EVAPOTRANSPIRATION BASED SCHEDULING OF IRRIGATION THROUGH DRIP SYSTEM FOR CASTOR CROP (*Ricinus communis* L.)

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IN

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BY

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ABSTRACT

EVAPOTRANSPIRATION BASED SCHEDULING OF IRRIGATION THROUGH DRIP SYSTEM FOR CASTOR CROP (*Ricinus communis* L.)

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ABSTRACT

An experiment was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District : Banaskantha (North Gujarat) on "Evapotranspiration based scheduling of irrigation through drip system for castor crop (*Ricinus communis* L.)" during *kharif* season of 2011-12.

The experiment comprised of four treatments of irrigation (0.6 Etc, 0.8 Etc, and 1.0 Etc under drip system) along with conventional method-surface irrigation and two sowing methods (paired row sowing and single row sowing) thereby making eight treatment combinations. The experiment was laid out in randomized block design with four replications. Castor variety GCH 7 was used as a test crop. The soil of experimental field was loamy sand having good drainage capacity. It was low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash.

The results revealed that plant height at 1st picking, number of branches per plant, number of spikes per plant, number of capsules per main spike, length of main spike, number of nodes to main receme, test weight, seed yield per plant, seed yield, stalk yield and oil yield were significantly influenced due to irrigation treatments. Application of irrigation water through drip system at 1.0 Etc recorded significantly higher values for all these attributes but were statistically at par with those recorded under 0.8 Etc treatment. More or less equal values of all these characters were recorded by schedule of 0.6 Etc under drip system and conventional method of irrigation.

Application of irrigation water through drip system at 1.0 Etc recorded significantly higher seed yield (3268 kg/ha) and stalk yield (3959 kg/ha) but these were statistically at par with treatment 0.8 Etc in respect of seed yield (3122 kg/ha) and stalk yield (3591 kg/ha).

The oil content of castor seed was not significantly influenced due to different irrigation treatments. However, oil yield increased with each successive increase in levels of Etc.

Treatment I_1 (0.6 Etc. under drip system) recorded significantly the highest WUE (13kg/ha-mm). The lowest WUE (4.0 kg/ha-mm) was recorded under I_4 treatment (conventional method). Maximum water saving was recorded by scheduling irrigation at 0.6 Etc.

The plant height at Ist picking, number of spikes per plant, number of capsules per main spike, length of main spike (cm), test weight (g), seed yield per plant, seed yield (kg/ha.), stalk yield (kg/ha.), oil content (%) and oil yield (kg/ha) were not significantly influenced by sowing methods. However, the values of all the growth parameters, yield and yield attributing characters and quality characters were higher with single row sowing than that of paired row sowing.

Sowing of castor in paired rows recorded higher net realization (₹87659/ha) and BCR (3.25).

Irrigating crop through drip system at 1.0 Etc with adopting paired row sowing (I_3S_1) gave maximum net realization (₹105760/ha) and BCR (3.43).

Castor crop should be sown in paired row system (135-60 cm × 45 cm) and scheduled irrigation at 1.0 Etc under drip method for securing higher seed yield and net realization as well as saving of 30 per cent saving of water.

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CERTIFICATE – I

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(SHIVPRAKASH)

Place : Sardarkrushinagar.

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ABBREVIATIONS USED

ADFPE	:	Alternate day fraction of pan evaporation
ANOVA	:	Analysis of variance
BCR	:	Benefit : Cost Ratio
C.V.	:	Coefficient of Variance
C.D.	:	Critical Difference
cm	:	Centimeter
°C	:	Degree Celsius
DAP	:	Di ammonium phosphate
DAS	:	Days after sowing
dSm^{-1}	:	Decisimens per meter
EC	:	Electrical conductivity
EP	:	Pan evaporation
et al.	:	et allii ; and other
etc.	:	Et citeras
Etc	:	Crop evapotranspiration
ET	:	Evapotranspiration
Epan	:	Pan evaporatin
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
hr.	:	Hour
i.e.	:	That is
kg	:	Kilogram
m	:	Meter
Max.	:	Maximum
MSS	:	Mean of sum of square
Mg	:	Milli gram
Min.	:	Minimum

mm	:	millimeter
NS	:	Not Significant
PEF	:	Fraction of pan evaporation
ppm	:	Part per million
PVC	:	Polly vinele chloride
Q	:	Quintal
R.H.	:	Relative Humidity
₹	:	Rupees
S.Em. ±	:	Standard Error of mean
t	:	Tonne
viz.	:	Namely
WUE	:	Water use efficiency

INTRODUCTION

I. INTRODUCTION

Castor (*Ricinus communis* L) is non edible oil seed crop having high industrial importance due to presence of unique fatty acid and ricinoleic acid. The crop is grown mainly under irrigated condition. Total area under castor crop in India is 8.59 lakh hectares with production of 11.90 lakh tonnes and average yield is 1385 kg/ha. Gujarat state covers total area of 4.83 lakh hectares under castor cultivation with an estimated total production of 8.60 lakh tonnes and productivity of 1781 kg/ha, respectively. (India budget, 2011).

In Gujarat, castor crop is mainly cultivated in Banaskantha, Mehsana, Patan and Sabarkantha districts of North Gujarat. The productivity of Gujarat state is highest as compared to other states because more than 90 per cent cultivated area covered by castor hybrids under irrigated conditions with special crop management practices.

Castor is an important oilseed crop with good export potentials which plays an important role in our national economy by earning foreign exchange worth of ₹ 70 crores through export of castor oil and cake. Its oil is used in the manufacture of high grade lubricant, paints, varnishes, textile dyeing, printing, perfumes, lubricating greases, polishes, plastics, soaps, tooth paste, medicinal purpose etc. Recently, use of castor oil in preparing carbon paper, ether, synthetic resins for surface coating, synthetic rubber and synthetic fibers has been reported. It is also used as bactericides and fungicides. Castor cake is an excellent source of manure having 4.5 per cent nitrogen, 2.6 per cent phosphorus and 1.0 percent potash (Raj *et al.* 2010). However, due to presence of ricin, it is unfit as cattle feed. The castor hulls are used as manure and its stalks are used in paper industries and as fuel in rural areas.

Castor is very hardy crops and grown under a wide range of soil and climatic conditions. It is grown on both sandy and rich alluvial soil at sea level up to an altitude of 5000 to 7000 feet.

Rainfall, rivers, canals, reservoirs, dams and ground water constitute the major sources of water in Gujarat and India. About 83 per cent of the fresh water resources are currently being used for agriculture. In the present era of all round development and demographic growth, all the sectors of economy are dependent on larger quantities of fresh water. There is a tremendous pressure on agriculture sector to reduce its share of water and at the same time to improve total production by enhancing productivity with increased WUE.

Water is the most important and critical input in agriculture. The efficient use of water for agriculture is intensifying due to increased competition for water resources among various sectors with increasing population. The need of the hour is therefore, maximizing the production per unit drop of water. Hence, in the present day context, lot of emphasis is being given in improving the irrigation practices to increase the production and to sustain the productivity levels.

In conventional methods of irrigation, the quantity of water used is based on availability of irrigation water but not in accordance with crop requirements. From the time immemorial more quantity of water is used per unit area for irrigation, but only 50 % of the supplied water is being efficiently used by the crop, rest is lost by seepage, percolation, evaporation as well as in earthen channel during conveyance of water under conventional method.

At field level, water use efficiency under conventional method of irrigation is very low (50 to 60%) as against drip method (95%). Reduction in water consumption due to drip method of irrigation over the surface method of irrigation varies from 30 to 70 per cent and yield increase in the range of 20 to 50 per cent for different crops (Raj *et al.* 2010). By introducing the drip irrigation, not only increase the yield potential of crops by 2 to 3 times but also doubled an area under crops with the same quantity of water.

Drip irrigation system optimizes the irrigation water and puts it uniformly and directly to the root zone of the plants at frequent interval based on crop water requirement through a closed net work of low pressure plastic pipes. Superiority of drip system in terms of water saving and increased in yield along with other benefits over surface method of irrigation is proved by many research evidences. Drip irrigation system improves the WUE by increasing yield of cotton with limited quantity of water. (Singh *et al.* 2005).

Castor generally sown at a row distance of 90 to 180 cm distance between two rows and 60 to 120 cm between two plants depending on the variety and soil type.

Drip irrigation system is an efficient method for irrigating this crop. Besides this, total cost of drip system per hectare is also less than other crops due to wider distance between rows and plants.

Among the net irrigated area of irrigation 407347 m ha irrigated through micro irrigation system (drip, sprinkler etc.) in Gujarat 226773 lakh hectares area covered under drip system. In north Gujarat, for micro irrigation purpose mostly underground water is utilized which is scare and costly. Hence, it is worthwhile to adopt micro irrigation system in this area (Rane *et al.* 2011).

Among the different criteria for scheduling of irrigation evapotranspiration based scheduling of irrigation is a scientific approach to find out required quantity of irrigation water through drip system for harnessing potential yield of this crop. It is an essential to find out how much quantity of water is to be applied at alternate day to crop for obtaining higher WUE and yield of crop without affecting soil health under drip system. Initial high cost of drip system is major constraint in adoption of system at farmers end. However, sowing of castor crop in paired row system may reduce the cost of drip system by about 50 per cent as compared to single row system without affecting plant population per unit area (Nalayani *et al.* 2006). Besides this, interculturing, weeding, spraying of pesticides, harvesting of spikes etc. become easier and convenient as this system provide sufficient space between two paired of crop rows.

As the wide space is available between two paired rows profitable short duration crop can be grown during early growth stages of crop as *kharif* intercrop which gives an additional income also.

Keeping this in view, the present experiment on "Evapotranspiration based scheduling of irrigation through drip system for castor crop (*Ricinus* *communis* L.) was planned and conducted at Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *kharif* season of 2011-2012 with following objectives:

- To determine the scheduling of irrigation for drip system based on evapotranspiration in castor crop.
- To find out suitable planting pattern for drip system in castor crop.
- To work out economics of different treatments.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The review of the relevant research work carried out by various investigators in respect of scheduling of irrigation and planting pattern under drip irrigation for castor and related crops are presented in this chapter.

1. Effect of irrigation scheduling

An experiment was carried out at S.K. Nagar on castor crop for scheduling of irrigation under drip system. Irrigating the crop at 0.8 ADFPE through drip system resulted in 25 percent saving of water (600 mm) and 36 percent yield of castor than surface method. Significantly the highest yield of castor (2635 kg/ha) was recorded with 0.8 ADFPE under drip system. (Anonymous, 1996).

Firake *et al.* (1998) carried out an experiment on feasibility of drip irrigation in castor cv. GAUCH 1 at Rahuri. They reported that daily application of water to castor at 75% Ep through drip after cessation of monsoon significantly increased 50 percent seed yield and 51 percent oil yield with 14.8 % saving of irrigation water over surface irrigation. They also observed higher plant height, number of branches, number of spikes per plant, number of capsules per main spike and 100 seed weight as compared irrigation scheduling at 25 % EP, 50% EP, 100% EP and furrow irrigation with same treatment.

Patel *et al.* (1998) reported that irrigation scheduling to castor crop at 0.2 PEF through drip after cessation of monsoon i.e. October to January gave significantly higher yield (2,122 kg/ha) as compared to surface irrigation (1,728 kg/ha) along with 73 percent water saving.

An experiment on feasibility of drip system in cotton under clayey soils of Narmada Command was conducted by Maliwal *et al.* (1999) at Khandha, GAU, Gujarat during 1992-93 to 1994-95. They revealed that the irrigation scheduling under drip method of irrigation at 0.5 PEF recorded 27 percent higher seed cotton yield (2995kg/ha) of cotton crop as compared to conventional method (2364 kg/ha). They further reported that 52.7% water saving was obtained with 0.5 PEF under drip. While WUE was higher with 0.3 PEF and decreased with an increase in the fraction of pan evaporation.

Sagarka *et al.* (2002) conducted an experiment on feasibility of drip irrigation in *rabi* cotton at Junagadh. They found that irrigation to cotton at 0.8 ADFPE gave significantly higher seed cotton yield (1535 kg/ha) as compared to conventional and alternate furrow method of irrigation. They further reported the higher boll size, number of squares, green bolls and picked bolls/plant under drip irrigation method at 0.8 ADFPE as compared to surface, alternate furrow method and other lower levels of drip irrigation.

Patel *et al.* (2004) carried out an experiment on feasibility of drip irrigation in castor under sandy loam soil of North Gujarat at S.K. Nagar. They reported that irrigation scheduling at 0.8 PEF through drip after cessation of monsoon gave significantly higher yield than other levels of irrigation and surface method of irrigation (60 mm depth) which was 36 percent higher than surface method of irrigation. The same treatment recorded 25 percent saving of irrigation water over surface irrigation with 6.57 kg/ha-mm WUE. (Farmers practice).

A field investigation was carried out at Junagadh, Gujarat, India, during the *kharif* seasons of 1997-98 to 1999-2000 to study the potentiality of drip system for castor crop. The results revealed that drip irrigation scheduled at 0.6 PEF significantly increased seed (2920 kg/ha) and stalk (3350 kg/ha) yield with remarkably higher water use efficiency and net returns as compared to surface irrigation (Lakkad *et al.* 2005).

Nalyani *et al.* (2006) reported that scheduling of irrigation at 0.8 Etc was at par with 1.0 Etc under drip method with respect to seed cotton yield in cotton at Coimbatore. The yield enhancement in cotton was obtained due to drip system during summer was 28.9%, 44.5 % and 61.5 % at 0.6, 0.8 and 1.0 Etc over conventional method of irrigation, respectively. This might be due to fevourable micro climate maintained under drip irrigation. The water use efficiency was ranged from 34.7 to 39.1 kg/ha-cm for drip irrigation as against 18.7 kg/ha -cm under conventional method. Scheduling of irrigation through drip at 0.8 Etc recorded the highest WUE of 39.1 kg/ha-cm in winter cotton. Scheduling of irrigation at 1.0 and 0.8 Etc through drip recorded statistically equal no. of bolls as well as boll weight but were higher as compared to 0.6 Etc and surface method.

An experiment was conducted on feasibility of drip irrigation in cotton crop at Coimbatore. Scheduling of irrigation through drip at 0.6 Etc recorded27.7% saving of water and 11 % increased in seed cotton yield over surface method of irrigation (Annual report, 2008).

An experiment was carried out by Ramamurthy *et al.* (2009) at Nagpur during 2006-07 to find out the effect of drip irrigation on cotton productivity and water use efficiency. Application of water to cotton through drip resulted in significantly higher seed cotton yield than the surface method. The yield increase due to drip method was 59 percent while saving of irrigation water was 44 to 57 percent over surface irrigation method. Among the irrigation schedules through drip irrigation at 0.6 Etc gave significantly higher seed cotton yield than 0.8 Etc and 1.0 Etc under drip system. Whereas the later two were at par with each other. Irrigation scheduling in hybrid cotton through drip at 0.6 Etc enhanced seed cotton yield by 37% over surface method.

An experiment was conducted by Desai *et al.* (2010) during 2002-03 to 2004-05 at Navsari in *rabi* castor to find out scheduling of irrigation under drip irrigation. They reported that irrigating the crop at 0.4 PEF resulted similar yield as obtained in surface method with 38 percent saving of water.

Patel *et al.* (2010) carried out an experiment during the 2006-07 and 2007-08 at Anand on castor crop for scheduling of irrigation under drip system. They found that significantly the highest seed yield of castor (2841 kg/ha) was obtained under drip irrigation by irrigating crop at 0.8 ADFPE among all the treatments under drip system. They also reported that oil content in castor seed progressively increased with increase in levels of drip irrigation from 0.4 to 0.8

ADFPE. Irrigation at 0.8 ADFPE registered maximum oil content 48.8 (%) in seed. Similar trend was also observed in test weight.

Patel *et al.* (2010) conducted an experiment on scheduling of irrigation through drip system for castor crop. They observed that irrigation to castor at 0.8 ADFPE gave significantly higher oil percent (48.8%) as compared to conventional method (47.9%).

A field experiment was conducted from 2007–08 to 2009–10 at Akola (Maharashtra) to compared irrigation levels based on crop evapotranspiration (Etc) under drip system against conventional method of irrigation in cotton. Results indicated that scheduling of irrigation at 1.0 Etc through drip, recorded the highest seed cotton yield (2.17 t/ha), which was at par with 0.8 Etc. The yield enhancement recorded due to drip system was 10.53, 11.49 and 12.39% at 0.6, 0.8 and 1.0 Etc. respectively when compared with application of irrigation by surface method of irrigation respectively (Bhalerao *et al.* 2011).

Irrigation to pigeon pea as *rabi* crop throughout crop period under drip system at 0.8 Epan produced maximum seed yield. However, performance of pigeon pea with 0.6 Epan up to flowering and 0.8 Epan later on or 0.6 Epan throughout crop life was more or less similar to 0.8 Epan and significantly superior over irrigation scheduling at 0.4 Epan throughout crop life, 0.4 Epan up to flowering and 0.8 Epan later on, drip irrigation at 0.4 Epan up to flowering, 0.6 Epan from flowering to pod initiation and 0.8 Epan later on and surface irrigation (Mahalakshmi *et al.* 2011).

2 Effect of plant geometry

An experiment was conducted at Junagadh, to reduce the cost of drip system through modifying planting geometry for castor crop. The results revealed that drip irrigation scheduled at 0.4 PEF in paired row planted recorded almost similar seed yield (2.3 t/ha) as obtained in surface method of irrigation with normal planting (2.5 t/ha) (Anonymous, 1998).

Normal planting (4' × 4') with drip lateral per row registered cotton yield of 30.87 q/ha which was higher by 2.22 q/ha than drip lateral per paired row planting under drip irrigation. Through the productivity of cotton in paired row planting was less than the normal planting. The paired row planting showed maximum returns as there was saving of 30 to 40 percent of initial cost on drip unit in addition to the advantages of easy in picking of cotton and spraying of insecticides (Pawar *et al.* 2001)

Higher plant height of castor (75 cm), number of leaves per plant (49) and dry matter accumulation in leaf, stem and ear head (58 g, 37 g and 14 g respectively) were observed with paired row planting as compared to single row planting (Anonymous, 2002).

Patel *et al.* (2003) reported that castor crop sown at paired row planting (150 cm x 75 cm) at S.K. Nagar recorded almost similar seed yield 3570 kg/ha as compared in single row planting (3620 kg/ha) (90 cm × 60 cm).

Patil *et al.* (2004) stated that cotton crop sown at paired row planting (60/120 cm x 60 cm)was better than single row planting (90 cm x 60 cm) with respect to saving of 40 % cost of drip system due to reduce cost of laterals.

Kalibavi *et al.* (2006) recorded significantly higher seed cotton yield in paired row planting (45-135-45 cm ×60 cm) under drip irrigation (2349 kg ha^{-1}), over furrow irrigation (1761 kg ha^{-1}) and alternate furrow irrigation (1893 kg ha^{-1}) with same system of planting.

Porwal *et al.* (2006) reported that sowing of castor crop as paired row system either at 120 × 60-30 cm (41.84 q/ha) or 160 × 80-40 cm (40.60 q/ha) recorded statistically equal yield as recorded in normal sowing i.e. 90 cm × 60 cm (39.60 q/ha).

Desai *et al.* (2010) reported that drip irrigation scheduled at 0.4 PEF in paired row planted castor (60 x 60 x 120 cm) recorded almost similar seed yield (2.3 t/ha) as obtained in surface method with normal planting (2.5 t/ha).

Manjunatha *et al.* (2010) reported that irrigation to paired row sown cotton crop produced statistically similar yield as obtained in single row sown crop when crop was irrigated at 1.0 ET.

Patel *et al.* (2010) reported that paired row planting (180-60-180 cm × 60 cm of castor at Thasra (Gujarat) recorded higher seed yield (2734 kg/ha) than normal planting (120 × 60 cm) (2573 kg/ha). They further reported that oil content, test weight and nitrogen uptake from seed and stalk were statistically similar in both the planting pattern.

Patel *et al.* (2010) reported that there was no significant effect of planting pattern of castor crop. Planting of castor crop either paired row (48.6 %) or single row (48.4) registered statistically similar value of oil content.

The effects of row spacing (60, 90 or 120 cm), and planting pattern on the performance of pigeon pea were studied at Prabhani, during the kharif season of 2001. Sowing of pigeon pea at row spacing of 120 cm resulted in the highest number of pods per plant (193.6), weight of pods per plant (77.93g), grain weight per plant (52.43g) and 1000 seed weight (112.40 g). The highest pod, grain, stalk, bhusa and biological yields (29.43 18.82, 34.98 and 78.24 quintal/ha, respectively were obtained with a row spacing of 90 cm. The paired planting has not significant effects on the evaluated parameters (Zote *et al.* 2011).

2. Economics

Patel *et al.* (1998) reported that irrigation to castor crop at 0.2 PEF through drip after cessation of monsoon i.e. October to January gave total income ((₹16720/ha) and net income over control (₹ 9674/ha).

Mane *et al.* (1998) reported the maximum benefit cost ratio of 2.03 at 75 % Ep irrigation level through drip tape amongst treatments in sunflower crop. The net extra income in this treatment over control was registered ₹6449 / ha.

Higher net return of ₹ 30,105/ha and B : C ratio of 2.75 were registered under drip irrigation as compared to furrow irrigation (₹ 21,750/ha and 2.04 respectively) in cotton crop. (Kumar *et al.* 2002).

Patel *et al.* (2004) carried out an experiment on feasibility of drip irrigation in castor crop at S.K. Nagar. They reported that irrigation to castor at 0.8 PEF through drip after cessation of monsoon gave higher net realization (₹ 12955/ha) and extra income (₹2280/ha) over control.

Kalibavi *et al.* (2006) revealed that the drip irrigation at 50 per cent PE recorded significantly higher net returns (₹ 42215/ha) as compared to other treatments and was followed by drip irrigation at 75 per cent PE (₹ 39915/ha) and alternate furrow irrigation at IW/CPE ratio of 0.80 (₹ 41264 /ha).

Manjunatha *et al.* (2010) carried out an experiment on response of cotton to single and paired row method of sowing under drip and furrow irrigation in saline vertisols at Dharwad. They reported that irrigation to cotton at 1.0 Et in paired row sowing underdrip system gave higher B : C ratio (1.54), net seasonal income (₹8713 /ha) and water use efficiency (17.19 kg/ha-cm) as compared to other treatments.

MATERIALS AND METHODS

III. MATERIAL AND METHODS

The detail of material used and the techniques adopted during the course of the present investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out in Plot No. B 9 of the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *kharif* season of 2011-12.

3.2 CLIMATE AND WEATHER CONDITIONS

Geographically, Sardarkrushinagar is situated at 24°-19' North latitude and 72°-19' East longitude with an elevation of 154.52 meter above the mean sea level. It is located in the North Gujarat Agro-Climatic Zone.

This zone is characterized by semi-arid climate with extreme cold winter and hot and dry windy summer. Generally, monsoon commences in the middle of June and retreats by the middle of September. Most of the precipitation is received from South- West monsoon, concentrating in the months of July and August. The annual average rainfall is about 550 mm with about 23 rainy days.

The winter season is fairly cold and dry starts from the end of October and continues till the end of February. The minimum temperature of the year is reached in the months of December or January. The temperature starts rising from February and reaches the maximum in the months of April or May. The wind velocity is very high during summer.

Table 3.1: Mean weekly weather parameters during the crop growth period

Months	Std. Week	Temp. (0°C)		RH (%)		Rainfall (mm)	Rainy Days	Evapo ration (mm)
		Max.	Min.	R-I	R-II			
August 2011	33	29.3	22.8	95	85	91.1	3	3.2
	34	31.4	23.8	94	83	30.7	2	3.4
September 2011	35	32.4	22.8	95	73	97.1	5	4.7
	36	30.7	23.1	95	80	114.0	7	4.4
	37	30.1	22.8	96	75	225.4	4	3.9
	38	31.8	21.6	92	59	6.8	2	4.8
	39	33.2	19.5	88	49	0.0	0	5.7
October 2011	40	33.6	18.0	85	43	0.0	0	6.1
	41	37.1	19.2	77	27	0.0	0	6.2
	42	37.5	17.6	67	24	0.0	0	6.7
	43	35.6	15.8	76	22	0.0	0	5.9
November 2011	44	34.1	15.9	68	26	0.0	0	5.0
	45	34.7	15.7	82	29	0.0	0	4.7
	46	34.6	14.2	85	26	0.0	0	4.8
	47	32.8	12.0	86	28	0.0	0	4.5
December 2011	48	31.1	13.2	81	29	0.0	0	4.5
	49	32.4	12.2	84	35	0.0	0	3.5
	50	28.0	4.9	74	18	0.0	0	3.9
	51	28.7	7.0	78	28	0.0	0	3.3
	52	26.8	6.0	92	28	0.0	0	3.4
January 2012	01	24.9	6.6	87	37	0.0	0.0	3.0
	02	24.5	4.6	63	21	0.0	0.0	3.9
	03	25.1	5.3	68	22	0.0	0.0	2.6
	04	25.6	5.5	84	29	0.0	0.0	3.0
February 2012	05	26.6	5.9	71	31	0.0	0.0	4.1
	06	23.8	5.9	57	20	0.0	0.0	5.2
	07	27.6	10.9	60	21	0.0	0.0	4.9
	08	30.4	11.6	71	19	0.0	0.0	5.6
March 2012	09	30.7	11.7	70	20	0.0	0.0	6.1
	10	30.7	12.2	72	18	0.0	0.0	6.6
	11	32.8	12.3	62	15	0.0	0.0	6.9
	12	35.8	15.6	66	17	0.0	0.0	7.1
	13	38.4	17.7	73	22	0.0	0.0	9.0
April 2012	14	40.4	21.1	62	16	0.0	0.0	9.5
	15	38.8	21.1	70	24	0.0	0.0	10.0
	16	37.1	21.7	66	24	0.0	0.0	9.5
	17	4.6	36.6	64	27	0.0	0.0	8.7

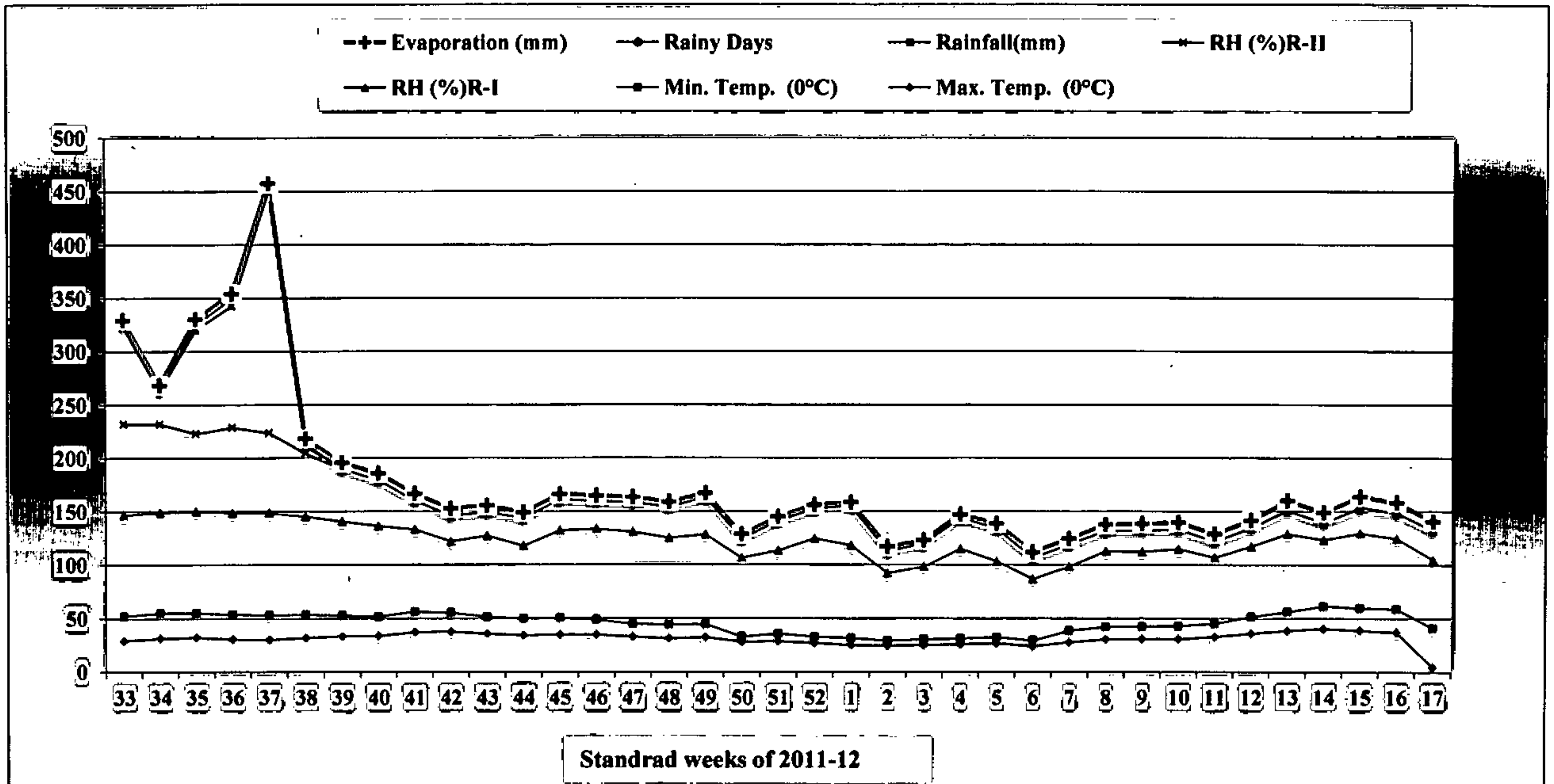


Fig. 3.1: Mean weekly weather parameters during the crop growth period

Weekly average meteorological data on maximum and minimum temperature, relative humidity, sunshine hours, wind velocity and evaporation pertaining to the period of this investigation recorded at the Meteorological Observatory of the Department of Agricultural Meteorology, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar are presented in Tables 3.1 and graphically depicted in Fig. 3.1. It could be seen from the meteorological data that weather conditions are more or less suitable for satisfactory growth and development of castor crop.

3.3 PHYSICO-CHEMICAL PROPERTIES OF SOIL

To ascertain physico-chemical characteristics of soil, soil samples were collected from different spots of the experimental field up to a depth of 0-15 and 15-30 cm and a composite soil sample for each depth were prepared and analyzed. The general physicochemical characteristics of the soils of the experimental plot as well as the methods followed for the soil analysis are given in Table 3.2.

The soil analysis indicated that the soils of the experimental field are loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash. The available zinc ranged between 0.52 to 0.55 ppm which indicate the soil of experimental field was medium in available zinc.

Table 3.2: Physico-chemical properties of soil of experimental plot

Sr. No.	Properties		Soil depth (cm) 0-15	15-30	Method employed
[1]	**MECHANICAL COMPOSITION**				
	(a)	Sand (%)	83.90	84.98	International Pipette method (Piper, 1966)
	(b)	Silt (%)	7.55	7.47	
	(c)	Clay (%)	7.09	6.93	
	(d)	Soil texture	Loamy sand		
[2]	**PHYSICAL PROPERTIES**				
	(a)	Field capacity (%)	7.8	7.7	Field method (Dastane, 1972)
	(b)	Permanent wilting point (%)	3.20	3.35	Pressure plate apparatus method (Richards, 1948)
	(c)	Bulk density (Mg m^{-3})	1.44	1.43	Core sampler method (Dastane, 1972)
[3]	**CHEMICAL PROPERTIES**				
	(a)	Soil pH (1 : 2.5, Soil : Water Ratio)	7.8	7.7	Potentiometric method (Jackson, 1978)
	(b)	Electrical Conductivity (dSm^{-1} at 25°C)	0.11	0.12	Schofield method (Jackson, 1978)
	(c)	Organic carbon (%)	0.24	0.18	Walkley and Black's rapid titration method (Jackson, 1978)
	(d)	Available N (kg/ ha)	159	148	Alkaline permanganate method (Subbiah and Asija, 1956)
	(e)	Available P_2O_5 (kg /ha)	38.9	40.33	Olsen method (Jackson, 1978)
	(f)	Available K_2O (kg /ha)	287	279	Flame photometer method (Jackson, 1978)
	(g)	Zn (ppm)	0.55	0.52	DTPA Extractants (Lindsay and Norvell, 1978)

3.5 CROPPING HISTORY

Detail regarding the cropping history of the experimental plot B-9 with respect to crops taken and fertilizers applied during the previous three years are summarized in Table 3.3.

Table 3.3 Cropping history of the experimental field

Year	Season	Crop	Fertilizers applied (kg/ha)		
			N	P_2O_5	K_2O
2008-09	*Kharif*	Guar	20	40	00
	Rabi	Fallow	-	-	-
	Summer	Sorghum	80	40	00
2009-10	*Kharif*	Guar (green manuring)	-	-	-
	Rabi	Mustard	75	50	00
	Summer	Fallow	-	-	-
2010-11	*Kharif*	Guar	20	40	00
	Rabi	Fallow	-	-	
	Summer	Sorghum	80	40	00
2011-12	*Kharif*	Castor (Present experiment)	120	60	00

3.6 SALIENT FEATURES OF THE VARIETY

The variety GCH 7 released from the Main Castor and Mustard Research Station, SDAU, Sardarkrushinagar (Gujarat) during year 2006 was selected for this study. This variety was developed through pedigree method from the cross of SKP-84 × SKI - 215 and its duration is 210 to 215 days. The colour of stem is usually lightly red with blooming. The spikes are dense, parallel in shape and dirty white. The grains are amber in colour and hard in texture. The weight of 100 seeds is 28.5 to 29.5 gram. This variety is resistant against wilt and highly responsive to fertilizers. It contains 48.5 to 49.5 percent oil content.

3.7 EXPERIMENTAL DETAILS

In order to study on "evapotranspiration based scheduling of irrigation through drip system for castor crop" an experiment was carried out during *kharif* season of 2011-12. The details of the experiment are given below.

3.7.1 Treatments

The details of treatments are as under.

A. Sowing method

S_1 Paired row (135 - 60 cm × 45 cm)

S_2 Single row (90 cm × 60 cm)

B Irrigation through drip method

I_1 0.6 Etc

I_2 0.8 Etc

I_3 1.0 Etc

I_4 Conventional method of irrigation

(Surface irrigation with 50 mm depth)

3.7.2 Treatment combinations

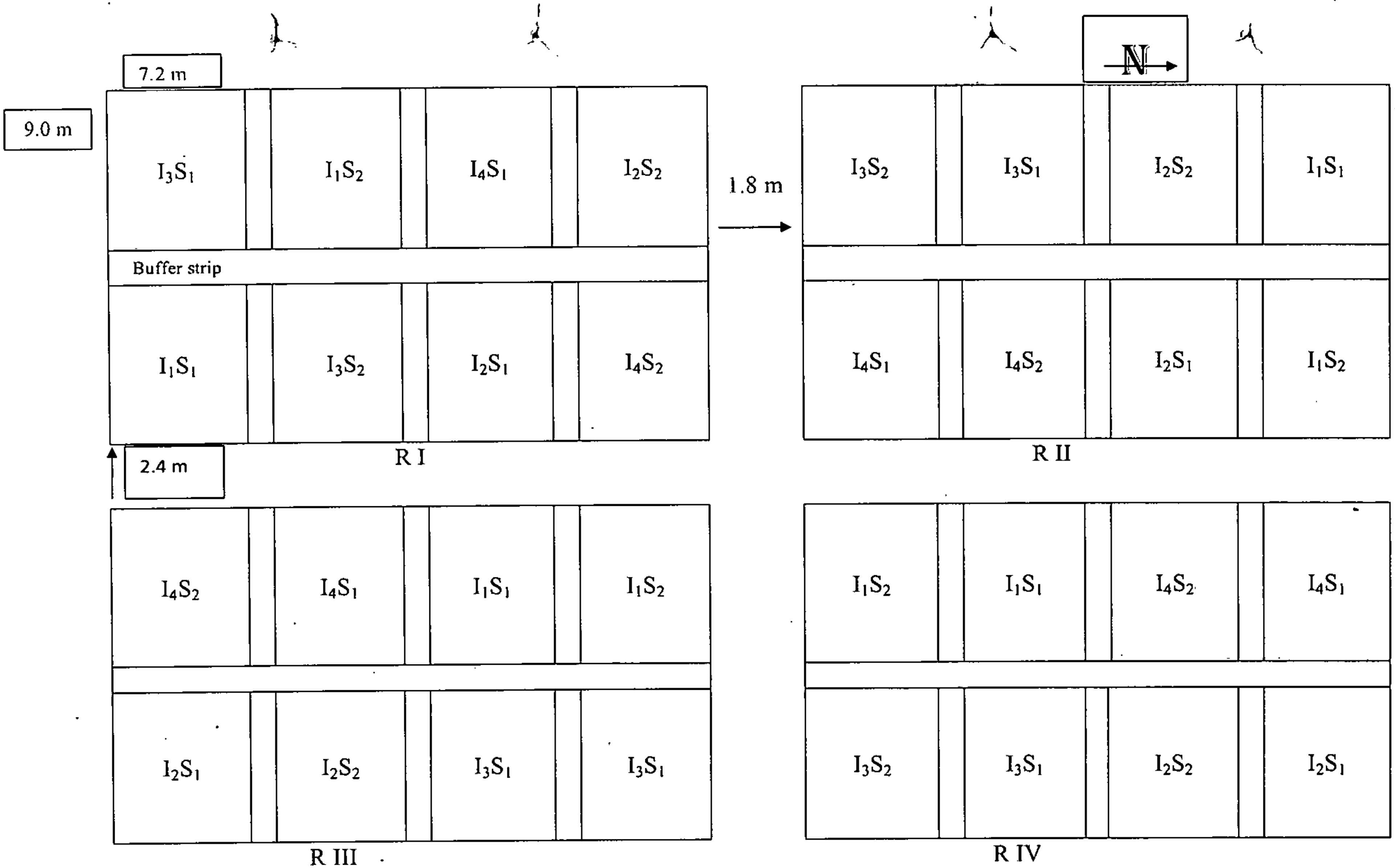
Total eight treatment combinations of two factors were employed as described in Table 3.4

Table 3.4 Treatment combinations

Sr. No.	Symbol	Sowing method	Irrigation
1.	S_1I_1	Paired row	0.6 Etc through drip irrigation
2.	S_1I_2	Paired row	0.8 Etc through drip irrigation
3.	S_1I_3	Paired row	1.0 Etc through drip irrigation
4.	S_1I_4	Paired row	Conventional method (surface irrigation)
5.	S_2I_1	Single row	0.6 Etc through drip irrigation
6.	S_2I_2	Single row	0.8 Etc through drip irrigation
7.	S_2I_3	Single row	1.0 Etc through drip irrigation
8.	S_2I_4	Single row	Conventional method (surface irrigation)

Table 3.5 Experimental design and layout

1.	Experimental design	:	RBD with factorial concept
2.	Number of replications	:	4 (Four)
3.	Total number of plots	:	32 (Thirty two)
4.	Plot size	:	Gross Plot : 9.0 m × 7.2 m Net Plot : 5.4 m × 3.6 m
5.	Spacing	:	As per treatment
6.	Crop and Variety	:	Castor, GCH 7
7.	Seed rate	:	5-6 kg/ha
8.	Recommended dose of fertilizer	:	120+60+00 NPK kg/ha



Gross plot size : 9.0 m × 7.2 m
Net plot Size : 5.4 m × 3.6 m

Fig. 3.2: LAYOUT PLAN

3.8 CULTIVATION OF EXPERIMENTAL CROP

The calendar of the cultural operations carried out for cultivation of the crop is presented in Table 3.6.

Table 3.6 Calendar of the cultural operations

Sr. No.	Operations	Frequency	Date
1	Cultivation with tractor drawn cultivator	1	29-07-2011
2	Harrowing and Planking	1	09-08-2011
3	Field layout and bed preparation	1	18-08-2011
4	Basal application of fertilizer and planking	1	19-08-2011
5	Dibbling of seeds	1	19-08-2011
6	Gap filling	1	05-09-2011
7	Drip installation	1	12-10-2011
7	Hand weeding	2	20-09-2011
			20-10-2011
8	Inter-culturing	1	19-10-2011
9	Top dressing	3	40, 70 and 100 DAS
10	Plant protection	1	---
11	Harvesting	3	05-03-12
			25-03-12
			15-04-12
12	Threshing	1	20-04-12

3.8.1 Preparation of land and layout

The experimental field was thoroughly cross cultivated with a tractor drawn cultivator. Residues and stubbles of the previous crop were removed from the experimental plot. The field was cultivated with tractor followed by planking. The experiment was laid out as per layout plan and plots were leveled manually to open furrows, as per treatment.

3.8.2 Fertilizer application

The crop was fertilized with recommended dose of fertilizers (120-60-00 NPK kg /ha). A whole dose of phosphorus in the form of DAP and one fourth dose of nitrogen in the form of DAP and urea was applied in furrows before sowing as a basal application. Remaining dose of nitrogen was top dressed in three splits at 5 cm away from the plant as ring method after 40,70, 100 days of sowing in the form of urea.

3.8.3 Sowing of crop

The required quantity of seeds was treated with thiram at 2.5 g/kg before sowing. The seeds of GCH 7 variety were dibbled in previously opened furrows in paired row system by maintaining distance of 45 cm between two rows, 60 cm between two plants and 135 cm between two pairs while nomal sowing (single row) was done at 90 cm × 60 cm distance at depth of 6 to 7 cm manually at seed rate of 6 kg/ha on 19^{th} August, 2011.

3.8.4 Gap filling

For maintaining the plant population gap filling was carried out at 15 DAS.

3.8.5 Installation of drip unit

The experimental site was marked for installation of drip unit. The unit was consisted of following components.

(i) A head unit connected to main water supply, which includes control valves, ventury, filter, pressure gauge etc.

(ii) Main and sub-main lines of PVC having 63 and 50 mm diameter, respectively.

(iii) Lateral pipes having 16 mm diameter and drippers having capacity of 4 l/hr.

The main pipe was connected with head unit. Lateral lines connected with sub-main and laid out at a distance of 180 cm in the centre of pair rows. While at a distance of 90 cm in normal sowing of castor (each line). The drippers were placed on lateral lines at a distance of 60 cm as inline drippers and each dripper serves one plant in normal sowing while two plants in paired row sowing. The pressure of flowing water was maintained at 1.2 Kpa for obtaining optimum discharge. The uniformity of dripper discharge was obtained more than 85 per cent.

3.8.6 Irrigation scheduling

Scheduling of irrigation for drip system was maintained by considering the evapotranspiration. Daily pan evaporation was measured with the help of open pan evpaporimeter installed in the meteorological observatory. The quantities of water delivered per dripper at different places were measured and average volume was utilized calculating the quantity of water to be delivered

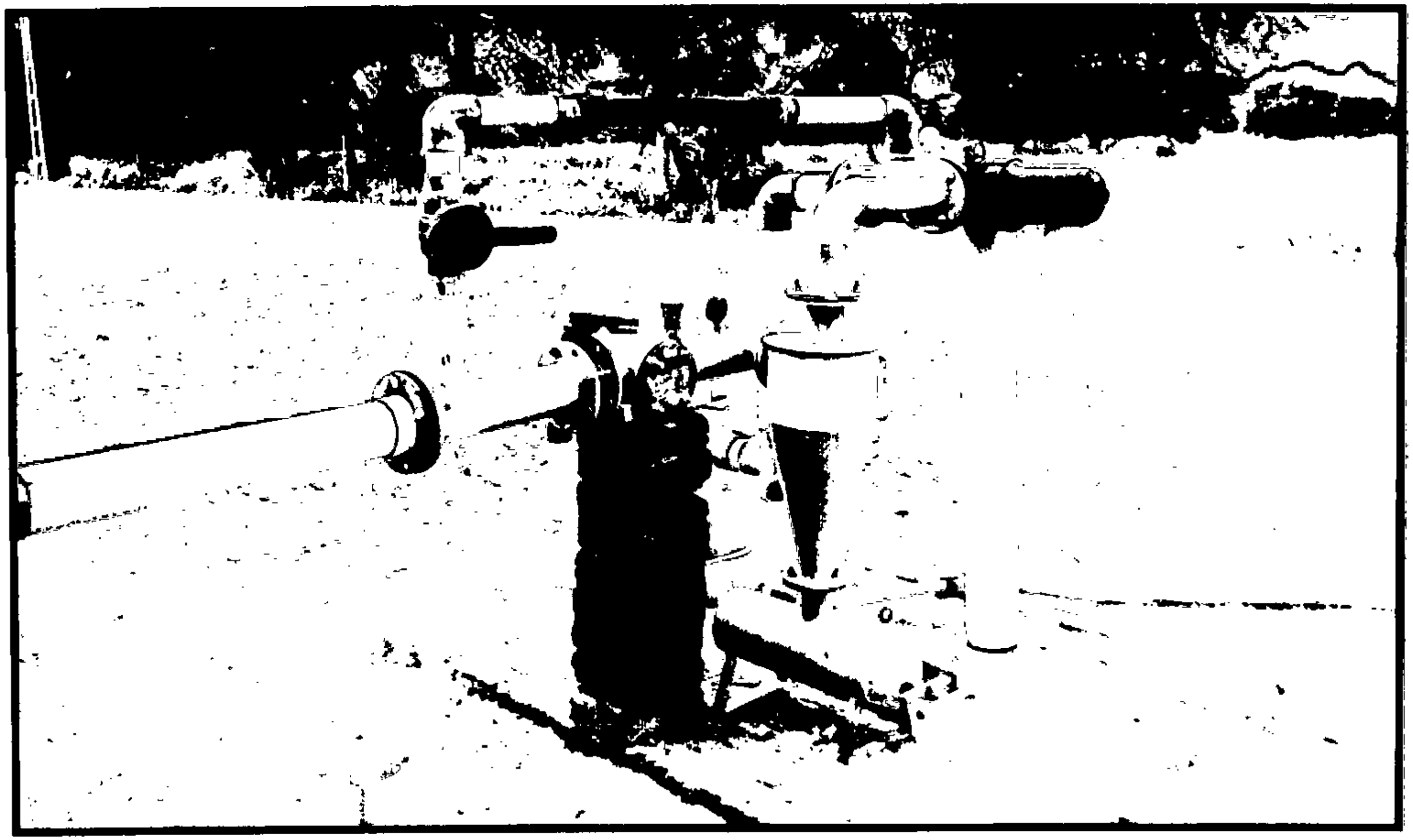


Plate 1. View of drip head unit

and time of operation as per treatments at every alternate day for the drip system.

3.8.7 Measurement of irrigation water

The volume of water to be given on alternate days through drip was calculated as :

$$V = E_P\,(mm) \times K_P\,(0.7) \times K_C\,(0.5) \times S_1 \times S_2$$

Where V = volume of water to be given/dripper

E_P = pan evaporation (mm)

K_p = pan coefficient (0.7)

K_c = crop coefficient (0.5)

S_1 = lateral spacing (m)

S_2 = dripper spacing (m)

While in conventional method (conventional method) crop was irrigated as per recommendation at 15 to 25 days interval with the 50 mm depth of irrigation. The quantity of irrigation water in this method was measured with 15 cm parshal flume. Date wise irrigation scheduling for conventional method is given in Table 3.7.

Table 3.7 Date wise irrigation scheduling for conventional method

Sr. No.	Date	Depth of irrigation (mm)
1	12/10/2011	50
2.	27/10/2011	50
3.	22/11/2011	50
4.	12/12/2011	50
5.	01/01/2012	50
6.	21/01/2012	50
7.	10/02/2012	50
8.	02/03/2012	50
9.	17/03/2012	50
10.	02/03/2012	50

3.8.5.3 Application of irrigation

Treatment wise total quantity of irrigation water under drip system and conventional method given during entire crop growth period are as under.

Quantity of irrigation water applied in each treatment

Sr. No.	Treatments	Quantity of water (mm)
1.	$I_1 S_1$	210
2.	$I_1 S_2$	210
3.	$I_2 S_1$	281
4.	$I_2 S_2$	281
5.	$I_3 S_1$	352
6.	$I_3 S_2$	352
7.	$I_4 S_1$	500
8.	$I_4 S_2$	500

3.9 Plant protection

No serious disease or pest was observed so that none of the plant protection was employed during the course of investigation.

3.10 Weeding

Attempts were made to keep the experimental field free from weed throughout the crop season. Two hand weeding and one interculturing in all treatments were done during crop season to keep the experimental field free from weeds.

3.11 Harvesting and threshing

The crop was threshed or harvested at the stage of normal maturity as per the dates shown in Table 3.6. The spikes of border line plants were picked up first and were placed away from the experimental area. The spikes of five selected plants were picked up separately for recording post harvest observations and their seed yield was added to final net plot yield. The spikes from each plot were picked up simultaneously and plot wise produce kept separately. After completion of final picking, net plot wise entire produce was sun dried, threshed and cleaned. After last picking stalks of each net plot were uprooted and left in field to sun dried.

3.11 BIOMETRIC OBSERVATIONS

The biometric observations were recorded from the randomly selected five plants (tagged) in each net plot.

3.11.1 Initial plant population

Plant population at 30 DAS was recorded by counting the number of plants in each net plot and converted to hectare basis.

3.11.2 Final plant population

Plant population at harvest was recorded by counting the number of plants in each net plot and converted to hectare basis at the time of harvest.

3.11.3 Plant height (cm)

The plant height was measured from ground level to the base of main spike in cm at the time of 1^{st} picking. The mean plant height of randomly selected plants was worked out and recorded for each plot.

3.11.4 Number of primary branches per plant

All the branches arising from the main shoot were counted from the selected plants in each plot at harvest. Average value was worked out and recorded separately.

3.11.5 Number of spikes per plant

Average number of spikes per pant was recorded at harvest on the basis of five randomly selected plants from each plot

3.11.6 Number of capsules per main spike

The total number of capsules collected from main spike of five selected plants was counted and average values per main spike was worked out and recorded for each treatment.

3.11.7 Length of main spike (cm)

The length of main spike was recorded at the time of harvest in centimeter from selected plants. The mean length of main spike for each treatment was worked out and recorded.

3.11.8 Number of nodes to main receme

The total number of nodes from cotyledonary node to the base of primary spike counted and recorded in each five tagged plants in each net plot at harvest.

3.11.9 100 seed weight (g)

A representative seed sample was collected randomly from the bulk produce of each net plot and 100 seeds were counted and weighted and recorded in grams.

3.11.10 Seed yield per plant (g)

Spikes of five selected plants were harvested first at each picking and allowed to sun dry for five to six days. After satisfactory drying, threshing and cleaning was carried out and seed yield of these five plants was noted. An average value of seed yield per plant in was gram recorded for each treatment.

3.12 YIELD

3.12.1 Seed yield (kg/ ha)

The seed yield after each picking from each net plot was recorded. The seed yield per plant was computed on net plot yield basis. It was summed up and total seed yield per net plot was obtained and converted to kilograms per hectare.

3.12.2 Stalk yield (kg/ha)

After final harvest of spikes from the net plots, the stalks of net plots were dugout and air dried. Thereafter, the weight of dry stalks per net plot was recorded and then converted in to kg per hectare.

3.13 QUALITY CHARACTERS

3.13.1 Oil content (%)

Random samples were drawn from produce of each treatment to estimate oil content of seeds. The oil content of the seeds was determined by

Nuclear Magnetic Response (NMR) as per the method suggested by Tiwari *et al.* (1974).

3.13.2 Oil yield (kg/ha)

The amount of oil yield in kg per hectare was calculated for different treatments by using the following formula

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil content of the seed (\%)} \times \text{Seed yield (kg/ha)}}{100}$$

3.14 ECONOMICS

3.14.1 Gross and net realization

The gross and net realization in term of rupees per hectare was worked out based on seed yield and stalk yield of each treatments and prevailing market price. The cost of cultivation of the crop under each treatment was worked out by considering the expenses incurred for all cultural operations as well as cost of various inputs. The net realization was worked out by deducting the cost of cultivation from the gross realization for the respective treatments.

3.14.2 Benefit cost ratio

The benefit cost ratio (BCR) was calculated as ratio of gross return to total cost of cultivation by using following formula.

$$\text{BCR} = \frac{\text{Gross return (₹/ ha)}}{\text{Total cost of cultivation (₹/ ha)}}$$

3.14.3 Net income per mm water used

Net income per mm water used under different irrigation treatments was calculated by the following formula.

$$\text{Net income per mm water used} = \frac{\text{Net income}}{\text{Total water applied (mm)}}$$

3.15 OTHERS

3.15.1 Water use efficiency (kg / ha-mm)

The water use efficiency was calculated by using following formula as suggested by Michael (1978).

$$\text{Water use efficiency (kg/ha – mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Total water applied (mm)}}$$

3.15.2 Water saving (%)

The water saving (%) in drip irrigation system for each treatment was calculated by comparing quantity of water applied in conventional method of irrigation.

3.16 STATISTICAL ANALYSIS

3.16.1 Analysis of variance and test of significance

The observations recorded for growth, yield and yield attributes were put to the statistical analysis in accordance with analysis of variance techniques as suggested by Panse and Sukhatme (1967) for randomized block design

(Factorial). Significance of the difference in the treatment effect was tested through 'F' test at 5 %. To elucidate the nature and the magnitude the effect found to be significant by the 'F' test, summary tables along with appropriate standard error of mean (S.Em. ±) were prepared. The critical difference (C.D.) at 5 per cent level of significance was given for these treatments which were found significant.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Results of the experiment entitled "Evapotranspiration based scheduling of irrigation through drip system for castor crop (*Ricinus communis* L.)" conducted at the Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District : Banaskantha (North Gujarat) during *kharif* season of 2011-12 are presented in this chapter along with statistical inferences and also illustrated graphically wherever necessary. The data concerning to individual effect and only significant interactions are presented in this chapter.

4. 1 GROWTH AND YIELD ATTRIBUTES

4.1.1 PLANT POPULATION

4.1.1.1 Plant population at 30 DAS

Data on plant population of castor as influenced by irrigation scheduling and sowing methods recorded at 30 days after sowing (DAS) are summarized in Table 4.1.

4.1.1.1.1 Effect of irrigation scheduling

Data presented in Table 4.1 indicated that initial plant population recorded at 30 DAS of castor was not significantly influenced due to irrigation scheduling.

4.1.1.1.2 Effect of sowing methods

An appraisal of data presented in Table 4.1indicated that plant population recorded at 30 DAS was found non-significant due to the sowing methods.

Table 4.1 Plant population of castor at 30 DAS as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	16506	16412	16459
I_2 : 0.8 Etc through drip system	17241	17143	17192
I_3 : 1.0 Etc through drip system	17374	17274	17324
I_4: Conventional method	16394	16300	16347
Mean	16879	16782	16830
	I	S	I × S
S. Em. ±	587	415	831
C. D. (P=0.05)	NS	NS	NS
CV %	9.87		

4.1.1.1.3 Interaction effect

Interaction effect of irrigation scheduling and sowing methods was found non-significant with respect to plant population of castor at 30 DAS.

4.1.1.2 Plant population at harvest

Data regarding the effect of irrigation scheduling and sowing methods on plant population per hectare of castor crop recorded at harvest of crop are presented in Table 4.2.

4.1.1.2.1 Effect of irrigation scheduling

The data given in Table 4.2 revealed that the differences in plant population due to levels of irrigation were found non-significant. Although, numerically the maximum number of plants/ha (16926 plants/ha) was recorded under treatment 1.0 Etc through drip system.

4.1.1.2.2 Effect of sowing methods

An appraisal of data presented in Table 4.2 indicated that plant population recorded at harvest was not significantly influenced due to the sowing methods.

4.1.1.2.3 Interaction effect

The interaction between irrigation scheduling and sowing methods was found non-significant with respect to plant population at harvest.

4.1.2 PLANT HEIGHT (cm)

The data pertaining to the effect of irrigation scheduling and sowing methods on plant height of castor recorded at first picking are resented in Table 4.3.

Table 4.2 Plant population of castor at harvest as influenced by scheduling of irrigation and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	16496	16402	16449
I_2 : 0.8 Etc through drip system	17233	17135	17184
I_3 : 1.0 Etc through drip system	17368	17268	17318
I_4: Conventional method	16385	16291	16338
Mean	16870	16774	16822
	I	S	I × S
S. Em. ±	588	416	831
C. D. (P=0.05)	NS	NS	NS
CV %	9. 88		

4.1.2.1 Effect of irrigation scheduling

Plant height of castor measured from ground level to the base of main spike at the time of I[st] picking was influenced due to levels of irrigation (Table 4.3). Application of irrigation water through drip system at 1.0 (84.6 cm) and 0.8 (76.7 cm) Etc were found statistically at par. However irrigating at both these treatments recorded significantly taller plants over treatments 0.6 Etc (72.8 cm) through drip system and conventional method (64.9 cm).

4. 1.2.2 Effect of sowing methods

Perusal of data presented in Table 4.3 indicate that plant height at I[st] picking was not significantly influenced due to sowing methods (Table 4.3). However, taller plants were recorded under single row method (77.0 cm) than paired row method (72.5 cm).

4.1.2.3 Interaction effect

Irrigation scheduling and sowing methods could not exert any significant interaction effect on plant height of castor at 1[st] picking.

4.1.3NUMBER OF PRIMARY BRANCHES PER PLANT

Data recorded on number of primary branches per plant of castor as influenced by scheduling of irrigation and sowing methods are presented in Table 4.4

4.1.3.1 Effect of irrigation scheduling

Different levels of irrigation caused significant effect on number of primary branches per plant of castor crop (Table 4.4). Application of irrigation water through drip system at 1.0 and 0.8 Etc was found statistically at par with

Table 4.3 Plant height (cm) of castor at I[st] picking as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Scheduling of irrigation	S_1 (Paired row method)	S_2 (Single row method)	Mean
Irrigation scheduling (I)			
I_1 : 0.6 Etc through drip system	70.4	75.1	72.8
I_2 : 0.8 Etc through drip system	74.2	79.1	76.7
I_3 : 1.0 Etc through drip system	81.8	87.3	84.6
I_4 : Conventional method	63.4	66.3	64.9
Mean	72.5	77.0	74.7
	I	S	I × S
S. Em. ±	3.1	2.2	4.4
C. D. (P=0.05)	9.1	NS	NS
CV %	11.82		

Table 4.4 Number of primary branches per plant of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (single row method)	Mean
I_1 : 0.6 Etc through drip system	5.3	6.1	5.7
I_2 : 0.8 Etc through drip system	7.8	7.9	7.9
I_3 : 1.0 Etc through drip system	8.0	8.5	8.2
I_4: Conventional method	5.4	5.5	5.4
Mean	6.6	7.0	6.0
	I	S	I × S
S. Em. ±	0.1	0.1	0.2
C. D. (P=0.05)	0.5	0.3	NS
CV %	7.11		

respect to number of primary branches per plant. However, both treatments recorded significantly higher number of primary branches per plant over rest of the treatments. The number of primary branches recorded under treatments 0.6, 0.8, 1.0 Etc through drip system and conventional method were 5.7, 7.9, 8.2 and 5.4, respectively.

4. 1.3.2 Effect of sowing methods

Perusal of data in Table 4.4 indicated that number of primary branches per plant was significantly influenced due to sowing methods. Significantly more number of primary branches per plant (7.0) was recorded under single row method than paired row method (6.6).

4.1.3.3 Interaction effect

The interaction effect between irrigation scheduling and sowing methods could not exert any significant influence on number of branches per plant

4.1.4 NUMBER OF SPIKES PER PLANT

Data on number of spikes per plant as influenced by irrigation scheduling and sowing methods are presented in Table 4.5 and graphically depicted in Fig 4.1.

4.1.4.1 Effect of irrigation scheduling

A perusal of data presented in Table 4.5 showed that scheduling of irrigation significantly influenced on number of spikes per plant. Number of spikes per plant was increased with increase in level of irrigation scheduling. Significantly maximum number of spikes per plant (8.8) was recorded with 1.0

Table 4.5 Number of spikes per plant of castor as influenced by scheduling of irrigation and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	7.4	7.9	7.7
I_2 : 0.8 Etc through drip system	7.8	8.3	8.1
I_3 : 1.0 Etc through drip system	8.5	9.2	8.8
I_4: Conventional method	6.7	7.1	6.9
Mean	7.6	8.1	7.9
	I	S	I × S
S. Em. ±	0.3	0.2	0.4
C. D. (P=0.05)	0.9	NS	NS
CV %	12.13		

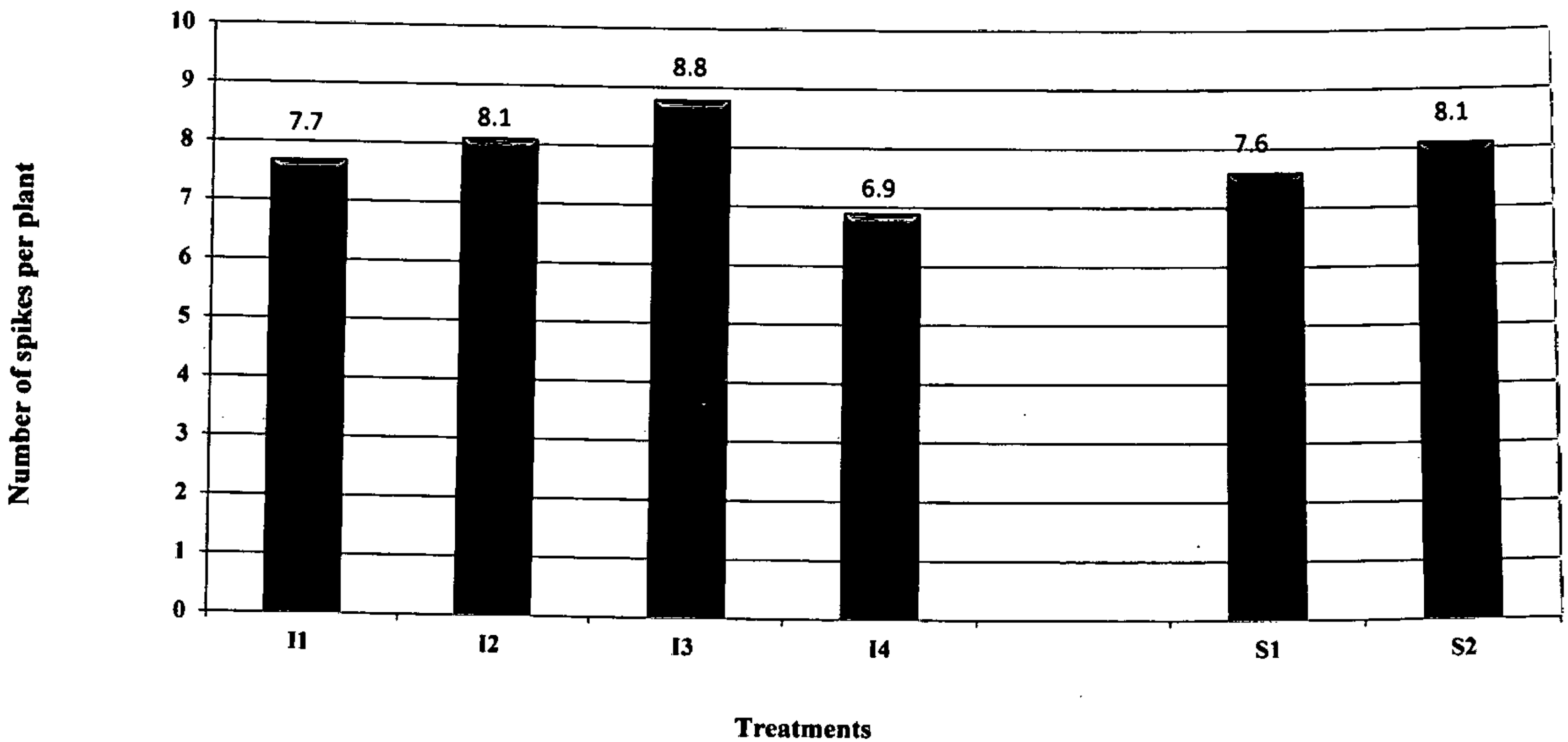


Fig. 4.1 Number of spikes per plant of castor as influenced by scheduling of irrigation and sowing methods

Etc through drip system (I_3) treatment but was at par with 0.8 Etc (8.1). Application of irrigation water as conventional method (surface irrigation) recorded significantly the lowest number of spikes per plant (6.9) and was at par with 0.6 Etc through drip method (7.7).

4. 1.4.2 Effect of sowing methods

An examination of data (Table 4.5) indicated that the number of spikes per plant was not significantly influenced due to sowing methods. However, numerically higher (8.1) number of spikes per plant was recorded under single row method as compared to paired row method (7.6).

4.1.4.3 Interaction effect

The data pertaining to the interaction effect between irrigation scheduling and sowing methods was non-significant with respect to number of spikes per plant.

4.1.5 NUMBER OF CAPSULES PER MAIN SPIKE

Data recorded on number of spikes per plant as influenced by irrigation scheduling and sowing methods are presented in Table 4.6 and graphically illustrated in Fig 4.2.

4.1.5.1 Effect of irrigation scheduling

The results revealed that number of capsules per main spike of castor was significantly influenced due to levels of irrigation. Application of irrigation water through drip system at 1.0 Etc (I_3) recorded significantly higher number of capsules (67.6) per main spike at harvest as compared to irrigating at 0.6 Etc and conventional method. This treatment was found statistically at par with 0.8

Table 4.6 Number of capsules per main spike of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	56.3	60.1	58.2
I_2 : 0.8 Etc through drip system	59.4	63.3	61.3
I_3 : 1.0 Etc through drip system	65.5	69.8	67.6
I_4: Conventional method	50.7	52.8	51.8
Mean	58.0	61.5	59.7
	I	S	I × S
S. Em. ±	2.4	1.7	3.5
C. D. (P=0.05)	7.3	NS	NS
CV %	11.79		

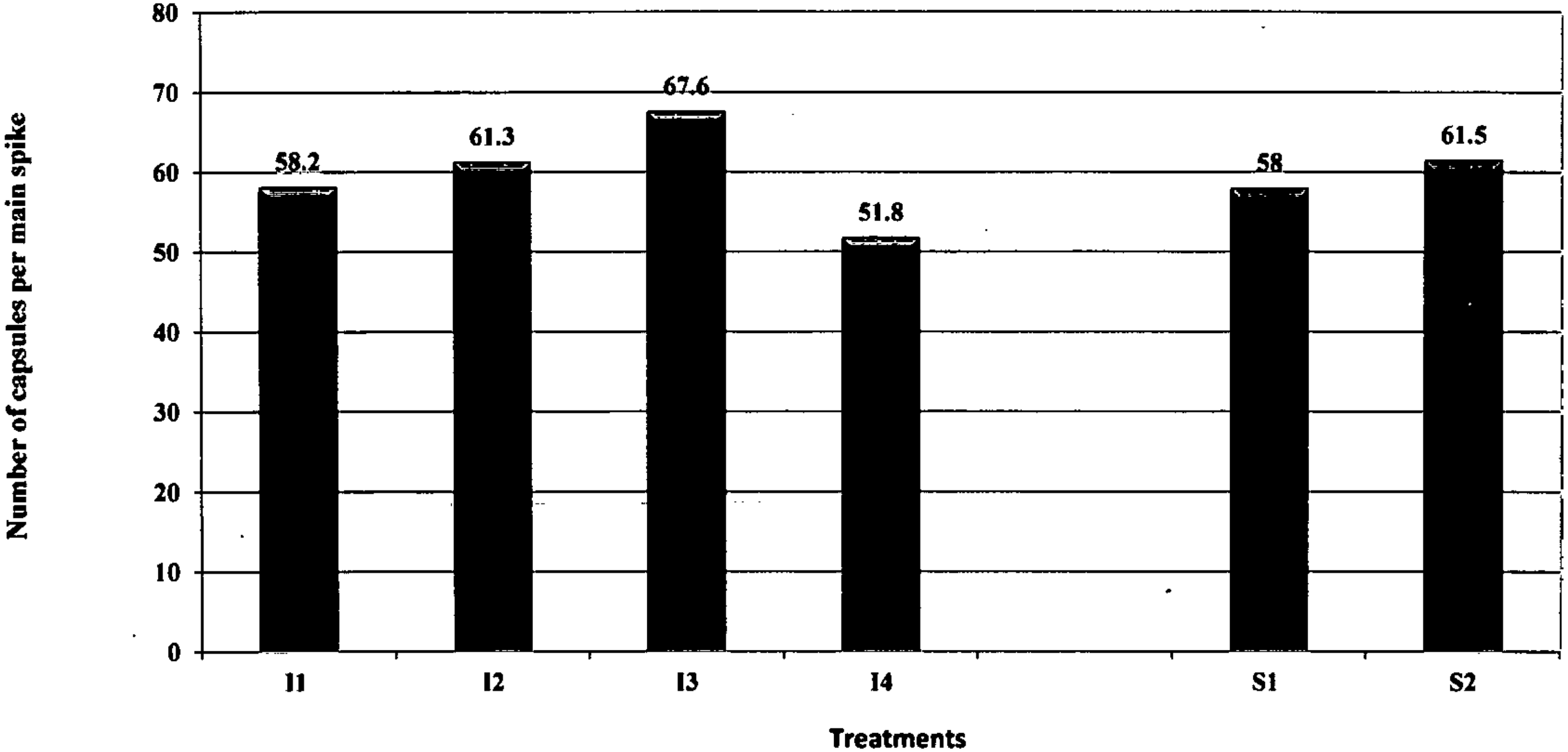


Fig. 4.2 Number of capsules per main spike of castor as influenced by scheduling of irrigation and sowing methods

Etc which recorded 61.3 capsules per main spike. Irrigation to castor through conventional method (surface irrigation) recorded significantly the lowest number of capsules (51.8) per main spike which was found statistically at par with 0.6 Etc.

4.1.5.2 Effect of sowing methods

Number of capsules per main spike was not significantly influenced due to sowing methods. However, numerically higher number of capsules (61.5) per main spike was recorded under single row method as compared to paired row method (58.0).

4.1.5.3 Interaction effect

Data presented in Table 4.6 revealed that interaction effect owing to irrigation scheduling and sowing method could not significantly affected on number of capsules per main spike.

4.1.6 LENGTH OF MAIN SPIKE (cm)

The data pertaining to the effect of different treatments of irrigation scheduling and sowing methods on length of main spike recorded at harvest are presented in Table 4.7.

4.1.6.1 Effect of irrigation scheduling

Length of main spike of castor was significantly influenced due to treatments of irrigation scheduling. Application of irrigation water at 1.0 and 0.8 Etc through drip system were found significantly more effective in enhancing the length of main spike at harvest as compared to irrigating at 0.6 Etc through drip system and conventional method which found at par in this

Table 4.7 Length of main spike (cm) of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	60.8	64.9	62.9
I_2 : 0.8 Etc through drip system	64.1	68.4	66.2
I_3 : 1.0 Etc through drip system	70.7	75.4	73.1
I_4: Conventional method	54.7	57.1	55.9
Mean	62.6	66.5	64.5
	I	S	I × S
S. Em. ±	2.6	1.9	3.8
C. D. (P=0.05)	7.9	NS	NS
CV %	11.80		

regard. Irrigation through conventional method recorded significantly minimum length (55.9 cm) of main spike and was at par with irrigating at 0.6 Etc through drip system (62.9).

4.1.6.2 Effect of sowing methods

Perusal of data in Table 4.7 indicated that length of main spike was not significantly affected due to sowing methods. However, numerically higher length of main spike (66.5 cm) was observed under single row method than paired row method (62.6 cm).

4.1.6.3 Interaction effect

Interaction effect between irrigation scheduling and sowing methods was found non-significant with respect to number of length of main spikes.

4.1.7 NUMBER OF NODES UP TO MAIN RECEME

The data pertaining to the effect of different irrigation scheduling and sowing methods on number of nodes up to main receme are presented in Table 4.8.

4.1.7.1 Effect of irrigation scheduling

The results summarized in Table 4.8indicatedthat number of nodes up to main receme of castor was significantly increased with different levels of irrigation. In case of drip irrigation significantly higher number of nodes up to main receme was recorded with application of irrigation at 1.0 and 0.8 Etc as compared to 0.6 Etc and conventional method. The difference between I_3 and I_2 treatments was non- significant. Irrigating the crop through conventional

Table 4.8 Number of nodes to main receme of castor as influenced by scheduling of and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	18.5	21.1	19.8
I_2 : 0.8 Etc through drip system	27.1	27.3	27.2
I_3 : 1.0 Etc through drip system	27.6	29.4	28.5
I_4: Conventional method	18.6	19.0	18.8
Mean	23.0	24.2	23.6
	I	S	I × S
S. Em. ±	0.5	0.4	0.8
C. D. (P=0.05)	1.74	1.23	NS
CV %	7.09		

method recorded the minimum number of nodes (18.8) up to main receme and was statistically at par with 0.6 Etc through drip system.

4.1.7.2 Effect of sowing methods

Data presented in Table 4.8 indicated significantly higher number of nodes up to main receme was recorded under single row (24.2) method compared to paired row method (23.0).

4.1.7.3 Interaction effect

Data recorded in Table 4.8 indicated that interaction effect between irrigation scheduling and sowing method was found non-significant with respect to the number of nodes up to main receme.

4.1.8 100 SEED WEIGHT (g)

The data recorded on 100 seed weight as influenced by irrigation scheduling and sowing methods along with statistical inferences are presented in Table 4.9 and graphically depicted in Fig. 4.3.

4.1.8.1 Effect of irrigation scheduling

The results summarized in Table 4.9 indicated that 100 seed weight of castor was significantly affected due to levels of irrigation. Application of irrigation water at 1.0 Etc recorded maximum (32.3 g) 100 seed weight but it was at par with 0.8 Etc (29.5 g) through drip system. Irrigating the crop under conventional method of irrigation recorded the lowest 100 seed weight (25.4 g) and it was statistically at par with irrigating at 0.6 Etc through drip system.

Table 4.9 100 seed weight (g) of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	27.3	28.9	28.1
I_2 : 0.8 Etc through drip system	28.8	30.2	29.5
I_3 : 1.0 Etc through drip system	31.2	33.4	32.3
I_4: Conventional method	24.6	26.2	25.4
Mean	28.0	29.7	28.8
	I	S	I × S
S. Em. ±	1.1	0.7	1.5
C. D. (P=0.05)	3.3	NS	NS
CV %	11.03		

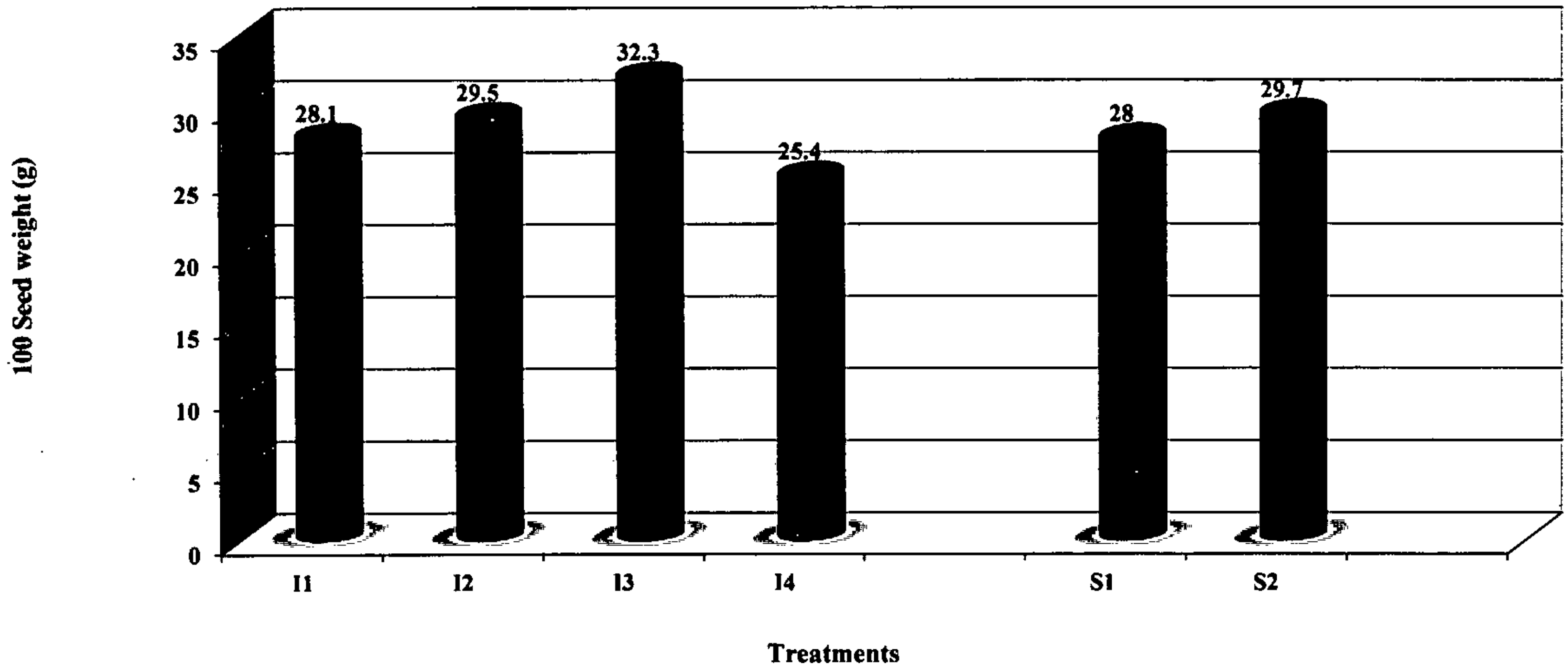


Fig. 4.3 100 seed weight (g) of castor as influenced by scheduling of irrigation and sowing methods

4.1.8. 2 Effect of sowing method

Perusal of data in Table 4.9 indicated that 100 seed weight was not significantly influenced due to sowing methods.

4.1.8. 3Interaction effect

Irrigation scheduling and sowing method failed to show any significant interaction effect with respect to 100 seed weight (Table 4.9).

4.1.9 SEED YIELD PER PLANT (g)

Data on seed yield per plant as influenced by irrigation scheduling and sowing methods are presented in Table 4.10 and graphically depicted in Fig 4.4.

4.1.9.1 Effect of irrigation scheduling

Significantly higher seed yield per plant was recorded when irrigation was applied at 1.0 Etc (169.2 g) and 0.8 Etc (153.5 g) compared to 0.6 Etc (145.6 g) under drip and conventional method (130.4 g) and both these treatments were found at par in this regard. Irrigating the castor crop under conventional method recorded the lowest (130.4 g) seed yield per plant which was at par with 0.6 Etc through drip system.

4.9. 2 Effect of sowing methods

Seed yield per plant (Table 4.10) was not affected significantly due to sowing methods. However, sowing of castor in single row recorded higher seed yield (154.4 g) per plant than paired row method (145.0 g).

Table 4.10 Seed yield (g) per plant of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	140.9	150.3	145.6
I_2 : 0.8 Etc through drip system	148.5	158.4	153.5
I_3 : 1.0 Etc through drip system	163.8	174.7	169.2
I_4: Conventional method	126.8	134.0	130.4
Mean	145.0	154.4	149.7
	I	S	I × S
S. Em. ±	6.3	4.4	8.9
C. D. (P=0.05)	18.5	NS	NS
CV %	11.90		

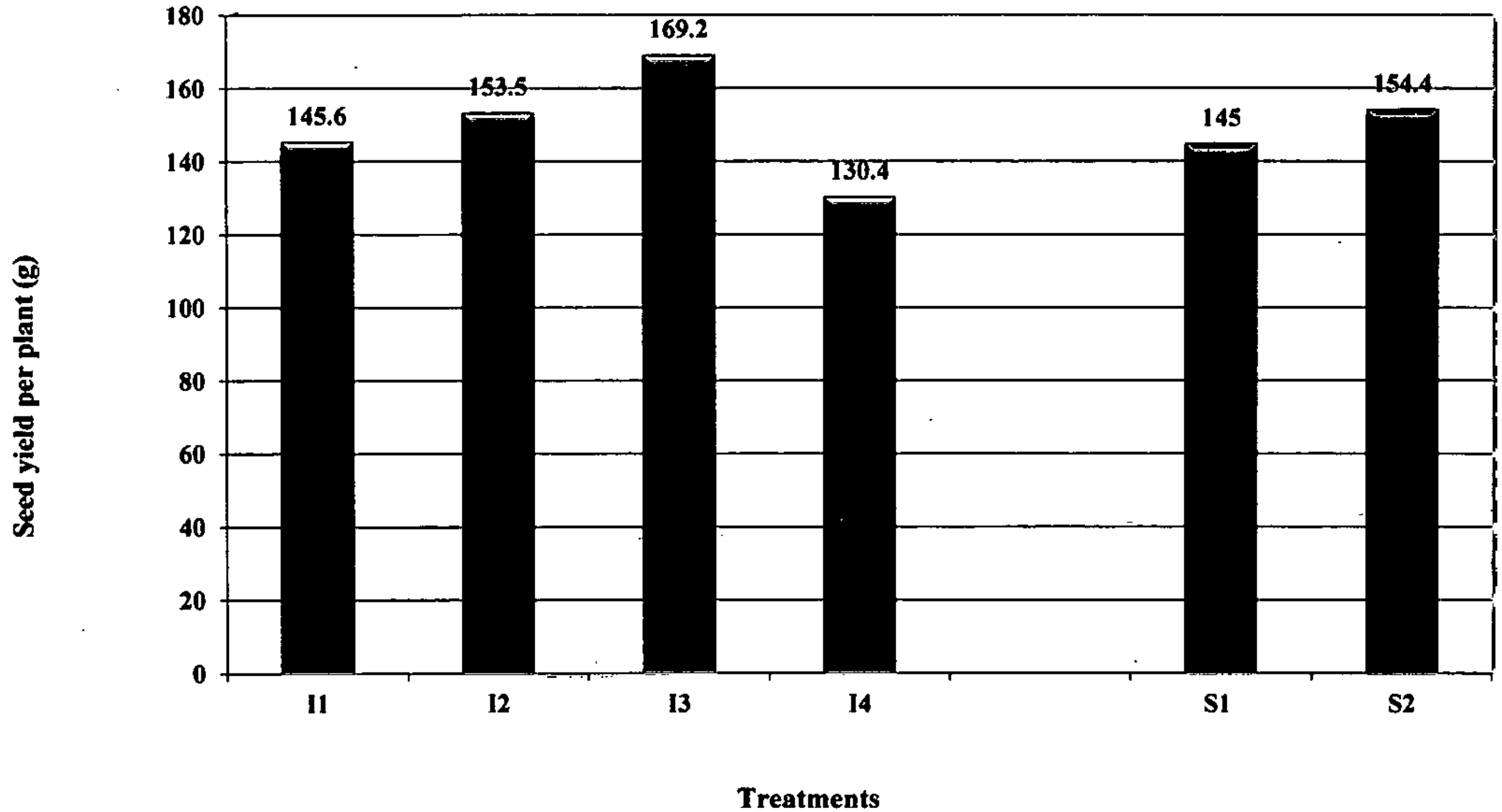


Fig. 4.4 Seed yield (g) per plant of castor as influenced by scheduling of irrigation and sowing methods

4.9.3 Interaction effect

Interaction effect between irrigation scheduling and sowing method was found non-significant with respect to seed yield per plant.

4.2 YIELD

Data regarding to the effect of different levels of irrigation and sowing methods on seed and stalk yield of castor along with statistical inferences are presented in Table 4.11 and 4.12.

4.2.1 SEED YIELD (kg/ha)

The seed yield as influenced by various treatments is presented in Table 4.11 and graphically depicted in Fig. 4.5.

4.2.1.1 Effect of irrigation scheduling

The results summarized in Table 4.11 indicated that seed yield of castor was significantly increased with an increase in levels of irrigation under drip irrigation system. Application of irrigation at 1.0 Etc (3268 kg/ha) and 0.8 Etc (3122 kg/ha) recorded statistically higher seed yield per hectare as compared to 0.6 Etc and conventional method but was at par with each other. Application of irrigation water under conventional method recorded significantly the lowest seed yield (2677 kg/ha) of castor and was found at par with 0.6 Etc treatment (2738 kg/ha) under drip system.

4.2.1.2 Effect of sowing method

A perusal of data in Table 4.11 indicated that seed yield was not significantly influenced due to sowing methods. Numerically higher seed yield per hectare was recorded under single row method (3008 kg/ha.) as compared

Table 4.11 Seed yield (kg/ha) of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	2743	2733	2738
I_2 : 0.8 Etc through drip system	3022	3223	3122
I_3 : 1.0 Etc through drip system	3233	3304	3268
I_4: Conventional method	1981	2048	2014
Mean	2744	2827	2786
	I	S	I × S
S. Em. ±	99	70	140
C. D. (P=0.05)	290	NS	NS
CV %	10.01		

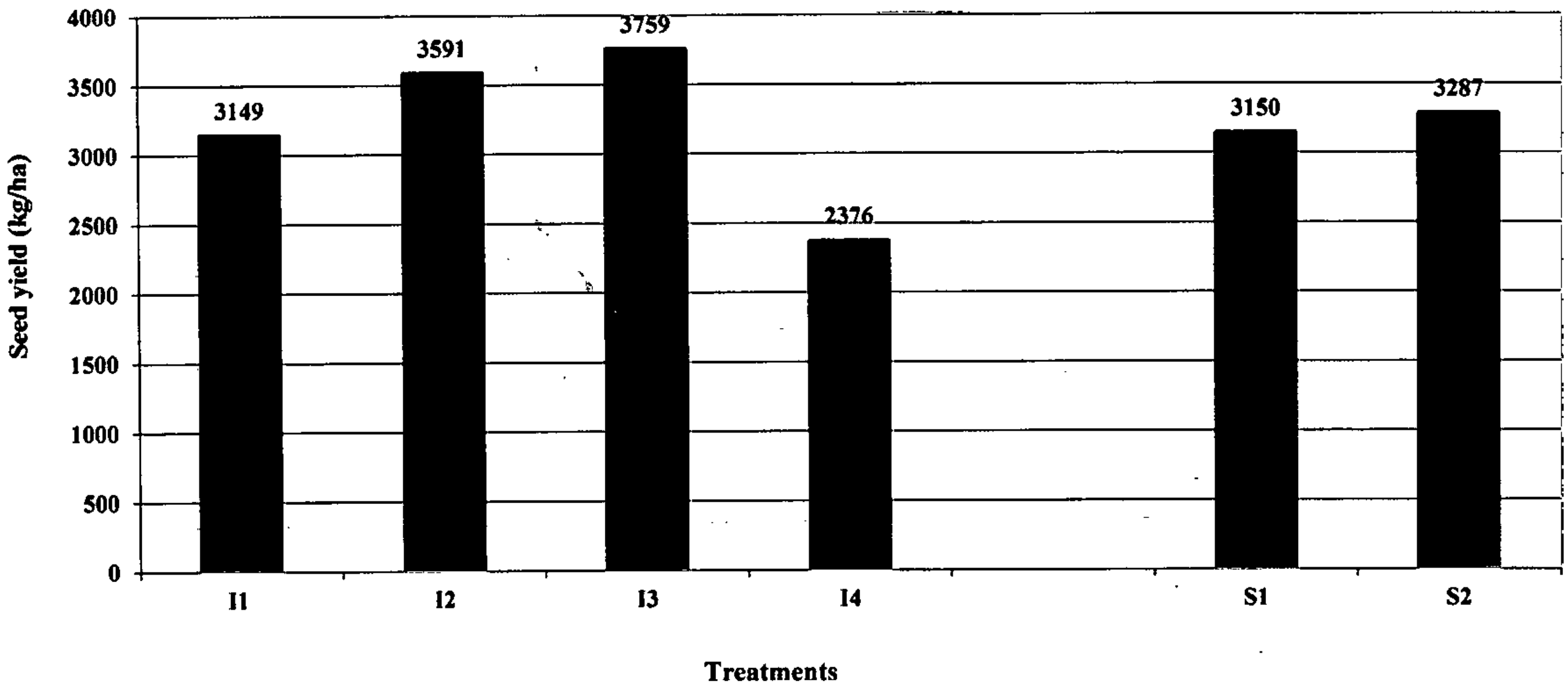


Fig. 4.5 Seed yield (kg/ha) of castor as influenced by scheduling of irrigation and sowing methods

to paired row method (2894 kg/ha.) which indicate that both the methods of sowing produced statistically similar seed yield.

4.2.1.3 Interaction effect

Data presented in Table 4.11 revealed that interaction effect between irrigation scheduling and sowing method was found non-significant with respect to seed yield per hectare.

4.2.2. STALK YIELD (kg/ha)

The stalk yields as influenced by various treatments are reported in Table 4.12 and graphically depicted in Fig. 4.6.

4.2.2.1. Effect of irrigation scheduling

The results presented in Table 4.12 revealed that stalk yield of castor was significantly influenced due to irrigation treatments. Application of irrigation at 1.0 Etc through drip system produced significantly the highest stalk yield (3759 kg/ha) which was at par with 0.8 Etc (3591 kg/ha). Though, application of water at 0.6 Etc recorded statistically similar stalk yield as produced by 0.8 Etc. Significantly the lowest stalk yield (2376 kg/ha) was obtained under conventional method of irrigation.

4.2.2.2 Effect of sowing method

Perusal of data in Table 4.12 indicated that stalk yield per hectare was not significantly affected due to different sowing methods. However, higher stalk yield (3287 kg/ha) was recorded under single row method as compared to paired row method (3150 kg/ha).

Table 4.12 Stalk yield (kg/ha) of castor as influenced by scheduling of irrigation and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	3154	3143	3149
I_2 : 0.8 Etc through drip system	3475	3706	3591
I_3 : 1.0 Etc through drip system	3717	3800	3759
I_4: Conventional method	2253	2499	2376
Mean	3150	3287	3218
	I	S	I × S
S. Em. ±	116	82	163
C. D. (P=0.05)	340	NS	NS
CV %	10.15		

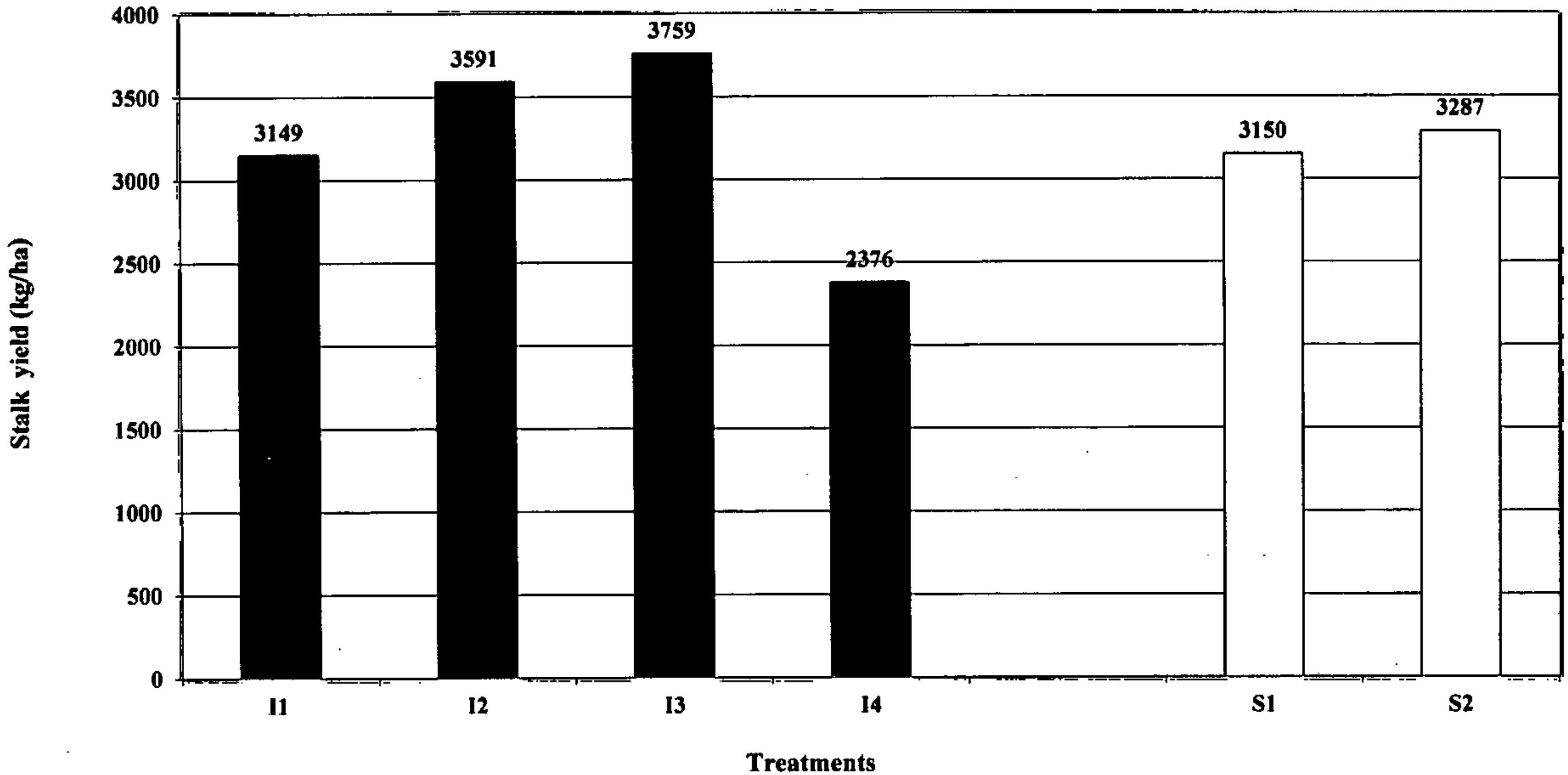


Fig. 4. 6 Stalk yield (kg/ha) of castor as influenced by scheduling of irrigation and sowing methods

4.2.2.3 Interaction effect

The data on interaction effect between irrigation scheduling and sowing methods given in Table 4.12 stated that stalk yield was not significantly influenced by combined effect of irrigation scheduling and sowing methods.

4.3 QUALITY PARAMETERS

4.3.1 OIL CONTENT

The data pertaining to effect of different irrigation scheduling and sowing methods on oil content (%) of castor are tabulated in Table 4.13 and graphically depicted in Fig 4.7.

4.3.1.1 Effect of irrigation scheduling

The results summarized in Table 4.13 indicated that oil content was not significantly influenced due levels of irrigation. Numerically the highest oil percent (49.0 %) was recorded at 1.0 Etc under drip system while the lowest was (47.6 %) recorded under conventional method of irrigation.

4.3.1.2 Effect of sowing method

The oil content in castor seed was not significantly influenced due to sowing methods. However, slightly higher oil content (48.6 %) was recorded under single row sowing as compared with paired row sowing (48.2 %).

4.3.1.3 Interaction effect

The data on interaction effect was found on significant between irrigation scheduling and sowing methods as given in Table 4.13.

Table 4.13 Oil content (%) of castor as influenced by scheduling of irrigation and sowing methods

Methods of sowing / Irrigation scheduling	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	48.1	48.4	48.3
I_2 : 0.8 Etc through drip system	48.8	48.5	48.7
I_3 : 1.0 Etc through drip system	48.5	49.6	49.0
I_4: Conventional method	47.4	47.8	47.6
Mean	48.2	48.6	48.4
	I	S	I × S
S. Em. ±	1.0	0.7	1.4
C. D. (P=0.05)	NS	NS	NS
CV %	5.84		

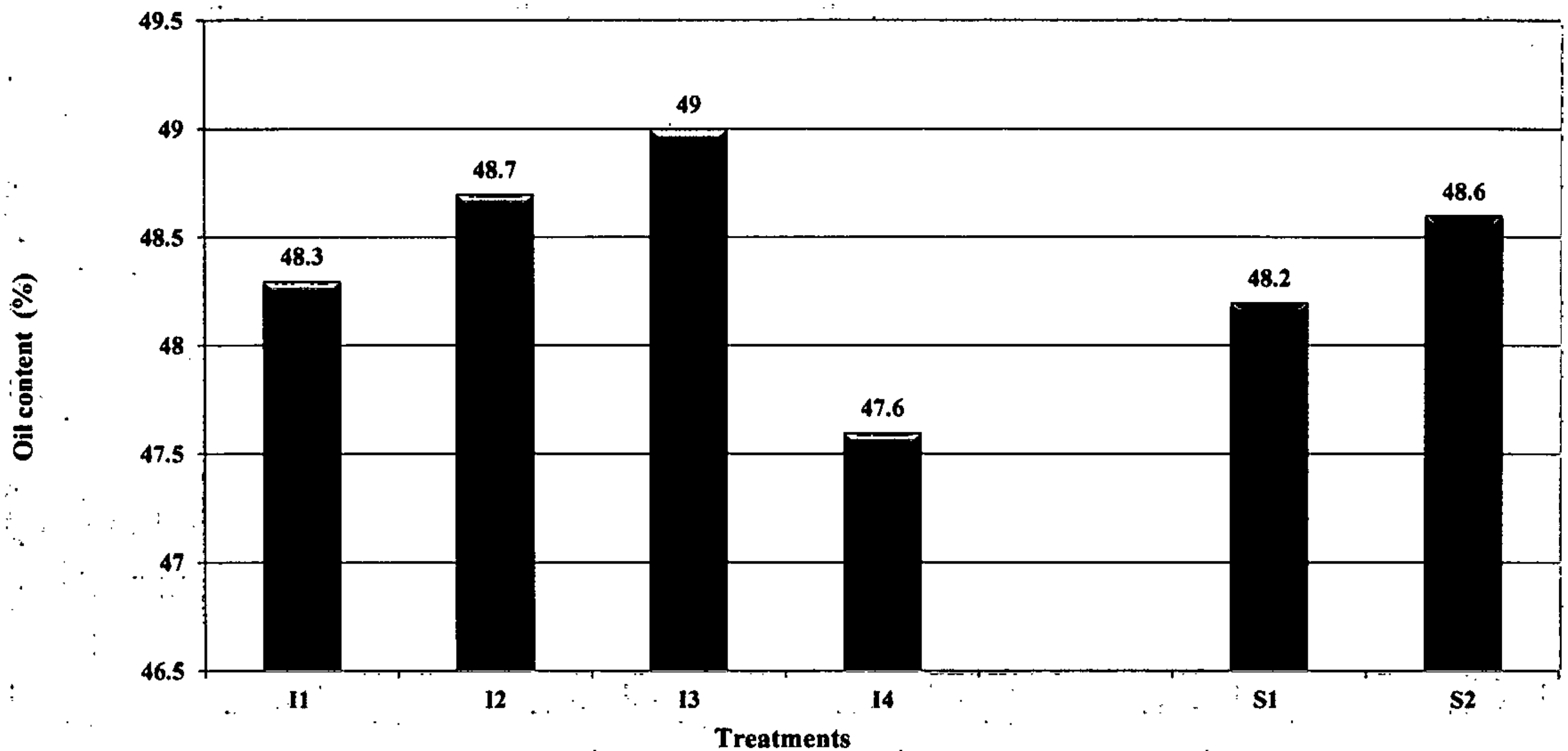


Fig. 4.7 Oil content (%) of castor as influenced by scheduling of irrigation scheduling and sowing methods

4.3.2 OIL YIELD (kg/ha)

Data under different irrigation scheduling and sowing methods on oil yield per hectare of castor are tabulated in Table 4.14andgraphically depicted in Fig 4.8.

4.3.2.1 Effect of irrigation scheduling

The results summarized in Table 4.14 indicated that oil yield increased significantly under drip method. Application of irrigation through drip method at 0.8 and 1.0 Etc produced statistically equal oil yield but significantly higher than that of 0.6 Etc under drip system. Significantly the highest oil yield (1606 kg/ha) was recorded irrigating at 1.0 Etc under drip method whereas it was the lowest (1278 kg/ha) under conventional method of irrigation.

4.3.2.2. Effect of sowing method

The perusal of data presented in Table 4.14 indicated that the oil yield was not significantly influenced due to sowing methods. Although, higher (1606 kg/ha) oil yield was observed under single row method as compared to paired row method (1329 kg/ha).

4.11.2.3 Interaction effect

Interaction was found non-significant between irrigation scheduling and sowing methods with respect to oil yield of castor.

4.4 ECONOMICS

On the basis of prevailing market prices of castor seed and stalk yields and different variable and non-variable inputs, the cost of production, gross

Table 4.14 Oil yield (kg/ha) of castor as influenced by scheduling of irrigation and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	1322	1327	1324
I_2 : 0.8 Etc through drip system	1477	1564	1521
I_3 : 1.0 Etc through drip system	1570	1642	1606
I_4: Conventional method	940	979	960
Mean	1327	1378	1353
	I	S	I × S
S. Em. ±	57	40	80
C. D. (P=0.05)	168	NS	NS
CV %	11.92		

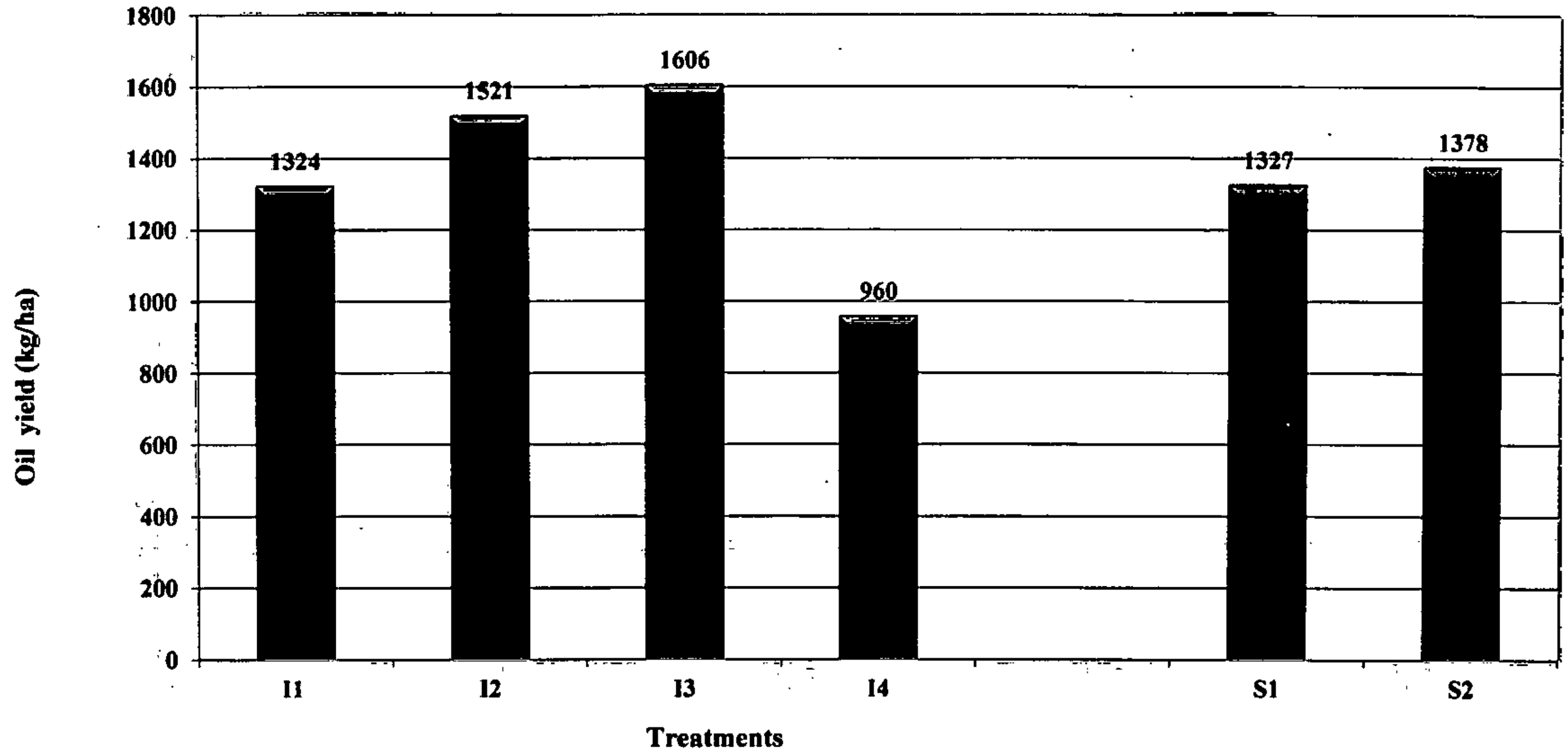


Fig. 4.8 Oil yield (kg/ha) of castor as influenced by scheduling of irrigation scheduling and sowing methods

realization, net realization along with the BCR were calculated for different treatment combinations are presented in Table 4.15 and 4.16.

The data presented in Table 4.15 showed that application of irrigation at 1.0 Etc under drip method recorded maximum net realization of 102289₹/haw ith the BCR of 3.11which was closely followed by 0.8 Etc under drip method (97508 ₹ /ha). Irrigating the crop through conventional method (surface method) recorded the least net realization of 60473₹/ha with the BCR value of 2.86.

Data presented in Table 4.15 revealed that paired row sowing of castor recorded higher net realization of 87659₹/ha with the BCR of 3.25 as compared to conventional method (surface method).

The data presented in Table 4.16 revealed that among the different treatment combinations, I_3S_1(irrigation at 1.0 Etc under drip method and paired row sowing) secured maximum net realization of 105760₹/followed by treatment combinations I_3S_2 and I_2S_1 with net realization of 98862 and98167₹ /ha, respectively. Treatment combination I_3S_1 ranked top with respect to BCR value (3.43) closely followed by I_2S_1(irrigation at 0.8 Etc under drip method and paired row sowing) with the value of (3.38).

Perusal of data presented in Table 4.17indicated that irrigation scheduling at 0.6 Etc through drip system along with paired row sowing recorded the highest net income per mm water used (417₹/mm). The lower net income per mm water was recorded with paired row or single row sowing under conventional method.

Table- 4.15 Economics of castor as influenced by individual effect of different irrigation scheduling and sowing methods

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Gross realization (₹/ha)	Total cost of cultivation (₹/ha)	Net realization (₹/ha)	BCR
Irrigation levels (I)						
I_1 - 0.6	2738	3149	126359	43978	82381	2.87
I_2 - 0.8	3122	3590	144080	46542	97538	3.09
I_3 - 1.0	3268	3759	150819	48530	102289	3.11
I_4. Surface method	2014	2376	93006	32533	60473	2.86
Sowing methods (S)						
S_1- Paired row method	2744	3150	126660	39002	87659	3.25
S_2- Single row method	2827	3287	130505	46790	83715	2.79

Table- 4.16 Economics as influenced by different treatment combinations of irrigation scheduling and sowing methods

Treatments	Seed yield (kg/ha)	Straw yield (kg/ ha)	Gross realization (₹/ha)	Total cost of cultivation (₹/ ha)	Net realization (₹/ha)	BCR
I_1S_1	2743	3154	126578	38966	87612	3.25
I_1S_2	2733	3143	126139	48990	77149	2.57
I_2S_1	3022	3475	139465	41298	98167	3.38
I_2S_2	3223	3706	148741	51785	96956	2.87
I_3S_1	3233	3717	149202	43442	105760	3.43
I_3S_2	3304	3800	152480	53618	98862	2.84
I_4S_1	1981	2253	91398	32300	59098	2.82
I_4S_2	2048	2499	94659	32765	61894	2.88

Table 4.17 Net income per mm water used of castor as influenced by scheduling of irrigation and sowing methods

Treatments	Net income (₹ /ha)	Total water applied (mm)	Net income per mm water used (₹/mm)
I_1S_1	87612	210	417
I_1S_2	77149	210	367
I_2S_1	98167	281	349
I_2S_2	96956	281	345
I_3S_1	105760	352	300
I_3S_2	98862	352	281
I_4S_1	59098	500	118
I_4S_2	61894	500	124

4.5 OTHERS

4.5.1 WATER USE EFFICIENCY

Data regarding to WUE as influenced by different treatments for irrigation scheduling and sowing methods are presented in Table 4.18 and graphically illustrated in Fig 4.9.

4.5.1.1 Effect of irrigation scheduling

Application of irrigation water through drip system recorded higher WUE as compared to conventional method. Among different treatments for scheduling of irrigation under drip system, application of water at 0.6 Etc recorded significantly the maximum value of WUE (13.0 kg/ha-mm) while the lowest value of WUE was obtained at 1.0 Etc (9.3 kg/ha-mm). Though, among all the treatments conventional method recorded minimum WUE (4.0 kg/ha-mm).

4.5.1.2 Effect of sowing methods

Data presented in Table 4.18showed that sowing methods did not exerted any significant effect on WUE. Numerically the higher (9.5 kg/ha-mm) WUE was recorded with single row method as compared to paired row method (9.2 kg/ha-mm).

4.5.1.3 Interaction effect

The combined effect of irrigation scheduling and sowing methods (I x S) was found non-significant with respect to the WUE.

Table 4.18 Water use efficiency (kg/ha-mm) of castor as influenced by scheduling of irrigation and sowing methods

Irrigation scheduling \ Methods of sowing	S_1 (Paired row method)	S_2 (Single row method)	Mean
I_1 : 0.6 Etc through drip system	13.1	13.0	13.0
I_2 : 0.8 Etc through drip system	10.8	11.5	11.1
I_3 : 1.0 Etc through drip system	9.2	9.4	9.3
I_4: Conventional method	4.0	4.1	4.0
Mean	9.2	9.5	9.4
	I	S	I × S
S. Em. ±	0.3	0.2	0.4
C. D. (P=0.05)	0.9	NS	NS
CV %	9.5		

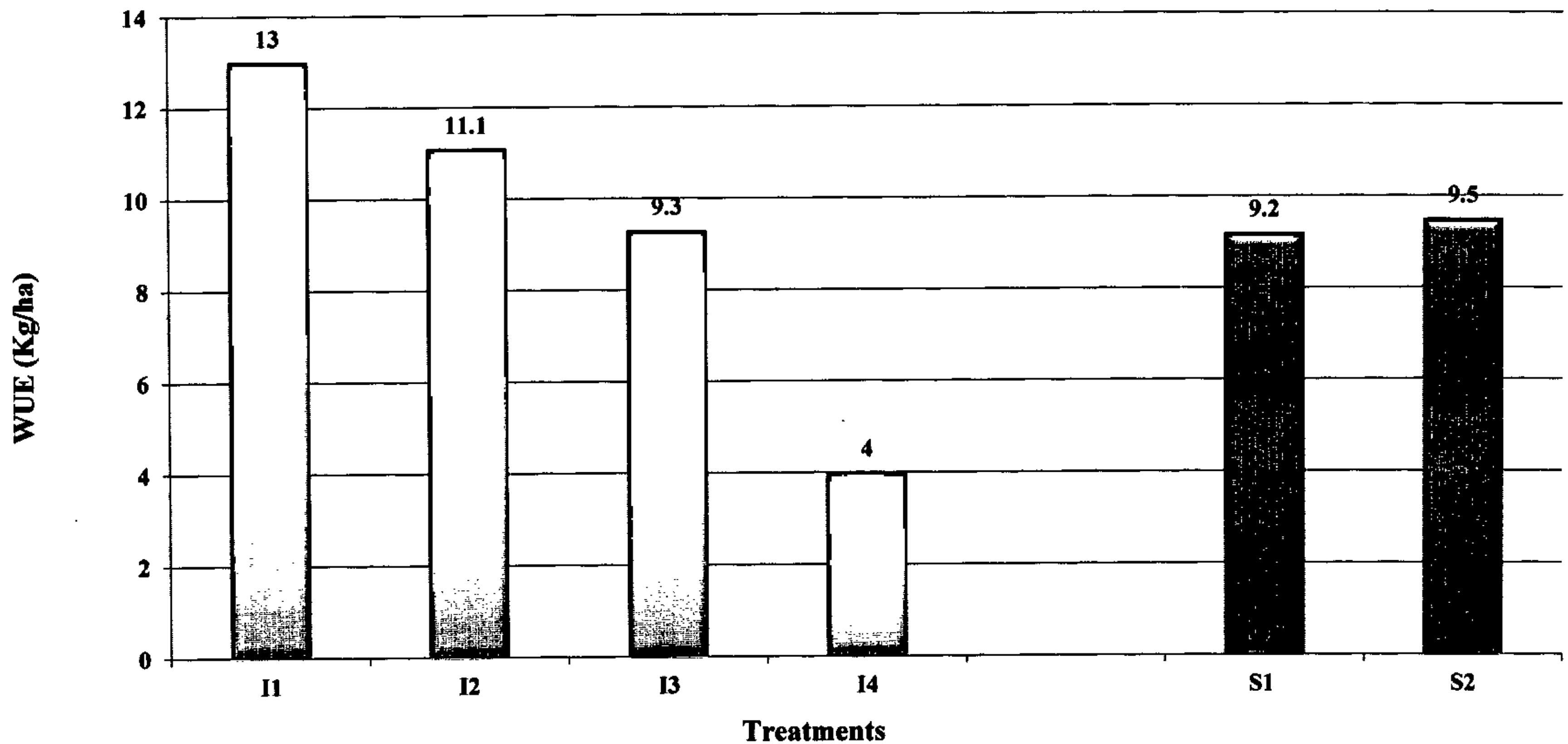


Fig. 4.9 Water use efficiency (kg/ha-mm) of castor as influenced by scheduling of irrigation and sowing methods

4.5.2 WATER SAVING (%)

Perusal of data presented in Table 4.19 with respect to water saving showed that application of water through drip system saved water from 30 to 58 per cent as compared to surface irrigation method without reducing the yield of castor in both the sowing methods. Scheduling of irrigation in drip method at 0.6 Etc saved 58 per cent irrigation water while treatment 1.0 Etc saved 30 per cent irrigation water as compared to surface method of irrigation.

Table 4.19 Water saving (%) of castor as influenced by scheduling of irrigation and sowing methods

Treatments	Water applied (mm)	Water saving (%)
I_1S_1	210	58
I_1S_2	210	58
I_2S_1	281	44
I_2S_2	281	44
I_3S_1	352	30
I_3S_2	352	30
I_4S_1	500	-
I_4S_2	500	-

Plate II. Drip irrigation method

Plate III. Surface irrigation method

PLATE IV. Irrigation to castor at 1.0 Etc with paired row sowing through drip system

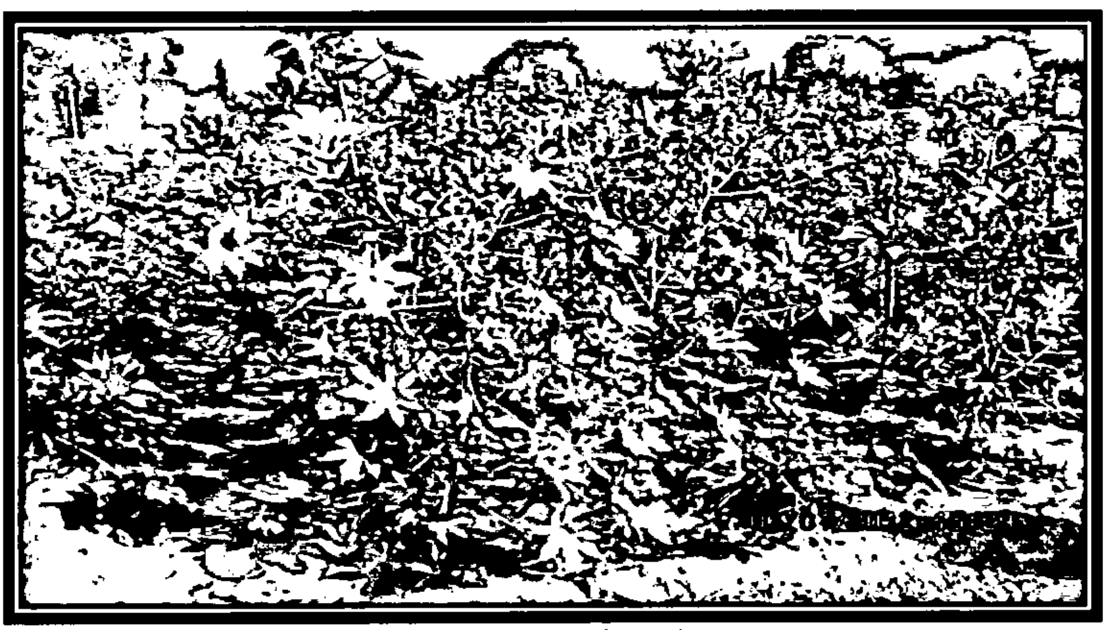


PLATE V. Irrigation to castor under surface method with single row sowing

PLATE VI. Irrigation to castor at 1.0 Etc with paired row sowing through drip system

PLATE VII. Irrigation to castor at 0.8 Etc with paired row sowing through drip system

DISCUSSION

V.DISCUSSION

The results reported in previous chapter concerning to the investigation carried out on "Evapotranspiration based scheduling of irrigation through drip system for castor crop (*Ricinus communis* L.)" showed many significant variations in biometric observations of castor under the influence of different treatments. In this chapter an attempt has been made to establish "effect and cause relationship" in the light of available evidences and available literature. Possible explanations are given for the variations observed and supported by relevant findings. For the sake of convenience, the results presented in the preceding chapter are discussed under following heads.

5. 1 EFFECT OF WEATHER ON CROP

5.2 EFFECT OF IRRIGATION SCHEDULING

5.3 EFFECT OF SOWING METHODS

5.4 INTERACTION EFFECT

5.5 ECONOMICS

5. 1 EFFECT OF WEATHER ON CROP

The crop responses are mainly governed by soil, available soil moisture and condition of certain weather parameters during growth and development.

During the period of investigation, meteorological data (Table 3.1) was favourable for normal growth and development of crop. It was observed that minimum temperature ranged between 4.6 to 23.8 ^{0}C, while maximum temperature was between 23.8 to 40.4 ^{0}C during the course of investigation. The average relative humidity and sunshine hours were optimum during the period of investigation. The rainfall was sufficient for better germination and crop growth (Table 3.1). Thus, the crop season was normal for growth and development of *kharif* castor. Likewise, no incidence of disease and pests were observed during crop growth period. Hence, whatever variations observed for different characters under the study were mainly attributed to different treatments imposed in this experiment.

5.2 EFFECT OF IRRIGATION SCHEDULING

Plant population per hectare at 30 DAS and at harvest of crop was not influenced significantly due to irrigation scheduling (Table 4.1 and 4.2). It is ascertained from the data that plant population in all the treatments was uniform due to timely and sufficient rainfall (Table 3.1) received at the time of sowing exerted better germination and consequently resulted into satisfactory plant population.

Plant height measured at first picking (Table 4.3) was significantly affected due to levels of irrigation. Drip irrigation proved better than conventional method of irrigation (surface method) with respect to plant height. Significantly maximum plant height (84.6 cm) was recorded with 1.0 Etc and was at par with 0.8 Etc under drip method (76.7 cm). Significantly the lowest plant height was obtained under conventional method. The magnitude of increase in plant height at Ist picking under 1.0, 0.8 and 0.6 Etc through drip system was to the tune of 23.9, 16.08 and 11.61 per cent respectively as compared to conventional method. Similar results were also reported by Firake *et al.* (1998), Nalayini *et al.* (2006), Manjunatha *et al.* (2010) and Bhalerao *et al.* (2011).

Similarly, maximum number of branches per plant (Table 4.4) was recorded under 1.0 Etc (I_3) but was at par with 0.8 Etc. The increase in number of branches under treatments 1.0, 0.8, and 0.6 Etc under drip system was to the extent of 34.15, 31.65 and 5.26 per cent respectively as compared to I_4 (conventional method). The values of number of branches per plant increased significantly with increasing levels of irrigation under drip irrigation system. The plant growth was higher under drip irrigation system and it turned into maximum value of branches per plant. The results of number of branches per plant are in close vicinity with findings of Firake *et al.* (1998), and Manjunatha *et al.* (2010).

Values of growth characters *viz.* plant height and number of primary branches per plant were higher under drip system might be due to frequent and consistent application of water in the vicinity of root zone increased the availability of water which provided better crop growth. In conventional method the irrigation interval was long due to which crop was suffered from moisture stress and plant growth was decreased. The results are in accordance with the research of Firake *et al.* (1998), Nalayini *et al.* (2006), Manjunatha *et al.* (2010) and Bhalerao *et al.* (2011).

Significant difference was observed in case of number of spikes per plant due to different levels for scheduling of irrigation (Table 4.5). Irrigating at 1.0 Etc under drip system recorded maximum number of spikes per plant

(8.8) which was at par with 0.8 Etc (8.1). Conventional method of irrigation (surface irrigation) recorded significantly the lowest number of spikes per plant (6.9) but was at par with 0.6 Etc under drip method. Irrigating the crop at 1.0 and 0.8 Etc increased number of spikes per plant to the extent of 21.59 and 14.81 percent respectively over conventional method. Drip method proved better with respect to producing number of spikes per plant might be due to frequent and continuous wetting of root zone which provided better growth and development of plant. The results are in accordance with Firake *et al.* (1998).

Similarly, maximum number of capsules per main spike (Table 4.6) was recorded by irrigating at 1.0 Etc under drip system (67.6) but was statistically at par with treatment 0.8 Etc (61.3). Irrigating crop through conventional method (I_4) recorded significantly the lower number of capsules per main spike (51.8) but at par with 0.6 Etc (58.2). The magnitude of increase in number of capsules per main spike under 1.0 and 0.8 Etc was to the tune of 23.17 and 15.5 per cent, respectively over conventional method (I_4). Better availability of soil moisture at frequent interval under drip system throughout the crop growth period favoured higher growth and development of plant due to which number of capsules per main spike were increased with the increase in level of irrigation. While in conventional method plant growth was slow due to unsteady supply of moisture consequently recorded minimum number of capsules per main spike. The results are in accordance with results reported by Firake *et al.* (1998).

Length of main spike was maximum with irrigating at 1.0 Etc under drip system (73.1cm) but was statistically at par with treatment 0.8 Etc (66.2 cm) (Table 4.7). Irrigating crop through conventional method (I_4) recorded significantly the lowest length of main spike (55.9 cm) as compared to drip irrigation treatments except 0.6 Etc (62.9 cm). The magnitude of increase in length of main spike under treatments 1.0 and 0.8 Etc was to the tune of 24 and 16 per cent over conventional method (I_4), respectively. This might be due to better availability of soil moisture under drip system throughout the crop growth period favoured more development of main spike.

Number of nodes up to main receme (Table 4.8) was recorded by 1.0 Etc under drip system (28.5) which was statistically at par with treatment 0.8 Etc (27.2). Irrigating crop through conventional method (I_4) recorded significantly the lowest number of nodes up to main receme (18.8) but at par with 0.6 Etc (19.8). The magnitude of increase in number of nodes up to main receme under 1.0 and 0.8 Etc was to the tune of 34 and 31 per cent over conventional method (I_4), respectively. The number of nodes increased with increased level of irrigation under drip system. The enhanced plant growth under drip system turned into maximum number of nodes to main receme.

The results summarized in Table 4.9 indicated that 100 seed weight of castor was significantly affected due to levels of irrigation. The highest 100 seed weight was observed with treatment 1.0 Etc (32.3 g) but statistically at par with 0.8 Etc (29.5 g) under drip irrigation system. The lowest 100 seed weight was recorded under conventional method of irrigation (25.4 g) which was statistically at par with 0.6 Etc through drip system (28.1g). The 100 seed weight under 1.0 and 0.8 Etc under drip system were higher to the extent of 21.36 and 13.89 per cent as compared to conventional method (I_4), respectively. Sufficient availability of water in I_3 treatment under drip enhanced nutrient absorption from the soil ultimately more growth of plant observed which turned into bold size of seed of castor with heavy seed weight. Similar results were also recorded by Firake *et al.* (1998).

The results (Table 4.10) revealed that different levels of irrigation significantly increased seed yield per plant of castor. Significantly highest (169.2 g) seed yield per plant was recorded when irrigation water was applied through drip system at 1.0 Etc. This treatment was statistically at par with 0.8 Etc. through drip system (153.5 g). Irrigating the castor crop under conventional method of irrigation recorded the lowest (130.4 g) seed yield per plant. The increase in seed yield per plant under treatments 1.0,0.8 and 0.6were to the extent of 22.9, 15.0 and 10.4per cent as compared to I_4 (conventional method). Similar results for seed yield per plant were recorded by Firake *et al.* (1998), Sagarka *et al.* (2002) and Bhalerao *et al.* (2011).

Higher values of growth and yield attributing characters under drip system over conventional method of irrigation might be due to more availability of moisture and nutrients resulted into higher growth and development of crop plants. At higher level of irrigation (1.0 and 0.8 Etc) for scheduling of irrigation under drip system recorded higher values of growth and yield attributing characters might be due to better growth and development under these treatments turned into higher yield attributing characters by assimilating higher photosynthesis resulting in more pertaining of dry matter to these characters.

Seed yield (kg/ha) of castor crop was significantly influenced due to scheduling of irrigation (Table 4.11). Application of irrigation water through drip method proved better than conventional method with respect to producing higher seed yield. Irrigating crop at 1.0 (3268 kg/ha) and 0.8 Etc (3122kg/ha) under drip method produced statistically equal yield but these both the treatments recorded significantly higher seed yield than 0.6 Etc (2738 kg/ha) and conventional method (2014 kg/ha). The increase in seed yield under treatments 1.0 and 0.8 Etc were to the tune of 38 and 35 per cent, respectively as compared to conventional method. Though, irrigating at 0.6 Etc through drip system produced 26 per cent higher seed yield than conventional method but difference was not remarkable. Higher seed yield under drip might be due to higher values of all the yield attributing characters in drip method. Enhancement in growth and yield attributing characters under treatments of irrigating at 1.0 and 0.8 Etc turned into higher yield with these treatments under drip method is a probable reason for higher seed yield. These findings were collaborate with those of Firake *et al.* (1998), Maliwal *et al.* (1999), Sagarka *et al.* (2002), Patil *et al.* (2004), Manjunatha *et al.* (2010) Nalayini *et al.* (2006), Bhalerao *et al.* (2011) and Mahalaxmi *et al.* (2011).

Significantly the highest value of stalk yield (3759 kg/ha) was observed under treatment 1.0 Etc under drip system which was at par with treatment 0.8

Etc (3591 kg/ha) (Table 4.12). Favorable effect on growth characters by better moisture availability under drip system is responsible for higher stalk yield as compared to conventional method of irrigation.

The results summarized in Table 4.13 indicated that oil content was not significantly influenced due to irrigation treatments. Numerically the highest (49.0 %) oil percent was recorded at 1.0 Etc under drip system while the lowest (47.6 %) oil percent was recorded under conventional method of irrigation. The data in respect of quality as judged by oil content in seed of castor indicated that oil content was not affected due to irrigation treatments as it is a genetical character of variety.

The increase in oil yield under treatments 1.0 and 0.8 Etc under drip system was to the tune of 40.22 and 36.88per cent, respectively than that of conventional method (Table 4.14). The oil yield increased with irrigating up to 0.8 Etc which is the function of oil content and seed yield. The drop in oil yield by 17.55 and 12.95 per cent under treatment 0.6 Etc as compared to 1.0 Etcand0.8 Etc was due to considerable drop in seed yield under these treatments. Similar results were also reported by Firake *et al.* (1998) and Bhalerao *et al.* (2011).

Perusal of data presented in Table 4.15 indicated that irrigation scheduling brought out significant influence on WUE of castor. Treatment I_1 (0.6 Etc through drip system) recorded significantly the highest WUE (13kg/ha-mm). The lowest WUE (4.0kg/ha-mm) was recorded under I_4 treatment (conventional method).This might be due to more with less amount of irrigation water under 0.6 Etc treatment. Seed yield of castor produced favourable effects of water on crop growth and ultimately seed yield per hectare which in turn resulted in substantial higher water use efficiency. These are in accordance with findings of Firake *et al.* (1998), Manjunatha *et al.* (2010), Nalayini *et al.* (2006) and Bhalerao *et al.* (2011).

Perusal of data presented in Table 4.19 regarding water saving indicated that irrigation at 0.6 Etc through drip system recorded the highest water saving (58 %) followed by 0.8 Etc (43 %) as compared to conventional method. It might be due to less water applied in these treatments as compared to conventional method. A loss of irrigation water through leaching or seepage can be eliminated in drip system and water applied in root zone in less quantity as compared to ET might be probable reason for higher water saving. The findings are according to finding suggested by Sagarka *et al.* (2002), Nalayini *et al.* (2006), Manjunatha *et al.* (2010) and Bhalerao *et al.* (2011).

5.3 EFFECT OF SOWING METHODS

Plant population at 30 DAS and at harvest was not influenced due to sowing methods. It might be due to equal plant population maintained in both the sowing methods.

Growth characters *viz.* plant height at Ist picking (Table 4.3) and number of primary branches (Table 4.4) were not significantly affected due to methods of sowing. Through, single row method of sowing recorded higher values of these characters as compared to paired row method. This might be due to optimum space available for better growth and development of plants.

Similarly yield and yield attributing characters *viz.* number of primary branches (Table 4.4)number of capsules per main spike(Table 4.6), number of spikes per plant (Table 4.5), length of main spike (Table 4.7), test weight (Table 4.9), seed yield per plant (Table 4.10) and seed and stalk yield (Table 4.11 and 4.12) not affected non-significantly due to methods of sowing. Sowing of castor either as paired row or single row method exerted not remarkable effects on all these characters. This might be due to similar growth and development of plants in both the methods of sowing. Though, single row method recorded numerically higher seed and stalk yield as compared to paired row system. Similar findings were also observes by (Anonymous, 1998), Patel *et al.* (2003), Kalibavi *et al.* (2006) Porwal *et al.* (2006) Desai *et al.* (2010) Manjunatha *et al.* (Zote *et al.* 2011).

The quality in terms of oil content is presented in Table 4.13 was not significantly influenced by sowing methods as it a genetical character of variety.

Sowing methods did not exert any significant effect on water use efficiency. Equal quantity of water either through drip system or in conventional method was given during experimental period in both the methods of sowing under different scheduling of irrigation. Similar results were found by Manjunatha *et al.* (2010).

5.4 INTERACTION EFFECT

Interaction effect of irrigation scheduling and sowing methods on plant population, growth characters, yield attributes, yield, quality parameters and water use efficiency were found non-significant.

5.5 ECONOMICS

The data presented in Table 4.15 showed that application of irrigation at 1.0 Etc through drip system recorded maximum net income of ₹102289/ha with the BCR of 3.11which was closely followed by treatment 0.8 Etc. Minimum net realization of ₹60473/ha and BCR of 2.86 was recorded when crop was irrigated through surface method. Sowing of castor crop as a paired row system recorded higher net realization of ₹ 87659/ha and BCR of 3.25 as compared to single row sowing.

Among the different treatment combinations, (Table 4.16) application of irrigation water at 1.0 Etc with paired row sowing (I_3S_1) recorded the highest net realization of ₹ 105760/ha and BCR 3.43 closely followed byI_3S_2 (₹ 98862/ha) and I_3S_1 (₹ 98167/ha).These findings are in accordance with Patel *et al.* (2004) and Manjunatha *et al.* (2010).

Higher net realization under treatment 1.0 Etc either with paired row or single row sowing might be due to higher seed yield obtained with these treatments. Paired row sowing of castor with drip system gave higher net realization as the lateral line of drip system reduced paired rows as compared to single line of crop, which saved the cost of drip system.

SUMMARY AND CONCLUSION

VI. SUMMARY AND CONCLUSION

An experiment entitled "Evapotranspiration based scheduling of irrigation through drip system for castor crop (*Ricinus communis* L.)" conducted at Agronomy Instructional farm, Chimanbhai Patel college of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District : Banaskantha (North Gujarat) during *kharif* season of 2011-12.The experiment consisted of eight treatment combinations comprised four levels of irrigation (0.6 Etc, 0.8 Etc and 1.0 Etc through drip system and conventional method) and two sowing methods (Paired row and single row sowing). The field experiment was laid out in randomized block design with factorial concept with four replications.

The research findings emerged out from the present investigation are summarized here under.

6.1 EFFECT OF IRRIGATION SCHEDULING

6.2 EFFECT OF SOWING METHODS

6.3 ECONOMICS

6.1 EFFECT OF IRRIGATION SCHEDULING

- Plant population of castor recorded at 30 DAS and at harvest was not influenced significantly due to different level of irrigation.
- Application of irrigation water at 1.0 Etc recorded significantly tallest plant when measured at Ist picking which was at par with irrigated at 0.8 Etc through drip system.

- Number of branches per plant (8.2), number of spikes per plant (8.8), number of capsules per main spike (67.6), number of nodes to main receme (28.5) and test weight (32.3 g) were significantly the highest under application of irrigation at 1.0 Etc through drip system except treatment of irrigation at 0.8 Etc. Irrigating crop as surface method recorded the lowest values of all these characters during study.
- Irrigating the crop at 1.0 Etc under drip irrigation system recorded highest seed yield per plant (169.2 g) but was at par with treatment 0.8 Etc (153.5 g) in this respect.
- Application of irrigation water through drip system at 1.0 Etc recorded significantly highest seed yield (3268kg/ha) and stalk yield (3959 kg/ha) but was statistically at par with treatment 0.8 Etc in respect of seed yield (3122 kg/ha) and stalk yield (3591 kg/ha).
- Though, oil content was not affected significantly due to irrigation treatments. However, the highest oil yield (1606 kg/ha) was obtained when crop was irrigated through drip system at 1.0 Etc but was at par with treatment 0.8 Etc (1521 kg/ha) in this respect.
- The water use efficiency was significantly higher under treatment under 1.0 Etc (13.0 kg/ha-mm) and being at par with treatment 0.8 Etc (11.1 kg/ha-mm) with respect to water use efficiency. Maximum water saving (58%) was recorded with treatment 0.6 Etc as compared to surface method of irrigation.

6.2 EFFECT OF SOWING METHODS

- Plant population at 30 DAS and at harvest was not influenced due to sowing methods. It might be due to equal plant population maintained in both the sowing methods.
- Growth characters *viz.* plant height at I[st] picking and number of branches per plant were not significantly affected due to methods of sowing. Through single row method of sowing recorded higher values of these characters as compared to paired row method.
- Similarly yield and yield attributing characters *viz.* number of capsules per main spike, number of spikes per plant, length of main spike, test weight, seed yield per plant and seed and stalk yield hectare were not affected significantly due to methods of sowing. Sowing of castor either as paired row system or single row system recorded nearly equal values of these characters.
- The quality of castor seed in terms of oil content and oil yield were significantly not influenced by sowing methods.
- Sowing methods did not exert any significant effect on water use efficiency.

6.3 ECONOMICS

- Maximum net realization of 102289 ₹ /ha and BCR value of 3.11was registered with irrigating at 1.0 Etc under drip irrigation system. Sowing of castor as paired row system recorded higher net realization (₹87659/ha) and BCR (3.25) than that of conventional method of irrigation.

❖ Irrigating crop through drip system at 1.0 Etc in case of paired row sowing (I_3S_1) recorded maximum net realization (₹105760/ha) and BCR (3.43) which was closely followed by as single row sowing with same level of irrigation.

❖ Irrigation scheduling at 0.6 Etc through drip system under paired row sowing recorded the highest net income per mm water used (417 ₹ /mm). The lowest net income per mm water used (121₹/mm) was recorded either paired row or single row sowing under conventional method of irrigation.

CONCLUSION

From the results of the one year experimentation it can be concluded that under adequate supply of water, castor crop should be shown in paired row system (135-60 cm × 45 cm) with scheduling irrigation at 1.0 Etc adopting drip method of irrigation for securing higher seed yield and net realization as well as obtaining 30 per cent water saving as compared to surface irrigation (conventional method).

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APPENDICES

Appendix-I

Analysis of variance for plant population, plant height (cm) and primary branches per plant

Source of variation	DF	M.S.S.			
		Plant population		Plant height (cm)	Number of primary branches per plant
		At 30 DAS	Harvest		Mean
Replication	3	1998587	3.0	1.8	0.3
Irrigation (I)	3	1988381	3.0	538.8*	16.5*
Sowing methods (s)	1	74436.8	4.3	162.8	1.0*
I x S	3	16.3	3.0	2.3	0.2
Error	31	2763071	3.0	78.1	0.2

*Significant at 5 per cent level of probability.

Appendix-II

Analysis of variance for plant population, plant height (cm) and primary branches per plant

Source of variation	DF	M.S.S.		
		Number of spikes per plant	Number of capsule per main spike	Length of main spike (cm)
Replication	3	0.0	1.6	3.5
Irrigation (I)	3	5.3*	350.0*	196.1*
Sowing methods (s)	1	2.4	100.7	12.4*
I x S	3	0.0	1.9	2.6
Error	31	0.9	49.7	2.8

*Significant at 5 per cent level of probability.

Appendix-III

Analysis of variance for 100 seed weight (g), Seed yield per plant (g) and Seed yield (kg/ha)

Source of variation	DF	M.S.S.		
		100 seed weight (g)	Seed yield per plant (g)	Seed yield (kg/ha)
Replication	3	0.1	3.3	23032
Irrigation (I)	3	65.4*	2090.8	2516824
Sowing methods (s)	1	23.2	698.2	54632
I x S	3	0.2	4.9	15219
Error	31	10.1	318.1	77887

*Significant at 5 per cent level of probability.

Appendix-IV

Analysis of variance for stalk yield (kg/ha) and oil content (%)

Source of variation	DF	M.S.S.	
		Stalk yield (kg/ha)	Oil content (%)
Replication	3	27482	7.8
Irrigation (I)	3	3054587	3.2
Sowing methods (s)	1	150637	1.0
I x S	3	30267	0.6
Error	31	106810	8.0

*Significant at 5 per cent level of probability.

Appendix-V

Analysis of variance for oil yield (kg/ha) and water use efficiency (kg/ha-mm)

Source of variation	DF	M.S.S.	
		Oil yield (kg/ha)	WUE (Kg/ha)
Replication	3	27482	7.8
Irrigation (I)	3	3054587	3.2
Sowing methods (s)	1	150637	1.0
I x S	3	30267	0.6
Error	31	106810	8.0

*Significant at 5 per cent level of probability.

Appendix -VI

Total cost of cultivation of castor and other details of cost incurred

Sr. No.	Particulars	Pair of bullock	Labor	frequency	Fixed cost	
					Conventional method	Drip
1	Field preparation with tractor (6 hrs)	-	-	2	1800	1800
2	Sowing	-	25	1	2500	2500
3	Seed	-	-	1	600	600
4	Interculturing	3	1/1	3/2	1500	1000
5	Weeding		10/5	3/3	3000	1500
	Total cost :-				9400	7400

- Field preparation @ 300 Rs. hr^{-1};
- Labour charges @ Rs. 100 day $labour^{-1}$;
- Cost of seed @ Rs 100 kg^{-1};
- Bullock charges 400/day

Appendix -VII

Economics of different treatments

Sr. No	Treatment combinations	Seed yield (kg/ha)	Stalk yield (kg/ha)	Gross realization (₹/ha)	Fixed cost (Drip) (₹/ha)	Common cost (₹/ha)	Irrigation cost (₹/ha)	Fertilizer cost (₹/ha)	Harvest cost (₹/ha)	Total cost of cultivation (₹/ha)	Net return (₹/ha)	B : C Ratio
T_1	I_1S_1	2743	3154	126578	15000	7400	4830	5122	6614	38966	87612	3.25
T_2	I_1S_2	2733	3143	126139	25000	7400	4830	5122	6638	48990	77149	2.57
T_3	I_2S_1	3022	3475	139465	15000	7400	6463	5122	7313	41298	98167	3.38
T_4	I_2S_2	3223	3706	148741	25000	7400	6463	5122	7800	51785	96956	2.87
T_5	I_3S_1	3233	3717	149202	15000	7400	8096	5122	7824	43442	105760	3.43
T_6	I_3S_2	3304	3800	152480	25000	7400	8096	5122	8000	53618	98862	2.84
T_7	I_4S_1	1981	2253	91398	-	9400	12500	5122	5278	32300	59098	2.82
T_8	I_4S_2	2048	2499	94659	-	9400	12500	5122	5743	32765	61894	2.88

Note : Selling price (₹/kg) Seed : 45.00 Stalk : 1.00

Input price (₹/kg)

CERTIFICATE

This is to certify that, I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference service in a library or documentation center.

Place : SARDARKRUSHINAGAR
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[SHIVPRAKASH]