stages**

| Days after sowing | Plant height (cm) | | Number of primary branches | | Number of secondary branches | | Leaf area $(dm)^2$ | | Total dry matter (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Absolute | Percentage | Absolute | Percentage | Absolute | Percentage | Absolute | Percentage | Absolute | Percentage |
| 30 | 13.49 | 20.49 | - | - | - | - | 5.72 | 19.20 | 2.67 | 7.72 |
| 45 | 31.97 | 48.57 | 8.66 | 45.15 | - | - | 12.49 | 41.94 | 4.28 | 12.37 |
| 60 | 49.94 | 75.88 | 9.51 | 49.58 | 8.95 | 44.90 | 20.83 | 69.94 | 8.45 | 24.43 |
| 75 | 55.65 | 84.56 | 13.10 | 68.30 | 12.69 | 63.67 | 28.13 | 94.45 | 18.43 | 53.29 |
| 90 | 63.71 | 96.80 | 14.77 | 77.00 | 14.25 | 71.50 | 29.78 | 100 | 28.41 | 82.15 |
| 105 | 64.66 | 98.25 | 15.49 | 80.76 | 15.48 | 77.67 | 18.28 | 61.38 | 33.43 | 96.67 |
| At harvest | 65.81 | 100 | 19.18 | 100 | 19.93 | 100 | 17.60 | 59.10 | 34.58 | 100 |

1. Emergence to early vegetative growth upto 30 days.
2. Grand growth phase from 31 to 120 days.
3. Maturity phase from 121 days upto harvest.

The first growth phase started from sowing to 30 days in which the growth was slow in respect of plant height, leaf area and total dry matter per plant. At this stage, plant had attained the height of 13.49 cm and produced 5.72 $dm^2$ of leaf area. Grand growth phase occurred between 31 to 105 days. By the end of this phase, plant attained the height of 64.66 cm, number of primary branches 15.49 per cent, number of secondary branches 15.48 per cent, 18.28 $dm^2$ of leaf area and 33..43 g of total dry matter per plant.

At the end of maturity stage, the plant attained at harvest height of 65.81 cm, number of primary branches 19.18, number of secondary 19.93 branches and 34.58 g total dry matter per plant at harvest.

The emergence count and final plant stand (Table 6) were not influenced due to various treatments. This means that the space viability per plant was uniform and the differences noted in growth, yield attributes per hectare were the real treatment effects.

**Land layout**

Safflower (*Carthamus tinctorius* L.) is an important *rabi* oilseed crop of Maharashtra. Apart from it's superior adaptability to scanty moisture conditions, it produces oil rich in polyunsaturated fatty acids (Linoleic acid 78%). Which play an important role in reducing the blood cholesterol level for centuries. It has been under cultivation in India either for it's colored florets and much valued oil.

Productivity of safflower needs to be increased, as this is a cash crop of medium and small holding farmers. It is hypothesised that this problem can be solved by introducing safflower in command areas with 2-3 protective irrigations. This will reflect in achieving the self sufficiency to some extent in oilseeds production of Maharashtra in general and Marathwada in particular. Farmers are using old method of irrigation i.e. flooding due to which wilting of plant occurs. The losses due to safflower wilt is more than 40%. To overcome this problem, modification in the land layout for scheduling of irrigation is the only one solution besides this growing of wilt tolerant variety should be preferred. The information on land layout, methods of scheduling of irrigation and depth of irrigation required is meagre. Hence, there is urgent need to know land layout for irrigation scheduling and depth of irrigation so as to make safflower cultivation a successful proposition under Jayakwadi and Purna command areas of vertisols and salt prone areas.

The increase in infiltration rate, moisture use and moisture use efficiency reflected in higher yield of crop Gram (607 kg/ha). Safflower (650 kg/ha) and Sorghum (928 kg/ha) in ridges and furrow than in flat bed (529, 511 and 655 kg/ha, respectively) Karle *et al.* (1995).

The field experiment conducted at Water Management Research Project, Marathwada Agricultural University, Parbhani and NARP, Aurangabad during *rabi* season 1990-91 and 1992-93 and reported that seed yield of safflower by seedling irrigation in furrow (60x15 cm) and skip row furrow (45x 20 cm) were on par and recorded significantly more yield than irrigation in alternate furrow (45x20 cm) and paired row planting (60+30x15 cm). However, irrigation to safflower in skip furrow method resulted in 35 per cent saving of irrigation water besides providing higher water use efficiency.

Seed yield is a function of yield contributing characters. Hence the increase in seed yield resulted due to increase in yield attributes viz. number of capitula per plant, weight of capitula per plant, number of seeds per capitulum, number of seeds per plant, test weight per plant and volume weight (Table 18 and 19).

The differences in yield components could be traced back to the favourable improvements in growth character which confirmed further with better growth functions like AGR, RGR and LAI.

It was observed from Table 20 that ridges and furrow method produced the biological yield of 4155 kg./ha. The results was similar to that of seed yield, which is also highest due to ridges and furrow method 1579 kg/ha and significantly superior over skip row method and paired row planting. It could be inferred that the plant characters like plant height, number of branches, mean leaf area and total dry matter per plant were responsible for influencing the biological yield and number of capitula per plant for safflower crop.

The increase in dry matter was the cumulative effect of increase in various growth characters like plant height, number of leaves, number of branches leaf area and number of capitula per plant.

The land layout played a conspicuous role in dry matter production. Ridges and furrow method produced more dry matter per plant than skip row method and paired row planting. Characters viz. plant height, number of branches, number of leaves, leaf area were higher due to ridges and furrow method of land layout than other methods.

The ridges and furrow produced more number of leaves at every growth stage than rest of the methods. Ridges and furrow method recorded higher leaf area than other land layouts.

The growth functions also reflected through improvements in AGR, RGR and LAI (Table 14, 15, 16 and 17) and showed positive trend increasing dry matter accumulation. These growth constants were observed to be in descending order in ridges and furrow, skip row and paired row planting.

Highest leaf area at ridges and furrow method was reflected in LAI leading to more photosynthetic surface area for tapping more assimilates, accumulating higher dry matter per plant as compared to other land layouts. The harvest index estimated for the different land layout and depth of irrigation was found significant (Table 20).

The oil content of seed estimated for different land layout was not influenced. This is depth of irrigation character and not affected by early or delayed land layout.

**Depth of irrigation**

As regards, the different depth of irrigation tested in present investigation, the depth of irrigation had profound influence on seed, biological yield and oil content (per cent).

Irrigation safflower at 60 mm depth produced higher seed and biological yield than $D_1$ (40 mm) and $D_2$ (50 mm), respectively..

The differences in seed yield due to depths of irrigation were significant on per hectare basis $D_3$ (60 mm) depth gave higher yield than $D_2$ (50 mm) and D (40 mm). The depth of irrigation showed profound influence on yield attributes. Depth of irrigation at (60 mm) recorded higher number of branches, weight of capitula, seed weight per plant, test weight and volume weight than $D_1$ (40 mm) and $D_2$ (50 mm). Thus number of branches, weight of capitula per plant, seed weight per plant, test weight were found important yield contributing characters. Similar type findings were also reported by Bansal and Katara (1993), Yusuf *et al.* (1981) and Mahapatra and Singh (1975).

The differences in yield could be traced back to the differences in growth characters which confirmed further by observing the different growth constant i.e. AGR, RGR and LAI.

It could be seen from Table 12 that $D_3$ (41.35) produced higher total dry matter per plant than $D_2$ (32.85) and $D_1$ (29.55) at harvest. It was followed by $D_2$ and $D_1$ recorded the lowest dry matter. It could be inferred that the plant characters like number of branches, number of leaves leaf area per plant and number of capitula (Table 8, 9, 10, 11 and 18) influenced the total dry matter accumulation due to various depths of irrigation.

Table 11 clearly showed that $D_3$ (60 mm depth) recorded higher leaf area than $D_2$ (50 mm) and $D_1$ (40 mm). Highest leaf area by $D_3$ was reflected in LAI leading to higher photosynthetic surface area for tapping more assimilates, accumulating higher dry matter per plant as compared to other depths of irrigation it is due to the availability of moisture in active root zone in abundant quantity which improves growth of the crop.

As regards to the oil content at different depths of irrigation were found significantly superior at irrigation scheduled at $D_3$ (60 mm) depth than irrigation given at $D_2$ (50 mm) and $D_1$ (40 mm) depths. This indicates that the oil content was increased due to the improvement in the yield attributes which are resistant effect of all growth parameters are improved at above irrigation scheduled due to favourable rhizospheric atmosphere created and prevailed throughout the crop growth period. Similar findings were reported by Ibrahim et al. (1991) and Wakil et al. (1987).

On the contrary, irrigation given at $D_1$ (40 mm) depth which received less water availability in the active root zone induced the moisture stress in the rhizosphere, hampered the root activity decreased the availability of moisture and resulted into nutrient stress. This adverse situation reflected on the growth and yield parameters negatively and finally low seed yield of safflower was obtained. Similar findings were reported by Suryanarayana (1975).

As regards water use efficiency for both seed and biological yield, there was progressive decrease with an increase in irrigation depths from 40 to 50 mm. The highest WUE for seed and biological yield were observed at $D_3$ (60 mm) and $D_1$ (40 mm) depth of irrigation. Ridges and furrow and skip row method recorded highest water use efficiency.

**Interaction**

The complementary effect of land layout x depths of irrigation on seed yield and yield attributes were found to be non-significant.

# Summary and Conclusion

Chapter VI

# SUMMARY AND CONCLUSION

A field trial was conducted at Agricultural College Farm, Parbhani to study "Optimization of safflower production through land layout and depth of irrigation" for the year 2004-2005.

The soil of the experimental site was fairly leveled, well drained, clayey in texture, moderately alkaline in reaction, medium in nitrogen, medium in P and rich in $K_2O$ contents. The moisture retention capacity of the soil was quite good.

The present investigation was laid out in split plot design with four replications. The treatments consisted of land layout (Ridges and furrow, skip row and paired row planting) as main plots and depth of irrigation (40, 50 and 60 mm) as sub plot.

The allotment of treatment to various plots was done by randomization. Each experimental unit was 5.4 m x 6 m and 4.5 m x 5.4 m as gross and net plot, respectively.

The presowing irrigation was applied on 14 November to facilitate the sowing, after bringing the soil in ideal tilth. The sowing was done on 17 November, 2004 after procuring the certified seeds of PBNS-12 from reliable source. The dibbling method of sowing was followed and maintained plant to plant spacings as per treatment viz. ridges and furrow method at 60 cm x 15 cm., skip row method at 45-90 cm x 13.33 cm and paired row planting at 30-60 cm x 20 cm. The basal dose of fertilizer was given at the time of sowing @ 30 kg N and 40 kg $P_2O_5$ through 20:20:0. Remaining half dose of nitrogen was applied as top dressing i.e. one month after sowing through urea. One common irrigation was given for establishment of crop. Scheduling of irrigation treatments were administered as per the treatment. The buffer strip of 1 m was kept between each plot and replication to facilitate drainage. The opening of ridges and furrow was done 30 days after sowing of crop. Thinning and gap filling were done 15 days after sowing so as to maintain optimum plant population. All other cultural practices were followed as per the recommendations during life cycle of crop.

The initial emergence count was taken 20 days after sowing from each gross plot. The final plant stand from each net plot was taken just before harvesting and percentage were calculated.

Data on different growth parameters viz., plant height, number of branches, leaf area, dry matter etc. were recorded periodically from observation plants under various treatments. The growth functions viz., AGR for height and dry matter accumulation, RGR and LAI were computed periodically from the above data. Similarly data on post harvest studies, including yield and yield attributes were also recorded under various treatments.

The soil moisture content were computed from different soil layer viz., 0-15, 16-30 and 31-45, 45-60 cm before 24 and 48 hours after each irrigation treatment to study the soil moisture behaviour.

The data on growth, and yield parameters along with seed and biological yields were subjected to statistical analvsis for quantifying the treatment effects and testing the significance at 5 per cent probability. The findings of investigation are narrated as below :

1. All the growth parameters viz., plant height, functional leaves, leaf area, primary branches, secondary branches and dry matter accumulation from various plant parts were significantly influenced by different land layouts. Adoption of ridges and furrow method recorded significantly higher values for all growth parameters. This was also supported by Yusuf *et al.*, (1981) and Mahapatra and Singh (1975).

Among depth of irrigations $D_3$ (60 mm) showed significantly higher values for above mentioned growth parameters and followed by $D_2$ (50 mm) and $D_1$ (40 mm), respectively.

2. The maximum values of AGR for height and dry matter 1.22 cm/day and 0.67 g/day respectively were observed during 31-45 and 61-76 days in ridges and furrow method (0.66). Among depth of irrigation $D_3$ (60 mm) recorded maximum AGR for height (1.32 cm/day) and followed by $D_2$ and $D_1$ respectively. The Depth of irrigation at 60mm recorded highest LAI (2.88) at 76-90 days and followed by $D_2$ and $D_1$.

3. The maximum seed, biological yield and oil content were obtained (1579 and 4155 kg/ha and 28.37 per cent respectively) under ridges and furrow method.

4. The highest water use efficiency was found in ridges and furrow method (7.95) by irrigating at 60 mm depth (8.80).

5. Application of ridges and furrow method of land layout for irrigation to safflower crop produced significantly highest seed yield (1579 kg/ha), net returns of Rs.14611/ha with B:C ration of 2.56 and it was followed by skip row method of land layout with seed yield of 1430 kg/ha, net returns of Rs.12733/ha and B:C ratio of 2.41.

# CONCLUSION

On the basis of above findings, it may be inferred that adoption of ridges and furrow method of land layout is suitable for obtaining highest seed yield of safflower (1579 kg/ha) net returns (Rs.14611/ha) and B:C ratio of 2.56. The irrigation should be scheduled at 60mm depth. Under limited irrigation conditions, skip row method of irrigation to safflower may be recommended as it saves 33 per cent water than other land layouts.

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