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Effects of mulching and irrigation levels on greenhouse capsicum (*Capsicum annuum*)

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ABSTRACT

The experiment was conducted during 2013–14, 2014–15 and 2015–16 under naturally ventilated greenhouse condition at Centre for Protected Cultivation Technology (CPCT), ICAR-Indian Agricultural Research Institute (IARI), New Delhi. The capsicum (*Capsicum annuum* L.) variety California Wonder was planted under colored plastic mulches (silver, yellow and black) and non-mulched (control) condition in combination with three levels of irrigation, viz. 100%, 80%, and 60% ET_c. The yield of capsicum was observed significantly higher under silver mulch (63–71.6 t/ha) followed by yellow mulch (60.04-67.04 t/ha) at 100% ET_c and silver mulch (59.72–70.8 t/ha) at 80% ET_c for three consecutive years. Growth parameters were significantly affected by different combination of treatments. The highest and lowest plant height (149.9 cm and 56.5 cm), leaf area (1.98 m^2/m^2 and 1.09 m^2/m^2) and total dry matter (120.4 g and 57 g) were observed under silver mulch with 100% and non-mulched with 60% ET_c respectively during all the three years of experiment. Highest growth parameters were at par with silver mulch with 80% ET_c treatment. Significantly higher crop water productivity (43.30-36.53 kg/m^3) in silver mulch with 80 % ET_c treatment was observed compared to other combination of treatments. The results revealed that, capsicum cultivation under silver coloured plastic mulch in the naturally ventilated greenhouse not only saved irrigation water but also enhanced yield, crop growth and crop water productivity at reduced level of irrigation (80% ET_c). Silver colour plastic mulch was found to be best suitable for growing capsicum crop inside the naturally ventilated greenhouse.

Keywords: Crop water productivity, Crop yield, Greenhouse, Plastic mulch

Increasing competition with the other water users and depleting natural water resources would limit the future water availability for expanding irrigated area. It would result in decreased share of water allocated to irrigation by 10–15% in the next two decades. In India, the irrigated area consists of about 37% of the net sown area (Anonymous 2012). Presently the agricultural sector accounts for about 90% of all water uses in India (OECD/Food and Agriculture Organization of the United Nations 2014). The best ways to mitigate the water scarcity is by enhancing water use efficiency. Water use efficiency (WUE) is a broad concept that can be defined as the yield of harvested crop produce achieved per unit crop evapotranspiration. With the increasing demand of water in agriculture sector in India, it is necessary to implement water conserving technique for increasing the water use efficiency. Mulching is an important water management practice for increasing water use efficiency (WUE). It is a technique that involves organic or synthetic materials on the soil around plants to provide a more favourable environment for growth and production.

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Plastic mulch gave advantages in terms of higher yield, high quality produce, weed control and control of the soil temperature, which is very important for overall crop growth (Sreedevi *et al.* 2017). Drip irrigation has the capacity to regulate irrigation water in the crop root zone (Hasan *et al.* 2010). A large number of experiments have been conducted to study the effect of drip irrigation and plastic mulch on yield improvement of many crops in different agro-climatic regions and soil conditions (Kasirajan and Ngouajio 2012, Agrawal and Agrawal 2005 and Paul *et al.* 2013). In greenhouse mostly plastic mulches in combination with drip fertigation were tried by many researchers (Nijamudeen *et al.* 2013, Kumari *et al.* 2019). The details of technical knowledge of different colored plastic mulches and their effect on crop parameters are not available particularly for greenhouse growers. Therefore, the present investigation was planned to determine the effect of irrigation levels and colored plastic mulch on greenhouse capsicum (*Capsicum annuum* L.) yield and crop water productivity (CWP), in addition to their effects on crop parameters under naturally ventilated greenhouse.

MATERIALS AND METHODS

The present study was carried out in naturally

Table 1 Twelve experimental treatments of combination of mulched and irrigation levels

Experimental treatments					
T_1:	Silver mulch+100% ET_c*	T_5:	Silver mulch +80% ET_c*	T_9 :	Silver mulch +60% ET_c*
T_2:	Yellow mulch+100% ET_c	T_6:	Yellow mulch +80% ET_c	T_{10}:	Yellow mulch +60% ET_c
T_3:	Black mulch+100% ET_c	T_7:	Black mulch +80% ET_c	T_{11}:	Black mulch +60% ET_c
T_4:	Non-mulched+100% ET_c	T_8:	Non-mulched +80% ET_c	T_{12}:	Non-mulched +60% ET_c

*100, 80 and 60% ET_c represent the application of water in percentage of evapotranspiration of crop: The irrigation treatments were imposed from 25 days after transplanting. Irrigation scheduling was done by using tensiometers. Irrigation was given where tensiometers reading reached 21 centibar at 15 cm below the surface in the non-mulched 100% ETc treatment. The volume of water applied was estimated based on pan evaporation, adjusted pan coefficient, crop coefficient of the capsicum, cropped area, percentage wetted area and application efficiency of the drip system for a plot. The reduced quantity of water under different irrigation treatments were estimated by reducing 40% and 20% of volume of water compared to non-mulched 100% ETc treatment. Fertigation were applied to ensure that all treatments received the same amount of fertilizer. Fertigation scheduling was done as suggested by Hasan *et al.* 2010).

ventilated greenhouse at the Centre for Protected Cultivation Technology, ICAR-Indian Agricultural Research Institute, New Delhi, during September to April for three successive years (2013-14, 2014-15 and 2015-16). The study site is situated between the latitudes 28°37'-28°39'N and longitudes 77°09'- 77°11' E with an altitude of 229 m above mean sea level. Experimental soil in the greenhouse was classified as sandy loam at varying soil depths of 0-30, 30-60 cm. The Soil had bulk density of 1.46 g/cm^3. The field capacity and permanent wilting point of the soil were measured to be 21.9% and 8.13% (soil moisture content on volumetric basis). The average EC and *p*H of the soil of experimental site is 0.31 dS/m and 7.4, respectively. The climate of experimental site is semi-arid and sub-tropical with hot and dry summers and cold winters. May and June is the hottest month with maximum temperature ranging between 41–46°C while temperature falls to its lowest during January with minimum temperature ranging between 4–7°C. The mean open pan evaporation reaches as high as 13.91 mm/day during the May. However, it reduces to 1.15 mm/day during January.

Experimental design and treatments: The experiments were laid out in randomized block design with 4 treatments of mulched (silver, yellow and black) and non-mulched conditions and 3 treatments of irrigation levels (100, 80 and 60% ET_c).Total twelve experimental treatments in combination with mulched conditions and irrigation levels (Table 1) were replicated thrice on the homogeneous plotof size 12 × 1.2 m^2 (Fig 1). The capsicum cv. California Wonder was selected for the experiment due to its popularity among growers. Thirty days old seedlings were planted at 0.45 m (plant to plant) × 0.45 m (row to row) distance.

Measurements of yield, CWP and growth parameters: Growth parameters such as plant height, plant dry matter content and leaf area index were recorded. Fruit weight was also recorded for calculation of total yield. Crop water productivity was calculated by dividing yield of capsicum and the volume of water consumed to produce that yield. Five plants were randomly sampled and labelled properly from each plot for the determination of leaf area index (LAI). Leaves were separated and leaf area was measured by using leaf area meter. LAI was calculated as the ratio of leaf area (m^2) to soil surface area covered by the plants (m^2). Specific leaf area also calculated as the ratio of leaf area (cm^2) to dry weight (g).There were total 8 harvests for crop period of one year. The first two harvests were made in green color stage and remaining was mixed with green and red color both.

The statistical software SPSS was used for the statistical analysis of data on different parameters. Treatment means were compared with the least significant difference test at the P<0.05 level.

RESULTS AND DISCUSSION

Plant height: Plant height was significantly (P<0.05) affected by different combinations of treatments (Table 2). At the end of growing season, the treatment with silver color plastic mulch with 100% of ET_c(T_1) showed significantly higher plant height (132.9-149.9 cm) and it was at par with silver color plastic mulch with 80% of ET_c (T_5) and yellow mulch with 100% of ET_c (T_2) during three growing seasons.

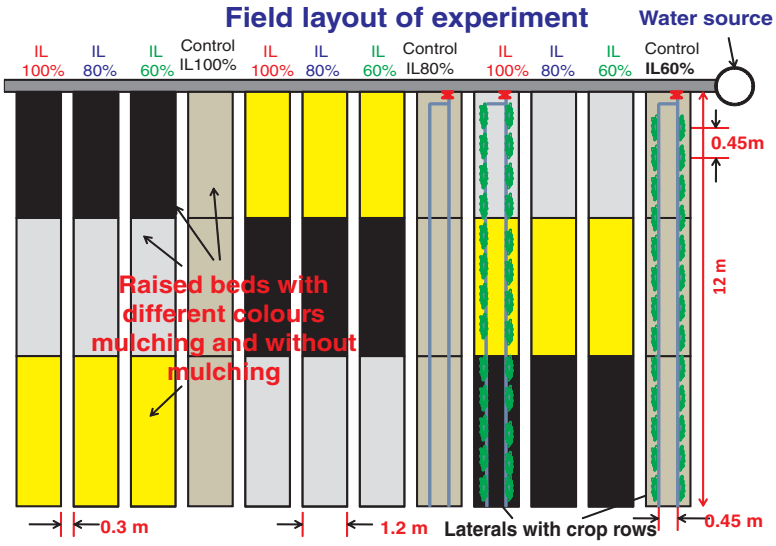

Fig 1 Field layout of experimental greenhouse.

Table 2 Effect of different mulched conditions and irrigation levels on growth and yield parameters of sweet pepper

Treatment	Yield (t/ha)			Plant height (cm)			Total dry matter (g)			Water productivity (kg/m^3)		
	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16
T_1	63.00a	68.60a	71.60a	132.9b	141.8a	149.9a	117.66a	121.3a	120.4a	30.82c	33.56c	35.03c
T_2	60.04ab	63.48ab	67.04b	129.2bc	139.16a	145.2ab	114.5a	118.8a	113.5b	29.37cd	31.06cd	32.80c
T_3	54.56c	58.55b	60.53c	125.13c	130.4b	135.1c	104.23c	106.7c	104.5c	26.69e	28.64d	29.61d
T_4	46.70d	48.90cd	52.00de	90.95g	92.95e	90.95h	92.5e	96.0e	93.5e	22.85f	23.92e	25.44e
T_5	59.72ab	67.74a	70.80a	138.75a	140.6a	148.6a	108.7b	113.5b	110.1b	36.53a	41.43a	43.30a
T_6	56.90bc	62.29b	64.50b	138.33a	137.3a	142.5b	99.33d	97.7e	98.5d	34.80ab	38.10b	39.45b
T_7	46.13d	52.44c	53.89d	118.5d	121.3c	125d	85f	92.0f	88.0f	28.21de	32.07c	32.96c
T_8	34.95f	35.65e	38.54g	79.05h	80.05f	81.85i	72h	74.0i	72.6i	21.38f	21.80ef	23.57e
T_9	41.48e	45.87d	46.98e	106.45e	105.9d	109.9e	98d	101.4d	96.9de	33.83b	37.41b	38.32b
T_{10}	43.58de	46.68d	48.87e	98.55f	101.7d	104.6f	79.66g	85.5g	82.4g	35.55ab	38.08b	39.86b
T_{11}	36.00f	38.00e	41.22f	95.5f	94.9e	97.8g	78g	79.5h	77.6h	29.36cd	30.99cd	33.62c
T_{12}	22.60g	24.50f	25.80g	58i	56.5g	60.15j	57.8i	59.0j	57.0j	18.43g	19.98f	21.04f
Mean	47.14	51.06	53.48	109.27	111.87	115.96	92.28	95.44	92.89	28.98	31.42	32.92
SEM	2.0016	2.268	2.299	4.152	4.493	4.801	2.966	3.039	2.994	0.962	1.138	1.134
F value	101.26	62.53	149.75	336.09	272.59	339.92	166.02	400.81	214.04	53.912	43.007	91.99

T_1, T_2….T_{12} represent experimental treatments of combination of mulched and irrigation levels (Table 1). Values within columns followed by different letters are statistically different at $P<0.05$

Non-mulched in combination with 60% of ET_c (T_{12}) was recorded the lowest plant height (56.5-60.15 cm). Moreover, the plant height decreased with decreasing level of irrigation. For 60% of ET_c, all the treatments of plastic mulch reported lower plant height compared to other treatments. The study revealed that the plant height of treatment of irrigation with 80% of ET_c was found nearly equal to 100% of ET_c. Paul *et al.* (2013) reported that 100% irrigation requirement resulted in highest plant height under mulched condition. The highest increase in vegetative growth in treatment T_1, T_2, T_5 and T_6 might be due to the availability of soil moisture at optimum level and similar results were reported by Tiwari *et al.* (1998) and Pattanaik *et al*. (2003). The lowest value of vegetative growth in T_{12} might be because of unfavourable moisture regime in the soil and competition of weeds for nutrients in non-mulched condition (Pattanaik *et al*. 2003, Agrawal and Agrawal 2005).

Plant dry matter content: Different treatments significantly affected total dry matter content per plant. The treatment with silver color plastic mulch with 100% of ET_c (T_1) showed significantly higher dry matter content (117.66 -121.3 g) followed by T_2 and T_5, throughout the growing seasons of three years. Whereas, Non-mulched with 60% of ET_c (T_{12}) showed lower (57-59 g) at different growing season (Table 2). The treatments (T_4, T_8 and T_{12}) produced the lowest level of dry matter content and ranged from 57 to 96 g for irrigation treatments in combination with 60% and 100% of ET_c. Influence of treatments was found to be in line for dry matter content with the plant height.

Leaf area index (LAI) and specific leaf area: LAI measured at the end of the season was found to be the highest (1.98 m^2/m^2) in the T_1 (Silver mulch with 100% of ET_c) and it was at par with T_2 (1.96 m^2/m^2) and T_3 (1.88 m^2/m^2) and significantly better than all the other treatments (Fig 2a). The lowest LAI (1.09 m^2/m^2) was observed in T_{12} (Non-mulched with 60% of ETc). The differences of LAI due to the treatments were tallied with the measurements of plant height and plant dry matter content. The results revealed that LAI increased with irrigation level with different color plastic mulches. Almost similar trend of LAI was observed with the plant height. The specific leaf area of the plant was non-significant at different combination of treatments (Fig 2b).

Crop water productivity: Crop water productivity was significantly affected by various combinations of colored plastic mulch and level of irrigation (Table 2). Water productivity of capsicum was observed higher under silver color plastic mulch with 80% ET_c (T_5), 36.53-43.30 kg/m^3) followed by yellow color plastic mulch with 80% ET_c(T_6), (34.8-39.45 kg/m^3). It was recorded lower (18.43-21.04 kg/m^3) in the treatment T_{12} (Non-mulched with 60% ET_c). Similar results for non-mulch condition was reported by Nijamudeen *et al.* (2013) that the water productivity of capsicum was in the range of 23.5 to 25.9 kg/m^3 under greenhouse conditions. It was 5.9 to 7.8 kg/m^3 in Lebanon (Karam *et al.* 2009) and 3.5 to 10.9 kg/m^3 in India (Singh 2008, Singh *et al*. 2010). Consistent with the findings by Singh *et al*. (2010), the greenhouse microclimatic condition resulted in increased water productivity as the evapotranspiration was less compared to the open field.

Capsicum yield: Different mulched conditions and irrigation levels affected the fruit yield during three years. The treatment T_1 (silver color plastic mulch with 100% of ET_c) showed significantly higher fruit yield and it was at

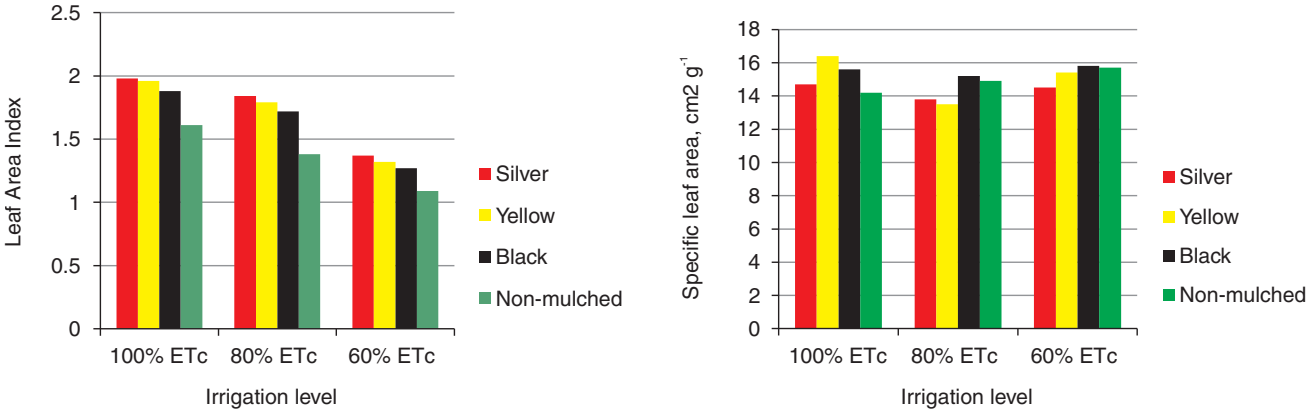

Fig 2 Effect of color plastic mulches on leaf area index (a) and specific leaf area (b) of capsicum at different irrigation level (Average mean data of three years; 2013-14, 2014-15 and 2015-16)

par with silver color plastic mulch with 80% of ET_c (T_5) and yellow mulch with 100% of ET_c (T_2) during three years (Table 2). The results revealed that the highest fruit yield (63-71.6 t/ha) was recorded under treatment T_1 followed by T_5 (59.72-70.80 t/ha) and T_2 (60.04-67.04 t/ha). The yield from the non-mulched treatment was lowest (22.6-25.8 t/ha) with 60% of ET_c. Moreover, lowest yields were observed in the treatments with non-mulched condition at reduced level of irrigation level.

Thus results revealed that the application of colored plastic mulches for capsicum in naturally ventilated greenhouse condition has enhanced the average yield for all colored mulches (silver, yellow and black) at different levels of irrigation (60, 80 and 100% ET_c). The silver color plastic mulch in combination with 100% and 80% of ET_c showed the higher yield and plant growth inside the greenhouse. Results suggested that application of plastic mulch inside the greenhouse was recommendable for optimum growth of capsicum. Silver color plastic mulch was found to be most suitable for vegetable growth followed by yellow color plastic mulch due to optimum microclimate maintained around the plant. Moreover, crop water productivity was higher under the treatment of silver color plastic mulch with 80% of ET_c. These results showed that the mulch practice in the naturally ventilated greenhouse not only saved irrigation water but also enhanced yield at reduced level of irrigation.

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REFERENCES

Agrawal N and Agrawal S. 2005. Effect of drip irrigation and mulches on the growth and yield of banana cv. Dwarf Cavendish. *Indian Journal of Horticulture* **62**(3): 238-40.

Anonymous. 2012. India: Issues and Priorities for Agriculture, World Bank Publishing. http://www.worldbank.org

Hasan M, Singh B, Singh M C, Singh A K, Kaore S V, Tarunendu, Sabir N and Tomar B S. 2010. *Fertigation scheduling for horticultural crops.* Tech. Bull. No. TB-1CN:80/2010, IARI, New Delhi.

Karam F, Masaad R, Bachour R, Rhayem C and Rouphael Y. 2009. Water and radiation use efficiency in drip-irrigated pepper (*Capsicum annuum* L.): Response to full and deficit irrigation regimes. *European Journal of Horticultural Science* **74**(2): 79–85.

Kasirajan S and Ngouajio M. 2012. Polyethylene and biodegradable mulches for agricultural applications: a review. *Agronomy for Sustainable Development* **32**: 501–29.

Kumari L, Hasan M and Singh D K. 2019. Response of different colour plastic mulches on water dynamics under drip fertigated greenhouse capsicum (*Capsicum annuum*). *Indian Journal of Agricultural Sciences* **89**(3): 469–74.

Nijamudeen M S, Singh M, Khanna M, Singh B, Singh R, Pandey R N and Hasan M. 2013. N and K fertilizer application rate under drip fertigation for greenhouse grown sweet pepper. *Indian Journal of Horticulture* **70**(1): 54-59.

OECD/Food and Agriculture Organization of the United Nations. 2014. OECD-FAO Agricultural Outlook 2014, OECD Publishing. http://dx.doi.org/10.1787/agr_outlook-2014-en

Pattanaik S K, Sahu N N, Pradhan P C and Mohanty M K. 2003. Response of Banana to drip irrigation under different irrigation designs. *Journal of Agricultural Engineering, ISAE* **40**(3): 29–34.

Paul J C, Mishra J N, Pradhan P L and Panigrahi B. 2013. 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. *European Journal of Sustainable Development* **2**(1): 99–108.

Singh A. 2008. Economic feasibility of growing capsicum crop under drip irrigation in West Bengal, India. *Irrigation and Drainage Systems* **22**: 179–88.

Singh K G, Singh A and Mahajan G. 2010. Response of sweet pepper (*Capsicum annuum* L.) to irrigation and fertigation grown in naturally ventilated polyhouse. *Indian Journal of Agricultural Sciences* **80**(5): 430–32.

Sreedevi S, Maheshwara Babu B, Kavita Kandpal, Satish kumar U and Kanannavar P S. 2017. Effect of colour plastic mulching at different drip irrigation levels on growth and yield of brinjal (*Solanumme longena L.*). *Journal of Farm Sciences* **30**(4): 525–29.

Tiwari K N, Mal P K, Singh R M and Chattopadhya A. 1998. Response of Okra to drip irrigation under mulch and non-mulch conditions. *Agricultural Water Management* **38**: 91–102.