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EFFECT OF DRIP IRRIGATION LEVELS AND SUBSTRATES ON GROWTH, YIELD AND QUALITY OF TOMATO UNDER PROTECTED CONDITION

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ABSTRACT

A pot experiment was conducted in the polyhouse at Saidapur farm, University of Agricultural Science, Dharwad during *Rabi* 2015. The experiment was laid out in CRD with two factors *viz*. I- drip irrigation at once day (I_1: 50 % of PE, I_2 : 75 % of PE and I_3 : 100 % of PE) and factor II includes different substrates with combinations. The results revealed that drip irrigation at 100 % PE (I_3) recorded significantly higher plant height at harvest (198.7 cm), number of fruits plant^{-1}(55.0), fruit yield plant^{-1} (2.54 kg), fruit yield (105.88 t ha^{-1}) and root parameters as compared to other levels. Quality parameters also behaved similarly with drip irrigation levels. The mixed substrates of cocopeat + perlite + vermiculite at 50:25:25 (M_6) recorded significantly higher plant height at harvest (183.9 cm), number of fruits plant^{-1}(52.9), fruit yield plant^{-1} (2.42 kg), fruit yield (100.90 t ha^{-1}), root length (935.2 cm) and water productivity (83.4 kg ha^{-1}). The interaction of I_3M_6 recorded significantly higher number of fruits plant^{-1} (65.3), fruit yield plant^{-1} (3.04 kg), fruit yield (126.69 t ha^{-1}) for the tomato hybrid STH-801 as compared to other treatment combinations.

INTRODUCTION

Annually of 4 per cent growth in agriculture is earmarked by the Indian policy makers to ensure national food security with limited availability of land and water resources. During 1950's and 1960 food security was prime concern and now emphasis is on ensuring agricultural sustainability and also simultaneously on addressing the concerns of global competitiveness of produce in the wake up of the new global trade regime and consumer preferences. Hence, avenue for achieving the demand is possible only by increasing the productivity and nutritional quality through effective use of new technologies such as soilless culture, nanotechnology, precision farming *etc*. Commercial vegetable production is very expensive as it involves many costly inputs. One of the major inputs is a suitable land which is becoming scarce day by day particularly in urban areas throughout the country.

Soilless culture can provide an important requirement for plant growth with equal growth and yield results as compared to field soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium. Various modifications of pure solution culture have occurred in the past. The retention of nutrients and water can be further improved through the use of different locally available substrates. Straw bales have been used as growing medium in England and Canada and rockwool (porous stone fiber) is used in Europe (Hussain *et al.,* 2014). Thus soilless culture is the method of growing plants which does not involve the employment of natural earth or specially compounded soil based compost and similar complexes (cocopeat, perlite and vermiculite *etc*.). Samiei *et al*. (2005) investigated the effect of peatmoss, cocopeat and date-palm wastes as substrates on growth of *Aglaonema commutatum* (silver queen) and showed that leaf area, dry and wet weight of plant biomass, stool shoots and length were higher under cocopeat substrate as compared to other two substrates. However above indices were similar in peatmoss and date-palm substrates.

Effect of different substrates on growth, yield and quality of watermelon grown on soilless culture was studied by Yetisir *et al*. (2006) and showed that the higher vegetative growth was observed in the basalticmix, sand, peat and soil substrates, similarly by Lopez *et al*. (2004) and Fandi *et al.,* 2007. There was no significant difference in the TSS (5.4°Brix) of tomato raised in cocopeat and rockwool (5.3°Brix) substrates by Luitel *et al*. (2012). The weakest growth was occurred in the mixture of andesitic tuff and peat, while the higher and lower yields were obtained from perlite and andesitic tuff. Today our aim is to increase the agricultural production per unit of water, per unit of cropped land in a unit time and the theme "**more crop per drop**" also appropriately emphasizes the same. Scientific management of irrigation water provides the insurance against weather induced fluctuation in total production. This is the only way in which we can make our agriculture competitive and profitable.

Hence the present investigation assumes the significance in view that water as a resource in agriculture and has become limiting factor, since agriculture and horticulture activities are heavily dependent on irrigation water which has become most precarious as rainfall distribution during the rainy season in this region is uncertain and erratic. In this context the present study has been planned with the objectives of improving the yield, quality and water productivity of soilless tomato under protected condition.

MATERIALS AND METHODS

A pot experiment was conducted inside the polyhouse at the Main Agricultural Research Station (MARS), Saidapur Farm, University of Agricultural Science (UAS) Dharwad. STH 801 cultivar of tomato was used. The experiment consisted of two factors *viz*. Factor - I drip irrigation levels, I_1: Once a day at 50 per cent of pan evaporation (PE), I_2 : Once a day at 75 per cent of PE and I_3 : Once a day at 100 per cent of PE. Similarly, factor-II includes media, M_1:Cocopeat, M_2: Perlite, M_3 : Vermiculite, M_4: Cocopeat + Perlite (50:50), M_5: Cocopeat + Vermiculite (50:50), M_6: Cocopeat + Perlite + Vermiculite (50:25:25), M_7: Sole soil (Grown in earthen pot) and M_8: Sole soil grown under normal condition. The pot experiment was laid out in completely randomized design as suggested by Senzen *et al*. (2010).

The growing system designed for this particular study was earthen pots of size 8.5 l capacity. Three different inert growing media combinations were used for the experiment and soil was used as check. The earthen pots were filled with different growing media as per the treatments and also measured amount of media was added to each pot with the help of digital weighing balance (Table 1) as guided by Ghehsareh *et al*. (2011). The pots were saturated with water before 24hrs of transplanting after filling the media.

A drip irrigation system was used for irrigating tomato plants grown in earthen pot filled with growing materials. Each earthen pot consisted of one dripper for irrigation. Irrigation continued until five days before the final harvest. One drip lateral was served for each plant row. On line emitters with discharge rate of 1.5 litre per hour (lph) at 40 cm spacing on laterals were used. To determine the amount of irrigation water, daily evaporation values were obtained from USWB Class - A open pan evaporimeter inside the polyhouse. The value of pan coefficient was taken as 0.70 for converting the observed pan evaporation for use in the study (Michael, 2009). Water soluble fertilizers were used in this experiment.

The analysis of root parameters was done after final harvest of the plant. The root washing was performed by removing the roots from the pots through root core sampler to the depth of 12 cm with a diameter of 8 cm. The washed roots were placed in root scanner trays in the root computer system (Regent - STD 1600 + which uses a win RHIZO ™ 2013 programme: Regent instrument, Canada). Root parameters such as estimate root length (cm), root diameter (mm) and root volume (cm^3) were anylased. The leachate collected at 90 DAT from each treatment was anylased and the amount of major nutrient content of nitrogen, phosphorous and potassium was expressed in mg l^{-1} (Tandon, 1998). Fisher's method of analysis of variance was applied for statistical analysis and interpretation of data was obtained as given by Gomez and Gomez (1984). The level of significance used in 'F' and 'T' test was P= 0.01. The critical difference was calculated whenever F test was significant.

RESULTS AND DISCUSSION

The yield of tomato differed significantly with different levels of irrigation. Yield is a complex character involving interaction between plant genetic characters and environment. The agronomic managerial practices to modify crop environment to suit crop requirement play a vital role in harvesting bumper yields. Among drip irrigation levels, drip irrigation at 100 per cent PE recorded significantly higher number of fruits plant^{-1} (55.0) and fruit yield (105.8 t ha^{-1}) as compared to 75 per cent PE (45.6 and 86.8 t ha^{-1} number of fruits plant^{-1} and fruit yield respectively) and 50 per cent PE (36.2 and 64.71t ha^{-1} number of fruits plant^{-1} and fruit yield respectively). The increased yield in drip irrigation with 100 per cent PE might be due to uniform supply of moisture to crop and its full pledge use by crop which resulted in manifestation of luxuriant growth and hence crop could put forth its full potential in terms of economic yield. The results are in agreement with findings of Ramniwas *et al*. (2012), Sharma *et al*. (2013) and Ughade and Mahadkar (2015).

The substrates had significant influence on fruit yield of tomato. Mixed substrates of cocopeat + perlite + vermiculite at 50:25:25 recorded significantly higher yield (100.9 t ha^{-1}) than sole vermiculite (91.2 t ha^{-1}), perlite (89.26 t ha^{-1}) and cocopeat (89.2 t ha^{-1}) substrates. However, it was on par with cocopeat + perlite at 50:50 (95.3 t ha^{-1}) and cocopeat + vermiculite at 50:50 (94.7 t ha^{-1}). The lower fruit yield (54.6 t ha^{-1}) was recorded in sole soil (Grown in earthen pot) as compared to tomato grown under normal conditions (69.3 t ha^{-1}). Similar findings were obtained by He *et al*. (2003), Joseph and Muthuchamy (2014). The increase in yield under cocopeat + perlite + vermiculite at 50:25:25 might be due to an increase in number of fruits plant^{-1} (52.9). The mixed substrates of cocopeat + vermiculite at 50:50 (50.8) were on par with cocopeat + perlite at 50:50 (50.0) substrates. The lower number of fruits plant^{-1} (31.2) observed in sole soil (Grown in earthen pot) as compared to tomato grown under normal conditions (37.6). The increase in yield attributes was probably associated with the conservation of moisture and improved

Table 1: The quantity of different substrates added to earthen pots

Sl. No.	Growing Media	Quantity of media filled for each pot (kg)
1	Sole Cocopeat	2.75
2	Sole Perlite	1.00
3	Sole Vermiculite	3.25
4	Cocopeat + Perlite (50:50)	1.37 + 0.5 = 1.87
5	Cocopeat + Vermiculite (50:50)	1.37 + 1.6 = 2.97
6	Cocopeat + Perlite + Vermiculite (50:25:25)	1.37 + 0.25 + 0.8 = 2.42
7	Sole Soil	8.00

Table 2: Growth, yield and water productivity as influenced by drip irrigation level and substrates

Treatment	Plant height 30 DAT	60 DAT	At harvest	Days to 50% flowering	No. fruits plant^{-1}	Fruit yield plant^{-1}(kg)	Fruit yield (t ha^{-1})	Water applied plant^{-1} (l)	Water productivity (kg ha^{-1})
Irrigation (I)									
I_1	56.8	100.4	149.6	41.7	36.2	1.55	64.7	20.83	74.6
I_2	64.5	124.2	171.9	45.4	45.6	2.08	86.8	29.24	71.2
I_3	73.9	135.9	198.7	47.0	55.0	2.54	105.9	37.65	67.5
S.Em±	0.65	1.06	1.01	0.38	0.56	0.02	1.00	-	0.95
C.D. at 1%	2.45	4.01	3.84	1.45	2.11	0.09	3.81	-	5.88
Media (M)									
M_1	66.6	119.8	175.1	45.0	47.0	2.14	89.2	-	73.9
M_2	67.6	121.2	176.4	44.6	47.1	2.14	89.3	-	74.0
M_3	67.7	120.7	176.2	44.6	48.3	2.19	91.2	-	75.8
M_4	67.1	124.4	181.4	45.7	50.0	2.29	95.3	-	78.9
M_5	69.3	126.2	180.6	45.3	50.8	2.27	94.7	-	78.2
M_6	70.6	128.4	183.9	46.1	52.9	2.42	100.9	-	83.4
M_7	53.1	106.7	151.4	42.4	31.2	1.35	56.4	-	47.5
M_8	58.3	114.1	162.1	44.0	37.6	1.66	69.3	-	57.1
S.Em±	1.06	1.73	1.65	0.62	0.91	0.04	1.64	-	1.55
C.D. at 1%	4.01	6.56	6.27	2.36	3.44	0.15	6.22	-	5.88
Interaction									
I_1M_1	56.7	100.7	151.3	42.7	36.33	1.59	66.3	20.83	76.4
I_1M_2	58.7	100.3	153.0	41.7	37.00	1.61	67.2	20.83	77.4
I_1M_3	59.7	101.7	152.3	41.7	38.33	1.66	69.3	20.83	79.9
I_1M_4	58.7	104.0	155.0	42.3	38.67	1.71	71.2	20.83	82.0
I_1M_5	61.0	105.0	154.3	41.3	41.67	1.67	69.8	20.83	80.4
I_1M_6	61.3	107.3	157.3	42.7	41.00	1.80	75.1	20.83	86.5
I_1M_7	46.3	88.0	132.0	39.7	28.00	1.16	48.4	20.83	55.8
I_1M_8	51.7	96.3	141.6	41.7	28.33	1.21	50.4	20.83	58.1
I_2M_1	66.0	124.0	175.0	45.3	48.33	2.20	91.8	29.24	75.3
I_2M_2	66.7	125.3	176.3	45.3	48.33	2.20	91.5	29.24	75.1
I_2M_3	67.3	124.7	175.6	45.0	50.00	2.26	94.1	29.24	77.3
I_2M_4	67.0	129.7	178.3	46.7	51.00	2.34	97.3	29.24	79.9
I_2M_5	68.0	131.3	177.7	46.3	50.00	2.31	96.1	29.24	78.9
I_2M_6	70.3	132.0	179.7	47.0	52.33	2.42	100.9	29.24	82.8
I_2M_7	53.3	112.0	153.7	42.7	28.33	1.28	53.3	29.24	43.7
I_2M_8	57.3	114.7	158.7	44.7	36.67	1.66	69.4	29.24	56.9
I_3M_1	77.2	134.7	199.0	47.0	56.33	2.63	109.6	37.65	69.9
I_3M_2	77.3	137.3	200.0	46.7	56.00	2.62	109.1	37.65	69.6
I_3M_3	76.0	135.7	200.7	47.0	56.67	2.64	110.1	37.65	70.2
I_3M_4	75.7	139.7	211.0	48.0	60.33	2.82	117.5	37.65	74.9
I_3M_5	79.0	142.3	209.7	48.3	60.67	2.84	118.3	37.65	75.4
I_3M_6	80.0	146.0	214.7	48.7	65.33	3.04	126.7	37.65	80.8
I_3M_7	59.7	120.0	168.7	45.0	37.33	1.62	67.7	37.65	43.1
I_3M_8	66.0	131.3	186.0	45.7	47.67	2.11	88.0	37.65	56.1
S.Em±	1.83	3.0	2.86	1.08	1.57	0.07	2.84	-	2.69
C.D. at 1%	NS	NS	NS	NS	5.96	0.26	10.78	-	NS

I: Irrigation level - I_1: Once a day at 50 per cent of pan evaporation, I_2: Once a day at 75 per cent of pan evaporation, I_3: Once a day at 100 per cent of pan evaporation, M: Media - M_1:Cocopeat, M_2: Perlite, M_3: Vermiculite , M_4: Cocopeat + Perlite (50:50), M_5: Cocopeat + Vermiculite (50:50) M_6: Cocopeat + Perlite + Vermiculite (50:25:25), M_7: Sole soil (Grown in earthen pot), M_8: Sole soil (Grown under normal condition) and NS: Non significant

micro-climate in soilless conditions. Owing to quicker root development of tomato in cocopeat resulted in better yield. Similar results were reported by Tehranifar *et al.* (2007) and Tzortzakis and Economakis (2008).

Water requirement of crop depends on soil, plant and climatological factors of the location. It is an important input for greenhouse tomato because irrigation is the only source for application of water to the plants. Several efforts have been made to use irrigation as efficient as possible under protected cultivation system. The use of drip irrigation saves water and gives better plant yield and quality as it reduces the humidity build up inside the greenhouse after irrigation due to precise application of water to the root zone of the crop. The total amount of water applied per plant was 20.83, 29.24, and 37.65 l for drip irrigation at 50, 75 and 100 PE levels respectively (Table 2). Similar findings were reported by Harmanto *et al.* (2005). They noticed that, tomato plants with 100% of ETc received a total of about 44 l of irrigation water during the growing season. Increase in the levels of drip irrigation helped for increasing the yield per hectare by 63.36 per cent in drip irrigation at 100 per cent PE and 34.10 per cent in drip irrigation at 75 per cent PE as compared to drip irrigation at 50 per cent PE.

In the present investigation, drip irrigation levels had a

Table 3: Quality, root parameters and nutrient content in leachates as influenced by drip irrigation level and substrates

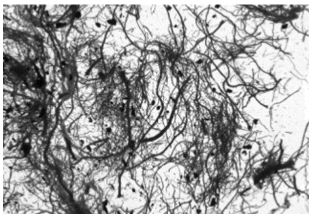
Treatment	Quality parameters				Root parameters			Nutrient content in leachates		
	Shelf life (days)	TSS (°Brix)	TA (% citric acid)	TSS/TA ratio	Root length (cm)	Root volume (cm^3)	Root diameter (mm)	Nitrogen (mg l^{-1})	Phosphorous (mg l^{-1})	Potassium (mg l^{-1})
Irrigation (I)										
I_1	20.71	0.63	7.19	11.47	764.6	2.1	0.8	79.2	18.1	8.0
I_2	19.54	0.64	7.02	11.00	783.4	2.3	0.9	74.1	17.1	7.6
I_3	18.33	0.57	6.22	10.68	792.0	2.4	0.9	71.8	16.4	7.3
S.Em ±	0.29	0.01	0.09	0.16	2.28	0.03	0.01	1.24	0.12	0.06
C.D. at 1%	1.09	0.03	0.33	0.61	8.65	0.12	0.05	4.70	0.45	0.22
Media (M)										
M_1	19.22	0.61	6.78	10.99	927.8	2.9	0.65	75.3	17.0	7.6
M_2	19.67	0.60	6.84	11.15	927.0	2.1	0.63	750	17.2	7.7
M_3	20.00	0.61	6.72	11.02	925.3	2.0	0.64	74.4	171	7.7
M_4	19.78	0.61	6.84	11.17	931.3	2.3	0.66	72.8	16.8	7.5
M_5	19.44	0.61	6.77	10.89	931.5	2.2	0.66	71.9	16.9	7.5
M_6	19.33	0.61	6.86	11.23	935.2	2.3	0.68	73.4	16.8	7.5
M_7	19.56	0.62	6.81	11.03	314.2	2.7	1.59	78.7	17.8	7.9
M_8	19.22	0.62	6.87	10.93	347.9	2.6	1.38	78.7	17.8	7.9
S.Em ±	0.47	0.01	0.14	0.26	3.72	0.05	0.02	2.03	0.19	0.09
C.D. at 1%	NS	NS	NS	NS	14.12	0.2	0.07	NS	0.73	NS
Interaction										
I_1M_1	20.67	0.61	7.10	11.64	911.6	2.0	0.58	79.3	17.9	7.8
I_1M_2	20.33	0.61	7.13	11.68	909.8	1.9	0.57	80.3	18.1	8.2
I_1M_3	21.67	0.62	7.17	11.58	906.2	1.9	0.58	79.3	18.0	8.1
I_1M_4	20.67	0.63	7.23	11.49	914.5	2.1	0.59	77.5	17.7	7.9
I_1M_5	21.00	0.64	7.13	11.15	915.2	2.1	0.59	76.5	17.4	7.8
I_1M_6	20.00	0.64	7.33	11.54	918.5	2.2	0.60	78.4	17.5	7.8
I_1M_7	21.00	0.63	7.17	11.43	302.7	2.5	1.40	81.2	19.1	8.2
I_1M_8	20.33	0.64	7.27	11.29	338.1	2.4	1.26	81.2	19.1	8.2
I_2M_1	19.00	0.65	6.97	10.74	930.2	2.2	0.67	73.7	16.9	7.6
I_2M_2	20.00	0.64	7.13	11.11	931.2	2.1	0.66	72.8	17.1	7.7
I_2M_3	20.33	0.63	6.93	11.00	933.4	2.0	0.65	73.7	16.7	7.6
I_2M_4	19.67	0.64	7.07	11.07	934.8	2.4	0.68	71.9	16.6	7.5
I_2M_5	19.00	0.64	7.03	11.08	934.0	2.2	0.69	70.9	17.0	7.5
I_2M_6	20.00	0.63	7.07	11.28	938.4	2.4	0.71	72.8	16.5	7.5
I_2M_7	19.00	0.64	6.97	10.84	316.7	2.8	1.68	78.4	17.8	7.9
I_2M_8	19.33	0.64	7.00	10.87	348.5	2.6	1.39	78.4	17.8	7.9
I_3M_1	18.00	0.57	6.27	10.59	941.6	2.3	0.68	72.8	16.1	7.4
I_3M_2	18.67	0.54	6.27	10.67	940.8	2.3	0.67	71.9	16.4	7.3
I_3M_3	18.00	0.58	6.07	10.47	936.2	2.2	0.69	70.0	16.5	7.3
I_3M_4	19.00	0.55	6.23	10.97	944.5	2.4	0.72	69.1	16.2	7.2
I_3M_5	18.33	0.57	6.13	10.46	945.2	2.3	0.71	68.1	16.3	7.3
I_3M_6	18.00	0.57	6.17	10.87	948.5	2.3	0.72	69.1	16.4	7.1
I_3M_7	18.67	0.58	6.30	10.82	323.0	2.9	1.70	76.5	16.6	7.5
I_3M_8	18.00	0.57	6.33	10.63	357.2	2.8	1.50	76.5	16.6	7.5
S.Em ±	0.81	0.01	0.14	0.46	6.45	0.09	0.03	3.51	0.33	0.16
C.D. at 1%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

I: Irrigation level - I_1: Once a day at 50 per cent of pan evaporation, I_2: Once a day at 75 per cent of pan evaporation, I_3: Once a day at 100 per cent of pan evaporation, M: Media - M_1:Cocopeat, M_2: Perlite, M_3: Vermiculite , M_4: Cocopeat + Perlite (50:50), M_5: Cocopeat + Vermiculite (50:50) M_6: Cocopeat + Perlite + Vermiculite (50:25:25), M_7: Sole soil (Grown in earthen pot), M_8: Sole soil (Grown under normal condition) and NS: Non significant

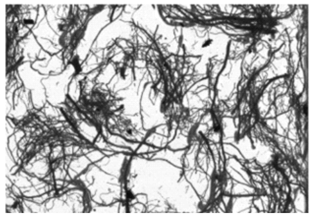
significant influence on water productivity (WP) of tomato. Drip irrigation at 50 per cent PE recorded significantly higher WP (74.6 kg m^{-3}) as compared to others. However,it was on par with drip irrigation at 75 per cent PE (71.2 kg m^{-3}). This might be due to efficient use of water at lower amount of irrigation than at higher amount of water applied. The results are in conformity with the findings of Sezen *et al.* (2010) and Sharma *et al.* (2013).

Similarly, substrates had a significant effect on WP of tomato. Mixed substrates with cocopeat + perlite + vermiculite at 50:25:25 recorded higher significantly higher WP (83.4 kg m^{-3}) as compared to others. However, it was on par with cocopeat + perlite at 50:50 (78.9 kg m^{3}) and cocopeat + vermiculite at 50:50 (78.2 kg m^{3}).This might be due to higher yield and precise water use by tomato. The results are in conformity with the findings of Sezen *et al.* (2010).

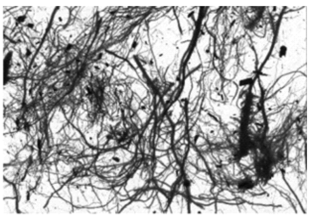
Plant height is one of the important growth parameters had an indirect effect on yield of tomato. As the plant height increases, there may be more light interception and dry matter accumulation which were reflected in higher yield. In the present investigation, drip irrigation with 100 per cent PE recorded (Table 2) significantly higher plant height at harvest



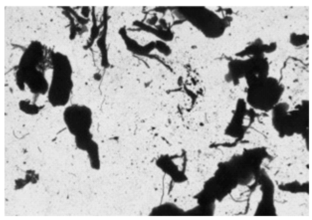
Drip irrigation at 100% PE along with Cocopeat + Perlite + Vermiculite (50:25:25)



Drip irrigation at 100% PE along with Cocopeat + Perlite (50:50)



Drip irrigation at 100% PE along with Cocopeat + Vermiculite (50:50)



Drip irrigation at 100% PE along with sole soil (grown on earthen pot)

Plate 1: Effect of drip irrigation levels and substrates on root parameters

(198.7 cm) over other levels. Similar findings were obtained by Dunage *et al.* (2009). The increment in plant height was due to higher availability of nutrients which accelerated the cell division and elongation. Whereas, drip irrigation at 50 per PE recorded significantly lower plant height at harvest (149.6 cm). The reduction in plant height might be due to poor nutrition as well as less water supply to plants. Different irrigation levels had a significant influence on all the growth parameters. Whereas, days to fifty per cent flowering (47.0 days) was higher at drip irrigation with 100 per cent PE as compared to other levels.

Similarly plant height (183.9 cm) and days to fifty per cent flowering recorded (46.1 days) (Table 2) under cocopeat + perlite + vermiculite at 50:25:25 was significantly higher over other substrates. Similar findings were reported by Haddad (2007). However, it was on par with cocopeat + perlite at 50:50 and cocopeat + vermiculite at 50:50. This could be due to no chance of soil-borne insect pest, disease attack or weed infestation which helped in efficient nutrient regulation and thus leading to increase in yield of tomato.

Roots are important to plant for wide variety of process including nutrient, water uptake and anchoring mechanical support. In addition many plants use roots for storage function. The root length (792.0 cm), root diameter (0.92 mm) and root volume (2.4 cm^3) were higher at drip irrigation with 100 per cent PE (Table 3). This might be due to an interdependent relationship existed between root and shoot. The active shoots can ensure a sufficient supply of carbohydrates to roots and maintain active root functions, which can improve shoot growth by supplying a sufficient amount of nutrients, water and phytoharmones. Thus increased crop productivity (Zhang *et al.,* 2009). It is also believed that longer root length and greater root density could benefit plant roots to increase the availability of nutrients in growing substrate/soil media. It was clear from Plate 1 indicating restricted root growth with drip irrigation at 50 per cent PE in sole soil (Grown in earthen pot) as compared to prolific root growth and spread in different mixed media at 100 per cent PE.

The root length was on par with soilless media. This might be due to proper utilization of potassium and nitrogen helped in increasing the cell division and elongation of roots. Whereas, root diameter (1.59 mm) and root volume (2.7 cm^3) were higher in sole soil grown in earthen pots as compared to other treatments. This might be due to the effect of increased cell size and accumulation of metabolites in storage roots. The quality parameters of tomato differed significantly with irrigation levels. Drip irrigation with 50 per cent PE recorded higher shelf life (20.71 days), TSS (0.63 °Brix), TA (7.19 % citric acid) and TSS/TA (11.47) as compared to other levels. The quality parameters did not differ significantly with substrates. Similar results were reported by Radhouani *et al.* (2011) and Luitel *et al.* (2012). The nutrient content in the leachate differed significantly (Table 3) with different drip irrigation levels. The nitrogen (79.2 mg l^{-1}), phosphorus (18.1 mg l^{-1}) and potassium (8.0 mg l^{-1}) contents in leachate were higher at drip irrigation with 50 per cent PE. This might be due to less utilization of nutrients for plant growth, due to ununiform distribution of moisture in the root zone as compared to other levels. Similarly, the nitrogen and potassium content in leachate did not differ significantly with substrates. Whereas, phosphorous (17.8 mg l^{-1}) content was higher in sole soil grown in earthen pots, but it was on par with sole perlite (17.2 mg l^{-1}) and vermiculite (17.1 mgl^{-1}).This might be due to fixation of nutrient in the soil and made less available to the plant.

Interaction effect differed significantly for fruit yield $plant^{-1}$ and yield ha^{-1} parameters. The treatment combination of drip irrigation at 100 per cent PE with cocopeat + perlite + vermiculite at 50:25:25 (I_3M_6) recorded significantly higher fruit yield $plant^{-1}$ (3.04 kg) and yield ha^{-1} (126.7 kg ha^{-1}) as compared to other combinations. Similarly the interaction effect due to plant height and root parameters did not differ significantly. However, numerically higher root length (948.5 cm) was observed at I_3M_6 treatment (Table 3). Whereas, root diameter (2.9 cm^3) and root volume (1.70 mm) were higher in drip irrigation at 100 per cent PE + sole soil grown in earthen pot (I_3M_7) combinations. The water productivity (86.5 kg m^{-3}) was numerically higher in drip irrigation at 50 per cent PE with cocopeat + perlite + vermiculite at 50:25:25 (I_1M_6) but, it did not differ significantly with any treatment combinations. The interaction effect due to quality parameters of tomato did not differ significantly. However, titratable acidity (0.65% citric acid), total soluble solids (7.27 °Brix), TSS/TA ratio (11.64) and shelf life of tomato fruit (21 days) were higher in drip irrigation at 75 per cent PE + cocopeat, drip irrigation at 50 per cent PE + sole soil grown in earthen pot drip irrigation at 50 per cent PE + cocopeat and drip irrigation at 50 per cent PE with cocopeat + vermiculite at 50:50 combinations respectively. The interaction effects of nutrient content in the leachate was non significant. However, nitrogen, phosphorous and potassium content in leachate were higher in combination of drip irrigation at 50 per cent PE with sole soil grown in earthen pot and drip irrigation at 50 per cent PE with conventionally grown tomato due to non availability adequate moisture. These results are fall in line with Natarajan *et al.* (2005) and Nagaraj *et al.* (2015).

Based on this study it can be conclude that, drip irrigation at 100 per cent pan evaporation once a day with mixed substrate of cocopeat + perlite + vermiculite at 50:25:25 was found to be optimum to achieve the better yield, quality and water productivity of tomato cultivar STH-801 under protected cultivation.

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