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Maximizing Water and Fertilizer Use Efficiencies under Drip Irrigation in Chili Crop

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Abstract
Field experiments were conducted at Agricultural Research Station, Bhavanisagar during 2007 and 2008 to maximize the water and fertilizer use efficiencies in Chili crop. The experiments were laid out in factorial randomized block design with nine treatments which included three irrigation levels 100, 75 and 50 per cent of PE along with three fertigation levels *viz.* 125, 100 and 75 per cent of recommended N and K fertigation through drip irrigation and replicated thrice. In chili, the highest yield was observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N & K with maximum shoot length and higher number of branches during I and II crops. The highest nitrogen and potassium use efficiency were observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N & K in both I and II crops with maximum benefit-cost ratio of 3.2 and 2.8 during I and II crops respectively.

Keywords: Drip fertigation, Water use efficiency, Fertilizer use efficiency

Introduction

The available water resource of Tamil Nadu is only 3.0 per cent of the country. The average rainfall in Tamil Nadu is 958.5 mm (India Meteorological Department, Chennai) as against the average rainfall of 1200.0 mm (The pulse of Indian agriculture, 2008) in the country. Water is the vital source for crop production and is the most limiting factor in Indian agricultural scenario. Though India has the largest irrigation network, the irrigation efficiency has not been achieved more than 40 per cent. Also, the per capita water availability, in terms of average utilizable water resources in the country, has dropped from 6008.0 m^3 in 1947 to 1250.0 m^3 now and is expected to dwindle down to 760.0 m^3 (Singh, 2006). There are 140.0 m-ha of arable land in India in which 41.2 m-ha are being irrigated (Ramah, 2008).

Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. The need of the hour is, therefore, to maximize the production per unit of water. Hence, further expansion of irrigation may depend upon the adoption of new systems such as pressurized irrigation methods with the limited water resources. Amongst those pressurized irrigation methods, drip irrigation has proved its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of root zone.

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In India, the potential for the drip irrigation system is estimated to be 21.27 m-ha (Narayanamoorthy, 2008). Water saving from drip irrigation system varied from 12 to 84 percentage for different crops besides increasing the production of crops. Maharastra and Tamil Nadu are the leading states using drip irrigation system in India (Ramah, 2008).

Vegetable production in Indian agricultural scenario has wider scope for increasing the income of the marginal and small farmers. Vegetables have vast potential in foreign exchange by the export of value added food commodities. India is the second largest vegetable producer next to China, with an estimated production of about 50.09 m-t from an area of 4.5 m-ha at an average production of 11.3 t ha^{-1}. India shares about 12 per cent of the world output of vegetables from about 2.0 per cent of cropped area in the country (Sidhu, 2008). To be more competitive in today's market of vegetables, the vegetable growers are looking for new ways to achieve superior quality produce with higher yields than the conventional methods. Presently, the vegetable crop production suffers mainly on the availability of water and nutrients. The water and fertilizer use efficiency through drip fertigation method can be maximized by the improved techniques introduced.

The field experiments were conducted at Agricultural Research Station, Bhavanisagar, Erode, Tamil Nadu during 2007 and 2008. The field is located at $11^0\ 29^{/}$ N latitude, $77^0\ 08^{/}$ E longitude with an altitude of 256 m above MSL. The mean annual rainfall is 696 mm, mean temperature is 27.5 ˚C. The soil of the experimental area belongs to sandy loam in texture. The physical properties of soil and irrigation water are given in Table 1.

Design and treatments

The experiment was laid out in a Factorial Randomized Block Design with nine treatments which included two factors such as irrigation level and fertigation level and replicated thrice.

Factor I. Irrigation levels

I_1 - Drip irrigation at 100 percentage of PE
I_2 - Drip irrigation at 75 percentage of PE
I_3 - Drip irrigation at 50 percentage of PE

Factor II. Fertigation levels

F_1 - Fertigation at 125 percentage of recommended N and K
F_2 - Fertigation at 100 percentage of recommended N and K
F_3 - Fertigation at 75 percentage of recommended N and K

Irrigation scheduling

The daily pan evaporation data was used for scheduling irrigation and irrigations were given once in three days interval through drip irrigation system.

Lateral Spacing	= 1.5 m
Emitter Spacing	= 0.6 m
Area coverage per emitter	= 0.6x1.5 = 0.9 m^2
Emitter Capacity	= 4 lph
Depth of irrigation (discharge ÷ area)	$= \frac{4}{1000} \times \frac{1}{0.9} \times 1000$ = 4.4 mm hr^{-1}

Fertigation scheduling

The fertigation was given at weekly intervals. The entire phosphorus was applied as basal and N and K were applied through fertigation with fifteen equal splits from 3rd week to 17th week after planting. The recommended N, P and K for chilli is given in Table. 2.

Planting

Healthy seedlings were planted in paired row geometry at 70 x 60 cm spacing.

First season - 06.07.2007 to 28.12.2007

Second season - 22.06.2008 to 22.12.2008

Effect of irrigation and fertigation levels on biometric parameters

The biometric observations such as shoot length and number of branches of chilli for I and II crops are graphically represented in Fig. 1 and 2. Shoot length and number of branches were significantly influenced by irrigation and fertigation levels in chili. During I crop, the highest shoot length of 37.57, 66.67, 93.63 and 108.83 cm at 30, 60, 90 and 120 DAP respectively and maximum number of branches of 5.17, 9.67, 13.93 and 15.83 at 30, 60, 90 and 120 DAP respectively were recorded in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K. This might be due to optimum availability of nutrients and moisture which improved the growth characters of chili.

The least shoot length of 31.3, 54.2, 84.23 and 100.90 cm at 30, 60, 90 and 120 DAP respectively and minimum number of branches of 2.60, 6.27, 7.87 and 9.47 at 30, 60, 90 and 120 DAP respectively were observed in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K. It might be due to higher irrigation with lower fertigation level which resulted in poor growth characters in chilli. A similar trend was observed during II crop also.

Effect of irrigation and fertigation levels on the yield

Among three irrigation levels tried, drip irrigation at 75 per cent of pan evaporation registered the maximum yield (11.56 t ha^{-1} in I crop and 10.25 t ha^{-1} in II crop) compared to drip irrigation at 100 per cent (7.78 t ha^{-1} in I crop and 6.79 t ha^{-1} in II crop) and drip irrigation at 50 per cent of pan evaporation (9.49 t ha^{-1} in I crop and 8.86 t ha^{-1} in II crop). This might be due to the optimum irrigation water used. Drip irrigation at 100 per cent PE was excess and drip irrigation at 50 per cent of pan evaporation was deficit application of water which reduced the yield of the crop.

In case of three fertigation levels tried, the highest yield of 9.81 t ha^{-1} in I crop and 8.89 t ha^{-1} in II crop were observed in fertigation at 75 per cent recommended N and K compared to fertigation at 125 per cent recommended N and K (9.49 t ha^{-1} in I crop and 8.54 t ha^{-1} in II crop) and fertigation at 100 per cent recommended N and K (9.52 t ha^{-1} in I crop and 8.48 t ha^{-1} in II crop). The reason for the highest yield might be due to optimum application of fertilizer required by the crop.

The yield recorded in I and II crops are presented in Table 3. The data presented in table clearly shows that the maximum yield (12.29 t ha^{-1}) was observed in treatment drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K and minimum yield (7.43 t ha^{-1}) was noted in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K. The increase in yield was mainly due to optimal irrigation and fertigation levels. During II crop, the highest yield of 11.05 t ha^{-1} in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K and the lowest yield of 6.29 t ha^{-1} in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K were recorded. Swarajyalakshmi *et al.* (2005) reported that the highest green chilli yield (21.56 t ha^{-1}) was recorded in chilli through drip method scheduled at 0.8 ET compared to 1.0 and 0.6 ET. Similar results were also reported by Dalvi *et al.* (1999); Malik and Kumar (1996); Solaimalai *et al.* (2005) that when NPK were applied through drip irrigation, higher yields in tomato and pomegranate were obtained with 75 per cent of recommended dose.

Water use efficiency (WUE) in chili

Total water used and water use efficiency were worked out for all the treatments in chilli and are presented in Table 4. Water use efficiency was calculated as the ratio of yield (kg ha^{-1}) and total water used (mm) by the crop. Total water used was obtained by adding depth of water applied in mm and effective rainfall in mm. The depth of water applied in treatments drip Irrigation at 100, 75 and 50 per cent of pen evaporation were estimated to be 448.2, 357.2 and 258.2 mm respectively and the effective rainfall during crop season was 237.8 mm. Hence the total water used by the crop in treatments drip Irrigation at 100, 75 and 50 per cent of pen evaporation were 686.0, 595.0 and 496.0 mm respectively. The Table 4 shows clearly that the highest water use efficiency of 20.6 kg ha^{-1} mm^{-1} was observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K and the lowest water use efficiency (10.8 kg ha^{-1} mm^{-1}) was observed in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K.

During II crop, the total water used was 626.9, 546.0 and 467.3 mm in drip Irrigation at 100, 75 and 50 per cent of pen evaporation respectively. The maximum water use efficiency of 20.2 kg ha^{-1} mm^{-1} in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K and minimum water use efficiency of 10.0 kg ha^{-1} mm^{-1} in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K were recorded which were similar to first crop. The reason for higher water use efficiency observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K might be due to higher yield registered through application of optimum irrigation and optimum fertigation of N and K. Similar results were reported by Bao-Zhong and Yuvan (2003) and they observed the maximum water use efficiency of 3.73 g mm^{-1} in drip irrigation at 0.75 PE than 1.00 PE (3.37 g mm^{-1}) and 0.50 PE (3.43 g mm^{-1}). Antony *et al.* (2004) found that the maximum water use efficiency of 59.9 kg ha^{-1} mm^{-1} was recorded in drip irrigation at 0.8 ET compared to drip irrigation at 1.0 ET (54.7 kg ha^{-1} mm^{-1}) and 1.2 ET (59.0 kg ha^{-1} mm^{-1}) in capsicum. Drip irrigation level of 75 per cent Pan-E coupled with 25 kg N ha^{-1} fertigation under drip irrigation was the optimum combination for maximizing water use efficiency and yields of peas grown on sandy loam soil in Himachal Pradesh (Malik and Kumar, 1996).

Fertilizer use efficiency (FUE) in chili

Fertilizer use efficiency was calculated as the ratio of yield (kg ha^{-1}) and fertilizer utilized by the crop. The fertilizer use efficiency of all the treatments for I and II crops are presented in Table 5. During I crop, the highest nitrogen use efficiency (136.51 kg kg of N^{-1}) was observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K and the lowest nitrogen use efficiency was recorded in drip irrigation at 100 per cent of PE with fertigation of 125 per cent of recommended N and K (54.60 kg kg of N^{-1}). During the II crop also, the same trend was noticed.

During I crop, the maximum potassium use efficiency (KUE) was observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K (546.03 kg kg of K^{-1}) and the minimum (218.41 kg kg of K^{-1}) was recorded in drip irrigation at 100 per cent of PE with fertigation of 125 per cent of recommended N and K. During the II crop also, the highest potassium use efficiency was observed in drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K as in I crop. The response of chilli crop for optimum N and K fertilizers, better uptake by the crop and the increased yield might be the reasons for increased NUE and KUE.

As the fertilizer levels decreased, the fertilizer use efficiency increased when there was less yield difference. Similar findings were observed by Selvaraj (1997); Singhandhupe *et al*. (2003); Arunadevi (2005); Hongal and Nooli (2007) and Badr and Abou Ei - Yaized (2007).

Cost economics in chili

The life of the drip material was taken as 10 years, interest at 12 per cent on fixed cost, the repair and maintenance cost at 1 per cent of fixed cost were taken in to consideration to work out the cost economics. The fixed cost of installation of drip system was 67,100 Rs ha^{-1} for all the treatments with the lateral spacing of 1.5 m and emitter spacing of 0.6 m along the lateral. Total operational cost of chilli crop for whole season was worked out to 5,121 Rs ha^{-1} (one third of the total operational cost of 15,372 Rs ha^{-1} was taken as operational cost for chilli crop as three crops could be raised in a year). The cost of cultivation was worked out to be 68,000 Rs ha^{-1}. Hence the total seasonal cost was 73,121 Rs ha^{-1}.

The benefit-cost ratios were calculated from net income of chilli crop and seasonal total cost of chilli. Among all the treatments, drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N and K registered the maximum benefit-cost ratio of 3.2 and 2.8 during I and II crops respectively. The increase in benefit-cost ratio in the above treatment might be due to higher yield registered because of optimal supply of irrigation water through drip and fertigation of N and K at optimum levels. The lowest benefit-cost ratio of 1.5 and 1.1 in I and II crop were recorded in drip irrigation at 100 per cent of PE with fertigation of 75 per cent of recommended N and K (Table 6).

Conclusions

From the present study it could be concluded that for chilli crop drip irrigation at 75 per cent of PE with fertigation of 75 per cent of recommended N & K is recommended for getting higher yield, water use efficiency, N and K use efficiency and net returns.

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Table 1 Physical properties of the soil and irrigation water

Particulars	Soil	Water
pH	7.8	7.2
EC, dS m^{-1}	0.17	1.1
Bulk density, kg m^{-3}	1.42	-
Infiltration rate, cm hr^{-1}	1.98	-
Field capacity, percentage	21.8	-
Permanent wilting point, percentage	10.8	-
Available N, kg ha^{-1}	229	-
Available P, kg ha^{-1}	10.1	-
Available K, kg ha^{-1}	179	-
Total suspended solids, ppm	-	404
Ca, meq l^{-1}	-	57.2
Mg, meq l^{-1}	-	73.8
Organic carbon, percentage	-	0.34

Table 2 Fertilizer requirement for chili (recommended N: P: K is 120:60:30 kg ha^{-1})

Treatments	**Fertilizer required, g**			
	Urea		**White Kcl**	
	Per split	**Total**	**Per split**	**Total**
125 percentage	411	6170	79	1182
100 percentage	329	4935	630	945
75 percentage	247	3702	47	710

Table 3 Effect of irrigation and fertigation levels on the yield of chili

Treatments	Yield, t ha^{-1}							
	I crop				II crop			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
I_1	8.19	7.71	7.43	**7.78**	7.33	6.76	6.29	**6.79**
I_2	11.14	11.24	12.29	**11.56**	9.81	9.90	11.05	**10.25**
I_3	9.14	9.62	9.71	**9.49**	8.48	8.76	9.33	**8.86**
Mean	**9.49**	**9.52**	**9.81**	**-**	**8.54**	**8.48**	**8.89**	**-**

Treatments	SED		CD (0.05)	
	I crop	II crop	I crop	II crop
I	0.04	0.09	0.08	0.19
F	0.04	0.09	0.08	0.19
If	0.07	0.15	0.14	0.33

Table 4 Water use efficiency in chili

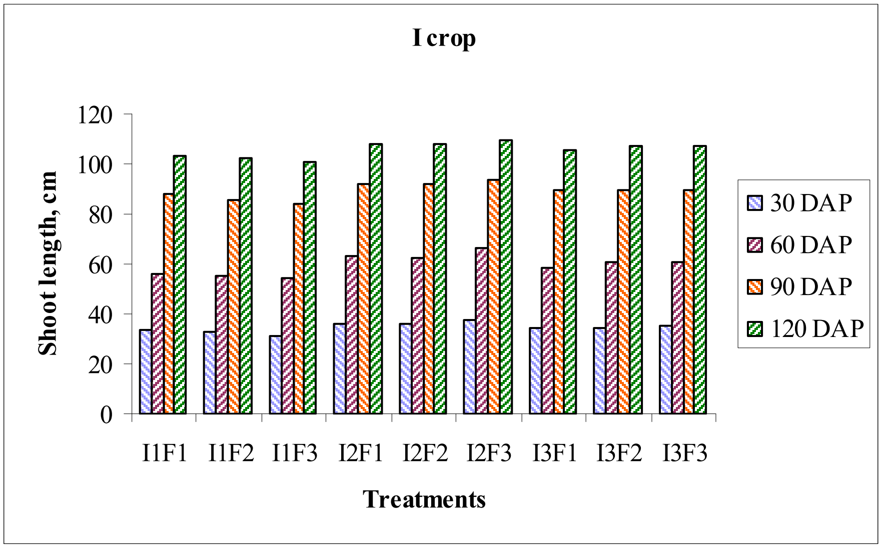
Treatments	I crop					II crop				
	Depth of irrigation, mm	Effective rainfall, mm	Total water used, mm	Yield, kg ha^{-1}	WUE, kg ha^{-1} mm^{-1}	Depth of irrigation, mm	Effective rainfall, mm	Total water used, mm	Yield, kg ha^{-1}	WUE, kg ha^{-1} mm^{-1}
I_1 F_1	448.2	237.8	686.0	8190	11.5	378.2	248.7	626.9	7333	11.9
I_1 F_2	448.2	237.8	686.0	7714	11.2	378.2	248.7	626.9	6762	10.8
I_1 F_3	448.2	237.8	686.0	7429	10.8	378.2	248.7	626.9	6286	10.0
I_2 F_1	357.2	237.8	595.0	11143	18.7	297.3	248.7	546.0	9810	17.6
I_2 F_2	357.2	237.8	595.0	11238	18.9	297.3	248.7	546.0	9905	18.1
I_2 F_3	357.2	237.8	595.0	12286	20.6	297.3	248.7	546.0	11048	20.2
I_3 F_1	258.2	237.8	496.0	9143	18.4	218.6	248.7	467.3	8476	18.1
I_3 F_2	258.2	237.8	496.0	9619	19.4	218.6	248.7	467.3	8762	18.8
I_3 F_3	258.2	237.8	496.0	9714	20.0	218.6	248.7	467.3	9333	19.6

Table 5 Fertilizer use efficiency in chili

Treatments	Fertilizer applied, kg ha^{-1}		I crop			II crop		
	N	K	Yield, kg ha^{-1}	NUE, kg kg of N^{-1}	KUE, kg kg of K^{-1}	Yield, kg ha^{-1}	NUE, kg kg of N^{-1}	KUE, kg kg of K^{-1}
$I_1 F_1$	150.0	37.5	8190	54.6	218.4	7333	48.9	195.6
$I_1 F_2$	120.0	30.0	7714	64.3	257.1	6762	56.3	225.4
$I_1 F_3$	90.0	22.5	7429	82.5	330.2	6286	69.8	279.4
$I_2 F_1$	150.0	37.5	11143	74.3	297.1	9810	65.4	261.6
$I_2 F_2$	120.0	30.0	11238	93.7	374.6	9905	82.5	330.2
$I_2 F_3$	90.0	22.5	12286	136.5	546.0	11048	122.8	491.0
$I_3 F_1$	150.0	37.5	9143	61.0	243.8	8476	56.5	226.0
$I_3 F_2$	120.0	30.0	9619	80.2	320.6	8762	73.0	292.1
$I_3 F_3$	90.0	22.5	9714	107.9	431.7	9333	103.7	414.8

Table 6 Benefit-cost ratio in chili

Treatments	Seasonal total cost, Rs. ha^{-1}	Selling price, Rs. t^{-1}	I crop				II crop			
			Yield, t ha^{-1}	Income from produce, Rs. ha^{-1}	Net income, Rs. ha^{-1}	B-C Ratio	Yield, t ha^{-1}	Income from produce, Rs. ha^{-1}	Net income, Rs. ha^{-1}	B-C Ratio
$I_1 F_1$	73121	25000	8.19	163810	131641	1.8	7.33	146667	110212	1.5
$I_1 F_2$	73121	25000	7.71	154286	119736	1.6	6.76	135238	95927	1.3
$I_1 F_3$	73121	25000	7.43	148571	112593	1.6	6.29	125714	84022	1.2
$I_2 F_1$	73121	25000	11.14	222857	205450	2.8	9.81	196190	172117	2.4
$I_2 F_2$	73121	25000	11.24	224762	207831	2.9	9.90	198095	174498	2.4
$I_2 F_3$	73121	25000	12.29	245714	234022	3.2	11.05	220952	203069	2.8
$I_3 F_1$	73121	25000	9.14	182857	155450	2.1	8.48	169524	138784	1.9
$I_3 F_2$	73121	25000	9.62	192381	167355	2.3	8.76	175238	145927	2.0
$I_3 F_3$	73121	25000	9.71	194286	169736	2.3	9.33	186667	160212	2.2



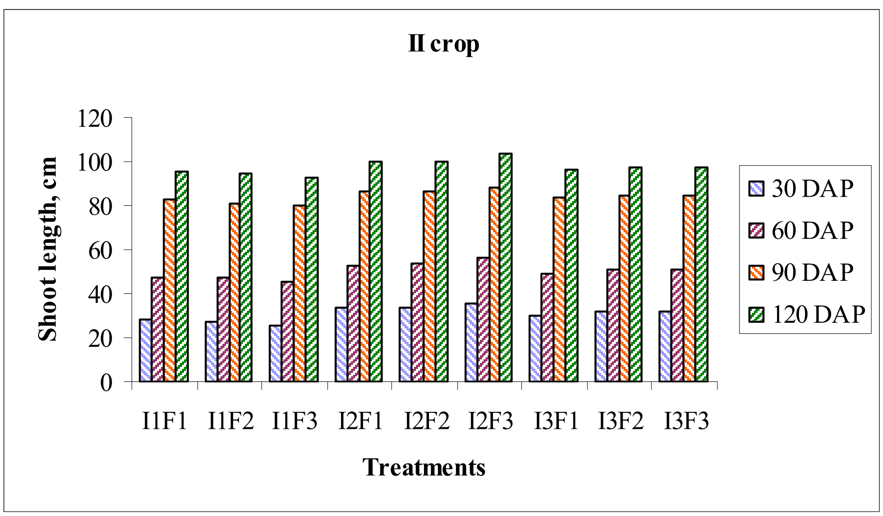
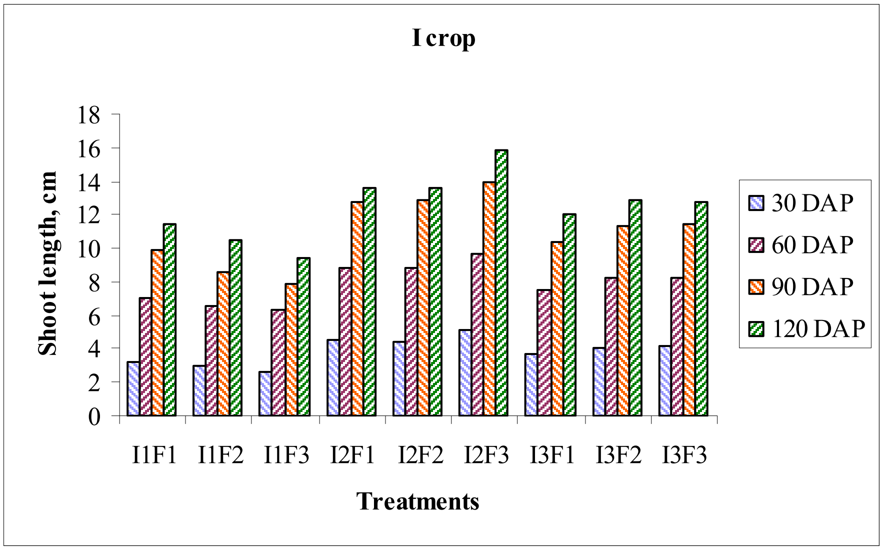


Fig. 1 Influence of irrigation and fertigation levels on shoot length



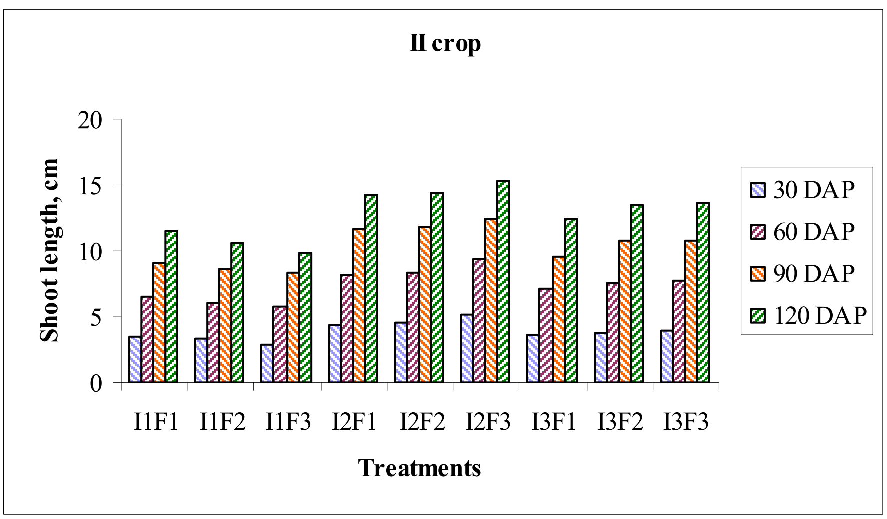


Fig. 2 Influence of irrigation and fertigation levels on No. of leaves