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The Effect of Electrical Conductivity of Irrigation Water on Water Uptake by Capsicum in Soilless Media

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A B S T R A C T

The experiment was conducted during the year of 2015-2016 under semi-climate greenhouse condition at Center for Protected Cultivation Technology (CPCT), farm at Indian Agricultural Research Institute (IARI), New Delhi, to study the effect of electrical conductivity of irrigation water on crop water uptake. The yellow colored popular and widely accepted capsicum variety Swarna was selected for the study. Four strategies/treatments based on electrical conductivity of the fertigation solution were applied with three replications during the entire growing period. The maximum water uptake was observed for fifteen plants are 246 kg and minimum 17.85 kg during Fruiting and Vegetative stage respectively corresponding to EC 2.8 and 2.7 dS/m for their respective stage.

Introduction

The demand for fruits, vegetables and other horticultural crops has been rising continuously in the 21st century. The vegetable sector has been growing rapidly to meet the rising demand of ever increasing population in order to ensure balanced diet to each and every person. On the other hand, the decreasing land holding of farmers has put lots of pressure to grow more from the limited cultivated area. Recent advancement in science and technology has provided scientific and advanced methods of cultivation, related cultural practices and input management techniques all over the world. The time has come to go beyond the boundaries of tradition way of cultivation and adopt such proven developed and advanced techniques. Protected cultivation, drip and sprinkler irrigation, off-season vegetables production, container and terrace gardening, green house technologies, soilless cultivation technologies have been found as proven advanced scientific techniques to increase the production, quality and productivity of horticultural crops in general and particularly for vegetables.

Protected cultivation technology has been continuously expanding on a commercial scale in more than 55 countries throughout the world (Nair and Barche, 2014). The development and rapid expansion of greenhouse technology in China has been faster than in any other country in the world (Shakuntala Pandey and Anil Pandey, 2015). The total protected cultivation area in India is approximately 50,000 ha (Hasan, 2015). The main purpose of protected cultivation is to facilitate suitable environment during the plant growth period so as to realize its maximum yield potential even in adverse climatic conditions (Nair and Barche, 2014). The major limitation of protected cultivation is various type of soil borne diseases (Fulya Baysal-Gurel *et al.*, 2012). Solar heat or soil solarization, leaching, chemicals are some possible control measures of soil borne pathogens (Nereu Augusto Streck *et al*., 1994) but they are not effective and permanent solution. The chemical methods of soil disinfestation are costly and hazardous and it requires trained personnel and special equipment. In the above scenario, soilless cultivation is the possible alternative solution for sustaining protected cultivation.

Soilless cultivation is a practice of growing plants in soilless media which provide the facilities to reduce the soil related problems experienced in conventional crop cultivation (Aatif Hussain *et al*., 2014). Suitable soilless substrates have been found to be useful and effective for high quality horticultural crop production in protected structures (Murumkar A. R. *et al.*, 2013). Soilless culture directly affects the development and maintenance of the extensive functional rooting system of the plants. A well growing substrate would provide sufficient anchorage to the plant, serves as reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate (Abad *et al.*, 2002). One of the widely available soilless materials in the India is coconut coir dust also known as cocopeat. Cocopeat is an eco-friendly growing medium obtained after the extraction of coir fiber from the coconut husk. Cocopeat is 100% organic substance and is free from any harmful substance. It is considered as a good and effective growing soilless media with acceptable pH, electrical conductivity and other chemical attributes (Awang *et al.*, 2009).

Capsicum (*Capsicum annuum* L. var. grossum Sendt) is also known as bell pepper or sweet pepper and is one of the most popular and highly remunerative annual herbaceous vegetable crops particularly for protected cultivation. It is a very rich source of vitamins A and C (ascorbic acid). It has been found that every 100 gram of edible portion of capsicum provides 24 kcal of energy, 1.3 gram of protein, 4.3 gram of carbohydrate and 0.3 gram of fat (Anon., 1997). The main chemical content in sweet pepper is Capsaicin. It has attained a status of high value crop in India in the recent years and occupies a pride place among vegetables in Indian cuisine, because of its delicate taste and pleasant flavour coupled with rich content of ascorbic acid and other vitamins and minerals. Sweet pepper consumption in India is increasing now-a day due to increasing demand by urban consumers and export sector. The export market needs fruits with longer shelf life, medium size, tetra lobed fruits with an attractive dark colour, mild pungency and good taste. Such fruit can be grown mainly in protected cultivation with soilless media.

Water and nutrient management through drip fertigation in soilless media improves water, nutrient and air distribution in the growing medium and subsequently improves crop health and productivity. Drip fertigation in soilless cultivation is used to supply complete nutrient solution with irrigation water. Fertigation scheduling is the process of determining how much water and nutrient solution to apply by fertigation volume and timing. The main goal of water and nutrient management for greenhouse soilless crops is to enhance crop growth and product quality and simultaneously reduce losses of water and nutrients to the environment. Precise amount of water and nutrients as per crop demand in different stages through drip fertigation is important to reach this goal. In order to do so, quantitative information on demand and uptake of water and nutrients and related information on crop behavior is required. Such information needs to be generated through controlled experiments inside greenhouse with soilless media. The electrical conductivity (EC), amount and frequency of fertigation (irrigation with nutrient solution) are the most necessary variables to control the supply of water and nutrients to the crops (Martine Dorai *et al.*, 2001).

Materials and Methods

Experimental site, plant and growth condition

The experiment was carried out in the semi climate controlled greenhouse of Centre for Protected Cultivation Technology (CPCT) farm in Indian Agricultural Research Institute (IARI), New Delhi (IARI is situated in west Delhi between latitude 28038'23"N and longitude 77009'27"E with an altitude of 228.61m above mean sea level), in 2015-16. The greenhouse experiment was laid in a complete randomized design with four treatments and three replications for each growing stage such as vegetative stage (1-52 DAT), flowering stage (53-133DAT) and fruiting stage (134-190) of the capsicum crop. Capsicum seeds were sown in mixture of cocopeat, vermiculite and perlite (3:1:1) in the trays (345 cells/tray). The seedlings were raised in modern nursery and watered twice a daily. At 30 days (when the seedlings were about 2 cm in height with 3-4 leaves), the plants were transplanted in cocopeat grow bag. In a cocopeat growbag three plants were placed at 30cm distance. Greenhouse capsicum cultivars generally have an indeterminate pattern of growth. Because the plants can grow up to 150cm tall during a growing season of 250 days, they need to be support vertically. The stems were clipped with the strings plastic clips. Regular training, pruning and trellising was done without damage to the crop (Singh and Kumar, 2004).

Electrical conductivity of the solution and irrigation

Capsicum is very susceptible to water stress condition and highly affected by electrical conductivity of the irrigation water. In soilless cultivation fertilizers are added to the irrigation water that increases the electrical conductivity of the solution and media. Four strategies/treatments based on electrical conductivity of the fertigation solution were applied with three replications during the entire growing period. Treatments were taken as (2.4, 2.6, 2.8), (2.3, 2.5, 3.0), (2.7, 3.0, 3.2) and (2.5, 2.5, 2.5) dS/m respectively for vegetative, flowering and fruiting stages.

Measurements and calculations

Physical and chemical properties (measured using instruments given in Table 1) of the cocopeat as soilless media are calculated by the standard procedure given in table 2. The irrigation water was applied to the experimental plots through drip irrigation method with the help of TDR. The volume of water applied was estimated based on pan evaporation, pan coefficient, crop coefficient of the sweet pepper, cropped area, percentage wetted area and application efficiency of the drip system. Also the value of coefficient (factor) of evapotranspiration under greenhouse was considered as 0.45 (Hasan *et al*., 2010) in the estimation of irrigation requirement.

Actual evapotranspiration (ETc) under greenhouse with drip irrigation system was estimated as follows

ETo = Kp*Epan

Where,

ETo = Reference crop evapotranpiration, mm
Epan = Pan evaporation, mm day^{-1}
Kp = Pan coefficient = 0.8; (FAO 56 – Allen *et al.*, 1998)

ETc = ETo*Kc

Where, ETc = Actual evapotranspiration, mm

Kc values for sweet pepper during the growing season was considered as follows (FAO 56 – Allen *et al.*, 1998)

Initial stage = Kc value of 0.6 for the duration 30 days

Development stage = Kc value of 0.9 for the duration 40 days (considered average of initial and mid stage)

Mid stage = Kc value of 1.15 for the duration 140 days

Late stage = Kc value of 0.9 for the duration 30 days

Greenhouse coefficient (Gc) for evapotranspiration was 0.45

Ideal percentage of wetted area (Wa) at maximum limit was considered for drip irrigation as 67 %; approx 0.7. (Keller and Bliesner, 1990)

The application efficiency was considered 90 % according to the past experience from the drip irrigation system which was taken on to the field experiment. By considering the above mentioned factors, to estimate the volume of water to be applied, ETc was estimated and multiplied by the cropped area. The pan data was available online at IARI web site.

Hence, ETc = Epan x Kp x Kc x Wa x Gc.

Water requirement for sweet pepper crop under drip irrigated greenhouse

= (Epan x Kp x Kc x Wa x Gc) / Application efficiency, mm (Majumdar, 2004)

= ((Epan x Kp x Kc x Wa x Gc) / Application efficiency) x Cropped Area (m^2), liters

Initial irrigation was estimated by using the soilless information as follows

Field capacity (FC) = 42.2 % (volumetric)

Permanent wilting point (PWP) = 18.2 % (volumetric)

Available water = FC – PWP = 24 % (volumetric)

Water requirement up to 50 mm effective root zone depth in soilless cocopeat grow bag

= 24 /100 x 50 mm x 100 m^2 x 0.2 = 240 liters (effective cropped area=0.2)

Water requirement of the capsicum crop and the irrigation applied are similar as there was no rainfall contribution to the field under the greenhouse.

The statistical analysis of data of each parameter was done by the statistical method known as "Analysis of Variance" appropriate for complete randomized design. The coefficient of variance (CV) was worked out. Where the results were significant, the least significant difference (LSD) at 5% level of significance was estimated. The statistical software of SPSS was used for the analysis.

Results and Discussion

Physical and chemical properties of cocopeat soilless media

The following important physical and chemical properties of cocopeat soilless media were determined as per the standard procedure (i.e. mentioned in earlier section) and presented in tabular form.

The pH and EC value showed that cocopeat media was acidic and slightly saline in nature. Its porosity was very high and the low values of available N, P and K showed that it was inert in nature. The above physical and chemical properties are required for irrigation and fertigation management in cocopeat soilless media.

Moisture retention curve for cocopeat soilless media

The moisture characteristic curve represents the volumetric water content and suction relation in one graph. From the above graph it is obvious that the higher the suction the less the soilless media water is available for the plant (Fig. 1).

Experiment has shown that cocopeat media water at a suction 15 bar cannot be taken up by plants and wilting occurs. This point is called “permanent wilting point”. This the lower limit of amount of available water for plant growth. Also an upper limit exist suction 1/3 bar and this point is known as field capacity.

The regression equation was developed ($Y= -7.2\ln(X) + 36.74$) with regression coefficient of 0.981. The volumetric water content was estimated as 42.20% at 18.20% at 1/3 bar and 15 bar respectively. It represented the field capacity and wilting point respectively of the soilless media. The volumetric water content at higher suction values and at ultimate wilting point (31 bar) can be estimated from the graph assuming the asymptotic behavior of the graph.

Effect of electrical conductivity on water uptake among the different treatments

Effect of electrical conductivity on the water uptake at different stages of the growing period

a) For vegetative stage

Crop water uptake during entire vegetative stage (52 days) was found to be maximum 30 kg and minimum 17.85 kg corresponding to EC 2.4 and 2.7 dS/m as per the treatments T1 and T_3 respectively for 15 plants (Fig. 2).

Higher the EC reduces the water uptake by plants due the reverse osmosis and too low a concentration causes mineral deficiency and restricts plant growth (Winsor and Adams, 1987). In this stage data showed the significant difference ($P \leq 0.05$) generally in favour Treatment 1 (EC 2.4 dS/m) and Treatment 2 (EC 2.3 dS/m).

b) For flowering stage

Crop water uptake during entire Flowering stage was found to be maximum 52.5 kg and minimum 36 kg corresponding to EC 2.6 and 3.0 dS/m as per the treatments T_1 and T_3 respectively for 15 plants). Treatment 1 (52.5 kg) exhibited greater ($P \leq 0.05$) uptake water over Treatment 4 (control, 41.25 kg). This was followed by Treatment 2 (47.25 kg) having significantly greater ($P \leq 0.05$) water uptake over the control (Treatment 4) (Fig. 3).

c) For fruiting stage

Increasing electrical conductivity of the irrigation water reduces the water uptake by the capsicum plants. Treatment T_3 having greater electrical conductivity compare to the other treatments. Crop water uptake during entire fruiting stage (98 days, including harvesting stage) was found to be maximum 246 kg and minimum 209.7 kg corresponding to EC 2.8 and 3.2 dS/m as per the treatments T_1 and T_3 respectively for 15 plants (Fig. 4). Figure 4 shows the Treatment T_3 (209.7 kg) registered significantly different ($P \leq 0.05$) from the other treatments. Water uptake by the plants did not show any significant difference among Treatment T_1 (246 kg), Treatment T_2 (234.45 kg) and treatment T_4 (221.25 kg).

d) Water uptake entire the growing period

Crop water uptake during entire growing period was found to be maximum 328.50 kg and minimum 263.55 kg corresponding to the treatments T_1 and T_3 respectively for 15 plants. Selection of the EC for the plant requirement is very necessary. (Bruggink *et al.*, 1987) proposed that it should be possible to enhance plant growth by adapting the EC level to the rate of transpiration. Adequate EC provide the good transpiration (Fig. 5).

Yield of capsicum

Capsicum colored fruit total yield from three harvesting and average yield of the three replications were found to be maximum 41.15 kg (in which applied solution EC was 2.4 dS/m for vegetative stage, 2.6 dS/m for flowering stage and 2.8 dS/m for fruiting stage) and minimum 20.05 kg (in which applied solution EC was 2.7 dS/m for vegetative stage, 3 dS/m for flowering stage and 3.2 dS/m for fruiting stage) from the treatments T_1 and T_3 each having 15 plants respectively (Fig. 6).

Table.1 Physical and chemical properties of soilless cocopeat media

Parameters	Instrument used (Methods)
Air filled porosity	Saturation and Drainage method
Bulk density	Gravimetric method
Field capacity	Pressure plate apparatus (Richard and Weaver, 1944)
Permanent wilting point	Pressure plate apparatus (Richard and Weaver, 1944)
Available nitrogen	Kjeldhal apparatus (Subbiah *et al.*, 1956)
Available potassium	Flame photometer (Hanway *et al.*, 1952)
Available phosphorous	Spectrophotometer (Olsen *et al.*, 1954)

Table.2 Physical and chemical properties of cocopeat soilless media

Parameters	Values
Air filled porosity (%)	30
Total Porosity (%)	90
Bulk density (g/cc)	0.1
Field capacity (% V/V)	42.2
Permanent wilting point (% V/V)	18.2
Available nitrogen (mg/l)	0.2
Available potassium(mg/l)	0.1
Available phosphorous (mg/l)	0.2
pH	5.6
EC (dS/m)	0.7

Table.3 Yield variation of capsicum during growing period

No. of treatment	EC in dS/m	R1			R2			R3			Yield in kg
		1st harvest	**2nd harvest**	**3rd harvest**	**1st harvest**	**2nd harvest**	**3rd harvest**	**1st harvest**	**2nd harvest**	**3rd harvest**	
		27/2/2016	16/3/2016	14/4/2016	27/2/2016	16/3/2016	14/4/2016	27/2/2016	16/3/2016	14/4/2016	
T1	2.4, 2.6, 2.8	13.4	14.6	10.4	14.15	16.75	12.45	14	15	12.7	41.15
T2	2.3, 2.5, 3	12.89	13.73	10.58	13.68	15.74	10.57	9.8	12.9	9.1	36.3
T3	2.7, 3, 3.2	4.06	7.43	7.7	5.8	7.3	6.7	6.2	8.6	6.8	20.05
T4	2.5, 2.5, 2.5	9.87	8.86	9.61	12	12	9	10.3	11.6	7.8	28.34
Total											**125.84**

Table.4 Treatment wise crop water productivity and yield estimation for capsicum grown in soilless cultivation

Treat-ment	Yield (kg)	Irrigation (cubic meter)	Crop Water Productivity (kg/m³)
T1	41.15	0.345	119.28
T2	36.3	0.330	110.00
T3	20.05	0.278	72.12
T4	28.34	0.316	89.68

Fig.1 Moisture characteristic curve for cocopeat

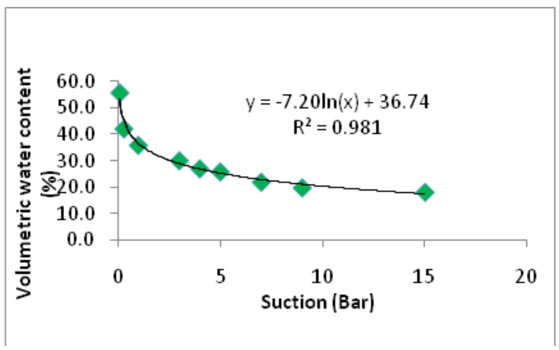


Fig.2 Water uptake by capsicum through different treatments in vegetative stage

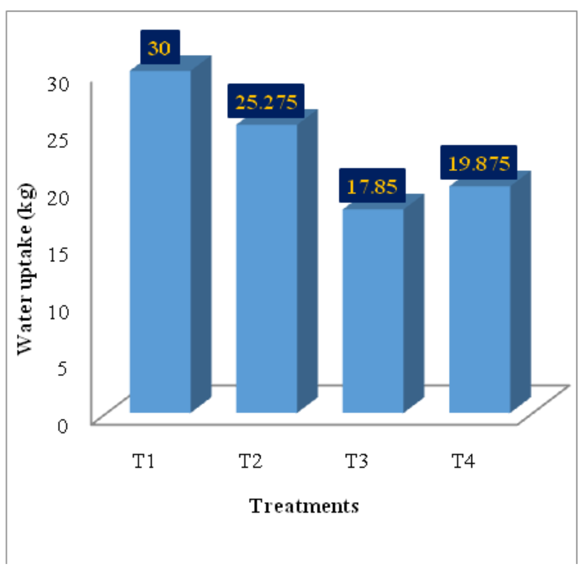


Fig.3 Water uptake by capsicum through each treatment in flowering stage

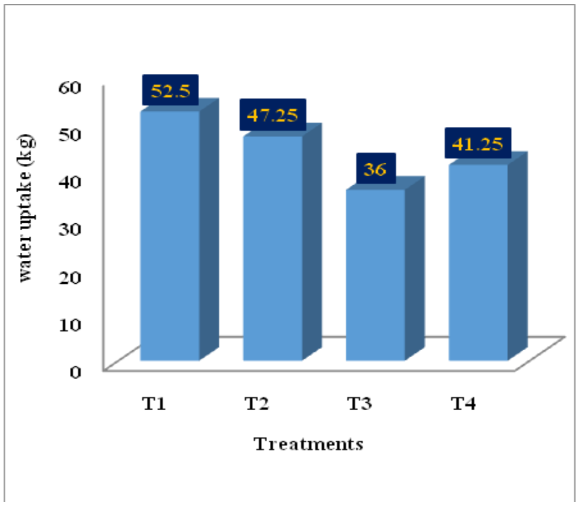


Fig.4 Water uptake by capsicum through each treatment in fruiting stage

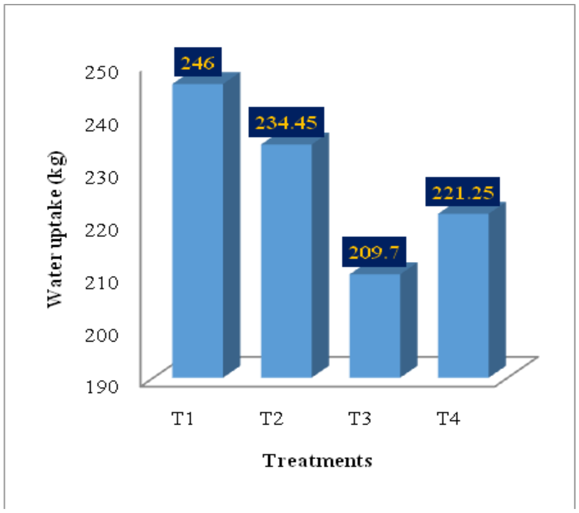


Fig.5 Water uptake by capsicum through each treatment during the entire growing period

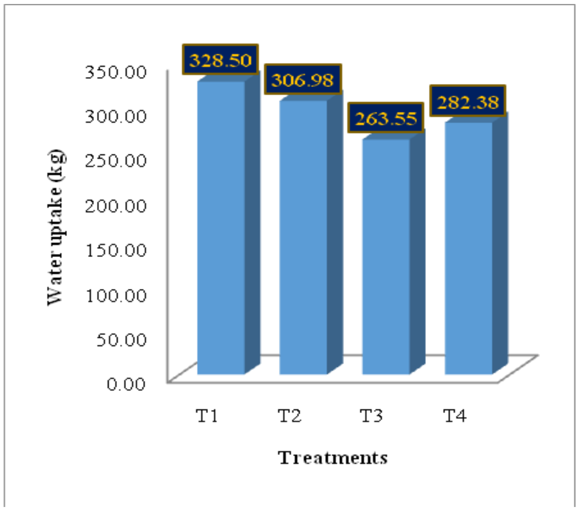


Fig.6 Yield of capsicum through each treatment

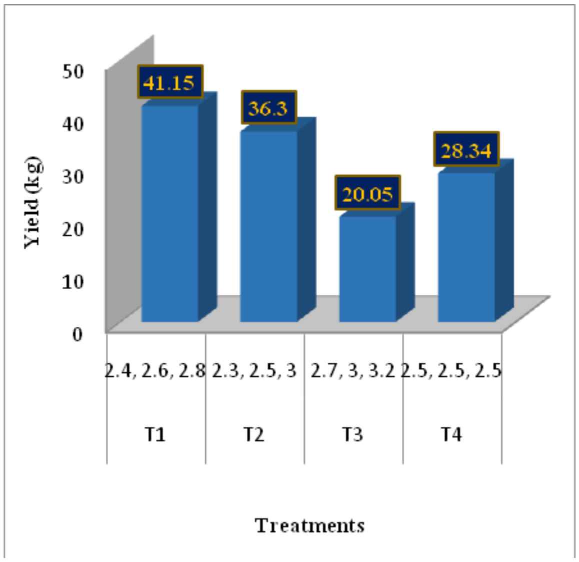
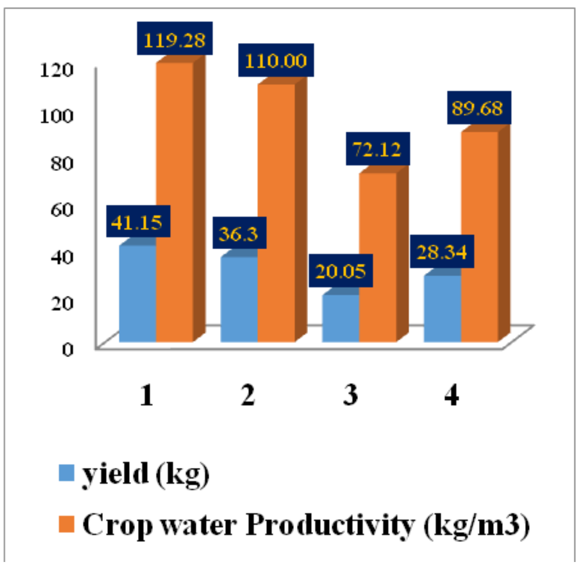


Fig.7 Relation between yield and crop water productivity



The large difference in yield was attributed to minor differences in fertigation EC during different crop stages. It showed the importance and sensitivity of fertigation EC (Fig. 7).

Yield of treatment T1 significantly increased ($P \leq 0.05$) over the other treatments (Table 3). This was followed by treatment T_2 which also registered significantly ($P \leq 0.05$) higher yield over the treatment T_3 and Treatment T_4.

Crop water productivity was found to be maximum 119.28 kg/m³ and minimum 72.12 kg/m³ corresponding to the treatments T_1 and T_3 respectively having 15 plants each. The corresponding yield was found to be maximum 41.15 kg and minimum 20.05 kg for the treatments T_1 and T_3 respectively. Crop water productivity was found to be very high for greenhouse capsicum grown in soilless media in comparison with soil due to the fact that ET was very low for soilless media grow bag (Table 4).

Summary and conclusion of the study are as follows

Water is the forerunner and sustainer of all life on the planet, especially the humankind. Use of soilless cultivation is one of the top priorities for conserving and utilizing the irrigation water judiciously. In soilless cultivation, cocopeat media having high water holding capacity causes poor air-water relationship, leading to low aeration within the medium and thus affecting the oxygen diffusion to the roots.

Application of adequate amount of water as per the plant requirement is very necessary for plant growth and production of high yield. Capsicum crop is found to be susceptible to water stress condition and electrical conductivity (EC) of the irrigation water. To overcome these problems, research was conducted in the research farm of Center for Protected Cultivation Technology (CPCT) in Indian Agricultural Research Institute, New Delhi, India during October 2015 to April 2016. Based on the results of this study the following conclusions were drawn.

Crop water uptake was found to be maximum 246 kg and minimum 17.85 during fruiting and vegetative stage respectively corresponding to EC 2.8 and 2.7 dS/m for entire crop duration. The maximum and minimum water consumption occurred during fruiting and vegetative stage respectively with minor difference in fertigation EC.

Capsicum colored fruit yield was found to be maximum 41.15 kg and minimum 20.05 kg corresponding to the treatments T_1 and T_3 respectively having 15 plant each. The large difference in yield was attributed to minor differences in fertigation EC during different crop stages. It showed the importance and sensitivity of fertigation EC.

Crop water productivity was found to be maximum 119.28 kg/m³ and minimum 72.12 kg/m³ corresponding to the treatments T_1 and T_3 respectively having 15 plant each. Crop water productivity was found to be very high for greenhouse capsicum grown in soilless media in comparison with soil due to the fact that ET was very low for soilless media.

The best strategy for capsicum was treatment T_1 in which the electrical conductivity of fertigation solution was maintained as 2.4, 2.6, 2.8 dS/m respectively for vegetative, flowering and fruiting stage.

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