Effect of drip and surface irrigation on yield, water-use-efficiency and economics of capsicum (c*apsicum annum* l.) Grown under mulch and non mulch conditions in eastern coastal india

By
J.C. Paul[1], J.N. Mishra[2], P.L. Pradhan[3] , B. Panigrahi[4]

Abstract

A field experiments was conducted on the loamy sand soil at Bhubaneswar in eastern coastal of India for two years (2007-08 and 2008-09) to evaluate the yield, water-use-efficiency and economic feasibility of capsicum grown under drip and surface irrigation with non-mulch and black Linear Low Density Poly Ethylene (LLDPE) plastic mulch. Actual evapotranspiration for capsicum crop was estimated using modified pan evaporation method. The net irrigation volume (V) was determined after deducting the effective rainfall. Effect of three irrigation levels viz. VD, 0.8 VD and 0.6 VD (VD = full irrigation volume with drip) in conjunction with LLDPE mulch and no mulch were studied on biometric and yield response of capsicum crop. The results of surface irrigation were compared with drip irrigation system under no mulch and in conjunction with LLDPE mulch. The study indicated better plant growth, more number of fruits per plant and enhancement in the yield under drip irrigation system with LLDPE mulch. The highest yield (28.7 t/ha) was recorded under 100% net irrigation volume with drip irrigation (VD) and plastic mulching as compared to other treatments. This system increased the yield and net seasonal income by 57 % and 54 % respectively as compared to conventional surface irrigation without mulch with a benefit cost ratio of 2.01. The benefit cost ratio was found to be the highest (2.44) for the treatment VD without mulch. Drip irrigation system could increase the yield by 28 % over surface irrigation even in the absence of mulch. Similarly, LLDPE mulch alone could increase the yield by 13 % even in the absence of drip irrigation system.

Key Words: surface irrigation*, capsicum annum,* vegetable, crop

1. Introduction

Presently in India 7.49 million ha area is cultivated with vegetable with an annual production of 116.03 million tonnes. It is estimated that, by 2020 the vegetable demand of the country would be around 135 million tonnes. To achieve

| [1,2,3] Associate Professor, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar, India.
[4] Professor, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar, India.

this target, attention must be focused on the vertical expansion, strengthened with the boon of the technology instead of horizontal expansion just by increasing the crop area (Rai and Pandey, 2008). The working group on horticulture constituted by the Planning Commission has recommended the deployment of hi-tech horticulture and precision farming for achieving vertical growth in horticulture. Hi-tech interventions in horticultural crops proposed by National Committee on Plasticulture Applications in Horticulture (NCPAH), Govt. of India include drip irrigation and greenhouse technology and the crops selected are capsicum, chilli, tomato and flowers like rose, carnation and gerbera (Samuel and Singh, 2004). Drip irrigation with its ability to small and frequent applications of water has created interest among the farmers because of less water requirement, increased production and better quality produce. Economic evaluation of drip irrigation in fruit crops (coconut, mango and sapota) in Orissa reveales that, this system conserves considerable amount of water and results better returns despite higher initial investment (Behera and Sahoo, 1998). The response of tomato and okra to drip irrigation in terms of yield improvement is found to be different in different agro-climatic and soil conditions in India (Shrivastava *et al,* 1994; Tiwari *et al*, 1998a; 1998b; Horo *et al*, 2003; Singh, 2007; Vankar and Shinde, 2007). Use of soil cover and mulching is also known to be beneficial chiefly through their influence on soil moisture conservation, solarization and control of weeds. Beneficial response of plants to mulch includes early production, more yield and reduced insect and disease problems (Tiwari *et al*, 1998a; Pattanaik *et al*, 2003). Linear Low Density Poly Ethylene (LLDPE) plastic films have been proved as better mulch because of their puncture resistance quality, thinness and lower cost (Panda, 2004).

Capsicum (*Capsicum annum* L.) or bell pepper is an important cool season vegetable crop of India. It is richer in vitamins than tomato, especially in A and C. In India, it is grown mainly during the cooler parts of the year (autumn-winter) when the temperature is low (Singh *et al.*, 1993). The production of this crop is affected adversely by moisture deficit. Productivity of the crop can be increased by adopting improved package of practices, particularly *in-situ* moisture conservation by mulching as well as high-tech irrigation especially drip irrigation with appropriate irrigation scheduling. Numerous experiments have reported the benefits of black LLDPE mulch in several crops, but research is limited on response of capsicum production by this method. Keeping this in background, the present study was undertaken to study the effect of drip irrigation system and plastic mulch on capsicum crop and compare the result with the conventional method of growing the crop under surface irrigation without mulch.

2. Materials and methods

A field experiment was conducted at Precision Farming Development Centre experimental site located at Orissa University of Agriculture and Technology, Bhubaneswar, India. The soil of the area is loamy sand and acidic in nature having p^H of 6.2. Capsicum seedlings (variety California Wonder) of 25 days were planted with a spacing of 60 cm x 45 cm during 1st week of November during the year 2007 and 2008. The experiment was laid out in randomized block design having eight treatments replicated thrice with a plot size of 4.5 m x 1.2 m. One metre gap was provided between each plot to avoid effect of irrigation treatment. The treatment details are as follows:

T_1 = 100% irrigation requirement through drip irrigation (VD)
T_2 = 80% irrigation requirement through drip irrigation (0.8VD)
T_3 = 60% irrigation requirement through drip irrigation (0.6VD)
T_4 = 100% irrigation requirement by surface irrigation (V)
T_5 = 100% irrigation requirement through drip irrigation with black LLDPE mulch (VD+M)
T_6 = 80% irrigation requirement through drip irrigation with black LLDPE mulch (0.8VD+M)
T_7 = 60% irrigation requirement through drip irrigation with black LLDPE mulch (0.6VD+M)
T_8 = 100% irrigation requirement by surface irrigation with black LLDPE mulch (V+M)

The cultural practices of the crop were followed as per the recommendations by Indian Council of Agricultural Research, New Delhi (Thamburaj and Singh, 2003). The LLDPE film of 50-micron thickness was used for mulching around the plant. The lateral lines of 12 mm diameter LLDPE pipes were laid along the crop rows and each lateral served two rows of crop. The laterals were provided with on line turbokey dripper of 4 lit/hr discharge capacity. LLDPE pipes of 75 mm diameter were used for main and 63 mm diameter was used for sub-main. The main line was directly connected to a 1.5 hp pump installed to lift water from an open sump. The manifold unit was connected with a screen filter, a pressure gauge and control valve. The duration of delivery of water to each treatment was controlled with the help of gate valves provided at the inlet end of each lateral. In case of surface irrigation, irrigation was scheduled at weekly interval (Fig. 1).

3. Estimation of irrigation water requirement

The water requirement of the crop was computed on daily basis by using the following equation as suggested by Shukla *et al.*, (2001).

$$V = E_p.K_p.K_c.S_p.S_r.W_p$$

Where,

V = Volume of water required (litre / day / plant)

E_p = Pan evaporation as measured by Class-A pan evaporimeter (mm / day)

K_c = Crop co-efficient (co-efficient depends on crop growth stage)

K_p = Pan co-efficient

S_p = Plant to plant spacing (m)

S_r = Row to row spacing (m)

W_p = Fractional wetted area, which varies with different growth stage (0.3 to 1.0)

The values of pan coefficient and crop coefficients were taken from (Doorenbos and Pruitt, 1977). The water requirement of capsicum crop was estimated on daily basis for all months considered under study. Daily time to operate drip irrigation system was worked out taking the application rate per plant. Drip system was scheduled on alternate days; hence total quantity of water delivered was cumulative water requirement of two days.

Observations on water requirement, growth character and yield of capsicum were recorded and analyzed statistically following the standard procedures (Panse and Sukhatme, 1985). The water use efficiency (WUE) of the crop was determined by dividing the yield with water requirement of the crop.

4. Economic analysis

Benefit-Cost ratio and net profit were carried out to determine the economic feasibility of the crop using surface and drip irrigation as suggested by Tiwari *et al.* (1998a). The seasonal system cost of drip irrigation system included depreciation, prevailing bank interest rate, and repair and maintenance cost of the system. The fixed cost of drip irrigation system was determined to be Rs 110000/ha. The useful life of drip system was considered to be 10 years. The system cost was evaluated by distributing the fixed cost of system over life period of drip irrigation set. For calculating depreciation, the life of the drip irrigation set and 10 % junk value was considered. The interest was calculated on the average of investment of the drip irrigation set taking into consideration the value of the set in the first and last year @ 10 % per annum. Cost of repairs and maintenance of set is @ 2 % of initial cost of the drip irrigation set per year. The cost of cultivation includes expenses incurred in land preparation, interculture operation, fertilizer, crop protection measures, irrigation water and harvesting with labour charges. Therefore, total seasonal cost was worked as: depreciation, interest, repairs and maintenance cost of set + cost of cultivation + cost of mulch. The income from produce was calculated using prevailing average market price of capsicum @ Rs 1000/ q.

5. Results and discussion

5.1 Growth and yield attributes

Two years pooled data of biometric parameters like plant height, number of leaves per plant and average yield attributing characters such as days taken to flowering, average single fruit weight, number of fruits per plant and the yield of capsicum are presented in Table 1. The results revealed that, these characters and yield are significantly superior in the treatment T_5 (100% irrigation requirement through drip irrigation with LLDPE mulch) as compared to the rest of the treatments. The height of plant under treatment T_5 (78.6 cm) was found to be significantly highest among all other treatments and is 55 % higher than the height of plant under surface irrigation without mulch (T_4). As regards to number of leaves per plant, maximum value was recorded in treatment T_5 (99.7) followed by treatment T_6 (97.3) and the lowest value was in treatment T_4 (76.7).

All the yield attributing characters are found to be significantly higher in treatment T_5 than other treatments. The treatment T_5 recorded 36 %, 43 % and 23 % higher number of fruits per plant, single fruit weight and days to flowering respectively than control (T_4). Mulch was observed to have significant effect on yield attributing characters than non-mulch treatments.

The highest increase in vegetative growth in treatment T_5 might be due to the availability of soil moisture as well as temperature at optimum level (Tiwari *et al*, 1998a; Tiwari *et al*, 1998b; Pattanaik *et al.*, 2003). The lowest value of vegetative growth in T_4 might be because of unfavourable moisture regime (moisture stress or excess moisture) in the soil through surface irrigation and competition of weeds for nutrients (Pattanaik *et al.*, 2003; Agrawal and Agrawal, 2005). The increased growth attributes might have supplied water and nutrients in adequate proportion, which resulted in triggering the production of plant growth hormone, viz. indole acetic acid (IAA) and higher number of leaves throughout the cropping period (Sankar *et al.*, 2008).

5.2 Crop yield

The drip irrigation in combination with mulch significantly increased the yield of capsicum as compared to drip irrigation without mulch (Table 1). Among various treatments, the highest yield (28.7 t/ha) was recorded under treatment T_5 , which increased by 57 % over surface irrigation. Drip irrigation with LLDPE mulch treatments (T_5, T_6 and T_7) increased the percentage in yield by 15 %, 14 %

and 16 % respectively as compared to drip irrigation without mulch treatments (T_1, T_2 and T_3). The low yield was recorded under surface irrigation method (18.2 t/ha). This might be due to water stress during the critical growth period, coupled with aeration problem in first few days immediately after irrigation. Another reason to get low yield by surface irrigation might be due to less availability of nutrients for crop growth due to leaching with high weed infestation between the crops (Pattanaik *et al*., 2003). This result corroborated the findings of Tiwari *et al.* (1998a); Tiwari *et al.* (1998b) and Singh (2007). In drip irrigation system, water is applied at a low rate for a longer period at frequent intervals near the plant root zone through lower pressure delivery system, which increases the availability of nutrients near the root zone with a reduction in leaching losses. More nutrient availability, especially near the root zone might have increased the translocation of photosynthetes to storage organ of capsicum resulting in an increased weight of capsicum (Sankar *et al*., 2008). Based on the results, drip irrigation treatments (T_1, T_2 and T_3) increased yield by 38 %, 30 % and 8 % higher respectively as compared to surface irrigation (T_4). Therefore the study revealed that, even if 40 % less quantity of water was supplied through drip irrigation (T_3), 8 % higher yield of capsicum was established as compared to surface irrigation. This result is in close agreement with the findings of Tiwari *et al.* (1998a). The beneficial effect of yield characters advantage *vis-à-vis* better water-use-efficiency through drip irrigation is attributed to the continuous supply of water in required quantity at right time without flooding to cause hypoxia. Therefore, the roots remain well aerated (Lingaiah *et al*, 2005). Mulch alone in surface irrigation method (T_8) could increase yield upto 13 % than without mulch treatment (T_4). The beneficial effect of black LLDPE mulch in tomato and okra was also reported earlier by Shrivastava *et al.* (1994); Tiwari *et al.* (1998a); Tiwari *et al.* (1998b); Horo *et al.* (2003); Singh (2007); Vankar and Shinde (2007).

The water requirement for 100 % net irrigation volume under drip irrigation system for capsicum was 319 mm. The highest yield was obtained under treatment T_5 with the same quantity of water requirement (319 mm). Thus it can be concluded that drip irrigation gave highest yield with the same quantity of 319 mm of water as compared to surface irrigation and drip irrigation system with LLDPE plastic mulch increased yield by 57 % over surface irrigation with same quantity of irrigation water. Similar results have been obtained by Tiwari *et al.* (1998a) for okra crop at Kharagpur, West Bengal.

5.3 Water use efficiency

Water use efficiency (yield per unit area per unit depth of water used) decreased with increase in irrigation levels i.e. 0.6 VD, 0.8 VD and VD for all the treatments of drip irrigation system. There was significant effect of LLDPE mulch over drip irrigation system alone. The increase in water use efficiency for drip irrigation system alone (T_1) and drip irrigation system with LLDPE mulch (T_5) over conventional surface irrigation (T_4) was 38 % and 57 % respectively. Similar trend has been reported in water use efficiency for okra crop by Tiwari *et al.* (1998a); for tomato crop by Tiwari *et al.* (1998b) and Singh (2007).

5.4 Economic feasibility

Maximum net profit of Rs 191600/ha with B: C ratio of 2.01 was recorded in treatment T_5 and lowest net profit of Rs 132600/ha with a B: C ratio of 1.39 in T_7 (Table 2). It is observed that, the mulched treatments T_5 , T_6 and T_7 gave better net return per ha than their corresponding treatments without mulching. But higher B: C ratios were recorded in treatments without mulch than their corresponding treatments of LLDPE mulch. The results are in conformity with the findings of Singh (2007). The B: C ratio was 2.1 in conventional irrigation method (T_4) due to comparatively lower system cost and no mulch was used. However, the net profit in drip irrigated treatments with mulch was observed to be maximum (Rs 191600) in treatment T_5 followed by T_1 (Rs 178100), T_6 (Rs 173600), T_2 (163100), T_7 (132600) and T_3 (123100). The net profit per mm of water used (Rs 670.2/ha) was maximum in case of T_6 , where the water used was also less (259 mm). High net return of Rs 178100 / ha was obtained in drip irrigated treatments without mulch (T_1) which is Rs 53500 / ha (43 %) higher than control (T_4), proving the beneficial effect of drip irrigation system. Similar trends have been reported in net profit, B.C. ratio and net profit per mm of water used for okra by Tiwari *et al.* (1998a) and for tomato crop by Tiwari *et al.* (1998b) and Singh (2007).

Conclusion

The drip irrigation system is observed to be economical and cost effective as compared with conventional surface irrigation. As a result, the use of drip irrigation system either alone or in combination with mulching, could increase the capsicum yield up to an extent of 57 % over surface irrigation method with the same quantity of water. It was also observed that, 319 mm of water would be sufficient to irrigate one hectare of capsicum crop with the drip irrigation system in the sub-humid agro-climatic conditions of Bhubaneswar. The net profit could be increased by 54 % over the normal surface method by adopting drip irrigation system with mulch.

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Table 1 Growth, yield, water requirement and WUE of capsicum as influenced by different treatments (average data of two years)

Treatments	Plant height, cm	No. of leaves/ plant	Days to first flowering	Average single fruit wt., g	No. of fruits per plant	Yield, t/ha	Water requirement, mm	Water use efficiency, kg/ha-mm
T_1	66.6	95.9	62.2	98.1	8.8	25.1	319	78.6
T_2	61.9	92.2	57.8	94.2	8.5	23.6	259	91.1
T_3	53.9	84.4	53.6	88.3	8.1	19.6	199	98.4
T_4	50.7	76.7	52.7	78.8	7.3	18.2	319	57.1
T_5	78.6	99.7	64.7	112.7	9.9	28.7	319	89.9
T_6	72.7	97.3	63.4	105.8	9.2	26.9	259	103.8
T_7	60.7	93.7	56.7	92.1	8.4	22.8	199	114.5
T_8	55.3	85.7	53.8	89.9	8.2	20.5	319	64.3
SE (m) $\pm$	1.02	0.72	0.21	0.86	0.09	0.42	-	-
CD (0.05)	3.07	2.17	0.64	2.62	0.27	1.26	-	-

Table 2 Economic analysis of various treatments for capsicum

Sl. No.	Cost Economics	Treatments							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1.	Fixed cost, Rs/ha	110000	110000	110000	-	110000	110000	110000	-
2.	Seasonal system cost, Rs/ha								
	a. Depreciation	9900	9900	9900	-	9900	9900	9900	-
	b. Interest	5500	5500	5500	-	5500	5500	5500	-
	c. Repair & maintenance	2200	2200	2200	-	2200	2200	2200	-
	d. Total	17600	17600	17600	-	17600	17600	17600	-
3.	Seasonal cost of cultivation, Rs/ha	55300	55300	55300	57400	55300	55300	55300	57400
4.	Cost of mulch, Rs/ha	-	-	-	-	22500	22500	22500	22500
5.	Seasonal total cost (2d+3+4), Rs/ha	72900	72900	72900	57400	95400	95400	95400	79900
6.	Water used, mm	319	259	199	319	319	259	199	319
7.	Yield of produce, t/ha	25.1	23.6	19.6	18.2	28.7	26.9	22.8	20.5
8.	Income from produce, Rs/ha	251000	236000	196000	182000	287000	269000	228000	205000
9.	Net profit (8-5), Rs/ha	178100	163100	123100	124600	191600	173600	132600	125100
10.	Benefit cost ratio (9/5)	2.44	2.23	1.69	2.1	2.01	1.82	1.39	1.57
11.	Net profit per hectare per mm of water used (9/6), Rs/mm/ha	558.3	629.7	618.6	390.6	600.6	670.2	666.3	392.2

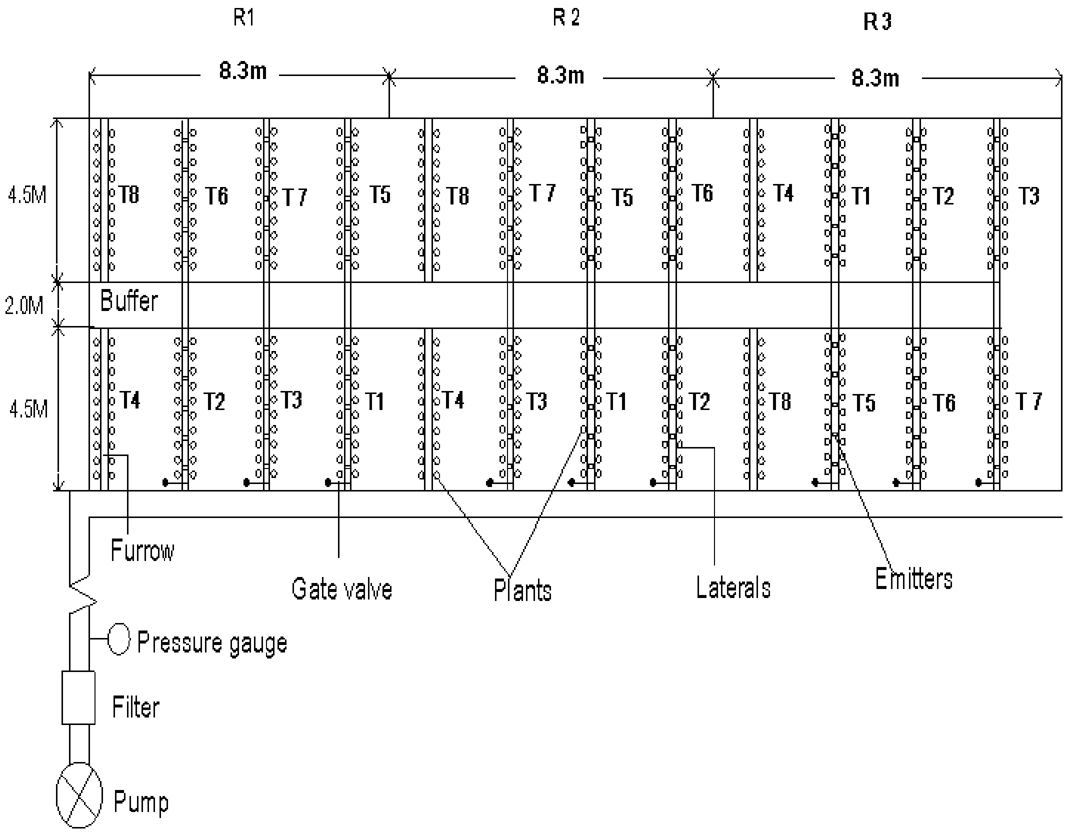

Fig.1: Drip irrigation layout for capsicum crop