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Effect of irrigation levels and frequencies on growth, yield and economics of capsicum production under naturally ventilated polyhouse

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Abstract

The present investigation was carried out with the objective to standardize irrigation scheduling for improving capsicum yield for higher benefit: cost ratio under naturally ventilated polyhouse. The experiment was laid down in Randomized Complete Block Design (RCBD) along with seven treatments comprising of three irrigation depths, two intervals and a farmers practice. The data were recorded on days to first flowering, plant height (cm), days to marketable picking, total harvest duration (days), number of fruits per plant and yield (kg/m^2). A perusal of the pooled data (2011 and 2012) revealed that different levels and frequencies of irrigation produced significant differences with regards to different traits under study. The treatment with 0.25 cm irrigation at alternate day (T_2) and farmer's practice resulted in earliest flowering (41.71 days) and days to marketable picking (72.49 days), respectively. However, application of 0.50 cm of irrigation at alternate day (T_4) resulted in maximum plant height (142.65 cm), total harvest duration (131.68 days), number of fruits per plant (18.26) and highest yield (12.76 kg/m^2) along with maximum benefit: cost ratio (6.53:1). Hence, treatment T_4 may be recommended for commercial cultivation of capsicum in the hilly regions of the country under naturally ventilated polyhouse.

Keywords: Benefit: cost ratio, capsicum, economic analysis, irrigation, yield

Introduction

Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.) also known as sweet pepper or bell pepper, is cultivated worldwide both under open as well as protected conditions. Due to erratic behaviour of weather, the crops grown in open field are often exposed to fluctuating levels of rainfall, temperature, humidity, wind flow etc., which ultimately affect the crop productivity adversely (Ochigbo and Haris 1989). Moreover, crops grown under open conditions fail to meet out the export standards (Kurubetta and Patil 2009). Recently, protected cultivation of capsicum is proving to be a very remunerative venture to the greenhouse growers as it fetches maximum returns in the markets as well as its benefit: cost ratio is also very high, since it is being grown in the cost effective naturally ventilated polyhouses (Ghosal and Das 2012). The high market price is attributed to the heavy demand from the urban consumers. However, the supply is inadequate due to the low productivity of the crop. The cultivation of crops under protected structures increases irrigation water use efficiency and produces yields that are about five to ten times greater than in the open field conditions (Vox et al. 2010). Hence, to obtain higher yields and good quality of produce, there is an immense need to standardize the production technology of capsicum under protected conditions.

The availability of optimum soil moisture throughout the growing season is an important factor in any crop production programme as both excess as well as scarcity of water affects total crop yields (Dagdelen et al. 2004). The irrigation system facilitates uniform soil moisture distribution in root zone continuously at an optimum level and leading to higher and better quality produce (Hardeman et al. 2000). In recent years, damaging effect of climate change on global food security has assumed a frightening dimension leading to food shortages due to water scarcity especially in developing nations (Akinbile and Yusoff 2011). In the hilly regions of the country, perennial sources of water are scare and farmers are mainly depended upon the *kharif* and *spring* season rainfall for their crop requirements, which is erratic in behavior. This leads to moisture stress during critical growth periods. Moreover, irrigation facilities in the hilly

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state like Himachal Pradesh are very limited due to undulating topography. Therefore, need for efficient irrigation scheduling for improving capsicum productivity has become imperative. Therefore, keeping in view the above facts in mind, the present investigation was carried out to standardize the water requirement under drip irrigation system for higher economic yields in capsicum.

Materials and Methods

Experimental site and layout plan:

The present investigation was carried out in a naturally ventilated polyhouse at Experimental Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *spring-summer* seasons of year 2011 and 2012. There were seven treatments comprising of three irrigation depths, two intervals and a farmers practice i.e., T_1: 0.25 cm irrigation daily; T_2: 0.25 cm irrigation at alternate day; T_3: 0.50 cm irrigation daily; T_4:0.50 cm irrigation at alternate day; T_5: 0.75 cm irrigation daily; T_6: 0.75 cm irrigation at alternate day; T_7: Farmer's practice (Two times irrigation per week till the establishment of seedlings and later on 1.0-1.5 cm irrigation with canes/pipes twice a week). Seeds of capsicum hybrid 'Bharat' were sown during the month of February, 2011 and 2012 in well prepared nursery beds and 30 days old seedlings were transplanted in the polyhouse. The experiment was laid down in Randomized Complete Block Design (RCBD) and 21 seedlings in each treatment combination were transplanted at a distance of 45 cm × 30 cm (1350 cm^2) in well prepared plots of 1.35 m × 2.10 m (2.835 m^2) size and were replicated four times in four different blocks. Each block was separated by 0.5 m wide bund and within blocks each treatment was arranged 45 cm apart to avoid lateral movement of water along the treatment. In each plot, three drip lines were installed for each row. Each emitter served water requirement for single plant placed at 30 cm distance. The duration of operation of drip system for different treatments of irrigation was controlled by a flow control valve. After establishment of seedlings, irrigation water was applied through drip irrigation system as per treatments assigned during the complete growing season. The amount of water actually applied by the way of drip irrigation system was based on evapo-transpiration basis (climatological approach). The amount of water discharged per minute was calculated to fix the time for supplying the desired quantity of water to each plot as per the treatments assigned. For applying 0.25, 0.50 and 0.75 cm water, drippers flow was run approximately for 15-17, 30-35 and 40-45 minutes, respectively. All the recommended cultural practices and plant protection measures standardized for ployhouses were followed time to time to ensure a healthy crop stand (Anonymous 2010).

Data recording and statistical analysis:

The observations pertaining to different traits under study viz., days to first flowering, plant height (cm), days to marketable picking, total harvest duration (days), number of fruits per plant and yield (kg/m^2) were recorded on 10 randomly selected plants from each treatment plot per replication. All the data pertaining to yield and its attributing traits were analyzed as per randomized complete block design (RCBD) suggested by Gomez and Gomez (1984). Further, economic analysis of different treatments was tested depending upon the locally existing fixed and variable costs of different inputs for poyhouse cultivation of capsicum. The cost of cultivation under different treatments was calculated by following Sharma et al. (2008). The net return per hectare was worked out for all the treatments by subtracting the cost of cultivation from the gross returns. The benefit: cost ratio as return per rupee invested was calculated by dividing net return with total cost of cultivation for each treatment under study.

Results and Discussion

The analysis of variance revealed the significant effect of irrigation levels and frequencies on yield and its attributing traits (Table 1), which have been described and discussed as follows:

Days to first flowering: Days to first flowering is an important attribute in capsicum, determining the earliness of the crop. Pooled analysis of data (2011 and 2012) revealed that 0.25 cm depth of irrigation water at an alternate day (T_2) resulted in earliest flowering (41.71 days) and flowering was delayed as the depth of irrigation water increased either daily or at alternate day (Table 2). It appears that amount of irrigation water supplied by T_2 (0.25 cm irrigation at alternate day) might have resulted into better micro-climate responsible for efficient water utilization (Taiz and Zeiger 2002) and excellent soil-air-water relationship with higher oxygen concentration in the root zone during early crop growth stage (Rathore and Singh 2009), which ultimately lead to earliest flowering. Moreover, plants in any kind of stress condition either tends to shorten life span or complete their life cycle in delayed period. In the present study, all other treatments due to excess of water might have resulted in un-favourable micro-climate which hindered the vegetative growth and development of the

Table 1: Analysis of variance for growth and yield traits in capsicum (Pooled analysis of 2011 and 2012)

Source \ Traits	df	Mean Sum of Squares					
		Days to first flowering	Plant height (cm)	Days to marketable picking	Total harvest duration (days)	Number of fruits per plant	Yield (kg/m^2)
Treatment	6	8.728*	1178.132*	63.319*	217.885*	14.814*	18.822*
Year	1	0.500	24.863	45.721*	3.445*	23.246*	5.126*
Treatment × Year	6	0.372	31.436	3.175	17.933*	0.528	0.450
Error	42	0.627	27.369	3.154	0.347	2.273	0.681
Total	55	10.227	1261.8	115.369	239.61	40.861	25.079

*Significant at 5% level of significance

plants. Present investigations are in line with Khan et al. (2005) and Sezen et al. (2011), who observed earlier flowering at lower irrigation frequencies as compared to higher irrigation frequencies in capsicum.

Plant height (cm): Plant height is an important parameter as more the plant height, more will be the number of laterals, fruits and ultimately yield. However, plant height being a genetically controlled character also influenced by the environment to a great extent. In present studies, both levels and frequencies of irrigation had significant effect on plant height. Pooled analysis of 2011 and 2012 (Table 2) showed that the tallest plants of 142.65 cm height were recorded in T_4 (0.50 cm of irrigation at alternate day), whereas minimum of 110.18 cm in T_7 (Farmer's practice). This might be due to better micro-climate responsible for efficient water utilization at early crop growth stages, which ultimately lead to maximum plant height in T_4. It was noticed that plant height decreased further with the increase in irrigation levels and frequencies. In contradict to present findings; Ertek et al. (2007) had reported significant positive linear correlation between plant height and irrigation water.

Days to marketable picking: Days to marketable picking determines the earliness of the crop in capsicum. Pooled analysis of data (2011 and 2012) showed that the effects of levels and frequencies of irrigation were significant on days to marketable picking (Table 2). Significantly earliest (72.49 days) marketable maturity was observed in T_7 (Farmer's practice) followed by T_2 (73.95 days) and T_1 (74.05 days) and delayed marketable maturity was recorded in T_6 (80.45 days). It has been noticed that early maturity increases as the amount of water increases, because capsicum is highly sensitive to water scarcity in early growing period, which decreases early green pepper yield (Ertek et al. 2007).

Total harvest duration (days): Prolonged and extended harvest duration is preferred under Indian conditions. This ensures continuous supply of the produce over a long period of time. Furthermore, it avoids glut in the market on one hand and increases profit on the other. This trend is also desirable to catch early market thus ensures higher returns to small and marginal farmers of the hilly state like Himachal Pradesh. Pooled data of both the years (2011 and 2012) showed significant effects of levels and frequencies of irrigation on total harvest duration (Table 2). Significantly longer harvest duration was recorded in T_4 (131.68 days). This might be due to better micro-climate responsible for efficient water utilization during entire crop growth stages, which has ultimately, lead to prolonged harvest duration in T_4. In the meanwhile, shortest harvest duration (117.16 days) was recorded in T_2. Results of present findings

Table 2: Effect of irrigation levels and frequencies on growth and yield of capsicum grown under naturally ventilated polyhouse (Pooled data of 2011 and 2012)

*Treatments \ Traits	Days to first flowering	Plant height (cm)	Days to marketable picking	Total harvest duration (days)	Number of fruits per plant	Yield (kg/m^2)
T_1	44.27	135.88	74.05	119.42	14.47	8.75
T_2	41.71	121.28	73.95	117.16	15.65	10.79
T_3	43.84	137.15	78.17	124.55	17.90	12.48
T_4	44.05	142.65	75.80	131.68	18.26	12.76
T_5	43.11	136.53	77.65	124.38	17.18	11.91
T_6	42.96	118.36	80.45	125.21	16.77	11.52
T_7	41.76	110.18	72.49	130.15	15.69	9.38
CD $_{(P=0.05)}$	0.80	5.28	1.74	0.59	1.52	0.83

*T_1: 0.25 cm irrigation daily; T_2: 0.25 cm irrigation at alternate day; T_3: 0.50 cm irrigation daily; T_4: 0.50 cm irrigation at alternate day; T_5: 0.75 cm irrigation daily; T_6: 0.75 cm irrigation at alternate day; T_7: Farmer's practice (Two times irrigation per week till the establishment of seedlings and later on 1-1.5 cm irrigation with canes/pipes twice a week).

are in line with Kumar and Verma (2009), who reported longer harvest duration with 40 kPa irrigation regime as compared to 20 kPa in capsicum grown under low cost naturally-ventilated polyhouse.

Number of fruits per plant: Number of fruits per plant is an important character, since it ultimately reflects the total marketable yield. Pooled data of both the years (2011 and 2012) as presented in Table 2 showed that maximum number of fruits (18.26) were recorded in 'T_4'. This might be due to better micro-climate responsible for efficient water utilization at early crop growth stages, which ultimately lead to more number of flowers and hence more number of fruits in 'T_4'.On the other hand, minimum (14.47) number of fruits per plant were observed in'T_1'. This might be attributed to reduced number of flowers produced rather than poor fruit set. It reveals that both the excess as well as less supply of water has resulted into less number of fruits per plant. Hence, controlled irrigation is essential for having higher fruit number in capsicum as this crop is highly sensitive to both excess and under irrigations (Anonymous 2009). Earlier workers like Chartzoulakis et al. (1997) had reported that number of fruits per plant was affected significantly by amount of irrigation water applied. In line with present studies, Rekha et al. (2017) observed highest number of fruits per plant with moderate irrigation regimes in capsicum, whereas Ertek et al. (2007) revealed that number of fruits per plant goes on increasing with the increase in irrigation levels and frequencies in capsicum, which contradicts the results of present investigations. This might be due to the difference in soil, climate and type of protected structure used during the investigations.

Yield (kg/m^2): Fruit yield is the resultant of yield

Table 3: Cost of cultivation of capsicum for best treatment 'T_4' under naturally ventilated polyhouse (area =160 m^2)

Cost components	Unit	Cost/unit	Quantity	Value/ Cost (Rs.)
A. Fixed Costs				
I) Rental value of polyhouse	Rs.	500/Month	8	4000.00
II) Maintenance cost on fixed assets	Rs.	100/Month	8	800.00
Total (A)				4800.00
B. Variable Costs				
1) Non-labour input				
i) Seeds	g	265.00	8	2120.00
ii) FYM	q	100.00	1.6	160.00
iii) Fertilizers				
A. Urea	kg	4.82	1.76	8.48
B. SSP	kg	6.30	5.2	32.76
C. MOP	kg	4.55	1.33	6.05
D. 19:19:19	g	0.13	355.2	46.176
iv) Others insecticide/pesticide				500.00
Sub-total (1) Cash costs				2873.47
2) Labour input–hired labour MD (Mandays)				
i) Field preparation	MD (8 hrs)	130	2	260.00
ii) Nursery raising	MD	16.25	5	81.25
iii) Trasplanting	MD	16.25	2	32.50
iv) Fertilizer application	MD	16.25	6	97.50
v) Weeding	MD	16.25	4	65.00
vi) Staking cost				650.00
vii) Irrigation	MD	16.25	49.5	804.38
viii) Harvesting	MD	16.25	19	308.75
ix) Irrigation water charge	Rs.	2.5	1	2.50
x) Electricity charges (drip irrigation)	Rs.			408.82
Sub-total (2) Opportunity costs				2710.70
3)Interest on working capital @ 10%				
i) Non-labour inputs	Rs.	-	-	287.35
ii) Hired labour	Rs.	-	-	271.07
Sub-total (3)	Rs.	-	-	558.42
Total variable cost (1)+(2)+(3)	Rs.	-	-	6142.58
Total cost (Fixed+Variable)	Rs.			10942.58
Total output from polyhouse (yield)	kg	35	12.76	71456.00
Net benifit	Rs.			60513.42
Benefit : cost ratio				6.53:1

Table 4: Economics of various treatments under naturally ventilated polyhouse cultivation of capsicum

*Treatments	Variable cost (Rs.)	Fixed cost (Rs.)	Total cost (Rs.)	Yield (kg/m^2)	Gross income (Rs.)	Net return (Rs.)	B:C ratio
T_1	6845.00	4800.00	11645.00	8.75	48944.00	37299.00	4.20:1
T_2	6003.58	4800.00	10803.58	10.79	60424.00	49620.42	5.59:1
T_3	6995.19	4800.00	11795.19	12.48	69888.00	58092.81	5.93:1
T_4	6142.58	4800.00	10942.58	12.76	71456.00	60513.42	6.53:1
T_5	6669.60	4800.00	11469.60	11.91	66696.00	55226.40	5.64:1
T_6	6126.48	4800.00	10926.48	11.52	64512.00	53585.52	5.90:1
T_7	5272.00	4800.00	10072.00	9.38	52528.00	42456.00	5.21:1

*T_1: 0.25 cm irrigation daily; T_2: 0.25 cm irrigation at alternate day; T_3: 0.50 cm irrigation daily; T_4: 0.50 cm irrigation at alternate day; T_5: 0.75 cm irrigation daily; T_6: 0.75 cm irrigation at alternate day; T_7: Farmer's practice (Two times irrigation per week till the establishment of seedlings and later on 1-1.5 cm irrigation with canes/pipes twice a week).

contributing traits of the plant especially number of fruits per plant and average fruit weight. A perusal of pooled data (2011 and 2012) in the Table 2 indicated that both levels and frequencies of irrigation had significant effect on yield. Maximum and significantly higher yield (12.76 kg/m^2) was observed with moderate irrigation level i.e, 'T_4' (0.50 cm of irrigation daily), which might be due to the higher average fruit weight and more fruit number in the treatment 'T_4'. It is revealed that optimum soil moisture availability in root zone of the crop results in higher fruit yield in capsicum (Gupta et al. 2010). Results of present investigations are in line with (Singh et al. 2011), who had also observed higher fruit yield in capsicum with moderate irrigation treatment viz., 0.8 potential evapo-transpiration (PET) as compared to 1.0 and 0.6 PET. Similarly, Rekha (2017) had also observed highest fruit yield at 0.75 IW/CPE as compared to 0.25, 0.50 and 1.0 0.75 IW/CPE in capsicum. In the mean while, minimum yield of 8.75 kg/m^2 was recorded in the treatment 'T_1', which might be due to water stress conditions during crop growth period. Ertek et al. 2007 had reported that the scarcity of water reduces the fruit yield in green capsicum.

Cost economics of treatments (Rs.): Economic importance of water used is beneficial under specific situations prior to large scale adoption for commercial plant production. However, use of irrigation intervals and levels of irrigation could be economically attractive to reduce the drought stress conditions in water limiting areas (Khan et al. 2005). In the present studies, economic analysis of different treatments was tested depending upon the locally existing fixed and variable costs of different inputs for poyhouse cultivation of capsicum (Table 3). The experimental results revealed that maximum gross and net income was observed in treatment T_4 (0.50 cm of irrigation at alternate day) and minimum was noticed in T_1 (0.25 cm irrigation daily). The treatment T_4 also produced maximum yield of 12.76 kg/m^2. The highest benefit: cost ratio of 6.53:1 under moderate soil moisture regime was also recorded with T_4 (Table 4). Similar results have also been revealed by Singh et al. (2011), who reported higher B: C ratio in capsicum under moderate irrigation level i.e., at 0.8 PET as compared to 1.0 and 0.6 PET in capsicum. Moreover, Khan et al. (2005) has observed high B: C ratio at more frequent irrigation intervals (3 days) as compared to infrequent intervals (6, 9 and 12 days).

सारांश

वर्तमान अध्ययन शिमला मिर्च में उपज का अधिक लाभ : लागत अनुपात ज्ञात करने के लिये सिंचाई कार्यक्रम मानक नियत हेतु प्राकृतिक हवादार पालीहाउस में किया गया। प्रयोग रेण्डोमाइज्ड कम्पलीट ब्लाक डिजाईन (आर.सी.बी.डी.) में कुल सात उपचारों जिनमें तीन सिंचाई की गहराई, दो अन्तराल व एक कृषक पद्धति को उपयोग कर किया गया। प्रथम पुष्पन के दिन, पौध ऊँचाई (सेन्टी मीटर), बाजार योग्य तुड़ाई के दिन, कुल तुड़ाई अवधि (दिनों), प्रति पौध फलों की संख्या एवं उपज (किग्रा./वर्ग मीटर) के आंकड़े एकत्रित किये गये। समूह आंकड़ा (2011–12) से स्पष्ट हुआ कि विभिन्न स्तर पर सिंचाई बारम्बारता के अध्ययन किये गये गुणों के प्रति सार्थक विविधता पायी गयी। एकान्तर दिन (टी–2) सिंचाई उपचार 0.25 सेन्टीमीटर व कृषक पद्धति के परिणामतः अगेती पुष्पन (41.71 दिन) एवं बाजार योग्य तुड़ाई के दिनों (72.49 दिनों), के लिए क्रमशः अच्छा पाया गया जबकि एकान्तर दिन सिंचाई (टी–4) उपचार 0.50 सेन्टी मीटर के परिणामतः पौध ऊँचाई (142.65 सेन्टी मीटर), कुल तड़ाई अवधि (131.68 दिनों), प्रति पौध ा फलों की संख्या (18.26) व अधिक उपज (12.76 किग्रा/वर्ग मीटर) के साथ अधिक लाभ : लागत अनुपात (6.53:1) पाया गया। चूंकि उपचार टी–4 की अनुशंसा शिमला मिर्च की व्यवसायिक खेती के लिए देश के पहाड़ी क्षेत्रों में प्राकृतिक हवादार पालीहाउस में की जा सकती है।

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