

Original Research Article

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## Response of Bell Pepper (*Capsicum annum* L. var. *grossum*) to Drip Irrigation Levels and Black Plastic Mulch under Naturally Ventilated Polyhouse

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### ABSTRACT

A study was conducted to quantify the effects of drip irrigation levels and black plastic mulch on bell pepper production under a naturally ventilated polyhouse in Tarai region of Uttarakhand during Rabi 2014-15. The experiment was laid out in randomized block design with three replications keeping four drip irrigation levels (100, 80, 60 and 40 % of crop water requirement) and surface irrigation in conjunction with black plastic mulch and without mulch. It was observed that plant morphological parameters viz. plant height, fresh and dry weight of plant and root and fruit characters such as number of fruits per plant, average fruit weight, fruit length & diameter, polar & lateral circumferences of fruit and total yield were significantly increased by drip irrigation alone as well as in conjunction with black plastic mulch. Drip irrigation at 80% of crop water requirement gave the highest yield of fruits (83.22 t/ha), whereas it was the least (66.99 t/ha) in case of surface irrigation. The yield was further increased by the use of black polyethylene mulch (88.99 t/ha). It was also observed that drip irrigation both with and without plastic mulch registered much higher water use efficiency (WUE) compared to surface irrigation. The minimum water use efficiency of 142.4 kg ha<sup>-1</sup> mm<sup>-1</sup> was obtained for the plots receiving surface irrigation without the mulch. The use of black film in case of surface irrigation increased the WUE to 163.2 kg ha<sup>-1</sup> mm<sup>-1</sup>.

#### Keywords

Drip irrigation, Crop water requirement, Black plastic mulch, Bell pepper, Water-use efficiency

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### Introduction

Bell pepper (*Capsicum annum* L. var. *grossum*) is a popular vegetable of the family Solanaceae. It is mainly grown in India during cooler part of the year (autumn–winter) when air temperatures are moderate (Singh *et al.*,

1993). It is a successful off season vegetable of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Nilgiri hills (Tamil Nadu) and Darjeeling district of West Bengal during summer- rainy months and autumn crop of Madhya Pradesh, Uttar Pradesh, Jharkhand, Maharashtra (Pune and Thane districts) and

Karnataka (Bangalore, Belgaum and Mysore districts). Bell pepper has both nutritional and nutraceutical importance; it contains an anticoagulant that helps in preventing the blood clots and reduces the risk of heart attack (Nadeem *et al.*, 2011).

Water is one of the most important inputs for the successful crop production. Water management in bell pepper is extremely important as soil moisture stress during the growing period reduces the yield and quality. Besides, water also contributes to the cooling of plants during the period of high temperature. In present conditions, water has become scarce natural resource due to rapid population growth, industrialization, urbanization and erratic rainfall. This is not only causing global warming but irrigation water is also becoming both scarce and expensive due to fast depletion of surface and sub-surface water resources. Hence, to achieve sustainable higher returns per unit area judicious use of irrigation water through drip system along with plastic mulch in naturally ventilated polyhouse has become inevitable. Keeping in view the above concerns the present investigation of drip irrigation levels and black plastic mulch on capsicum production under naturally ventilated polyhouse” was undertaken during the rabi season of 2014-15 under the agro-climatic condition of *Tarai* region of Uttarakhand, India.

### **Materials and Methods**

The study was undertaken at Vegetable Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), India during Rabi cropping season from September 2014 to May 2015. The experiment consisting of 10 treatments was laid out in randomized block design with three replications. The treatment details are given in the table below. The

volume of water for 100% crop water requirement based on pan evaporation was computed using the following equation (Allen *et al.*, 1998)

$$V = E_p \times K_p \times K_c \times S_p \times S_r \times W_p$$

Where, V= Water requirement of plant per day (l),  $E_p$ = PAN evaporation,  $K_p$ =Pan Coefficient,  $K_c$ = Crop coefficient varies according to growth,  $S_p$ = Plant to plant spacing (m),  $S_r$ =Row to Row spacing (m),  $W_p$ = Fraction wetted area

The experiment was carried out in a medium cost naturally ventilated polyhouse of 100 m<sup>2</sup> area. The polyhouse was not equipped with any heating or cooling system and the side walls of the polyhouse was covered with insect proof net to prevent the entry of insect pests. Before transplanting the seedlings, the experimental field was well prepared with the help of spade followed by breaking of clods and levelling. After levelling, the field was divided into plots with walking strips in between the plots. After field preparation 15 cm raised beds of 150 cm width were made and over these, black plastic mulch of 40 micron thickness was spread according to the treatments and their corners and sides were covered with soil. Holes were made at a spacing of 60 × 50 cm for easy transplanting of seedlings. Healthy seedlings of capsicum cv. *Indira* were transplanted in the polyhouse on 17<sup>th</sup> October, 2014. Once the seedlings were established, all the necessary recommended cultural and plant protection practices were followed. Observations were recorded for plant height, days to 50 percent flowering, days to first picking, number of fruits per plant, fruit length (cm), fruit diameter (cm), fruit polar circumference (cm), fruit lateral circumference (cm) and fruit yield using standard methods. After the final harvest, the plants were dug out and the dry weight of shoot (stem and leaves) and root

were determined after complete drying at 60°C. The water use efficiency was computed by dividing the yield with water requirement of the crop.

### **Soil data**

To characterize the soil at experimental plot, the soil of experimental field was analyzed for the physical and chemical properties by collecting a composite soil sample from 0-15 cm soil depth before transplanting of seedlings (Fig. 1). The soil test values are given in Table 2.

## **Results and Discussion**

### **Growth characters**

Data in Table 3 for plant growth parameters indicate that drip irrigation, with or without mulch had significantly increased the plant height, fresh and dry weight of plant and root compared to surface irrigation. The maximum plant height of 108.30 cm, fresh (591.050 g) and dry (178.72 g) weight as well as fresh (55.08 g) and dry weight (15.78 g) of root at final stage of crop were recorded in treatment T<sub>4</sub> (80 percent water requirement with black plastic mulch) followed by irrigation at 60 percent water requirement under mulched condition (T<sub>6</sub>). The minimum values for these three plant parameters were obtained in treatment receiving surface irrigation without use of mulch (T<sub>9</sub>). It is noticed that increasing and decreasing the irrigation volume above and below 80 percent of crop water requirement significantly reduced the plant height, fresh and dry weight of plant and root. Significant improvement in plant growth parameters was also noticed by the use of plastic mulch. With respect to root length, minimum length of 16.01 cm was measured at 100 percent drip irrigation level without mulch condition and thereafter it gradually increased to 23.30 cm under mulched condition with the reduction in irrigation volume up to 40 percent.

The higher plant height, fresh and dry weight of plant under drip irrigation could be attributed to vigorous growth of plants due to better absorption and uptake of plant nutrients under optimum soil moisture range. Similarly, increase in growth characters in plastic mulched plots might be due to capabilities of mulch to maintain thermo-moisture regime in the soil which increased efficiency of water uptake by plants. These results are in conformity with the findings of Singh *et al.*, (2009). The more root weight due to increase in irrigation level might be attributed due to frequent and consistent application of water in the vicinity of the roots, which provides better soil moisture regime in the crop root zone throughout the crop growth period. Osmotic adjustment and prolonging root cell expansion might be the reasons for increased root length in mildly stressed plants than well-watered plants and the roots go deeper for the uptake of nutrients (Sharp *et al.*, 2009). These observations are in conformity with the findings of Antony and Singandhupe (2004). The more root length under plastic mulching could be attributed because of favourable influence of soil moisture and temperature. Wien *et al.*, (1993) also found significantly longer roots in mulched tomato as compared to the unmulched tomato.

### **Maturity**

Drip irrigation levels and black plastic mulch had shown significant impact on days to 50 percent flowering and days to first fruit picking (Table 3). The minimum number of days (38.42) to 50 percent flowering was noticed in the treatment receiving 40 percent irrigation and using black plastic mulch. In contrast, plants receiving 100 percent irrigation water without the use of black plastic mulch took the maximum days (43.01) for achieving 50 percent flowering. Treatment T<sub>8</sub> (40 percent water through drip and use of black plastic mulch) resulted into the earliest

fruit picking which was statistically at *par* with T<sub>5</sub> (54.31 days). Maximum days (55.34) for first fruit picking were taken for T<sub>1</sub> T<sub>2</sub> and T<sub>9</sub> being statistically same as T<sub>1</sub>. Black plastic mulch advanced the flowering and harvesting time of capsicum fruits compared to unmulched condition.

Delay in flowering and harvesting with increasing irrigation volume could be attributed to the increased vegetable growth at higher soil moisture levels which ultimately delayed the reproductive phase. This result is in agreement with the findings of Lodhi *et al.*, (2014). Earliness in flowering and harvesting under low irrigation volume could be attributed to the low availability of water at optimum level for growth and development which possess mild moisture stress than well-watered plants and under such conditions plants tend to shorten their life span and enter into reproductive phase faster.

These results are in agreement with the findings of Antony and Singandhupe (2004).

Optimum soil temperature and better microclimate under plastic mulch lead to early growth and development with advanced flowering and fruit setting (Bhatt *et al.*, 2011).

### **Fruit characters**

Significant differences for fruit number per plant of capsicum were observed in mulched and unmulched treatments and also among various levels of drip irrigation under naturally ventilated polyhouse (Table 4).

Maximum number of fruits per plant (28.60) was obtained in treatment T<sub>4</sub> (Irrigation at 80 percent of crop water requirement along with black plastic mulch) followed by irrigation at 60 percent irrigation along with black plastic mulch (T<sub>6</sub>). Fruit number was found to be the minimum (21.18) in T<sub>9</sub>. Use of plastic mulch and 80 percent of irrigation volume increased the fruits per plant by 35 % over the unmulched plot with surface irrigation (T<sub>9</sub>).

**Table.1** Details of treatments are given below

<b>Treatments</b>	<b>Specifications</b>
<b>T<sub>1</sub></b>	Irrigation at 100% crop water requirement without black plastic mulch
<b>T<sub>2</sub></b>	Irrigation at 100% crop water requirement with black plastic mulch
<b>T<sub>3</sub></b>	Irrigation at 80% crop water requirement without black plastic mulch
<b>T<sub>4</sub></b>	Irrigation at 80% crop water requirement with black plastic mulch
<b>T<sub>5</sub></b>	Irrigation at 60 % crop water requirement without black plastic mulch
<b>T<sub>6</sub></b>	Irrigation at 60 % crop water requirement with black plastic mulch
<b>T<sub>7</sub></b>	Irrigation at 40% crop water requirement without black plastic mulch
<b>T<sub>8</sub></b>	Irrigation at 40 % crop water requirement with black plastic mulch
<b>T<sub>9</sub></b>	Surface irrigation without black plastic mulch
<b>T<sub>10</sub></b>	Surface irrigation with black plastic mulch

**Table.2** Physico- chemical composition of soil of the experimental plot

Sl. No.	Characters	Values obtained	Method of analysis followed
1.	Texture	Sandy- loam	Feeling method
2.	pH	7.15	Glass electrode method (Jackson, 1967)
3.	Available nitrogen (kg/ha)	145.2	Alkaline KMnO <sub>4</sub> (Subbiah and Asija, 1956)
4.	Available phosphorus (kg/ha)	20.78	Olsen's method (Olsen <i>et al.</i> , 1967)
5.	Available potash (kg/ha)	126.01	NH <sub>4</sub> OAc (Pratt, 1965)
6.	Organic carbon (%)	0.90	Titration method (Walkey and Black, 1934)

**Table.3** Effect of drip irrigation levels and black plastic mulch on plant growth characters and maturity of capsicum under naturally ventilated polyhouse

Treatments	Plant height (cm)				Days to 50% flowering	Days to first fruit picking	Weight/plant (g)		Root weight/plant (g)		Root length (cm)
	45 DAT	90 DAT	135 DAT	Final stage			Fresh	Dry	Fresh	Dry	
T <sub>1</sub>	55.77	62.73	68.45	95.17	43.01	55.34	481.35	149.69	43.22	11.86	16.01
T <sub>2</sub>	56.44	63.73	71.15	96.51	42.12	55.12	518.18	158.05	45.75	12.07	16.15
T <sub>3</sub>	56.10	62.63	71.08	102.47	42.10	55.01	524.34	158.33	50.41	14.36	17.58
T <sub>4</sub>	58.24	65.97	75.15	108.30	40.15	54.04	591.05	178.72	55.08	15.78	17.62
T <sub>5</sub>	55.53	63.87	70.68	100.07	42.02	54.31	504.01	150.06	46.03	11.86	17.64
T <sub>6</sub>	57.11	64.37	73.20	101.70	40.08	53.15	556.70	164.37	50.10	14.01	18.01
T <sub>7</sub>	54.48	60.35	66.28	92.12	40.05	54.02	417.37	131.04	42.32	10.75	22.14
T <sub>8</sub>	54.84	61.07	66.84	93.83	38.42	53.06	428.12	141.91	43.65	10.90	23.30
T <sub>9</sub>	52.14	57.03	63.41	88.83	41.80	55.08	411.36	128.64	40.36	10.67	20.19
T <sub>10</sub>	52.06	58.28	66.72	90.32	41.00	55.04	454.70	139.00	43.19	11.63	21.23
CD at 5%	1.18	3.23	2.66	3.44	0.71	0.32	36.31	9.41	1.57	1.34	0.68

**Table.4** Effect of drip irrigation levels and black plastic mulch on fruit characters of capsicum under naturally ventilated polyhouse

Treatments	Number of fruits per plant	Fruit length (cm)				Fruit diameter (cm)				Fruit polar circumference (cm)				Fruit lateral circumference (cm)				Average dry matter content of fruit (%)	Fruit weight (g)
		2 <sup>nd</sup> pickin g	4 <sup>th</sup> picki ng	6 <sup>th</sup> picki ng	8 <sup>th</sup> picki ng	2 <sup>nd</sup> pickin g	4 <sup>th</sup> pickin g	6 <sup>th</sup> pickin g	8 <sup>th</sup> picki ng	2 <sup>nd</sup> pickin g	4 <sup>th</sup> pickin g	6 <sup>th</sup> pickin g	8 <sup>th</sup> picking	2 <sup>nd</sup> picki ng	4 <sup>th</sup> picki ng	6 <sup>th</sup> picki ng	8 <sup>th</sup> picki ng		
T <sub>1</sub>	24.44	7.15	6.70	6.40	5.32	5.94	6.15	6.22	6.23	17.50	16.66	19.51	19.13	19.12	19.46	20.60	20.23	6.69	94.70
T <sub>2</sub>	26.25	7.35	7.15	6.82	5.65	6.06	6.52	6.55	6.30	17.92	17.19	19.72	19.24	20.15	19.67	21.07	20.39	7.10	94.83
T <sub>3</sub>	26.57	7.52	6.97	6.92	6.15	6.82	6.40	6.80	6.45	17.92	18.20	20.47	19.21	19.87	20.16	21.97	20.14	7.02	95.56
T <sub>4</sub>	28.60	7.72	7.22	7.15	6.82	7.12	6.76	7.08	6.57	18.42	18.49	23.45	21.17	21.00	20.76	24.22	22.62	7.18	98.04
T <sub>5</sub>	25.83	7.30	6.92	6.72	5.57	5.97	6.27	6.75	6.25	18.10	17.92	21.09	19.82	19.70	19.91	22.10	20.51	7.20	94.94
T <sub>6</sub>	27.10	7.52	7.15	7.12	5.75	6.82	6.55	6.97	6.51	18.18	18.10	22.03	19.57	19.97	20.17	23.37	21.22	7.24	95.12
T <sub>7</sub>	23.41	6.37	6.37	6.55	5.45	5.80	5.99	6.21	6.07	17.17	16.67	19.23	18.98	19.30	19.36	20.12	17.71	7.20	93.52
T <sub>8</sub>	26.25	6.72	6.61	6.67	5.60	5.93	6.02	6.37	6.12	17.50	17.12	19.22	19.14	19.52	19.49	20.61	19.80	7.49	94.19
T <sub>9</sub>	21.18	6.25	6.20	6.20	5.16	5.62	5.85	6.12	6.00	16.97	16.53	19.05	18.76	19.16	19.14	19.48	19.03	7.32	90.09
T <sub>10</sub>	23.45	6.53	6.48	6.48	5.25	5.82	5.95	6.15	6.06	17.10	16.95	19.06	19.04	19.23	19.20	20.14	19.37	7.43	92.35
CD at 5%	1.29	0.28	0.21	0.28	0.32	0.25	0.16	0.28	0.17	0.49	0.45	0.79	0.33	0.82	0.52	0.96	0.83	NS	4.30

**Table.5** Effect of drip irrigation levels and black plastic mulch on yield and water use efficiency (kg ha<sup>-1</sup> mm<sup>-1</sup>) of capsicum under naturally ventilated polyhouse

Treatments	Average yield/ plant (kg)	Average yield/ha (t)	Water use efficiency (kg ha <sup>-1</sup> mm <sup>-1</sup> )
T <sub>1</sub>	2.42	80.66	171.4
T <sub>2</sub>	2.60	86.66	184.2
T <sub>3</sub>	2.50	83.22	221.1
T <sub>4</sub>	2.67	88.99	236.4
T <sub>5</sub>	2.47	82.44	292.1
T <sub>6</sub>	2.64	87.88	311.4
T <sub>7</sub>	2.33	77.66	412.8
T <sub>8</sub>	2.47	82.33	437.6
T <sub>9</sub>	2.01	66.99	142.4
T <sub>10</sub>	2.30	76.77	163.2
CD at 5%	0.79	2.66	-

**Fig.1** View of experimental site



Maximum fruit length & diameter and polar & lateral circumferences of fruits were also recorded for treatment T<sub>4</sub>. The maximum fruit length of 7.72 cm and fruit diameter of 7.12 cm were measured at 2<sup>nd</sup> picking. Fruit length was found to be decreasing gradually in the subsequent pickings.

The trend was just opposite for fruit diameter. The maximum fruit polar circumference of 23.45 cm was measured at 6<sup>th</sup> picking and thereafter it showed decreasing trend up to 8<sup>th</sup> picking (21.17 cm). Similar to polar circumference, maximum lateral fruit circumference of 24.22 cm was noted at 6<sup>th</sup> picking in T<sub>4</sub>. The same treatment had also shown maximum average fruit weight of 98.40 g. So far fruit dry matter content is concerned, it showed non-significant impact under. Besides deficit irrigation in the study in plants increased the dry matter content of fruit.

Increase in number of fruits at 80 percent water requirement could be due to availability of just sufficient soil moisture which enhanced photosynthetic area and better partitioning of

dry matter ultimately leading to the positive effects on growth parameters (Choudhary and Bhambri, 2012).

The increase in fruit length, diameter, polar and lateral circumference under drip irrigation may be attributed to the frequent and consistent application of water in the vicinity of the roots which provide better soil moisture regime in the crop root zone throughout the crop growth. These results are in agreement with the findings of Sezen *et al.*, (2006) in bell pepper.

All the fruit characters were found to be increased in the treatments having black plastic mulch as those without mulch. Nagalakshmi *et al.*, (2002) also obtained the maximum length and diameter of fruits in chilli with the application of black plastic mulch.

### **Yield**

The data on fruit yield of capsicum in Table 5 indicate that drip irrigation had significant

impact on fruit yield over surface irrigation, with or without mulching. The maximum yield of fruits per plant of 2.67 kg and total yield of 88.99 t/ha were obtained in treatment T<sub>4</sub> (irrigation at 80 percent of crop water requirement in black plastic mulched plots) which were 31.27 percent and 15.91 percent higher over surface irrigation treatment under unmulched and mulched conditions, respectively. The minimum per plant yield of 2.01kg was obtained under unmulched cultivation with surface irrigation followed by use of plastic mulch in surface irrigated plots (2.30 kg). Increasing the volume of water from 80 percent to 100 percent of crop water requirement decreased the yield from 83.22 to 80.66 t/ha and from 88.99 to 86.66 t/ha in unmulched and mulched conditions, respectively. Use of plastic mulch also significant impact on crop yield. Use of the mulch alone increased the fruit yield by 6.93 percent and 14.59 percent in case of 80 percent of irrigation water supplied through drip and surface irrigation, respectively.

Higher yield under drip irrigation with favourable moisture is attributed to the higher uptake of nutrients and excellent soil-water relationship with higher oxygen concentration in the root zone (Gornat *et al.*, 1973). Swarajyalakshmi *et al.*, (2005) also reported the highest green chilli yield through drip method scheduled at 0.8 ET under black polythene mulch. Pattanaik *et al.*, (2003) reasoned that the minimum yield under surface irrigation was due to the water stress during the critical growth period coupled with aeration problem due to application of excess of irrigation water and high weed infestation.

### **Water use efficiency**

As evident from Table 5, drip irrigation with and without polyethylene mulch registered higher water use efficiency as compared to surface irrigation. The highest water use

efficiency (437.6 kg ha<sup>-1</sup> mm<sup>-1</sup>) was recorded in treatment T<sub>8</sub> (irrigation at 40 percent drip irrigation with black plastic mulch followed by T<sub>7</sub>). The minimum water use efficiency was observed for the surface irrigated plot without mulching (142.4 kg ha<sup>-1</sup> mm<sup>-1</sup>), indicating excessive application of water. Table 5 also reveals that as the irrigation volume is increased from 40 to 100 percent of crop demand there was simultaneous reduction in water use efficiency both in mulched and unmulched plots. In un-mulched plots it showed reduction from 412.8 to 171.4 kg ha<sup>-1</sup> mm<sup>-1</sup>, whereas the reduction in mulched plots was from 437.6 to 184.2 kg ha<sup>-1</sup> mm<sup>-1</sup>. Higher yield and lower amount of applied water are the main reasons for increasing the water use efficiency indicating higher return per unit of applied water. Reduced amount of water through drip system during irrigation was helpful for achieving higher water use efficiency. These results are in conformity with the observations of Veeranna *et al.*, (2001). Mulches help in better utilization of applied water by reducing the rate of water loss through evaporation from soil surface. Paul *et al.*, (2013) also found the significant effect of black plastic mulch over drip irrigation alone on water use efficiency of capsicum as compared to unmulched soil.

The present study has indicated that Indira variety of capsicum produced with drip irrigation at 80% of crop water requirement and 40 micron black polyethylene mulch under naturally ventilated polyhouse in the agro climatic condition of Tarai region of Uttarakhand resulted into better plant morphological characters viz. plant height, fresh and dry weight of plant and root and fruit characters such as number of fruits per plant, average fruit weight, fruit length and diameter, polar & lateral circumstances of fruit and total a yield of 89 t/ha, the highest among all treatments. The combination of drip irrigation (80% crop water requirement) and



black plastic mulch (40 micron) increased the water use efficiency from 142 to 236 kg/ha.mm.

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