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Irrigation scheduling for high value vegetable crops grown under protected cultivation in the hilly ecosystem of north-east India

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ABSTRACT

Irrigation scheduling plays a vital role in the efficient utilization of water to obtain optimum yield, particularly for high value crops grown under protected conditions. The present experiment was conducted during 2020–22 at Horticulture Experimental Farm, ICAR-Research Complex for North Eastern Hill Region, Umiam, Meghalaya to standardize the irrigation scheduling (IS) (5, 7, and 10-days interval) in high-value vegetable crops [tomato (*Solanum lycopersicum* L.), capsicum (*Capsicum annuum* L.) and king-chilli (*Capsicum chinense* Jacq.)] grown under naturally ventilated low-cost polyhouse in the mid-hill conditions of Meghalaya. The results revealed a significant effect of IS on plant growth (reduction in plant height, leaf area) and yield attributes (fruit setting, fruit size, fruit weight and total yield) of the crops with an increase in level of moisture stress. The highest yield of tomato (82.7 t/ha), capsicum (40.8 t/ha) and king-chilli (11.8 t/ha) was recorded in the 5-day interval of IS and on increasing the IS interval to 7-days, the yield decreased by 28.7, 36.1 and 35.7%, respectively. Among the crops, capsicum was found to be more sensitive to water stress, followed by king-chilli and tomato. Among the crops, water productivity with respect to irrigation water was maximum in tomato (60.0 g/kg) followed by capsicum (17.2 g/kg) and king-chilli (10.0 g/kg). Among the varieties grown, Megha Tomato-3 of tomato, hybrid Mahabharat of capsicum and landrace Red Long of king-chilli were found superior for growth and yield attributes at different levels of moisture regime. The farmers of the region can get higher yield using identified varieties with irrigation at 5-days intervals.

Keywords: Capsicum, Irrigation scheduling, King-chilli, Tomato, Water productivity

Protected cultivation of high value vegetable crops is gaining importance due to its year-round production, higher yield and quality. Due to its economic advantages in establishment and lower running costs under conducive mild weather, the naturally ventilated polyhouse has been found suitable structure for the region. In the north-eastern hill (NEH) region, along with tomato (*Solanum lycopersicum* L.) and capsicum (*Capsicum annuum* L.), the indigenous high value crop king-chilli (*Capsicum chinense* Jacq.) has also been found a potential crop with a benefit cost ratio of 4.2 (Verma *et al.* 2018) under protected cultivation. This has been attributed to a higher market price of the produce (₹200–400/kg) in the local markets and richness in pungency due to its high capsaicin content. Besides, this crop is also grown for different value-added products such as pickles as well as some traditional medicines by local tribes.

Water is one of the most precious and scarce resources in the hills, especially during the dry, rainless winters that limit the year-round production of crops. In the greenhouse, crops require frequent irrigation to increase water use efficiency, minimize water stress, and obtain maximum production and high quality. Scheduling irrigation is very critical, as excessive irrigation reduces yield, while inadequate irrigation or water stress reduces plant size, fruit set and causes blossom shed that ultimately leads to a reduction in total production (Dagleden *et al.* 2004). Further, an imbalance in the soil moisture regime often causes physiological disorders like blossom drop and blossom end rot in tomatoes and capsicum. In addition, water stress also increases the susceptibility of plants to attack by pathogens (Celebi 2014). There are different methods, viz. gravimetric method, soil water tension, pan evaporation, ET (evapotranspiration) etc. (Smittle *et al.* 1994, Ertek *et al.* 2007) being used for irrigation scheduling under protected conditions. To optimize the irrigation water requirement of high-value crops and achieve higher yield under protected conditions, the present investigation was undertaken to standardize the irrigation scheduling (time interval) based on growth and yield performances of high-value vegetable crops (tomato, capsicum and king-chilli), to suggest the suitable varieties of each crop for growing

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under water stress-free and water stressed conditions in naturally ventilated polyhouse, and to estimate the water productivity of the identified high value vegetable crops.

MATERIALS AND METHODS

The present experiment was conducted during 2020–22 at Horticulture Experimental Farm, ICAR Research Complex for North Eastern Hill Region, Umiam (25°41ʹN and 91°55ʹ E at an altitude of 980 m msl), Meghalaya under a protected structure (a naturally ventilated polyhouse). The average day and night temperature under the polyhouse ranged from 22–27°C and 15–20°C, respectively. The average relative humidity during crop growing periods varied from 47–68%. The soil of the experimental site was coarse (sandy) with an acidic reaction (*p*H=5.44).

The experiment was conducted in factorial completely randomized block design (F-CRBD) with 3 replications consisted of 3 high-value crops of the region tomato, capsicum and king-chilli were selected. In tomato, 4 popular cultivars, viz. Megha Tomato-3 (V_1); VL Tomato-4 (V_2); Sel-9A (V_3); and Megha Tomato-2 (V_4), in capsicum 2 cultivars, viz. F_1 Mahabharat (V_1) and California Wonder (V_2) and in king-chilli 2 local landraces Red Long (V_1) and Chocolate Long (V_2) were grown under naturally ventilated polyhouse conditions. For irrigation scheduling (IS), the crops were irrigated with an equal amount of water (1.5 litre) in each time at 3 intervals, viz. 5 days (L_1); 7 days (L_2); and 10 days (L_3). The soil moisture content (wt/wt) and soil moisture tension in each IS (L_1–L_3) was also measured using the soil MP Kit- Soil Moisture (ICT International, NSW, Australia) and tensiometer, respectively, from seedling to harvest stage of each crop across all plots at two depths (0–15 and 15–30 cm).

Under the experiment, crops were grown in sequence as tomato (July–January) followed by capsicum (February–June) crop rotation. King-chilli being a long duration crop (240 days), it was grown during March–November. The 30 days old seedlings of tomato, capsicum and 40 days old seedlings of King-chilli were transplanted in a double row system at 60 cm × 45 cm and 50 cm × 30 cm and 90 cm × 75 cm spacing, respectively. The seedlings were irrigated uniformly from transplanting up to 4 weeks and then treatments were imposed for the rest of the growth periods. All the plots across treatments were mulched with black polythene mulch of 40 μ thickness. The plants of tomato, capsicum and king-chilli were trained with the help of bamboo sticks.

The soil was drenched with lime (@250 kg/ha) 20 days before transplanting of the seedlings in each year. The standard package of practices was followed throughout the crop growth periods. The observations for growth and yield related attributes were taken from the six randomly selected plants in each replication.

The irrigation water productivity was estimated as:

$$\text{Irrigation water productivity (WP)} = \frac{\text{Yield/plant (g)}}{\text{Total water applied/plant (kg)}}$$

Statistical analysis: SAS Version 9.2 (SAS Institute Inc., Cary, NC, USA) was used to perform statistical analysis. SAS's PROC GLM procedure was used to conduct Analysis of Variance to determine the statistical significance of treatment effects.

RESULTS AND DISCUSSION

The irrigation scheduling considerably influenced the measured soil moisture and tension at flowering stages of growth in all three crops. The soil moisture content (wt/wt) consistently decreased both in the surface (0–15 cm) and sub-surface (15–30 cm) layers with the imposition of water stress (lengthening irrigation intervals from 5–10 days). The sub-surface layer had relatively higher moisture content (32.14, 24.67 and 20.66%) than the surface layer (26.63, 21.37 and 18.33%) across all three levels of irrigation ($L_{1,}$ L_2 and L_3), respectively. This was also reflected in measured soil water tensions: it increased consistently from 13.3 kPa in L_1–23.00 in L_2 and a further 40.67 kPa in L_3 in the surface layer (Table 1). A similar increase was also observed as 11.17 kPa in L_1; 19.670 in L_2 and a further 32.20 kPa in in L_3 in the sub-surface layer.

The different levels of irrigation and varieties showed a significant effect on the growth and yield attributes of the tomato (Table 2). Among the tomato varieties, the maximum plant height (PH) was recorded in the cultivar Sel-9A (139.1 cm and 130.0 cm) at L_1 and L_2. Likewise, the maximum leaf area was observed at L_1 in Megha Tomato-3 and VL Tomato-4 and both were statistically at par (*P*<0.05). Both plant height, leaf area, and fruit setting decreased with the increase in irrigation interval (L_1–L_3). Taking an average of all four varieties, the fruit set was reduced by 3–4% in L_2 over L_1 (62.1–73.0%). Likewise, fruit yield and attributing traits like fruit length, diameter, and weight were also reduced significantly with an increase in the level of moisture

Table 1 Effect of level of irrigation on soil moisture content and soil moisture tension

Soil depth (cm)	Irrigation intervals/level of irrigation					
	Soil moisture (%) (wt/wt)			Soil moisture tension (kPa)		
	5 Days (L_1)	7 Days (L_2)	10 Days (L_3)	5 Days (L_1)	7 Days (L_2)	10 Days (L_3)
0–15	26.63±1.05	22.37±0.86	18.33±1.12	13.33±0.77	23.00±0.67	40.67±1.28
15–30	30.14±0.76	24.67±0.34	20.67±0.45	11.17±0.54	19.67±0.55	32.20±1.40

*Mean ± SE of the crop growing periods-seedling to harvest.

Table 2 Effect of level of irrigation on growth and yield of tomato, capsicum and king chili genotype grown under protected condition

Variety/traits	Plant height (cm)			Leaf area (cm^2)			Fruit set (%)			Fruit length (cm)			Fruit diameter (cm)			Fruit weight (g)			No. of fruits/ plant			Yield/plant (kg)		
V/L	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
											Tomato													
Megha Tomato-3	130.0^{b}	116.1^{c}	86.5^{b}	77.33^{a}	62.33^{a}	56.6^{ab}	73.0	69.5	55.7	5.0b	4.8^{b}	4.3^{bc}	6.1^{a}	5.6^{a}	5.0^{a}	76.3^{a}	64.6^{a}	55.0^{a}	38.7^{a}	27.6^{b}	26.0^{ab}	2.90^{a}	1.86^{a}	1.46^{a}
VL Tomato-4	126.5^{b}	122.5^{b}	115.2^{a}	76.66^{a}	63.60^{a}	58.3^{a}	66.5	69.1	55.1	4.7c	4.6^{c}	4.2^{c}	6.0^{a}	5.4^{a}	5.1^{a}	73.4^{b}	62.6^{a}	51.6^{b}	34.6^{ab}	26.3^{b}	25.3^{b}	2.60^{b}	1.80^{a}	1.26^{ab}
Sel-9A	139.1^{a}	130.0^{a}	113.3^{a}	69.30^{b}	65.70^{a}	53.3^{b}	62.1	64.5	48.0	4.2^{d}	4.0^{d}	4.4^{b}	4.6^{c}	4.6^{b}	5.2^{a}	62.8^{c}	48.7^{b}	39.8^{c}	31.3^{b}	30.7^{ab}	24.6^{b}	2.06^{c}	1.50^{b}	1.23^{b}
Megha Tomato-2	112.9^{c}	87.76^{d}	77.5^{c}	69.20^{b}	58.00^{b}	46.6^{c}	71.7	67.5	56.0	5.6^{a}	5.2^{a}	4.8^{a}	5.6^{b}	5.5^{a}	4.7^{b}	73.9^{b}	65.9^{a}	46.3^{bc}	34.6^{ab}	32.3^{a}	26.3^{a}	2.50^{b}	1.93^{a}	1.36^{ab}
LSD (V)		4.52			4.05			NS			0.19			0.27			2.31			4.48			0.21	
LSD (L)		5.78			3.86			4.17			0.22			0.30			2.60			4.40			0.22	
LSD (V × L)		15.71			5.58			3.99			0.51			0.31			5.10			4.45			0.30	
											Capsicum													
Mahabharata	121.0^{a}	93.6^{b}	84.3^{b}	134.3^{a}	103.0^{b}	70.5^{c}	28.3^{a}	25.5^{b}	21.3^{c}	6.73^{a}	5.46^{b}	4.90^{c}	4.63^{a}	4.40^{ab}	3.80^{c}	64.7^{a}	48.3^{b}	32.0^{c}	15.6^{a}	11.3^{b}	7.3^{c}	0.81^{a}	0.55^{b}	0.26^{c}
California Wonder	138.3^{a}	102.6^{b}	65.3^{c}	121.5^{a}	100.6^{b}	64.3^{c}	27.3^{a}	26.0^{a}	21.0^{b}	6.40^{a}	5.70^{b}	5.10^{c}	4.20^{a}	3.80^{b}	3.17^{c}	55.0^{a}	42.5^{b}	41.5^{b}	13.3^{a}	10.3^{b}	6.6^{c}	0.75^{a}	0.41^{b}	0.28^{c}
LSD (L)		11.07			8.84			2.40			0.28			0.19			5.10			1.08			0.07	
LSD (V)		10.49			6.04			NS			0.29			0.13			6.14			0.66			0.06	
LSD (V × L)		11.25			15.77			2.45			0.20			0.19			8.51			1.73			0.079	
											King-chilli													
Red Long	162.3^{a}	147.7^{b}	102.6^{c}	147.0^{a}	106.3^{b}	66.0^{c}	66.3^{a}	64.0^{b}	47.7^{c}	5.0^{a}	4.8^{a}	4.3^{c}	3.5^{a}	3.2^{b}	2.6^{c}	5.6^{a}	5.1b	4.3^{c}	177.5^{a}	107.5^{b}	95.4^{c}	1.05^{a}	0.70^{b}	0.53^{c}
Chocolate Long	133.0^{a}	121.0^{b}	87.7^{c}	134.6^{a}	85.0^{b}	48.7^{c}	66.6^{a}	60.3^{b}	47.4^{c}	4.7^{a}	4.3^{b}	3.8^{c}	3.3^{a}	3.1^{b}	2.6^{c}	5.1^{a}	4.4^{b}	3.7^{c}	163.3^{a}	97.9^{b}	67.5^{c}	0.95^{a}	0.55^{b}	0.48^{c}
LSD (L)		5.8			3.3			2.1			0.3			0.06			0.15			3.9			0.03	
LSD (V)		5.3			2.5			NS			0.2			0.08			0.20			3.8			0.03	
LSD (V × L)		8.45			10.27			5.04			0.37			0.15			0.10			9.03			0.05	

*Means with the same letter (column) are not significantly different at $P<0.05$. L, Level of irrigation; V, Variety. L_1, 5 days; L_2, 7 days; and L_3, 10 days.

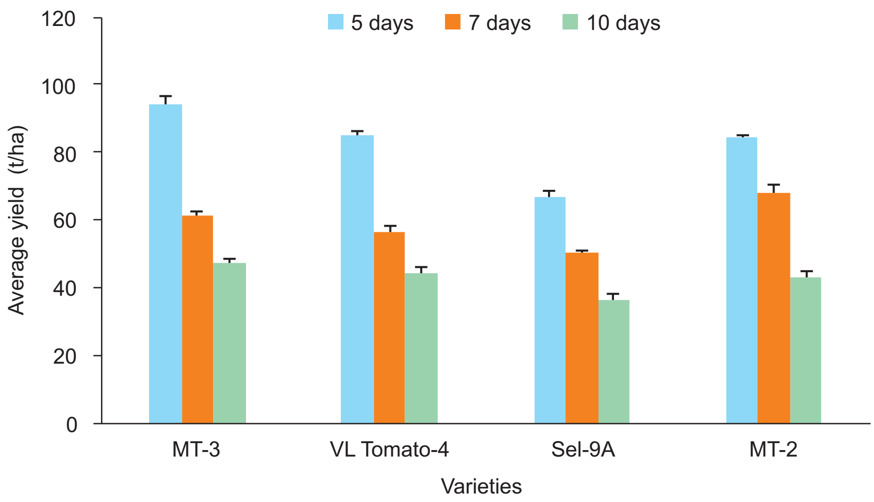

Fig. 1 Effect of irrigation levels on yield of tomato.

stress. Moreover, V_1 produced the highest fruit yield/plant (2.9 kg) followed by V_2, V_4 while V_3 produced the lowest (2.06 kg) in water stress-free conditions (L_1). A similar trend was observed under water-stressed conditions (L_2 and L_3). From pooled data, among the genotypes, Megha Tomato-3 was identified as high yielding (94.4 t/ha) at 5-day irrigation intervals followed by VL Tomato-4 and Megha Tomato-2. However, at 7-day intervals, Megha Tomato-2 (68.2 t/ha) was found to be superior (Fig. 1).

The performance of capsicum was also significantly affected by the level of moisture stress as well as genotypes (Table 2). Plant height and leaf area both get reduced significantly with an increase in the level of moisture stress. Like tomato, there was no significant difference for fruit set between the hybrid and variety at different levels of moisture; however, it was significantly influenced by IS. The highest fruit set (28.3%) was observed in hybrid Mahabharat at 5-day irrigation intervals and lowest (21.0%) in cultivar California Wonder at 10-day irrigation intervals. From the overall varietal mean, the reduction in fruit set with imposition of subsequent increase in moisture stress was 7.37 and 17.86% in L_2 over L_1 and L_3 over L_2, respectively, Further, yield attributes like fruit size (length and diameter) were affected by IS and both genotypes showed a reduction in size with an increase in the level of moisture stress (Table 2). The overall mean value of the fruit yield/plant showed a decrease in yield by 24.14 and 19.05% with an increase in the level of moisture stress in L_2 over L_1 and L_3 over L_2, respectively. From pooled data, hybrid Mahabharat was found to be superior, with higher yields of 42.3 and 29.0 t/ha at L_1 and L_2 IS, respectively. However, under a higher level of moisture stress (L_3) both the genotypes were statistically at par (Fig. 2).

In king-chilli, the maximum plant height and leaf area were recorded from landrace Red Long under moisture stress-free conditions (L_1). Both plant height and leaf area decrease with a decrease in the level of soil moisture (Table 2). Red Long was found to be superior for plant height as well as leaf area at all three levels of the moisture regime. Further, for fruit set, there was no significant difference in the landraces, but the percent fruit set reduced significantly with the increases in soil moisture tension. The maximum fruit set (66.6%) was observed under L_1 (moisture stress-free conditions), while it was minimum (47.4%) in landrace Chocolate Long at L_3 (moisture stress conditions). The reduction in fruit set was observed as 6.47 with an imposing increase in the level of moisture stress from L_1–L_2, and a further 23.5% from L_2–L_3. For fruit characteristics, the maximum fruit length (5.0 cm), diameter (3.5cm), weight (5.6 g), number of fruits/plant (177.5) and yield (1.05 kg) were observed in genotype Red Long under moisture stress-free conditions over Chocolate Long (Table 2). Unlike capsicum and tomato, fruit length and diameter in king-chilli also reduce with an increase in the level of soil moisture stress. From pooled yield data, genotype Red Long was found to be superior, with higher yields of 12.87 t/ha and 8.62 t/ha at L_1 and L_2, respectively. However, under a higher level of moisture stress (L_3) both the genotypes were statistically at par (P< 0.05) (Fig. 3).

Water is essential for the uptake and mobilization of nutrients from the soil to different parts of the plant. Under water stress conditions, decrease in photosynthesis

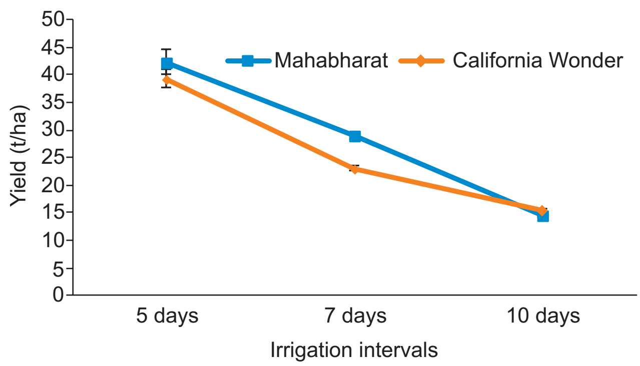

Fig. 2 Effect of irrigation levels on yield of capsicum.

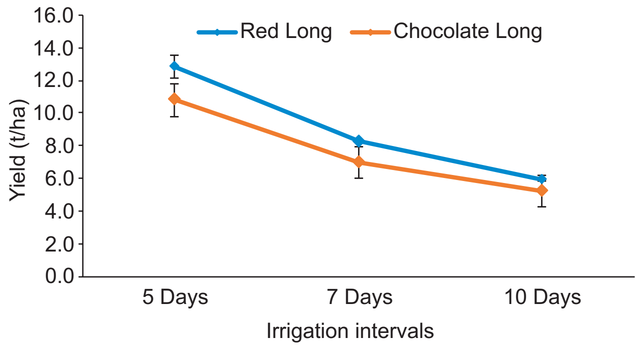

Fig. 3 Effect of irrigation levels on yield of king-chilli.

and consequently, a reduction in the amount of metabolites and energy (Kulkarni and Phalke 2009). Moisture stress influences plant growth at various levels, from the cell to the microbial community. In the present investigation, a significant reduction in plant height, and leaf area was observed in all the crops with the increase in level of moisture tension at increase in frequency period of irrigation (Table 2). This shows that the relative growth rate decreased in response to the decrease in water availability. This reduction could be attributed to a reduction in leaf cell expansion and possibly by a lower rate of cell division in the plant (Tadesse 1997). Furthermore, water reduction leads to a reduction in sunlight absorption and the photosynthesis level of the plant resulting from reduced leaf area, which leads to a reduction in plant yield (Hong-Bo *et al.* 2008). The reduction in plant height in capsicum (Ertek *et al.* 2007) and tomato (Khan *et al.* 2015) and leaf area in capsicum (Ferrara *et al.* 2011) has been observed with an increase in the level of moisture stress. The moisture stress has shown a significant impact on fruit set in all the tested crops and it reduces with increases in the level of moisture stress. The decrease in fruit set under moisture stress could be attributed to an increased abscisic acid (ABA) concentration in the reproductive structures as a result of moisture stress. A similar finding was also observed by Abdulmalik *et al.* (2012) in capsicum.

The fruit number, size, and weight are important yield-attributing traits. Abayomi *et al.* (2012) have demonstrated that the number and weights of marketable fruits of pepper were decreased by low soil moisture. In this study, all the crops have shown a significant decrease in the number, size, and weight of fruits. This could be due to a reduction in the plant's ability to adequately feed the fruits by increasing the level of moisture stress. Reduction in the size and number of fruits/plant and individual fruit weight with an increase in the level of water stress was also observed in tomato (Smajstrla *et al.* 1990) and capsicum (Ertek *et al.* 2007 and Ferrara *et al.* 2011).

The reduction in overall mean yield was from 82.7–42.7 t/ha in tomato, 40.8–15.0 t/ha in capsicum and

Table 3 Water productivity of tomato, capsicum and king-chilli under protected condition

Crop/Variety	Water productivity (g/kg water)			
	L_1	L_2	L_3	Mean
Tomato				
Number of irrigation	27	20	15	-
Water applied (litre/plant) in entire growth period (150 days)	40.5	30.0	22.5	-
Megha Tomato-3	71.60	62.00	64.89	66.16
VL Tomato-4	64.20	60.00	56.00	60.07
Sel-9A	50.86	50.00	54.67	51.84
Megha Tomato-2	61.73	64.33	60.44	62.17
Mean	62.10	59.08	59.00	60.06
LSD (V)		3.30		
LSD (L)		5.95		
Capsicum				
Number of irrigation	25.0	19.0	13.0	-
Water applied (litre/plant) in entire crop period (150 days)	37.5	28.5	19.5	-
Mahabharata	21.6	18.9	13.6	18.0
California Wonder	19.9	14.4	14.5	16.3
Mean	20.8	16.7	14.1	17.2
LSD (V)		3.24		
LSD (L)		2.40		
King-chilli				
Number of irrigation	44	32	22	-
Water applied (litre/plant) in entire crop period (240 days)	66.0	47.1	33.0	-
Red Long	15.91	14.86	16.06	15.61
Chocolate Long	14.39	11.68	14.55	13.54
Mean	15.15	13.27	15.30	14.57
LSD (V)		0.87		
LSD (L)		1.05		

Variety and irrigation level details are given under Materials and Methods.

11.8–5.6 t/ha in king-chilli by increasing the irrigation interval from 5 days (13.33±0.77 kPa moisture tension) to 10 days (at 40.67±1.28 kPa, respectively). Kirda *et al.* (2007) also observed a yield reduction from 37.4–20.3 t/ha when irrigation was reduced from 344–173 mm in pepper. Likewise, the overall percent reduction in yield over (L_1) soil moisture stress-free conditions (13.33±0.77 kPa soil moisture tension) was 28.7% and 48.3% in tomato, 36.1% and 63.3% in capsicum and 35.7% and 53.0% in king-chilli with the IS at L_2 and L_3, respectively. Our results are in agreement with the findings of Antony *et al.* (2004) in capsicum and Celebi (2014) in tomato.

The higher yield of tomato, capsicum and king-chilli was recorded when crop irrigated at 13.33±0.77 kPa (5 days irrigation intervals) followed by 23.0±0.67 kPa (7-days irrigation intervals) soil moisture tension. Ertek *et al.* (2007) observed higher yield in capsicum with irrigation at 5-days intervals. A substantial reduction in yield has also been observed in many vegetable crops when soil tension is above 25.0 kPa and a higher crop yield in capsicum was recorded by Smittle *et al.* (1994) when irrigated at 25.0 kPa soil moisture tension. The reduction in growth and yield of the crop under moisture stress may be due to decrease in relative water content, net photosynthesis with a reduction in leaf area and chlorophyll content in different vegetable crops (Antony *et al.* 2004, Khan *et al.* 2015).

Moreover, the results of the estimated water productivity have shown statistically significant (P<0.05) differences among the genotype and level of irrigation (Table 3). Among the genotypes, the tomato cultivar Megha Tomato-3 has shown maximum water productivity at 5 and 10-day irrigation intervals and indicated tolerance to moisture stress. While comparing the yield, the results of the present investigation suggest irrigation of tomato crops at 5-days intervals with a total water application of 40.5 litres/plant for the entire growing period. Similarly, Harmanto *et al.* (2005) also estimated the water requirement 0.3–0.4 litre/plant/day in tomato to get a higher yield.

The maximum water productivity in capsicum (21.60 g/kg water) and king-chilli (16.06 g/kg water) was recorded from hybrid Mahabharat at L_1 and L_2 and landrace Red Long under soil moisture stress conditions (L_3), respectively. Among the tested crops, the maximum water productivity was observed in tomato (62.10 g/kg) followed by capsicum (20.8 g/kg) and king-chilli (15.15 g/kg), at (L_1) 5 days' irrigation intervals or irrigation at 13.33±0.77 kPa (Table 3). Similar findings were also observed by Parameshwarareddy *et al.* (2018) in tomato and Kumari *et al.* (2021) in capsicum. The higher water productivity of tomato over capsicum has also been observed by other researchers under open conditions (Kuşçu *et al.* 2009). In the comparative results with other researchers, our study suggested higher water productivity under protected conditions over open conditions. This could be due to more consumptive uses and less evaporative loss of irrigation water.

From the above findings, it has been observed that soil moisture regimes have a significant effect on the growth and yield attributes of the crop. For a higher yield with maximum water productivity in the coarse (sandy) texture soil under protected conditions, the crop should be irrigated at 13.33±0.77 kPa soil moisture tension. Among these high-value crops, the water productivity of tomatoes is higher than that of capsicum and king-chilli. Likewise, capsicum is more sensitive to water stress, followed by king-chilli and tomato. The varieties Megha Tomato-3 (tomato), hybrid Mahabharat (capsicum), and local landrace Red Long of king-chilli should be promoted for better yield and income.

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