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Response of Sweet Pepper (*Capsicum annuum)* under Varying Fertigation and Irrigation Applications Grown in Naturally Ventilated Greenhouse

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ABSTRACT

The present study was carried out at Punjab Agricultural University's Krishi Vigyan Kendra, Gurdaspur in main crop season during the years 2015-16 and 2016-17. Target yield 3 kg/plant approach was followed and there were three levels of fertigation *i.e.* F_1: 120 per cent, F_2: 100 per cent and F_3: 80 per cent of targeted dose of fertilizer. The targeted dose was calculated as 3.1 kg/t for nitrogen (N), 0.9 kg/t for phosphorus (P) and 5.3kg/t for potassium (K) element with recovery factor of 1.1 for N, 1.5 for (P_2O_5) and 1.3 for (K_2O). There were three irrigation levels *i.e.* I_1:100 per cent, I_2: 80 per cent and I_3: 60 per cent replenishment of crop evapotranspiration (ETc). Crop evapotranspiration was calculated on daily basis using Penman-Monteith equation. The study revealed that, there was a significant response of fertigation and irrigation levels on sweet pepper production under greenhouse. Treatment combination F_1I_1 performed as the best treatment combination among all combinations and produced average yield as 101.6t/ha by giving targeted dose as 3 kg fruit yield/plant. In yellow coloured sweet pepper, WUE was recorded more in treatment combination F_1I_2 as 8.7 q/ha-cm followed by F_1I_1 and F_1I_3 treatment combination as 8.4 and 7.6 q/ha-cm. The highest FUE was recorded in the treatment combination of F1I1 as 0.69 q/ha-kg of NPK. The lowest FUE was recorded in the treatment combination of F3I3 as 0.41 q/ha-kg of NPK.

Key Word: Fertigation, Greenhouse, Irrigation, Sweet pepper, Fertilizer Dose.

INTRODUCTION

Capsicum (*Capsicum annuum* L.) plants are propagated by seeds and transplanted in autumn in north India (Sanatombi and Sharma, 2006) and are sensitive to the moisture presence and temperatures in vicinity of plant. Although sweet pepper are commercially very important crop but, farmers are not getting advantage of it because the yield are being affected by several biotic and abiotic factors. Low temperature coupled with high humidity condition further reduces the yield under open field conditions. As the major crop season coincides with winter season, Punjab's climatic conditions low temperature, rainfall, high humidity and less sunshine hours affect overall performance of the crop.

Protected cultivation of sweet pepper, inside the naturally ventilated greenhouse can be a profitable venture as it provides a controlled environment to the crop and enhances the crop yield due to the long crop season as compared with outside field crop production (Nilesh *et al*, 2015 and Kumar *et al*, 2016).

Under naturally ventilated greenhouse not only crop yield increases but also the crop water use efficiency increases five to ten times as compared to open field crop production (Vox *et al*, 2010). Under protected cultivation the crop receives irrigation water through drip irrigation system which allows crop to grow under stress free condition with optimized water availability in the root zone of the

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crop. That leads to higher yield with good quality fruits. During summer season when crop encounters heat and dry environment inside the greenhouse, foggers control the environment and reduce the excess temperature which is not favourable for the plants. In Gurdaspur district of Punjab, summer and winter extreme exists as in whole Punjab, which is not favourable for sweet pepper production in open fields. Therefore, the present study was undertaken to find out the optimized irrigation and fertigation level for sweet pepper maximizing the crop yield with increased irrigation water and fertilizer use efficiencies.

MATERIALS AND METHODS

The present study was carried out at Punjab Agricultural University's KrishiVigyan Kendra, Gurdaspur during main crop season (September to April) in the years 2015-16 and 2016-17. Target yield per plant (3kg/plant) approach was followed and three levels of fertigation *i.e.* F_1: 120 per cent, F_2: 100 per cent and F_3: 80 per cent of targeted dose of fertilizer. The targeted dose was calculated as 3.1kg/t for nitrogen (N), 0.9kg/t for phosphorus (P) and 5.3kg/t for potassium (K) element with recovery factor of 1.1 for N, 1.5 for (P_2O_5) and 1.3 for (K_2O), respectively. Total amount of fertilizer applied to the crop on the basis of target yield is presented in Table 1.

There were three irrigation levels *i.e.* I_1:100 per cent, I_2: 80 per cent and I_3: 60 per cent replenishment of crop evapotranspiration (ET_c). Crop evapotranspiration was calculated on daily basis using Penman-Monteith equation. To meet the irrigation demand, 16 mm diameter lateral pipes with 2.1l/hr discharge emitters placed at 30 cm distance were used. The total amount of irrigation water applied to the sweet pepper during crop season was 132, 105 and 80 cm during 2015-16 under treatments I_1, I_2 and I_3, respectively, whereas during 2016-17 these values were 112, 90 and 68.0 cm under I_1, I_2 and I_3, respectively.

Thirty five days old seedlings of the Nunhems yellow and red varieties were transplanted inside the naturally ventilated greenhouse having floor area of 560 m^2 in second week of September (10-14, September) in the years 2015-16 and 2016-17. Each seedbed had dimension of 4.5m x 3.0m with were three replications of each treatment. Before seedbed preparation, soil fumigation was done with 2 per cent formaldehyde for checking soil borne pathogens. After application of formaldehyde, the entire soil in the greenhouse was immediately covered with black polythene sheet of 25 micron for one week. After removing polythene sheets proper drenching by flooding with water was done. The initial soil status of the experimental area can be summarized as, pH: 7.8, EC (m mhos/cm): 0.20 and 0.22, Organic Carbon (%): 0.43 and 0.44, Nitrogen (kg/ha):370 and 362.5, Phosphorus (kg/ha): 97.5and 105 and Potassium (kg/ha): 212.5 and 227.5, respectively in the years 2015-16 and 2016-17.

Seedlings were planted at 0.45m (plant to plant) x 0.50m (row to row) distance in zigzag manner so that 3 plants were covered in 1 m^2 area. Four shoots were maintained per plant to get the adequate yield per plant. Leaf area index (LAI) was measured

Table 1. Total quantity of fertilizer applied during crop season.

Treatment	Quantity of fertilizer applied (kg/ha)					
	N		P		K	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
F_1	1015	985	87	75	410	386
F_2	846	821	73	63	342	322
F_3	677	657	58	50	273	257

Table 2. Average plant and yield related parameters of sweet pepper under differential fertilizer and irrigation application.

Treatment	Plant Height (cm)	LAI (m^2/m^2)	DMP (%)	Yield (t/ha)	WUE (q/ha-cm)	FUE (q/ha-kg of NPK)
Nunhems Yellow						
F_1I_1	154.4	2.3	22.8	101.6	8.4	0.69
F_1I_2	134.8	2.2	21.6	84.2	8.7	0.68
F_1I_3	104.9	1.9	19.2	55.9	7.6	0.57
F_2I_1	145.3	2.3	21.9	85.6	7.1	0.58
F_2I_2	103.2	2.1	20.2	69.0	7.1	0.56
F_2I_3	92.1	1.8	18.7	49.7	6.8	0.50
F_3I_1	132.1	2.3	19.8	67.6	5.6	0.46
F_3I_2	98.7	2.0	19.1	52.8	5.5	0.43
F_3I_3	87.0	1.7	18.1	39.9	5.4	0.41
S E (±)	16.85	0.14	1.27	15.53	0.75	0.067
C D ($p \leq 0.05$)	F: 3.42 I: 2.53 FxI: 4.39	F: 0.07 I: 0.08 FxI: NS	F: 0.18 I: 0.12 FxI: 0.20	F: 2.42 I: 2.11 FxI: 3.66	F: 0.24 I: 0.21 FxI: 0.27	F: 0.019 I: 0.016 FxI: NS
Nunhems Red						
F_1I_1	176.8	2.3	23.4	107.5	8.9	0.73
F_1I_2	149.0	2.0	22.4	94.5	9.7	0.77
F_1I_3	109.5	1.8	20.0	72.0	9.8	0.73
F_2I_1	148.7	2.1	22.5	102.2	8.5	0.69
F_2I_2	108.5	1.9	21.3	83.7	8.6	0.68
F_2I_3	97.6	1.8	19.5	68.1	9.3	0.69
F_3I_1	132.3	1.9	20.9	72.7	6.0	0.49
F_3I_2	95.9	1.8	19.7	56.5	5.9	0.46
F_3I_3	94.8	1.8	18.8	45.4	6.3	0.46
S E (±)	20.4	0.13	1.14	15.42	0.68	0.064
C D ($p \leq 0.05$)	F: 3.32 I: 2.13 FxI: 3.47	F: 0.085 I: 0.052 FxI: 0.042	F: 0.21 I: 0.17 FxI: 0.31	F: 3.31 I: 2.18 FxI: 3.28	F: 0.32 I: 0.18 FxI: 0.31	F: 0.028 I: 0.008 FxI: NS

120 day after transplanting (DAT) when plants reached at mid-season stage and attained maximum vegetative growth. All other plant related parameters *i.e.* plant height, dry matter were analyzed after 120 DAT. Water use efficiency (q/ha-cm) was calculated by dividing the total yield (q/ha) by total irrigation water applied (cm). Similarly, fertilizer use efficiency (q/ha-kg of NPK) was calculated by dividing the total yield (q/ha) total amount of fertilizers applier. Dry matter was calculated by taking the plant sample and drying it at 105°C for 72 hr in oven in the laboratory.). Length, width, girth and pericarp thickness of fruit was recorded with the help of Vernier caliper (cm). Measurement

of ascorbic acid was done with the help of titration method, metaphosphoric acid as the solvent and 2, 6 dicholoroindophenol as the standard solution. Climatic data were collected on daily basis from the Punjab Agricultural University's Agro-meteorology station Gurdaspur. Split plot design was used to analyze the data statistically. Other agronomical and plant protection practices were adopted as per the recommendations given in Package of Practice for Vegetables from Punjab Agricultural University, Ludhiana (Anonymous, 2019).

RESULTS AND DISCUSSION

Effect on plant and yield parameters

The experimental data (Table 2) showed that there was a significant difference between various treatment combinations for plant height. The maximum plant height was obtained in treatment combination F_1I_1 in both the years for both the varieties. It was recorded as 154.4 cm and 176.8 cm in yellow and red varieties, respectively. The plant height under F_1I_2, F_2I_1 and F_3I_1 was same and it can be concluded that the high amount of irrigation water supplied with fertilizer boosted up the vegetative growth and plant height.

The height of the plant was less in the treatment combination where irrigation water and fertilizers were given in lesser doses i.e.F_3I_3 and F_3I_2. The least plant height recorded as 87.0 cm and 94.8 cm in yellow and red varieties, respectively. It was mainly due to the fact that the required amount of irrigation water and fertilizer was not available to meet the vital activities of the plant and that affected the plant height. The vegetative growth of sweet pepper also affected the LAI. It was recorded maximum under the treatment combination of the maximum irrigation water supplied with the highest amount of fertilizer given i.e. F_1I_1 as 2.3. Although, differences were found between the treatment combinations but these differences were non-significant. For the treatments F_1I_2, F_2I_1 and F_3I_1 the value of LAI was almost same mainly due to the fact that at mid-season when LAI was recorded (non-destructive type measurement) maximum there were overlapping of leaves from ground to the top of the plant and due to the lateral spreading of the branches (leaves) of the plant in vicinity.

Similar results were obtained for DM as the maximum values were recorded under the F_1I_1 for yellow and red varieties as 22.8 per cent and 23.4 per cent, respectively. More vegetative growth and plant height produced more DM and less vegetative growth and plant height produced lesser DM i.e. 18.1 and 18.8 per cent for yellow and red coloured varieties, respectively.

The data (Table 2) revealed that, during both the years 'Nunhems red' produced total average yield as 67.4 t/ha whereas the 'Nunhems yellow' produced 78.1 t/ha, respectively. In both the years treatment combination F_1I_1 (120 per cent of the targeted fertilizer dose and 100 per cent replenishment of crop evapotranspiration) produced the maximum average yield as compared with other treatment combinations for yellow (101.6 t/ha) and red varieties (107.5 t/ha). The minimum average yield for both the years was recorded in the treatment combination of F_3I_3 as 39.9 t/ha and 45.4 t/ha for yellow and red varieties, respectively.

Effect on water use efficiency

Evapotranspiration based water use efficiency (WUE) was calculated on the basis of total water applied to the crop during all crop growing season. In yellow coloured sweet pepper, WUE was recorded more in treatment combination F_1I_2 as 8.7 q/ha-cm followed by F_1I_1 and F_1I_3 treatment combination as 8.4 and 7.6 q/ha-cm. But in case of red coloured sweet pepper, the maximum WUE was calculated as 9.8q/ha-cm in treatment combination F_1I_3 followed by F_1I_2 and F_1I_3 as 9.7 and 8.9 q/ha-cm. The minimum WUE were recorded for yellow and red coloured sweet pepper as 5.4 q/ha-cm under the treatment combination of F_3I_3; whereas, it was 5.9 q/ha-cm under treatment combination F_3I_2. This was mainly due to the fact that the treatment combination produced more yield by using

Table 3. Average fruit and quality parameters of sweet pepper under differential fertilizer and irrigation application.

Treatment	Fruit length (cm)	Fruit width (cm)	Fruit girth (cm)	Fruit volume (cc)	Pericarp thickness (cm)	Fruit weight (g)	Shelf life (days)	Ascorbic acid (mg/100g fresh wt.)
Nunhems Yellow								
F_1I_1	7.7	7.4	22.7	464.5	0.45	160.8	8.6	128.0
F_1I_2	7.4	7.1	20.5	453.2	0.40	138.1	7.6	123.4
F_1I_3	6.6	6.3	16.3	443.3	0.33	101.1	6.9	108.9
F_2I_1	7.5	6.7	20.7	453.9	0.35	141.7	8.2	123.3
F_2I_2	7.1	6.1	17.8	448.5	0.29	125.2	7.3	117.9
F_2I_3	6.2	5.7	14.3	438.5	0.28	94.1	6.2	108.4
F_3I_1	7.1	6.0	18.8	447.1	0.34	89.8	5.9	108.1
F_3I_2	6.4	5.5	16.3	431.1	0.27	72.2	5.2	108.2
F_3I_3	5.9	5.0	13.1	399.0	0.25	57.4	5.0	106.3
S.E.(±)	0.45	0.6	2.26	15.45	0.051	25.85	0.84	5.62
C D (p≤0.05)	F: 0.012 I: 0.14 FxI: 0.041	F: 0.013 I: 0.011 FxI: 0.017	F: NS I: NS FxI: NS	F: 3.97 I: 2.23 FxI: 3.88	F: 0.023 I: 0.014 FxI: NS	F: 1.77 I: 1.08 FxI: 1.86	F: 0.041 I: 0.0.35 FxI: NS	F: 1.16 I: 1.74 FxI: 3.02
Nunhems Red								
F_1I_1	10.7	8.2	31.8	512.4	0.49	231.7	11.8	138.9
F_1I_2	10.2	8.0	27.6	480.9	0.45	218.5	11.0	132.5
F_1I_3	8.2	7.4	23.8	460.6	0.38	194.8	10.0	122.3
F_2I_1	9.7	8.1	29.8	458.8	0.31	196.7	10.9	133.6
F_2I_2	9.3	7.6	24.6	457.1	0.34	188.0	9.7	124.8
F_2I_3	7.1	6.3	17.5	439.8	0.31	162.6	8.9	116.0
F_3I_1	9.2	7.1	18.9	443.3	0.34	109.9	6.4	129.3
F_3I_2	6.8	6.2	16.4	421.6	0.29	91.0	5.5	120.6
F_3I_3	6.5	5.7	14.2	407.8	0.24	73.0	5.2	110.3
S.E.(±)	1.15	0.7	4.78	24.68	0.060	34.62	1.55	7.13
C D (p≤0.05)	F: 0.29 I: 0.11 FxI: 0.16	F: 0.011 I: 0.009 FxI: NS	F: 0.016 I: 0.014 FxI: 0.024	F: 4.32 I: 2.81 FxI: 4.72	F: 0.098 I: 0.022 FxI: 0.038	F: 5.61 I: 3.42 FxI: 4.89	F: 0.031 I: 0.0.22 FxI: NS	F: 1.54 I: 1.04 FxI: 1.49

F-Fertilizer I-Irrigation FxI; Fertilizer x Irrigation Interaction.

relatively less irrigation water gave more values of WUE and for the lowest yield the WUE values were found as the least.

Effect on fertilizer use efficiency

Fertilizer use efficiency (FUE) (Table 2) showed that, the highest FUE was recorded in the treatment combination of F_1I_1as 0.69 q/ha-kg of NPK. The lowest FUE was recorded in the treatment combination of F_3I_3 as 0.41 q/ha-kg of NPK. This was mainly due to the fact that the higher fertilizer doses through targeted yield approach provided adequate amount of nutrient to plant for its growth and other vital activities. The study revealed that the treatments received higher fertilizer doses produced more sweet pepper yield as compared with the lower fertilizer doses and the FUE in higher fertilizer doses recorded more values than the lower doses.

Effect on quality parameters

The average values of fruit parameters revealed that the higher levels of fertigation and irrigation has more fruit length, fruit width, fruit girth, fruit volume pericarp thickness and fruit weight as compared with the lower levels of fertilizers and irrigation (Table 3). The maximum fruit length, width, girth, volume and pericarp thickness were recorded under the treatment combination F_1I_1 as 7.7 cm, 7.4 cm, 22.7 cm, 464.5 cc and 0.45 cm, respectively. Shelf life under ambient temperature was found more in F_1I_1 treatment combination as 8.6 days followed by F_2I_1 and F_1I_2 as 8.2 and 7.6 days respectively. Ascorbic acid content was found significantly higher in higher irrigation levels as 128.0, 123.3 108.1 mg/ 100g of fresh weight.

This was mainly due to the fact that plants under higher levels of fertigation and irrigation never gone through the stress due to soil moisture and/or fertilizers and produced good quality fruits which were healthier and having more fruit length, width and weight. There was a significant effect of fertigation as well as irrigation levels on quality parameters. The different treatment combinations of fertigation and irrigation have significant effect on shelf life of sweet pepper. Shelf life is directly correlated with the pericarp thickness and fruit weight. In higher level of fertigation and irrigation the recorded fruit weight was more than the treatment combination having lesser levels. The Ascorbic acid content is import parameter in sweet pepper. It was affected by fertigation and irrigation levels but there was no significant effect of these combinations on Ascorbic acid.

CONCLUSION

The present study revealed that there was a significant response of fertigation and irrigation levels on sweet pepper production under greenhouse. Treatment combination of 120 per cent of targeted dose of fertilize and 100 per cent replenishment of crop evapotranspiration i.e. F_1I_1 performed as the best treatment combination among all combinations and produced average yield as 101.6 t/ha by giving targeted dose as 3 kg yield per plant. Quality parameters were found significantly higher in higher irrigation level I_1 as compared with I_2 and I_3.

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