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RESEARCH ARTICLE :

Response of capsicum to different irrigation schedules under protected and open cultivation

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SUMMARY : The experiment was conducted during late *Rabi* season (December to May) in year 2013-14, at trial cum demonstration field of Precision Farming Development Centre, Central Institute of Agricultural Engineering, Bhopal (M.P.) to check response of capsicum to different irrigation schedules under protected and open cultivation.The treatment comprising of three growing environments *viz.*, naturally ventilated polyhouse, shadehouse and open field and three irrigation levels at 100% ETc, 80% ETc and 60% ETcin Factorial Randomized Block Design with nine treatment combinations and three replications. The study revealed that under polyhouse the crop yield was increased over open field cultivation along with water saving in covered cultivation.In case of vegetative character like plant height, number of leaves per plant and Spad value which depicts chlorophyll content in plant, reproductive parameters like number of flowers and fruits per plant, was maximum under naturally ventilated polyhouse followed by shadehouse and then open field at all growth stages. Days taken for flower initiation and fruit set were significantly lower in naturally ventilated polyhouse followed by shadehouse then open field.Higher yield with minimum crop water requirement gives maximum water use efficiency which is observed in treatment T_9 (drip irrigation at 60% ETc under polyhouse) *i.e.* 30.29 q/ha-cm. However, minimum water use efficiency was noticed in treatment T_4 (drip irrigation at 100% ETc under shadehouse) *i.e.* 12.25 q/ha-cm although it having higher yield than open field but also it required maximum consumptive use.The significantly superior yield was recorded under the growing condition C_3 *i.e.*polyhouse and irrigation level I_3 *i.e.* drip irrigation at 60% ETc, whereas in treatment combination I_3C_3 (drip irrigation at 60% ETc under polyhouse) are found significantly superior yield (1163.7 q/ha) over rest combination.

KEY WORDS :
Protected cultivation, Drip irrigation, Plastic Mulch,WUE, Crop yield

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BACKGROUND AND OBJECTIVES

Protected cultivation is a unique and specialized form of agriculture. Devices and technology for protected cultivation (windbreak, irrigation, soil mulches) or structures (greenhouse, tunnels, rowcovers) may be used with or without heat. The intent is to grow crops where otherwise they could not survive by modifying the natural environment to prolong the harvest period, often earlier maturity, to increase yields, improve quality, enhance the stability of production and make commodities available when there is no outdoor production (Wittwer and Castilla, 1995).

Capsicum is a cool season crop, but under protected cultivation it can be grown round the year using protected structures where temperature and relative humidity (RH) can be manipulated. Capsicum is one of the leading vegetables grown in open conditions as well as under protected conditions. Because of its economic importance as a high value vegetable crop both in domestic and overseas markets, quality production of capsicum is the need of the day.

Agriculture is the main user of the available water resources. Water resources decrease worldwide and increases pressure due to increasing and competing demands of freshwater for drinking, agricultural, urban and industrial uses. About 75 to 80% of the available freshwater resource in many parts of the world is used for agriculture. Global population by 2025 will likely increase to 7.9 billion, more than 80 % of people will live in developing countries (UN, 1998). Around 36% of the 2025 world population is projected to be living in India and China alone (Dam and Malik, 2003). The irrigated area should be increased by more than 20% and the irrigated crop yield should be increased by 40% by 2025 to secure the food for 8 billion people (Lascano and Sojka, 2007). Therefore, the higher requirement of food to feed the increased population with reduced water availability for crop production forces the irrigation researchers and managers to use water-saving irrigation strategies to improve the water productivity (WP) in recent years.

Irrigation scheduling is the systematic method by which producer can decide on when to irrigate and how much water to apply. The goal of effective scheduling programmes is to supply the plants with sufficient water while minimizing losses to deep percolation or runoff. Drip irrigation, a technique that provides crops with water through a network of pipe lines at a high frequency but with a low volume of water applied directly to the root zone in a quantity that approaches consumptive use of the plants, can be combined with fertilizer application, to offer fertigation.The utilization of water by crop varies with different irrigation levels and methods. Optimum irrigation levels with suitable plant growing environment would help in enhancing yields apart from higher water use efficiency.

Mulching is an appropriate approach to enhance efficiency level of irrigation besides improving crop yield. Other reason for high mulching use includes soil temperature modification, soil conservation, nutrient addition, improvement in soil structure, weed control and crop quality control (Kumar, 2012). Drip irrigation under mulching provides potential to achieving moderate crop yields through improved water use efficiency and control of the soil environment, including water conservation (Diaz-Parez *et al.*, 2010).

The water requirement of crop varies in open and protected cultivation. But usually water is provided on the basis of pan evaporation data in open field. This may lead to wastage of water in protected cultivation. Considering the water scarcity in future, there is a need to optimize the irrigation plan using different scheduling approach and crop yield response to water.

RESOURCES AND METHODS

Experimental site:

The experiment was laid out at trial cum demonstration field of Precision Farming Development Centre, Central Institute of Agricultural Engineering, Bhopal (M.P.) during late *Rabi* season of 2013-14. The naturally ventilated polyhouse (500 m^2) and shadenet house (500 m^2) with 50% shading factor wasalso available at the experiment site. The Bhopal region falls under 'Agro-Ecological Region 7'of India (Semiarid Lava Plateau and Central Highlands). The farm is situated between 23^{0}18' to 23^{0}20' North latitudes and 77^{0}24' to 77^{0}25' East longitudes with an altitude of 490 m above mean sea level. The topography of the field was fairly uniform and leveled. The climate of Bhopal is subtropical semi-arid. The meteorological data during the period of experimentation was obtained from Meteorological

Table A: Physico-chemical properties of soil at experimental site

Soil depth cm	Sand %	Silt %	Clay %	Textural class	Bulk density g cm^{-3}	Water retention at, cm^{3}cm^{-3}		Saturated moisture content, cm^{3}cm^{-3}	K_s, cm day^{-1}	EC dS/m	pH
						0.33 bar	15 bar				
0-45	18.8	29.2	52.0	Clay	1.39	0.30	0.15	0.40	22.10	0.19	7.53

Observatory, CIAE, Bhopal. Physico-chemical properties of soil at experimental site were presented in Table A.

Experimental details:

The field experiment was laid out in Factorial Randomized Block Design (FRBD), having nine treatment combinations based on different levels of crop evapotranspiration (ETc) and growing environment under silver mulch and drip irrigation with three replications. The details of treatment combinations are presented in Table B. The size of a unit plot was 3 m x 2.5 m. Two adjacent unit plots and blocks were separated by 0.5 m and 0.2 m, respectively. Recommended fertilizer dose 250:150:150 (N:P:K) were applied by drip fertigation in 10 equal splits. Pest and disease control by chemical was carried out as per requirement. During the weeding, soil earthing up was done for the development of plant roots.

Table B : Details of treatment

Treatments	Particulars
T_1	Drip irrigation at 100% ETc in open field (I_1C_1)
T_2	Drip irrigation at 80% ETc in open field (I_2C_1)
T_3	Drip irrigation at 60% ETc in open field (I_3C_1)
T_4	Drip irrigation at 100% ETc under shadenet house (I_1C_2)
T_5	Drip irrigation at 80% ETc under shadenet house (I_2C_2)
T_6	Drip irrigation at 60% ETc under shadenet house (I_3C_2)
T_7	Drip irrigation at 100% ETc under polyhouse (I_1C_3)
T_8	Drip irrigation at 80% ETc under polyhouse (I_2C_3)
T_9	Drip irrigation at 60% ETc under polyhouse (I_3C_3)

Irrigation scheduling details :

Data of open pan evaporation and other climatic parameters was collected daily from Meteorological Observatory, Central Institute of Agricultural Engineering, Bhopal. Drip irrigation to capsicum crop was scheduled every two days interval based on pan evaporation. The effective rainfall was considered practically null, in all three due to covering the soil. Thus, the irrigation water requirement was equal to the crop water requirement. Total water requirement of the crop under drip irrigation at 100% replenishment of evapotranspiration was computed on cumulative pan evaporation.

Common irrigation :

Before transplanting, common irrigation was applied to bring the soil to field capacity in each plot. The amount of irrigation water required in all treatments to bring the soil to field capacity was calculated by using Eq. 1 (Bhadane, 2015).

$$IW = \left[\frac{\theta_{FC} - \theta_{BI}}{100}\right] x\ \gamma\ x\ Z_r\ x\ 1000 \quad .....(1)$$

where,

IW - Net amount of water to be applied during irrigation, mm

θ_{FC} - Moisture content at field capacity, (%)

θ_{BI} - Moisture content before irrigation, (%)

γ - Bulk density, (g/cm^3)

Z_r - Effective root zone depth, (m)

The effective root zone depth was considered as 45 cm for calculating the net water requirement of capsicum crop (FAO, 2013). The moisture content before transplanting was actually measured using gravimetric method. Accordingly the depth of irrigation to be applied before transplanting was calculated.

Water requirement of capsicum :

The water requirement of capsicum under drip irrigation at 100% ETc, 80% ETc and 60% ETc, was worked out on the basis of pan evaporation. Crop evapotranspiration was calculated using the following relationship recommended by the FAO (Doorenbos and Pruitt, 1977 and Allen *et al.*, 1998).

$$ET_c = E_{pan} x\ K_c\ x\ K_p \quad .... (2)$$

ET_c - Water requirement per plant, mm day^{-1}

E_{pan} - Cumulative evaporation, mm

K_c - Crop co-efficient

K_p - Pan co-efficient (0.8)

Volume of water to be applied per treatment in litres

$$V = ET_c\ x\ A\ x\ N \quad ......(3)$$

where,

V - Volume of water requirement per treatment, lit day^{-1}

ET_c - Water requirement per plant, mm day^{-1}

A - Area of one plot, m^2

N - Number of plot.

Measurements of growth and yield attribute:

For recording observations of vegetative, reproductive and yield contributing parameters five plants were randomly selected and labeled. All observations were taken on these labeled plants. Water use efficiency (WUE) was estimated by dividing the yield (q/ha) with the amount of water consumed by the crop (*i.e.* crop water use, cm) during its growth period under different treatments of irrigation.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Vegetative parameters:

Growth is an irreversible increase in size of the plants and it is affected by growing condition and irrigation level. The different growing condition with different irrigation level exerted a significant difference on growth parameters, such as plant height, number of leaves and Spad value.

Influence of growing condition and irrigation level on height of capsicum:

The data presented in Table 1 indicated the interaction effect of growing condition and irrigation level on plant height of capsicum after 30, 60 and 90 days were found to be significant. Maximum plant height was recorded with treatment combination I_3C_3 (drip irrigation at 60% ETc under polyhouse) at all the stages of growth such as 30 (54.30 cm), 60 (88.36 cm) and 90 (129.53 cm). However, minimum plant height was noticed with the treatment combination I_3C_1 (drip irrigation at 60% ETc in open field) at all the stages of observation such as 30 (28.44 cm), 60 (56.50 cm) and 90 (95.67 cm).This agrees with results of Ramesh and Arumugam (2010) on vegetables grown under polyhouse, Rylski (1986) and El-Aidy *et al*. (1988) in sweet pepper under shadenet house. The results are in the confirmity with those reported by several researchers like Bora and Babu (2014) and Juan and Diaz-Perez (2009) in capsicum.

Influence of growing condition and irrigation level on leaves per plant of capsicum:

The data presented in Table 1 indicated that the interaction effect of growing environment and irrigation level on leaves plant^{-1} of capsicum after 30, 60 and 90 days was found to be significant. Maximum leaves per plant was recorded with the treatment combination I_3C_3 (drip irrigation at 60% ETc under polyhouse) at 30 (49.23), 60 (65.25) and 90 (83.31) days after transplanting. Minimum leaves per plant were registered with the treatment combination I_3C_1 (drip irrigation at 60% ETc in open field) by recording the values 21.66, 40.47 and 58.36 for the stages of 30, 60 and 90 days after transplanting, respectively. These results are in close agreement with the findings of Ali and Kelly (1993); Polowick and Sawlancy (1985); Kumari (1998) and Beese *et al*. (1982) in capsicum.

Influence of growing condition and irrigation level on spad value of capsicum plant:

The data presented in Table 1 indicated that the interaction of growing environment and irrigation level on Spad value of capsicum after 30, 60 and 90 days was found to be significant. Maximum Spad value was recorded with the treatment combination I_3C_3 (drip

Table 1 : Interaction effect of growing condition and irrigation level on height of capsicum plant

Treatment combinations	Vegetative parameters								
	Plant height (cm)			Number of leaves			Spad value		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1 (I_1C_1)	30.15	59.21	99.38	25.43	43.38	60.31	25.00	34.13	45.39
T_2 (I_2C_1)	32.28	62.34	102.51	27.44	45.30	63.38	26.13	36.39	46.37
T_3 (I_3C_1)	28.44	56.50	95.67	21.66	40.47	58.36	23.48	33.38	43.56
T_4 (I_1C_2)	37.21	70.63	107.44	34.41	49.49	68.52	28.89	38.60	53.03
T_5 (I_2C_2)	39.33	72.39	110.56	37.62	51.30	70.26	30.88	40.68	55.20
T_6 (I_3C_2)	43.34	76.75	115.68	40.76	54.40	75.20	32.46	42.77	57.98
T_7 (I_1C_3)	48.49	82.55	120.83	42.51	59.33	76.30	35.52	45.40	61.30
T_8 (I_2C_3)	50.26	84.32	124.49	45.53	61.49	79.24	37.63	47.70	63.41
T_9 (I_3C_3)	54.30	88.36	129.53	49.23	65.25	83.31	42.26	51.12	65.39
F test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E.$\pm$	0.115	0.153	0.133	0.156	0.121	0.155	0.337	0.233	0.554
C.D. (P=0.05)	0.345	0.459	0.399	0.467	0.364	0.465	1.011	0.699	1.660

irrigation at 60% ETc under polyhouse) at 30 (42.26), 60 (51.12) and 90 (65.39) days after transplanting. Minimum Spad value was registered with the treatment combination I_3C_1 (drip irrigation at 60% ETc in open field) by recording the values 23.48, 33.38 and 43.56 for the stages of 30, 60 and 90 days after transplanting, respectively. It is clear from the Table 1 that, the maximum Spad value was recorded for the plants receiving optimum microclimatic condition which was significantly superior in polyhouse over other treatments at all the stages of observations. The favourable environment provided due to protected structure, a plant was accelerated by their increased chlorophyll content. These results are in confirmity with the results obtained by Naik (2005) and Ngouajio *et al.* (2008) in capsicum and Hartz (1993) in tomato.

Reproductive parameters:

Reproductive parameters directly contribute to production of capsicum and it is affected by growing condition and irrigation level. The growing condition and irrigation level shows a significant effect on number of flowers per plant, number of fruits per plant, number of days for first flowering and number of days for first harvesting.

Influence of growing condition and irrigation level on number of flowers and fruits per plant:

The data presented in Table 2 indicated that the interaction of growing condition and irrigation level effect on number of flowers and fruits per capsicum plant was found to be significant. Minimum number of flowers and fruits per plant was recorded with the treatment combination I_3C_1 (drip irrigation at 60% ETc in open field) *i.e.*8.18 and 4.70 over the rest of treatments. However, maximum number of flowers and fruits per plant was recorded due to the treatment combination I_3C_3 (drip irrigation at 60% ETc under polyhouse) *i.e.*15.14 and 11.77 respectively. Gupta (1987) reported that flower and fruit number per plant is directly related to the frequency of irrigation. Soil moisture enhanced the reproductive capability of plant which might have consequently helped to increase the number of flowers and fruits per capsicum plant, and excessive irrigation reduced its productivity through reduction in fruit number (Hedge, 1988).The results are in confirmity with findings of Rajbir Singh *et al.* (2003) and Buoczlowska (1990) in capsicum.

Influence of growing condition and irrigation level on number of days for first flowering and harvesting:

The data presented in Table 2 indicated that the interaction of growing condition and irrigation level on days required for flower initiation and fruit set of capsicum crop was found to be significant. Minimum period *i.e.*33.39 and 47.10 days was required for flower initiation and fruit set of capsicum crop in treatment combination I_3C_3(drip irrigation at 60% ETc under polyhouse) whereas the treatment combination I_3C_1 (drip irrigation at 60% ETc in open field) took the maximum period *i.e.*52.44 and 65.45 days for the maturity of

Table 2: Interaction effect of growing condition and irrigation level on reproductive parameters of capsicum plant

Treatment combinations	Reproductive parameters			
	Number of flowers per plant	Number of fruits per plant	Number of days for first flowering	Number of days for first harvesting
T_1 (I_1C_1)	8.84	5.15	50.23	64.38
T_2 (I_2C_1)	9.07	5.74	48.70	63.23
T_3 (I_3C_1)	8.18	4.70	52.44	65.45
T_4 (I_1C_2)	10.99	7.24	42.92	57.53
T_5 (I_2C_2)	11.78	8.13	41.37	55.51
T_6 (I_3C_2)	12.92	9.42	38.95	54.15
T_7 (I_1C_3)	13.93	10.26	36.34	51.27
T_8 (I_2C_3)	14.27	10.83	35.59	49.66
T_9 (I_3C_3)	15.14	11.77	33.39	47.10
F test	Sig.	Sig.	Sig.	Sig.
S.E.±	0.114	0.101	0.610	0.148
C.D. (P=0.05)	0.342	0.303	1.829	0.443

capsicum crop over the rest of treatments, respectively. Microclimate inside greenhouse during winter months was mainly responsible for better yield due to their beneficial effects on early flowering and fruiting. Nimje *et al.* (1990) and Rylski and Halevy (1974) have also observed similar results in capsicum.

Yield and water use efficiency for different treatments :

As the capsicum is vegetable crop, its harvesting was done from time to time by picking of fruits. The complete harvesting was obtained by 8 to 10 pickings. The data pertaining to average yield of capsicum as interaction effect of growing condition and irrigation levels is presented in Table 3. During year 2013-14, it is observed that treatment T_9 (drip irrigation at 60% ETc under polyhouse) recorded significantly higher yield of capsicum (1163.7 q/ha) and followed by treatment T_8 (drip irrigation at 80% ETc under polyhouse), T_7 (drip irrigation at 100% ETc under polyhouse). The lowest yield of capsicum (468.1 q/ha) was recorded in treatment T_3 (drip irrigation at 100% ETc in open field).

Table 3 : Yield and WUE of capsicum as influenced by growing condition and irrigation levels in 2013-14

Treatments	Yield of capsicum (q/ha)	Consumptive use (ha-cm)	Water use efficiency (q/ha-cm)
T_1	534.2	41.20	12.97
T_2	557.0	33.86	16.45
T_3	468.1	26.52	17.65
T_4	749.1	61.13	12.25
T_5	827.8	49.81	16.62
T_6	941.7	38.42	24.51
T_7	1042.6	61.13	17.05
T_8	1077.4	49.81	21.63
T_9	1163.7	38.42	30.29
F – test	Sig.	-	-
S.E. ±	1.140	-	-
C.D. (P=0.05)	3.417	-	-

It is also observed from the result that treatments T_4 and T_7 were having highest consumptive use (61.13 ha-cm) due to maximum crop duration under protected structure result in higher water requirement, followed by treatments T_5 and T_8 (49.81 ha-cm) and lowest in treatments T_3 (26.52 ha-cm). Higher yield with less amount of consumptive use gives maximum water use efficiency which is observed in treatment T_9 (drip irrigation at 60% ETc under polyhouse) *i.e.* 30.29 q/ha-cm, followed by T_6, T_8, T_3, T_7, T_5, T_2 and T_1. However minimum water use efficiency was noticed in treatment T_4 (drip irrigation at 100% ETc under shadehouse) *i.e.* 12.25 q/ha-cm although it having maximum yield but it required maximum water also.Nagalakshmi *et al.* (2002) and Christopher *et al.* (1996) reported similar findings in chilli and tomato.

Conclusion:

TreatmentT_9 (drip irrigation at 60% ETc under polyhouse) had recorded significantly highest water requirement, maximum water use efficiency, growth and fruit yield parameters of capsicum were found to be superior over rest of the treatments.

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