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Deficit Drip Irrigation Scheduling for Capsicum in Eastern India

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ABSTRACT: *Water scarcity is one of the major causes of low productivity of vegetables in eastern India. Deficit irrigation (DI) under drip system has been proposed as an efficient irrigation strategy in irrigated agriculture. The present study was planned with a hypothesis that drip irrigation scheduling with DI technique could save a substantial amount of water over full irrigation (FI, 100% ET_c), without affecting the yield significantly in capsicum (Capsicum annum, L.). The experiment was conducted in rabi season (December–March) of 2013–2014, with drip-irrigated capsicum at Bhubaneswar, Odisha. The crop responses to DI scheduled at 50% FI (DI_{50}), 75% FI (DI_{75}) throughout the crop season, was compared with that under FI. DI_{75} at 1.0 m lateral spacing produced marginally lower fruit yield (4.5%), with lower vegetative growth of the plants in comparison with that under FI. The heavier fruits were harvested in DI_{75} compared to that in FI. However, the water productivity under DI_{75} was observed to be 13% higher over FI. The concentration of available nutrient (N, P and K) in soil was more in fully-irrigated plots compared to that in other treatments. However, P did not show any significant ($P < 0.05$) variation in soil under irrigation treatments. Overall, these results reveal that DI_{75} with drip irrigation is a potential water saving strategy producing higher water productivity in capsicum cultivation in eastern India.*

INTRODUCTION

Water availability is one of the major constraints in crop production due to higher water demand for industrialization and population growth. Further, the share of water for agriculture is going to be reduced significantly in future years. Therefore, the efficient water conservation and management practices are need of the hour to sustain production and productivity of agricultural crops even in high rainfall areas (Panda *et al.*, 2004). Moreover, the harvest per every drop of water should be enhanced while considering the best productivity level of any crop (Panigrahi *et al.*, 2011).

In recent years, irrigated agriculture is shifting the paradigm of irrigation management from full to the partial supply of water in water scarce regions. Water scarcity in irrigation sector demands for the improvement in water use efficiency in any cropping system. One of the most promising techniques that would help to attain this objective is the use of deficit irrigation (DI) in crop production. DI is a reduced water supply strategy in which irrigation can be scheduled in such a way that the soil and plant water status can be maintained at optimum level to control transpiration without bringing a significant change in photosynthesis rate of leaves (Kriedemann and Goodwin, 2001). The knowledge of yield response to irrigation is essential for deciding the best DI regime in any crop. In regions where water is scarce, DI can be more profitable for a farmer to maximize crop water productivity instead of maximizing the harvest per unit land.

Capsicum (*Capsicum annum*, L.) is one of the important vegetables grown in India. India contributes 25% of the total capsicum produced in world (Sreedhara *et al.*, 2013). The eastern India, one of the major capsicum growing region of the country, is characterized by a long dry season with an amount of 1200 to 1500 mm average annual rainfall concentrated mainly (>85 %) in three to four months (July–October) of the year. The crop is normally grown in open fields during winter season (December–March) in eastern India. The crop is very sensitive to both excess and shortage of soil water in any stage of its growth. Cultivation of capsicum with irrigation facility is a common practice in this region. However, limited fresh water availability due to the regional saline aquifer restricts irrigation water

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supply for the crop. Drip irrigation has been found as a productive and water saving technique in capsicm (Antony and Singandhupe, 2004). Optimum irrigation scheduling is one of the key options to enhance water use efficiency under any irrigation system. It is therefore essential to study the response of capsicum to DI under drip system.

MATERIALS AND METHODS

The experiment was conducted during December 2013 to March 2014 to study the response of capsicum to DI under drip system at Deras Research Farm, Mendhasal of ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha. The plants were transplanted in paired rows on beds keeping the drip lateral pipes at the centre of the beds. The capsicum seedling (variety Indam Bharat) of 20 days was transplanted for the study. The plant to plant and row to row distances were maintained at 0.4 m on bed. Two lateral layouts were tried with lateral to lateral spacing of 1.4 m and 1.0 m with four DI regimes. DI imposed were at 75% crop water requirement (ET_c), 50% ET_c, 50% ET_c except flowering and fruiting stage (FFS) and compared with full irrigation (FI, 100% ET_c).

The texture of soil is sandy loam (45% sand, 24% silt and 31% clay) with bulk density of 1.44 g cm^{-3}. The field capacity and permanent wilting point were 0.17–0.31 cm^3/cm^3 and 0.05-0.12 cm^3/cm^3, respectively with mean pH of 5.91. The experimental soil is acidic in nature. The hydraulic performance of the drip system was studied from time to time and found satisfactory with emitter flow rate variation (Q_v) of 9%, co-efficient of variation (CV) of 7.5% and distribution uniformity (DU) of 92%. The groundwater level was at 8 m depth from land surface of the experimental site.

The experimental site is having sub-tropical climate with hot and humid summers. The hottest months of the year are May and June with maximum daily temperature of 44 ^{0}C, whereas January is the coldest month with mean temperature of 12 ^{0}C. The mean annual rainfall of the site is 1500 mm, out of which around 85% is concentrated mainly during June-September.

The irrigation was continued from December to Mid-march of the year of experiment. The experiment was laid out in split plot design with irrigation as main-plot treatment and lateral layout as sub-plot treatments. Each treatment plot size was 8 m x 7 m. The irrigation water quantity was estimated using the formula, $ET_c = \{(E_p \times K_p \times K_c) - ER\}/ (IE)$, where ET_c is the crop evapotranspiration (mm day^{-1}); E_p the pan evaporation rate (mm day^{-1}); K_p the pan evaporation co-efficient; K_c the crop coefficient; ER, Effective rainfall (mm day^{-1}) and IE the irrigation efficiency (90%). The effective rainfall during the experiment was worked out as the summation of change in soil water content in root zone of the plants before and after rainfall and potential crop evapotranspiration for the day of rainfall, as suggested by FAO-25 (Dastane, 1978). The irrigation volume (l day^{-1}) was calculated by multiplying ET_c with 90% of crop area in m^2.

The required amount of water to each irrigation treatment was regulated by adjusting the operating hours based on the actual discharge of the emitters from time to time. The flow of irrigation water in lateral pipes was controlled by lateral valves provided at the inlet end of lateral pipes. The application of NPK-based fertilizers (120 kg ha^{-1} N and 120 kg ha^{-1} K through drip system and 60 kg ha^{-1} P through soil application) was performed once in fifteen days as per recommendation. Intercultural operation and the plant protection measures against insect pests and diseases were adopted uniformly for all treatments following the recommendations given for the crop in the region.

The volumetric soil-water content at 30 cm, 60 cm and 90 cm depths was measured two times in a week. Soils samples at 0-30 cm, 30-60 cm and 60-90 cm depths and at 10 cm, 20 cm, 30 cm and 40 cm distances from lateral pipes were collected from beds and analyzed for available macronutrients (N, P and K) following standard procedures. The vegetative growth of plants (plant height, number of branches and canopy diameter), yield parameters (number of fruits, average fruit weight and yield) were recorded from time to time and irrigation water productivity (IWP) was estimated by calculating yield per unit quantity of water used. The data generated were subjected to analysis of variance (ANOVA) and critical difference (CD) at 5% level was obtained using the methods described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The mean monthly soil water content (SWC) observed at 30 cm, 60 cm and 90 cm depths during irrigation seasons indicates that FI resulted in significantly higher SWC compared to other treatments (Fig. 1). The highest fluctuation in SWC was observed at 0–30 cm depth, which might be due to maximum evaporation coupled with higher root water uptake from this soil layer. In all soil depths, the SWC consistently reduced from December to March due to higher crop water uptake with increased crop growth and fruit yield. The SWC in 30 cm and 60 cm soil depths was nearly at field capacity. However, at 90 cm the SWC was at par in different treatments, indicating the maximum wetting of top 60 cm soil under drip irrigation in this trial. The mean soil water fluctuation between two consecutive measurements during irrigation season under FI was observed to be highest followed by DI_{75} treatment, reflecting the highest evapo-transpiration rate of the plants under higher level of irrigation. The higher moisture depletion under FI over other treatments was due to increased water extraction rate by plants from partially wetted soil volume. The similar trend of water extraction by plants with higher level of irrigation under drip was observed by Cohen (2001).

The available N, P and K status in the soil under different irrigation strategies showed an increasing trend (Table 1). The increase in N, P and K was due the application of NPK-based fertilizers to the plants during irrigation seasons. The maximum increase in the available nutrients was observed under FI, whereas the minimum was with DI_{50}. The higher availability of N, P and K under FI was due to increased soil water content in this treatment which induced better nutrients concentration in soil water in *rhizosphere*. Moreover, the lower later to lateral distances (1.0 m) induced higher available N, P and K in soil. However, the annual increase in available nutrients under the treatments suggests for both annual-soil nutrients based fertilization strategies for the plants. Further, the studies on fertigation with deficit water supply in capsicum are suggested under drip irrigation.

The vegetative growth parameters of plants (plant height, number of branches and canopy diameter) were significantly affected by irrigation treatments and lateral layouts (Table 2). The highest growth of the plants was observed with FI, followed by DI_{75}. The higher vegetative growth under higher irrigation regime was probably due to higher photosynthesis rate and its proportionate partioning towards vegetative growth under this treatment. Previously, Sezen *et al.* (2011) showed the similar findings of decrease in vegetative growth of deficit-irrigated plants. The treatment DI_{50} produced the minimum growth of the plants. However, the growth parameters were not affected significantly by lateral lay outs.

The yield parameters yield parameters (number of fruits, average fruit weight and yield) in various treatments are presented in Table 2. The maximum number of fruits was harvested from fully-irrigated plants followed by DI_{75}. However, the maximum fruit weight was recorded with DI_{75}. The more number of fruits might be a cause of smaller size fruits in DI_{75}. The maximum fruit yield per plant was observed with FI. The fruit yield per hectare was decreased with decrease in irrigation regimes. The fruit yield at 75% ET_c was statistically at par with that in FI. The possible reasons for higher fruit yield under DI_{75} may be that the water deficit created under this treatment suppressed the vegetative growth of the plants without bringing much effect on leaf photosynthesis rate and the plants invested higher quantity of photosynthates towards reproductive growth (fruiting) than vegetative growth. The similar results of lower fruit yield with DI over FI were earlier reported by Antony and Singandhupe (2004) and Karam *et al.* (2009).

The IWP was computed to be highest under DI_{75}, followed by FI. The higher IWP resulted in DI_{75} was attributed to higher increase in fruit yield with

Table 1
Changes in available N, P and K (mg kg^{-1}) in soil under different irrigation treatments in capsicum

Treatments		*0–30 cm*			*30–60 cm*			*60–90 cm*		
		N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
DI_{100}	L_1	+1.60	+0.72	+3.00	+0.57	+0.45	+1.12	+0.07	+0.23	+1.06
	L_2	+1.71	+0.74	+3.14	+0.66	+0.50	+1.60	+0.06	+0.34	+1.10
DI_{75}	L_1	+1.53	+0.64	+2.74	+0.55	+0.38	+1.03	+0.05	+0.18	+1.02
	L_2	+1.64	+0.67	+3.00	+0.61	+0.42	+1.48	+0.04	+0.22	+1.07
DI_{50}	L_1	+1.15	+0.50	+2.55	+0.13	+0.27	+1.05	+0.03	+0.11	+0.82
	L_2	+1.24	+0.57	+2.56	+0.26	+0.33	+1.36	+0.04	+0.15	+0.88
DI_{50} EFFS	L_1	+1.00	+0.84	+2.14	+0.18	+0.20	+0.73	+0.05	+0.14	+0.92
	L_2	+1.81	+0.94	+2.44	+0.26	+0.21	+0.86	+0.06	+0.16	+0.95
$CD_{0.05}$	I	0.13	ns	0.11	ns	ns	ns	0.03	ns	0.13
	L	ns	ns	ns	ns	ns	ns	ns	ns	ns
	IxL	0.04	ns	0.03	ns	ns	ns	0.01	ns	0.08

DI_{100}: Drip irrigation at 100% ET_c; DI_{75}: Drip irrigation at 75% ET_c; DI_{50}: Drip irrigation at 50% ET_c; L_1: 1.4 m lateral distance; L_2: 1.0 m lateral distance

Table 2
Vegetative growth, yield and WUE of capsicum under different irrigation regimes and lateral layouts

Treatments		*Vegetative growth*			*Yield parameters*				
		Plant height (m)	*Branches (number)*	*Canopy diameter (m)*	*No. fruits/ plant*	*Average fruit weight (g)*	*Yield (kg/plant)*	*Yield (t/ha)*	*WP (kg/m³)*
DI_{100}	L_1	66.9	7.6	56.2	2.53	97.1	0.246	11.84	4.80
	L_2	66.7	7.3	54.1	2.50	97.1	0.241	15.40	4.53
DI_{75}	L_1	61.9	6.6	53.3	2.31	98.7	0.228	11.00	5.33
	L_2	61.6	6.2	53.0	2.21	98.3	0.218	14.73	5.11
DI_{50}	L_1	53.9	5.2	49.8	1.68	68.8	0.116	5.60	3.46
	L_2	53.7	5.0	49.5	1.59	68.5	0.109	5.20	3.28
DI_{50} EFFS	L_1	60.1	6.1	54.2	2.04	76.4	0.156	7.52	3.55
	L_2	60.0	5.9	54.0	2.00	76.0	0.152	1.25	3.46
$CD_{0.05}$	I	3.7	0.6	4.2	0.6	0.5	0.02	4.7	--
	L	ns	ns	ns	ns	ns	ns	6.6	
	IxL	2.8	0.4	2.7	0.5	0.3	0.05	7.9	

DI_{100}: Drip irrigation at 100% ET_c; DI_{75}: Drip irrigation at 75% ET_c; DI_{50}: Drip irrigation at 50% ET_c; L_1: 1.4 m lateral distance; L_2: 1.0 m lateral distance

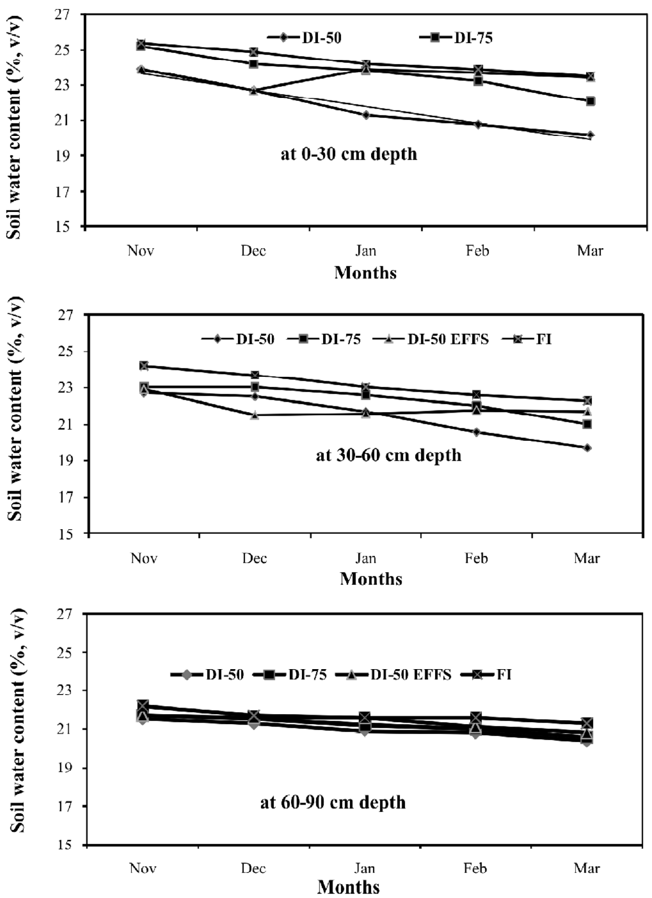

Figure 1: Soil water content at 30 cm, 60 cm and 90 cm depths under different drip irrigation treatments in capsicum

comparatively less increase in irrigation water use under this treatment over other treatments. An improvement in IWP with DI was also earlier reported in capsicum (Antony and Singandhupe, 2004).

CONCLUSIONS

The higher soil water fluctuation between two observations under full irrigation indicated the greater water uptake by the plants under this treatment compared to other treatments. The significant soil water content variation at 0–30 cm depth reflects the confinement of effective root zone of the plants in top 30 cm soil. Irrigation at 100% ETc produced higher vegetative growth and fruit yield of the plants with 1.0 m lateral spacing. However irrigation at 75% ET_c with 1.0 m lateral spacing produced only 4.5% less yield with 25% irrigation water saving. Thus drip irrigation at 75% ET_c and 1.0 m lateral-to-lateral spacing may be used in capsicum cultivation

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