Original Research Article

IMPACT OF LOW TUNNEL HEIGHTS AND IRRIGATION REGIMES ON GROWTH PARAMETERS OF CAPSICUM

ABSTRACT

The cultivation of Capsicum, commonly known as sweet pepper, is a critical component of global agriculture. As the demand for high-quality peppers continues to rise, there is a growing need to explore innovative cultivation practices that enhance yield and resource efficiency. This manuscript delves into the intricate interplay between low tunnel heights and irrigation regimes, seeking to unravel their collective impact on the growth parameters of capsicum. From the experiments, the data clearly revealed that plant height, leaf area index and dry matter accumulation was highestin 75 cm tunnel height followed by 90 cm and 60 cm tunnel height treatmentsthroughout the crop season.Among all the irrigation treatments drip irrigation with 0.90 IW/CPE ratio gave the highest plant height and leaf area indexthan other irrigation treatments.Whereas drip irrigation with0.75 IW/CPE ratio gave the highest dry matter accumulation than the other irrigation treatments.

Keywords: Low tunnel, Drip irrigation, Capsicum, Sweep pepper, IW/CPE.

1. INTRODUCTION

Capsicum, scientifically known as Capsicum annuum L. var. grossum, boasts its uniqueness as a sweet pepper, also affectionately termed bell pepper. This distinctive vegetable stands out as one of the most favored and economically significant crops globally, primarily cherished for its tender, unripe fruits (1,2). The journey of sweet pepper, however, is not without its intricacies, with environmental factors, particularly soil moisture and temperature, playing pivotal roles in its cultivation.

Cultivating capsicum under the convergence of low tunnel technology and drip irrigation epitomizes a cutting-edge approach to horticulture, marked by precision and resource efficiency (3). This innovative integration empowers growers to navigate and potentially overcome the challenges associated with climate variations, ensuring a controlled and optimal environment for capsicum cultivation. Through the harmonious synergy of protective low tunnels and the water-efficient precision of drip irrigation, this method not only extends the growing season but also fosters an environment conducive to the healthy development of capsicum plants (4). In this exploration, we embark on a journey

through the meticulous steps and considerations involved in growing capsicum under the embrace of low tunnel technology with drip irrigation, unraveling the potential for enhanced yields, resource conservation, and sustainable agricultural practices.

To underscore the importance of the current investigation, it proves beneficial to offer a succinct exploration of notable research initiatives conducted by diverse practitioners, thereby shedding light on the pertinent and consequential endeavors within the same scholarly domain.

Arin and Ankara conducted a study to determine the effect of low tunnel, mulching and pruning treatment on yield and earliness of tomato. It was reported that there was an increase of 643.42 per cent in height (relative to height at the planting time) of the plants grown under low tunnel than those grown without tunnel (602.87 per cent). Stem diameter increase was higher in plants tunnelled (265.63 per cent) than plants growing without tunnel (233.83 per cent) (5).

Amer carried out a study on protection effect of low-temperature on some snap bean (*Phaseolus vulgaris* L) varieties green yield and some isozyme levels. It was found that protected plants recorded higher vegetative growth as well as total, early and exportable yields compared with those of the open field. Plants grown under plastic low tunnels recorded higher vegetative growth and total green yield compared with agrel-covered plants (6).

Singh et al. conducted a study on effect of plastic tunnel and mulching on growth and yield of strawberry. It was found that use of plastic tunnel along with control (without tunnel) were taken as main factors and mulching materials, viz. black polyethylene, transparent polyethylene and straw mulch as sub factors and laid out in split plot design replicated four times. Use of plastic tunnel resulted into significantly higher plant spread, dry matter accumulation and yield attributing characters compared to control. Further plastic tunnel enhanced earliness by 16 days besides 19per cent higher yield over control (7).

Antony and Singandhupe conducted study on impact of drip and surface irrigation on growth, yield and WUE (water use efficiency) of capsicum (*Capsicum annum* L.). It was observed that 100 per cent drip irrigation gave maximum yield in capsicum grown in loamy soil of humid subtropical region. At 100 per cent drip treatment plants had more height and more number of branches, characters of an ideal high yielding plant (8).

Acharya et al. observed that LT increased vegetative growth of brussels sprouts as measured by plant leaf area, leaf dry weight, plant dry weight, and plant height in all trials in comparison with open field. It was found that low tunnels increased leaf area by 57% and 67%at 60 DATin Spring 2017 and 2018, respectively. Plant height at harvest was 45%, 43%, and 62% taller under LT than in open field (9).

2. MATERIAL AND METHODS

Extensive field experiments were conducted at the Research Farm of the Department of Soil and Water Engineering, PAU, Ludhiana. Ludhiana is situated at latitude of 30^{o} 54`N and longitude of $75^{o}$ 48`E and at a mean height of 247 meters above sea level. This place is characterized by very hot and dry summer (April to June) followed by a hot and humid monsoon period and cold winters during December to January. The average rainfall of the area is 600 mm most of which is received during the monsoon season. Average minimum and maximum temperature in the region varies from 3^{o}C to 43^{o}C respectively.

A field plot measuring approximately 550.8 m^2 (54mx10.2m) was prepared and the experiment was laid out in split plot design keeping five irrigation treatments (drip irrigation with 0.60 IW/CPE ratio (I1), drip irrigation with 0.75 IW/CPE ratio (I2), drip irrigation with 0.90 IW/CPE ratio (I3), furrow irrigation paired row planting (I4) and furrow irrigation single row planting(I5)) in main plots and three different heights of low tunnel (60cm(H1), 75cm(H2) and 90cm (H3)) in sub plots and replicated three times.Nursery raising of sweet pepper of “Bharath” variety was done in polyhouse and after 30 days transplanting was done in the field. In paired sowing 60 cm wide beds were raised, row to row space between paired rows was 45 cm and row space between pairs was 75 cm but plant to plant space was kept as 30 cm. Irrigation was applied as per the treatments. In the single furrow the row to row spacing was 60 cm and plant to plant spacing was 30 cm.

After transplanting the crop, it was covered with polysheet of 50-micron thickness with width of 150cm, 185cm and 240cm over the low tunnel frame heights of 60cm, 75cm and 90cm respectively, to protect crop from frost and other injury. The low tunnel frames were kept at beginning and at end of the row and distance between successive frames was kept as 2.50m.The irrigation time through drip system and furrow irrigation was calculated and given in Lodhi et al (2014).

To study the effect of low tunnel height and irrigation regimes on growth parameters (i.e. plant height, leaf area index and dry matter accumulation) of crop following measurements were takenat the interval of 15 days.

2.1 Plant height

Five plants were selected at random from each sub-plot to measure their height at regular intervals (15 days) viz. 30, 45, 60, 75, 90, 105,120, 135, 150, 165, 180 and 195 days after transplanting. It was measured in centimetres from base of the plant to the longest point with the help of scale and an average value was worked out for each treatment.

2.2 Leaf area index (LAI)

To estimate LAI, one middle plant from each sub-plot was taken at 30, 45, 60, 75, 90, 105,120, 135, 150, 165, 180 and 195 days after transplanting. The leaf area index was measured using PAR/LAI Ceptometer LP-80 electronic leaf area meter.

2.3 Dry matter accumulation (DMA)

Sample taken from each sub-plot, first air dried and then oven dried at 55ºC to a

constant weight to record the dry matter accumulation of plants at 30, 45, 60, 75, 90, 105,120, 135, 150, 165, 180 and 195 days after planting.

The data collected from the field experiments were analyzed using ANOVA. For the split plot design, irrigation treatments were considered as main plot and different low tunnel heights as sub-plot. The significance of differences was tested at 5 per cent level.

3. RESULTS AND DISCUSSION

3.1 Plant height

The results obtained for plant height under different irrigation and low tunnel heights treatments are presented in Table 1. It can be seen from the data that the plant height increased substantially till 165 DAP (days after transplanting) for all the treatments and after that it increased marginally. The data clearly revealed that throughout the crop season, plant height in 75 cm tunnel height was highest followed by 90 cm and 60 cm tunnel height treatments this may be due to higher air and soil temperature in 75 cm tunnel height. Among all the irrigation treatments drip irrigation with 0.90 IW/CPE ratio gave the highest plant height throughout the season followed by drip irrigation 0.75 IW/CPE ratio, drip irrigation 0.60 IW/CPE ratio, furrow irrigation paired row planting and furrow irrigation single row planting this may be due to better moisture distribution in drip irrigation than the conventional irrigation. The results are in line with that of Horton et al. (10) who observed that deficient drip irrigation strongly reduces plant growth. For treatment combination, in the I3H2 treatment plant height was highest (62.23cm) and lowest in I5H1 treatment (53.33cm).

Table 1 Variation of plant height with different treatments

Days after transplanting of crop	Treatment Irrigation (I) / height (H)	Plant height (cm) 60cm	 75cm	 90cm	Mean
30	**Drip irrigation, IW/CPE = 0.60**	9.56	10.00	9.43	**9.66**
	Drip irrigation, IW/CPE = 0.75	9.26	10.33	10.23	**9.94**
	Drip irrigation, IW/CPE = 0.90	10.66	11.70	10.73	**11.03**
	Furrow irrigation (paired row)	8.60	9.56	9.13	**9.10**
	Furrow irrigation (single row)	8.26	9.26	9.06	**8.86**
	Mean	**9.27**	**10.17**	**9.72**	
	CD (5%) I = 1.06 CD (5%) H = 0.60 CD (5%) IH = NS				
45	**Drip irrigation, IW/CPE = 0.60**	12.40	13.56	13.00	**12.98**
	Drip irrigation, IW/CPE = 0.75	12.43	14.73	13.53	**13.56**
	Drip irrigation, IW/CPE = 0.90	14.36	16.03	14.86	**15.08**
	Furrow irrigation (paired row)	11.96	12.86	12.16	**12.33**
	Furrow irrigation (single row)	11.40	12.43	11.86	**11.90**
	Mean	**12.51**	**13.92**	**13.08**	
	CD (5%) I = 1.56 CD (5%) H = 1.07 CD (5%) IH = NS				
60	**Drip irrigation, IW/CPE = 0.60**	17.36	19.56	18.76	**18.56**
	Drip irrigation, IW/CPE = 0.75	18.53	22.60	21.06	**20.73**
	Drip irrigation, IW/CPE = 0.90	21.63	24.40	22.53	**22.85**
	Furrow irrigation (paired row)	16.86	18.73	18.23	**17.94**
	Furrow irrigation (single row)	16.63	18.20	17.20	**17.34**
	Mean	**18.20**	**20.70**	**19.56**	

	CD (5%) I = 2.10 CD (5%) H = 1.41 CD (5%) IH = NS				
75	**Drip irrigation, IW/CPE = 0.60**	21.93	25.10	23.76	**23.60**
	Drip irrigation, IW/CPE = 0.75	22.93	27.16	26.86	**25.65**
	Drip irrigation, IW/CPE = 0.90	26.73	29.86	27.40	**28.00**
	Furrow irrigation (paired row)	21.23	23.73	22.76	**22.57**
	Furrow irrigation (single row)	21.00	23.00	22.50	**22.16**
	Mean	**22.76**	**25.77**	**24.66**	
	CD (5%) I = 1.86 CD (5%) H = 1.49 CD (5%) IH = NS				
90	**Drip irrigation, IW/CPE = 0.60**	26.06	28.83	27.86	**27.58**
	Drip irrigation, IW/CPE = 0.75	27.46	31.23	30.26	**29.65**
	Drip irrigation, IW/CPE = 0.90	31.56	34.20	32.36	**32.71**
	Furrow irrigation (paired row)	25.60	27.86	27.16	**26.87**
	Furrow irrigation (single row)	25.30	27.13	26.26	**26.23**
	Mean	**27.20**	**29.85**	**28.78**	
	CD (5%) I = 1.78 CD (5%) H = 1.54 CD (5%) IH = NS				
105	**Drip irrigation, IW/CPE = 0.60**	30.46	33.93	32.33	**32.24**
	Drip irrigation, IW/CPE = 0.75	32.70	36.66	33.93	**34.43**
	Drip irrigation, IW/CPE = 0.90	35.33	38.93	36.40	**36.88**
	Furrow irrigation (paired row)	29.60	33.13	31.46	**31.40**
	Furrow irrigation (single row)	29.10	32.36	31.10	**30.85**
	Mean	**31.44**	**35.00**	**33.04**	
	CD (5%) I = 1.99 CD (5%) H = 1.63 CD (5%) IH = NS				
120	**Drip irrigation, IW/CPE = 0.60**	35.30	40.60	36.43	**37.44**
	Drip irrigation, IW/CPE = 0.75	38.10	42.43	39.86	**40.13**
	Drip irrigation, IW/CPE = 0.90	40.80	43.60	42.56	**42.32**
	Furrow irrigation (paired row)	33.66	37.26	35.56	**35.50**
	Furrow irrigation (single row)	32.60	36.33	35.10	**34.67**
	Mean	**36.09**	**40.04**	**37.90**	
	CD (5%) I = 1.79 CD (5%) H = 1.33 CD (5%) IH = NS				
135	**Drip irrigation, IW/CPE = 0.60**	40.46	44.86	42.30	**42.54**
	Drip irrigation, IW/CPE = 0.75	43.90	47.56	45.16	**45.54**
	Drip irrigation, IW/CPE = 0.90	46.93	49.53	47.76	**48.07**
	Furrow irrigation (paired row)	38.60	42.86	40.40	**40.62**
	Furrow irrigation (single row)	37.40	41.70	39.43	**39.51**
	Mean	**41.46**	**45.30**	**43.01**	
	CD (5%) I = 1.49 CD (5%) H = 1.40 CD (5%) IH = NS				
150	**Drip irrigation, IW/CPE = 0.60**	45.50	49.83	46.63	**47.32**
	Drip irrigation, IW/CPE = 0.75	48.43	52.66	50.20	**50.43**
	Drip irrigation, IW/CPE = 0.90	51.36	54.50	52.36	**52.74**
	Furrow irrigation (paired row)	44.20	48.23	46.06	**46.16**
	Furrow irrigation (single row)	42.80	47.76	45.66	**45.41**
	Mean	**46.46**	**50.60**	**48.18**	
	CD (5%) I = 0.92 CD (5%) H = 1.35 CD (5%) IH = NS				
165	**Drip irrigation, IW/CPE = 0.60**	50.50	54.46	52.26	**52.41**
	Drip irrigation, IW/CPE = 0.75	53.60	57.23	54.80	**55.21**
	Drip irrigation, IW/CPE = 0.90	56.10	58.93	57.13	**57.38**
	Furrow irrigation (paired row)	49.30	52.80	51.00	**51.03**
	Furrow irrigation (single row)	47.50	52.43	49.96	**49.96**
	Mean	**51.40**	**55.17**	**53.03**	
	CD (5%) I = 1.62 CD (5%) H = 1.23 CD (5%) IH = NS				
180	**Drip irrigation, IW/CPE = 0.60**	53.76	58.20	56.43	**56.13**
	Drip irrigation, IW/CPE = 0.75	56.20	60.83	58.40	**58.47**
	Drip irrigation, IW/CPE = 0.90	59.06	61.80	60.10	**60.32**
	Furrow irrigation (paired row)	53.23	57.13	54.73	**55.03**
	Furrow irrigation (single row)	51.63	56.20	53.76	**53.86**
	Mean	**54.77**	**58.83**	**56.68**	

	CD (5%) I = 1.49 CD (5%) H = 1.40 CD (5%) IH = NS				
195	**Drip irrigation, IW/CPE = 0.60**	54.83	58.76	57.20	**56.93**
	Drip irrigation, IW/CPE = 0.75	56.60	61.13	58.76	**58.83**
	Drip irrigation, IW/CPE = 0.90	59.63	62.23	60.50	**60.78**
	Furrow irrigation (paired row)	54.10	58.03	56.66	**56.26**
	Furrow irrigation (single row)	53.33	57.10	54.83	**55.08**
	Mean	**55.70**	**59.45**	**57.59**	
	CD (5%) I = 1.33 CD (5%) H = 1.16 CD (5%) IH = NS				

Statistical analysis for different irrigation treatments and different tunnel height given in Table 1 revealed that there was significant effect of irrigation and tunnel height on plant height while the interaction of irrigation treatments and tunnel height was found to be non significant.

3.2 Leaf area index

The results obtained for LAI (leaf area index) under different irrigation and low tunnel heights treatments are presented in Table 2. It can be seen from the data that the LAI increased substantially till 150 DAP for all the treatments and after that it increased marginally. The data clearly revealed that throughout the crop season, LAI in 75 cm tunnel height was highest followed by 90 cm and 60 cm tunnel height treatments this may be due to higher air and soil temperature in 75 cm tunnel height. Among all the irrigation treatments drip irrigation with 0.90 IW/CPE ratio gave the highest LAI throughout the season followed by drip irrigation 0.75 IW/CPE ratio, drip irrigation 0.60 IW/CPE ratio, furrow irrigation paired row planting and furrow irrigation single row planting this may be due to better interception of solar radiation and better moisture distribution in drip irrigation than the conventional irrigation. The results are in accordance with Hsiao (11) who reported lower LAI for the most deficient treatment in drip irrigation treatment. For treatment combination, in the I3H2 treatment LAI was highest (4.38) and lowest in I5H1 treatment (3.92).

Table 2 Variation of leaf area index with different treatments

Days after transplanting of crop	**Treatment** Irrigation (I) / height (H)	**Leaf area index** 60cm	75cm	90cm	**Mean**
30	**Drip irrigation, IW/CPE = 0.60**	0.53	0.58	0.55	**0.55**
	Drip irrigation, IW/CPE = 0.75	0.54	0.65	0.59	**0.59**
	Drip irrigation, IW/CPE = 0.90	0.64	0.77	0.69	**0.70**
	Furrow irrigation (paired row)	0.51	0.56	0.53	**0.53**
	Furrow irrigation (single row)	0.43	0.53	0.48	**0.48**
	Mean	**0.53**	**0.61**	**0.57**	
	CD (5%) I = 0.12 CD (5%) H = 0.04 CD (5%) IH = NS				
45	**Drip irrigation, IW/CPE = 0.60**	0.74	0.82	0.79	**0.78**
	Drip irrigation, IW/CPE = 0.75	0.78	0.93	0.86	**0.86**
	Drip irrigation, IW/CPE = 0.90	0.89	0.98	0.93	**0.93**
	Furrow irrigation (paired row)	0.71	0.78	0.75	**0.75**
	Furrow irrigation (single row)	0.69	0.75	0.72	**0.72**
	Mean	**0.76**	**0.85**	**0.81**	

	CD (5%) I = 0.10 CD (5%) H = 0.05 CD (5%) IH = NS				
60	**Drip irrigation, IW/CPE = 0.60**	0.99	1.13	1.05	**1.06**
	Drip irrigation, IW/CPE = 0.75	1.06	1.27	1.15	**1.16**
	Drip irrigation, IW/CPE = 0.90	1.24	1.42	1.32	**1.32**
	Furrow irrigation (paired row)	0.94	1.06	1.00	**1.00**
	Furrow irrigation (single row)	0.92	1.02	0.97	**0.97**
	Mean	**1.03**	**1.18**	**1.10**	
	CD (5%) I = 0.09 CD (5%) H = 0.08 CD (5%) IH = NS				
75	**Drip irrigation, IW/CPE = 0.60**	1.31	1.42	1.39	**1.37**
	Drip irrigation, IW/CPE = 0.75	1.39	1.56	1.50	**1.48**
	Drip irrigation, IW/CPE = 0.90	1.53	1.69	1.62	**1.61**
	Furrow irrigation (paired row)	1.23	1.37	1.31	**1.30**
	Furrow irrigation (single row)	1.21	1.31	1.25	**1.25**
	Mean	**1.33**	**1.47**	**1.41**	
	CD (5%) I = 0.11 CD (5%) H = 0.06 CD (5%) IH = NS				
90	**Drip irrigation, IW/CPE = 0.60**	1.65	1.80	1.72	**1.73**
	Drip irrigation, IW/CPE = 0.75	1.72	1.96	1.85	**1.84**
	Drip irrigation, IW/CPE = 0.90	1.99	2.18	2.06	**2.08**
	Furrow irrigation (paired row)	1.55	1.72	1.63	**1.63**
	Furrow irrigation (single row)	1.48	1.63	1.59	**1.57**
	Mean	**1.68**	**1.86**	**1.77**	
	CD (5%) I = 0.105 CD (5%) H = 0.08 CD (5%) IH = NS				
105	**Drip irrigation, IW/CPE = 0.60**	2.06	2.24	2.19	**2.16**
	Drip irrigation, IW/CPE = 0.75	2.23	2.48	2.35	**2.35**
	Drip irrigation, IW/CPE = 0.90	2.35	2.58	2.46	**2.46**
	Furrow irrigation (paired row)	1.98	2.14	2.06	**2.06**
	Furrow irrigation (single row)	1.91	2.07	1.99	**1.99**
	Mean	**2.11**	**2.30**	**2.21**	
	CD (5%) I = 0.08 CD (5%) H = 0.09 CD (5%) IH = NS				
120	**Drip irrigation, IW/CPE = 0.60**	2.62	2.76	2.69	**2.69**
	Drip irrigation, IW/CPE = 0.75	2.67	2.97	2.82	**2.82**
	Drip irrigation, IW/CPE = 0.90	2.89	3.13	3.04	**3.02**
	Furrow irrigation (paired row)	2.44	2.66	2.55	**2.55**
	Furrow irrigation (single row)	2.41	2.57	2.51	**2.50**
	Mean	**2.61**	**2.82**	**2.72**	
	CD (5%) I = 0.11 CD (5%) H = 0.11 CD (5%) IH = NS				
135	**Drip irrigation, IW/CPE = 0.60**	3.09	3.26	3.17	**3.17**
	Drip irrigation, IW/CPE = 0.75	3.23	3.55	3.40	**3.39**
	Drip irrigation, IW/CPE = 0.90	3.38	3.69	3.51	**3.52**
	Furrow irrigation (paired row)	2.97	3.18	3.08	**3.07**
	Furrow irrigation (single row)	2.94	3.15	3.06	**3.05**
	Mean	**3.12**	**3.36**	**3.24**	
	CD (5%) I = 0.14 CD (5%) H = 0.12 CD (5%) IH = NS				
150	**Drip irrigation, IW/CPE = 0.60**	3.62	3.80	3.65	**3.69**
	Drip irrigation, IW/CPE = 0.75	3.63	3.89	3.82	**3.78**
	Drip irrigation, IW/CPE = 0.90	3.71	4.07	3.95	**3.91**
	Furrow irrigation (paired row)	3.44	3.71	3.56	**3.57**
	Furrow irrigation (single row)	3.40	3.62	3.51	**3.51**
	Mean	**3.56**	**3.81**	**3.70**	
	CD (5%) I = 0.14 CD (5%) H = 0.14 CD (5%) IH = NS				
165	**Drip irrigation, IW/CPE = 0.60**	3.79	4.08	3.95	**3.94**
	Drip irrigation, IW/CPE = 0.75	3.89	4.17	4.05	**4.04**
	Drip irrigation, IW/CPE = 0.90	4.00	4.28	4.12	**4.13**
	Furrow irrigation (paired row)	3.72	4.01	3.90	**3.88**
	Furrow irrigation (single row)	3.68	3.92	3.79	**3.79**
	Mean	**3.82**	**4.09**	**3.96**	

	CD (5%) I = 0.16 CD (5%) H = 0.12 CD (5%) IH = NS				
180	**Drip irrigation, IW/CPE = 0.60**	3.96	4.18	4.05	**4.06**
	Drip irrigation, IW/CPE = 0.75	4.03	4.25	4.16	**4.14**
	Drip irrigation, IW/CPE = 0.90	4.10	4.34	4.22	**4.22**
	Furrow irrigation (paired row)	3.92	4.12	4.01	**4.02**
	Furrow irrigation (single row)	3.88	4.03	3.96	**3.95**
	Mean	**3.98**	**4.18**	**4.08**	
	CD (5%) I = 0.15 CD (5%), H = 0.13 CD (5%) IH = NS				
195	**Drip irrigation, IW/CPE = 0.60**	4.01	4.23	4.12	**4.12**
	Drip irrigation, IW/CPE = 0.75	4.05	4.29	4.19	**4.17**
	Drip irrigation, IW/CPE = 0.90	4.13	4.38	4.26	**4.26**
	Furrow irrigation (paired row)	3.95	4.15	4.05	**4.05**
	Furrow irrigation (single row)	3.92	4.06	3.98	**3.98**
	Mean	**4.01**	**4.22**	**4.12**	
	CD (5%) I = 0.15 CD (5%), H = 0.13 CD (5%) IH = NS				

Statistical analysis for different irrigation treatments and different tunnel height given in Table 2 revealed that there was significant effect of irrigation and tunnel height on LAI while the interaction of irrigation treatments and tunnel height was found to be non significant. The results are in line with Jolliffe and Gaye (12).

3.3 Dry matter accumulation

The results obtained for DMA (dry matter accumulation) under different irrigation and low tunnel heights treatments are presented in Table 3. It can be seen from the data that the DMA increased substantially till 165 DAP for all the treatments and after that it increased marginally. The data clearly revealed that throughout the crop season, DMA in 75 cm tunnel height was highest followed by 90 cm and 60 cm tunnel height treatments this may be due to higher air and soil temperature in 75 cm tunnel height. Among all the irrigation treatments drip irrigation with 0.75 IW/CPE ratio gave the highest DMA throughout the season followed by drip irrigation 0.90 IW/CPE ratio, drip irrigation 0.60 IW/CPE ratio, furrow irrigation paired row planting and furrow irrigation single row planting this may be due to different solar radiation and thermal conditions and better moisture distribution in drip irrigation than the conventional irrigation. For treatment combination, in the I2H2 treatment DMA was highest (97.5 g/plant) and lowest in I5H1 treatment (85.63 g/plant). The results are in line with those of Siwek and Libik (13).

Statistical analysis for different irrigation treatments and different tunnel height given in Table 3 revealed that there was significant effect of irrigation and tunnel height on DMA while the interaction of irrigation treatments and tunnel height was found to be non significant.

Table 3 Variation of dry matter accumulation with different treatments

Days after transplanting	Treatment	Dry matter accumulation (g/plant)	Mean

of crop	Irrigation (I) / height (H)	60cm	75cm	90cm	
30	Drip irrigation, IW/CPE = 0.60	4.50	5.20	5.03	4.91
	Drip irrigation, IW/CPE = 0.75	5.20	6.06	5.63	5.63
	Drip irrigation, IW/CPE = 0.90	4.86	5.70	5.30	5.28
	Furrow irrigation (paired row)	4.13	4.80	4.60	4.51
	Furrow irrigation (single row)	3.93	4.56	4.43	4.31
	Mean	4.52	5.26	5.00	
	CD (5%) I = 0.10 CD (5%) H = 0.21 CD (5%) IH = NS				
45	Drip irrigation, IW/CPE = 0.60	9.50	10.50	9.90	9.96
	Drip irrigation, IW/CPE = 0.75	10.70	13.20	11.80	11.90
	Drip irrigation, IW/CPE = 0.90	9.93	12.10	11.30	11.11
	Furrow irrigation (paired row)	9.23	10.00	9.56	9.60
	Furrow irrigation (single row)	9.00	9.80	9.30	9.36
	Mean	9.67	11.12	10.37	
	CD (5%) I = 0.18 CD (5%) H = 0.23 CD (5%) IH = 0.53				
60	Drip irrigation, IW/CPE = 0.60	18.90	20.30	19.80	19.66
	Drip irrigation, IW/CPE = 0.75	19.60	21.50	20.70	20.60
	Drip irrigation, IW/CPE = 0.90	19.10	20.90	20.20	20.06
	Furrow irrigation (paired row)	18.50	19.90	19.40	19.26
	Furrow irrigation (single row)	18.30	19.70	19.20	19.06
	Mean	18.88	20.46	19.86	
	CD (5%) I = 0.43 CD (5%) H = 0.23 CD (5%) IH = NS				
75	Drip irrigation, IW/CPE = 0.60	27.80	28.90	28.60	28.43
	Drip irrigation, IW/CPE = 0.75	28.60	30.30	29.70	29.53
	Drip irrigation, IW/CPE = 0.90	28.20	29.50	29.30	29.00
	Furrow irrigation (paired row)	27.60	28.50	28.30	28.13
	Furrow irrigation (single row)	27.40	28.30	28.20	27.96
	Mean	27.92	29.10	28.82	
	CD (5%) I = 0.54 CD (5%) H = 0.55 CD (5%) IH = NS				
90	Drip irrigation, IW/CPE = 0.60	36.50	38.56	38.06	37.71
	Drip irrigation, IW/CPE = 0.75	39.23	41.23	40.53	40.33
	Drip irrigation, IW/CPE = 0.90	37.83	40.26	39.66	39.25
	Furrow irrigation (paired row)	35.80	37.33	36.46	36.53
	Furrow irrigation (single row)	35.36	36.86	36.06	36.10
	Mean	36.94	38.85	38.16	
	CD (5%) I = 1.02 CD (5%) H = 0.53 CD (5%) IH = NS				
105	Drip irrigation, IW/CPE = 0.60	47.70	49.36	48.96	48.67
	Drip irrigation, IW/CPE = 0.75	50.13	52.03	50.83	51.00
	Drip irrigation, IW/CPE = 0.90	49.50	50.46	50.06	50.01
	Furrow irrigation (paired row)	46.06	48.80	46.63	47.16
	Furrow irrigation (single row)	45.33	47.63	46.53	46.50
	Mean	47.74	49.66	48.60	
	CD (5%) I = 0.63 CD (5%) H = 0.95 CD (5%) IH = NS				
120	Drip irrigation, IW/CPE = 0.60	58.23	60.43	59.70	59.45
	Drip irrigation, IW/CPE = 0.75	61.66	64.90	62.40	62.98
	Drip irrigation, IW/CPE = 0.90	60.33	63.36	61.63	61.77
	Furrow irrigation (paired row)	57.66	59.46	58.43	58.52
	Furrow irrigation (single row)	57.43	59.13	58.33	58.30
	Mean	59.06	61.46	60.09	
	CD (5%) I = 1.25 CD (5%) H = 0.84 CD (5%) IH = NS				
135	Drip irrigation, IW/CPE = 0.60	67.56	70.13	69.36	69.02
	Drip irrigation, IW/CPE = 0.75	72.63	75.30	73.83	73.92
	Drip irrigation, IW/CPE = 0.90	70.26	72.33	71.53	71.37
	Furrow irrigation (paired row)	65.50	68.66	67.30	67.15

	Furrow irrigation (single row)	64.83	68.20	66.83	**66.62**
	Mean	**68.16**	**70.92**	**69.77**	
	CD (5%) I = 0.98 CD (5%) H = 0.96 CD (5%) IH = NS				
150	**Drip irrigation, IW/CPE = 0.60**	76.30	79.83	77.73	**77.95**
	Drip irrigation, IW/CPE = 0.75	81.70	84.63	83.20	**83.17**
	Drip irrigation, IW/CPE = 0.90	79.83	82.13	81.30	**81.08**
	Furrow irrigation (paired row)	74.70	76.53	75.03	**75.42**
	Furrow irrigation (single row)	74.06	76.03	74.70	**74.93**
	Mean	**77.31**	**79.83**	**78.39**	
	CD (5%) I = 1.67 CD (5%) H = 0.89 CD (5%) IH = NS				
165	**Drip irrigation, IW/CPE = 0.60**	83.26	87.60	85.43	**85.43**
	Drip irrigation, IW/CPE = 0.75	88.20	92.56	90.23	**90.33**
	Drip irrigation, IW/CPE = 0.90	85.73	89.83	88.33	**87.96**
	Furrow irrigation (paired row)	80.90	85.70	82.73	**83.11**
	Furrow irrigation (single row)	79.33	84.70	81.33	**81.78**
	Mean	**83.48**	**88.07**	**85.61**	
	CD (5%) I = 1.14 CD (5%) H = 0.86 CD (5%) IH = NS				
180	**Drip irrigation, IW/CPE = 0.60**	87.83	91.43	89.63	**89.63**
	Drip irrigation, IW/CPE = 0.75	91.23	96.63	93.46	**93.77**
	Drip irrigation, IW/CPE = 0.90	89.86	93.86	91.73	**91.82**
	Furrow irrigation (paired row)	85.86	89.66	87.30	**87.61**
	Furrow irrigation (single row)	84.56	89.26	86.46	**86.76**
	Mean	**87.87**	**92.17**	**89.72**	
	CD (5%) I = 1.21 CD (5%) H = 0.74 CD (5%) IH = NS				
195	**Drip irrigation, IW/CPE = 0.60**	88.83	92.40	90.43	**90.55**
	Drip irrigation, IW/CPE = 0.75	91.86	97.50	94.13	**94.50**
	Drip irrigation, IW/CPE = 0.90	90.63	94.73	92.30	**92.55**
	Furrow irrigation (paired row)	87.03	90.50	88.26	**88.60**
	Furrow irrigation (single row)	85.63	90.36	87.20	**87.73**
	Mean	**88.80**	**93.10**	**90.46**	
	CD (5%) I = 0.63 CD (5%) H = 0.95 CD (5%) IH = NS				

CONCLUSION

Extensive field experiments were conducted at the Research Farm of the Department of Soil and Water Engineering, PAU, Ludhiana. From the experiments it was observed that, the highest plant height and leaf area index were observed in H2 and I3 treatments among the tunnel heights and irrigation treatments. For the treatment combinations, in I3H2 highest plant height and leaf area index were recorded as 62.23cm and 4.38 respectively but in I5H1 it was lowest 53.33cm and 3.92 respectively. There was significant effect of irrigation and tunnel height on plant height and leaf area index while the effect of their interactions were found to be non significant.

The highest dry matter accumulation (DMA) was observed in H2 and I2 treatments among the tunnel heights and irrigation treatments. For the treatment combinations, in I2H2 treatment DMA was highest (97.5 g/plant) and in I5H1 it was lowest (85.63 g/plant). There was significant effect of irrigation and tunnel height on dry matter accumulation while the effect of their interactions were found to be non significant.

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