Journal of Agrometeorology 21 (1) : 12-17 (March 2019)

Microclimate suitability for green and coloured sweet pepper hybrids in open and protected structures in sub-tropical humid climate of West Bengal

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ABSTRACT

A study was undertaken for two consecutive seasons (autumn-winter) to evaluate the performance of three green, red and yellow-fruited sweet pepper hybrids in open field and under two protected structures (50% green shade net house and naturally-ventilated polyhouse) to understand the microclimate suitability for maximizing the productivity of these hybrids under sub-tropical humid climatic condition of eastern India. In this climatic condition, naturally-ventilated polyhouse was most suitable for enhancing fruit yield of both green and coloured fruited hybrids. Open field condition was not suitable for both yellow and red-fruited hybrids. Though green-fruited hybrids could be grown in open field condition, fruit yield was more than double under polyhouse. Shade net house could not be considered as a suitable protected structure for sweet pepper in this climatic condition because of reduced light intensity and high relative humidity inside it causing low fruit set and high incidence of bacterial wilt disease. Maximum/minimum temperature 30°C to 33°C / 14°C to 17°C with comparatively reduced light intensity of 35,000 to 55,000 lux, prevention of adverse effect of low night temperature during winter and ≤ 60 per cent relative humidity condition during flowering, fruit set and fruit development period inside the naturally ventilated polyhouse were most suitable growing conditions for getting maximum productivity of both green and colour-fruited hybrids of sweet pepper.

Key words: Polyhouse, shade net, sweet pepper hybrid, microclimate, insect-pest.

Sweet pepper (*Capsicum annuum*) is grown worldwide for its delicate taste, pleasant flavour and colour. They also add crunch to many low-calorie dishes. The fruits are also known to have high nutritional values as they contain different pigments particularly, carotenoids (β carotene, capsanthin, leutin, zeaxanthin, etc.) and xanthophylls, different vitamins, particularly vitamin C, dietary fibre and several essential minerals. Diversification of the vegetable basket with this delicate vegetable crop is important in improving taste well as nutrients in the diets.

Sweet pepper has become very popular among the sprawling urban and peri-urban population throughout the country including West Bengal. It is one of the many vegetable crops that are sensitive to high temperature. Optimum temperature favourable for growth and fruit set has been recorded to be 25°C/18°C day/ night (Rylski and Spigelman, 1982). Due to climatic advantages, the major sweet pepper producing areas of the country are located in Karnataka, Himachal Pradesh, Uttarakhand and Jharkand, accounting for 70 per cent of the total production of 182.50 thousand tonnes during 2014-2015 (Indian Horticulture Database, National Horticulture Broad, 2015). Reports of several earlier research works indicated substantial abortion of floral buds when day temperatures were ≥ 34 °C and/or night temperatures were ≥ 21 °C for extended periods of time (Rylski and Spigelman 1982; Erickson and Markhart 2001). For this reason, even green-fruited hybrids cannot be grown successfully in open condition during either spring-summer or early autumn season in West Bengal. Low night temperature condition below 16°C hampers efficient self-pollination (Kato 1989) and favour parthenocarpic development of small, flattened and deformed fruits (Aloni *et al*. 1999).

Studies carried out in different parts of the country adequately supported that the protected growing conditions *viz*., polyhouses and poly-tunnels were suitable for enhancing fruit yield of both green and colored sweet pepper (Chandra *et al*. 2000). Microclimatic studies (Brar *et al*. 2006 a,b; Shukla *et al*. 2016) have been carried out to study the PAR interception, evapotranspiration and crop coefficients of capsicum under protected structures.

However, no research work has so far been done on

the suitability of growing condition for the sweet pepper hybrids in this sub-tropical humid climatic condition. Hence, the present study was undertaken to evaluate the performance of three green, red and yellow-fruited hybrids in open field and under two protected structures to understand the micro-climate suitability for maximizing the productivity in this climatic condition.

MATERIALS AND METHODS

Field experiments were carried out at Nadia Krishi Vigyan Kendra of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, situated at 22.97° N latitude and 88.49° E longitude with average altitude of 9.75 m above the mean sea level. The experimental site comes under sub-tropical humid climate with the soils of Gangetic New Alluvial plains where average day/night temperature during the experimental period ranges between 20ºC and 33ºC /17ºC and 29ºC and average rainfall is about 1500 mm.

Plant growth, fruit characters, fruit yield and incidence of major insect-pest and disease of three green, red and yellow-fruited hybrids were evaluated in open field condition and under two protected structures during autumn-winter seasons of 2013-14 and 2014-15. The hybrids employed in this investigation were Indra of Syngenta, Arya and Ayesha of Known-You seed company. Fruits of the hybrid Indra were harvested at mature green stage while that of Ayesha and Arya were harvested at full maturity stage when the colour turned red and bright yellow, respectively. The crops were grown between September to March in open field and under two protected structures: 50 per cent green shade net house and naturally-ventilated poly house. In the poly house, shade was provided with 30 per cent shade net for initial 2 months which was removed later to reduce the incident light intensity and temperature inside in the early stage. The hybrids were evaluated in three growing conditions following randomized block design with four replications each comprising of 16 plants. Healthy seedlings of 35 days old raised under poly house with insect-proof net were transplanted in the double row bed with spacing 60 cm x 30 cm. Irrigation was applied through low pressure surface drip system fitted in the protected structures and by furrow method in open field cultivation. Standard agronomic practices were followed for crop management and adequate plant protection measures were taken against major insect pest and diseases *viz*., cut worm, thrips, white fly, mite, fruit borer, damping off, bacterial wilt and fruit rotting.

Data on different characters viz., plant height (cm) at 90 days after transplanting (DAT), days to first harvest, fruits plant^{-1}, fruit weight (g), fruit yield plant^{-1} (g) and projected fruit yield (q.ha^{-1}) were recorded from 10 randomly selected plants from each replication. Ten fruits from the selected plants per replication were sampled periodically at full maturity stage for recording average fruit weight. Total number of fruits of marketable size and maturity of the periodical harvests were considered in recording fruit yield per plant. Total fruit weight of the 10 selected plants per replication was converted to projected yield per hectare considering plant population of 35,000 per hectare. Percentage infestation of thrips-mite-whitefly complex at 70 DAT and per cent crop loss due to bacterial wilt up to harvest was recorded considering all the 16 plants per replication. Important climatic parameters *viz*, temperature, relative humidity, rainfall and light intensity were recorded in all the growing conditions during the period of investigation. Maximum and minimum temperature was recorded daily with mercury thermometer (make : Zeal, England) by placing it at 1.25 m height at 7.00 a.m. for minimum temperature and 2.00 p.m. for maximum temperature. Analog type hair hygrometer (make: Fischer, GDR) placing at 1.25 m height was used to record relative humidity daily at 7a.m. and 2p.m. Digital lux meter (make: TES (1332A), Taiwan) placing at 1.00 m height over the crop was used to record the light intensity. The data recorded in two consecutive seasons were pooled and analyzed statistically using OPSTAT of Hisar Agricultural University (Sheoran *et. al*., 1998).

RESULTS AND DISCUSSION

Plant height, irrespective of the hybrids increased considerably under protected condition compared to the plants grown in open field condition. The tallest plant (average of 3 hybrids: 111.16 cm) was produced under shade net house followed by in poly house (average of 3 hybrids: 96.00 cm). Both yellow and red-fruited hybrids, Arya and Ayesha, respectively were highly sensitive to open growing condition registering almost three times increase in height under protected structures (Table 1). The hybrid Indra showed comparatively less sensitivity to open growing condition. Days to first harvest in all the three hybrids did not vary much with the growing condition provided in this investigation which suggested that reproductive ontogeny was not influenced markedly by the maximum/minimum temperature range of 27 –37^{o}C/12 – 24^{o}C during first three months growth stage spanning from October to December which covered full vegetative and early reproductive stage

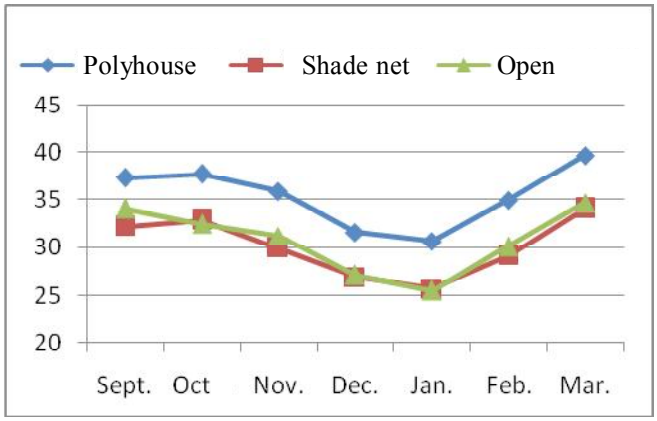

Fig.1: Monthly variation of maximum temperature (°C) under open (O), shade net (S) and Poly house (P) condition

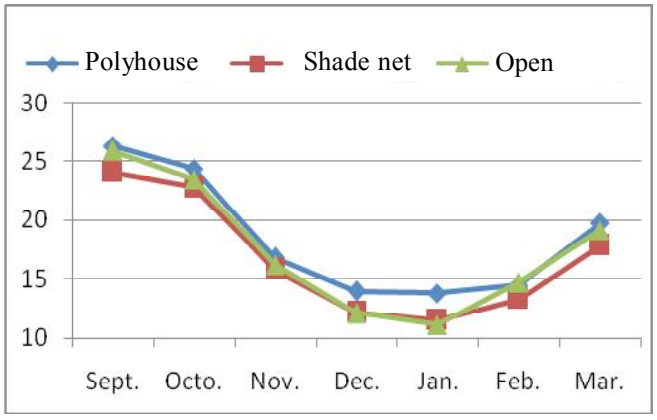

Fig.2: Monthly variation of minimum temperature (°C) under open (O), shade net (S) and Poly house (P) condition

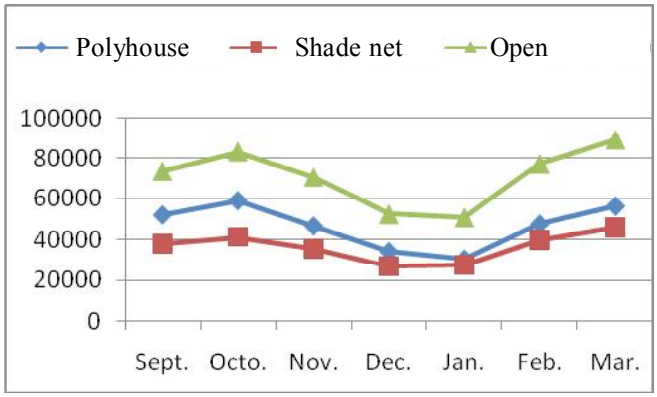

Fig.3: Monthly variation of mid day light intensity (lux) under open (O), shade net (S) and Poly house (P) condition

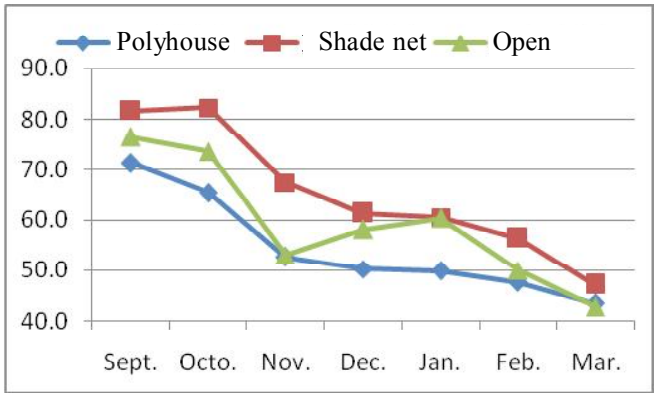

Fig.4: Monthly variation of relative humidity (%) under open (O), shade net (S) and Poly house (P) condition

of the plant.

Fruits per plant in all the three hybrids increased considerably under polyhouse condition compared to the open field condition, the increase being most conspicuous in the yellow-fruited variety Arya (242.2%) followed by the red-fruited variety Ayesha (161.6%). However, the increment was comparatively less in Indra (62.6%) of which fruits were harvested at mature green stage. Fruits per plant increased marginally in the hybrids, Ayesha and Arya but decreased in the hybrid Indra under shade net house compared to open field condition. Reduced fruit set amply suggested that comparatively low light intensity of 30,000 to 35,000 lux under shade net house during full vegetative and early reproductive stage of the plant (Fig. 3) might have resulted high flower drop causing low fruit set. Very high light intensity of 55,000 to 80,000 lux under open field condition was also not congenial for fruit set particularly for the red and yellow-fruited hybrids. Light intensity of 35,000 to 55,000 lux coupled with the maximum/minimum temperature 30°C to 33°C / 14°C to 17°C under the poly house condition have been found to be the most suitable microclimate for fruit set in sweet pepper (Table 1).

Average fruit weight in all the three hybrids increased considerably under both shade net and poly house compared to the open field condition. Irrespective of the hybrids, fruit weight was the highest in the plants grown under shade net condition and it increased by 522.7 per cent in the yellow-fruited hybrid Arya, by 399.3 per cent in red-fruited hybrid Ayesha and by 76.5 per cent in the green-fruited hybrid Indra over that recorded in the plants grown in open field condition (Table 1). Fruit weight recorded in the three hybrids grown under poly house was slightly lesser than that produced in the plants grown under shade net house. High fruit weight produced in the plants grown under shade net house indicated that prevailing light intensity of 30,000 to 35,000 lux under this condition during full vegetative and early reproductive stage of the plant appeared to be low enough to cause low fruit set but adequate for the gain in

Table 1: Variation in yield contributing characters of three hybrids under different growing conditions

	Plant height (cm) at 90 DAT					Days to first harvest			
	O	S	P	Mean		O	S	P	Mean
Indra(G)	60.9	105.4	92.1	86.1	Indra(G)	90.8	92.1	89.9	91.0
Ayesha(R)	42.5	112.2	94.3	83.0	Ayesha(R)	97.8	116.6	111.0	108.5
Arya(Y)	30.8	115.9	96.0	80.9	Arya(Y)	119.8	125.6	118.3	121.2
Mean	44.7	111.2	94.1		Mean	102.8	111.4	106.4	
Factors	A	B		A x B	Factors	A	B		A x B
SEm±	0.86	0.86		1.49	SEm±	1.06	1.06		1.83
C.D.(P=0.05)	2.53	2.53		4.37	C.D.(P=0.05)	3.10	3.10		5.37
	Fruits plant^{-1}					Fruit weight (g)			
	O	S	P	Mean		O	S	P	Mean
MeanIndra(G)	8.0	6.5	13.1	9.2	Indra(G)	120.1	212.0	208.4	180.2
Ayesha(R)	4.5	5.6	11.9	7.3	Ayesha(R)	45.7	228.1	210.0	161.3
Arya(Y)	3.1	5.2	10.7	6.3	Arya(Y)	35.2	219.0	213.2	155.8
Mean	5.2	5.8	11.9		Mean	67.0	219.7	210.5	
Factors	A	B		A x B	Factors	A	B		A x B
SEm±	0.10	0.10		0.18	SEm±	1.21	1.21		2.09
C.D.(P=0.05)	0.30	0.30		0.52	C.D.(P=0.05)	3.55	3.55		6.15

G= Green , R=Red, Y= Yellow, O= Open, S= Shade, P= Polyhouse, Factor A = Color of fruit , Factor B= Growing condition

Table 2: Variation in biotic stress and fruit yield of three hybrids under different growing conditions

	Fruit yield plant^{-1} (g)					Infestation percentage at 70 DAT			
	O	S	P	Mean		O	S	P	Mean
Indra(G)	964.4	1383.8	2723.1	1690.4	Indra(G)	23.8	19.9	16.1	20.0
Ayesha(R)	206.0	1281.6	2493.8	1327.2	Ayesha(R)	62.4	18.5	18.6	33.2
Arya(Y)	109.3	1139.3	2271.1	1173.2	Arya(Y)	80.0	19.9	20.5	40.1
Mean	426.6	1268.2	2496.0		Mean	55.4	19.4	18.4	
Factors	A	B		A x B	Factors	A	B		A x B
SEm±	12.83	12.83		22.22	SEm±	0.60	0.60		1.03
C.D.(P=0.05)	37.66	37.66		65.23	C.D.(P=0.05)	1.75	1.75		3.03
	Percentage crop loss due to bacterial wilt					Projected fruit yield (q ha^{-1})			
	O	S	P	Mean		O	S	P	Mean
Indra(G)	6.5	10.3	4.6	7.1	Indra(G)	253.2	342.5	622.9	406.2
Ayesha(R)	6.5	10.8	3.7	7.0	Ayesha(R)	50.6	317.2	570.5	312.8
Arya(Y)	6.4	11.6	3.7	7.2	Arya(Y)	26.8	282.0	519.5	276.1
Mean	6.5	10.9	4.0		Mean	110.2	313.9	571.0	
Factors	A	B		A x B	Factors	A	B		A x B
SEm±	0.42	0.42		0.72	SEm±	3.07	3.07		5.31
C.D.(P=0.05)	NS	1.22		NS	C.D.(P=0.05)	9.01	9.01		15.60

G= Green , R=Red, Y= Yellow, O= Open, S= Shade, P= Poly house, Factor A = Color of Fruit , Factor B= Growing Condition

Table 3: Correlation coefficients among fruit yield, yield components, weather parameters and disease incidence

	Plant Height	Days to first harvest	Fruit plant^{-1}	Fruit weight	Fruit yield plant^{-1}	Infestation percentage	Percentage crop loss	Projected fruit yield	Max day temp.	Min night temp.	Relative humidity	Light Intensity
Plant height	1.000											
Days to first harvest	0.181	1.000										
Fruits plant^{-1}	0.371	-0.313	1.000									
Fruit weight	0.972*	0.120	0.545*	1.000								
Fruit yield plant^{-1}	0.634*	-0.118	0.937*	0.777*	1.000							
Infestation percentage	-0.870*	0.138	-0.643*	-0.921*	-0.770*	1.000						
Percentage crop loss	0.355	0.209	-0.595*	0.193	-0.389*	-0.105	1.000					
Projected fruit yield	0.663*	-0.132	0.930*	0.802*	0.998*	-0.804*	-0.353	1.000				
Max. day temp.	0.163	-0.050	0.893*	0.341	0.831*	-0.336	-0.753*	0.800*	1.000			
Min. night temp.	-0.142	-0.127	0.797*	0.046	0.640*	-0.098	-0.871*	0.602*	0.950*	1.000		
Relative humidity	0.298	0.162	-0.714*	0.113	-0.513*	-0.032	0.898*	-0.473*	-0.884*		-0.986*	1.000
Light Intensity	-0.960*	-0.245	-0.268	-0.923*	-0.572*	0.741*	-0.403*	-0.594*	-0.120	0.197	-0.357	1.000

*Significance at P= 0.01

fruit weight. Comparatively less fruit number in the shade net house-grown plants might also have resulted in high average fruit weight.

In open field condition, percentage infestation of thrips-mite-white fly complex was the highest in all the three hybrids, the most severe was 79.8 per cent in the yellow-fruited hybrid Arya followed by 62.4 per cent in red-fruited hybrid Ayesha and 23.8 per cent in the green-fruited hybrid Indra. High relative humidity condition of above 75.0 per cent coupled with occasional moderate to heavy rainfall (7-12 rainy day in September and 3-8 rainy day in October) during the early vegetative stage of about 45 days from mid September to last week of October aggravated the infestation of these damaging sucking pests. Infestation of these sucking pests in 3 hybrids reduced considerably under both shade net and poly house with little difference between these two structures. On the other hand, percentage crop loss due to bacterial wilt was the highest (average 10.8% over 3 hybrids) under shade net house compared to the average of 6.4 per cent in open field condition and 4.0 per cent under poly house. High incidence of bacterial wilt under shade net house might have occurred due to low light intensity (30,000 to 40,000 lux) coupled with ≥ 80 per cent relative humidity inside the structure during the early vegetative stage of the crop.

Highest fruit yield (both per plant and projected yield) in all the three hybrids was recorded in poly house. Increase in fruit yield in the poly house compared to the open field condition was consistently high, more than twelve times in the yellow-fruited hybrid Arya and red-fruited hybrid Ayesha (Table 2). The hybrid Indra also registered more than double fruit yield in poly house. Fruit yield also enhanced under shade net house but it was almost half of that recorded under poly house condition (Table 2).

Simple correlation coefficients among fruit yield per plant, fruit yield components, weather parameters and disease incidence (Table 3) clearly indicated fruit yield components and yield itself was significantly and positively correlated with maximum and minimum temperature, these are also significantly and negatively correlated with light intensity, relative humidity, infestation percentage of pest complex and crop loss due to bacterial wilt disease.

High fruit yield under poly house resulted due to concomitant enhancement of two most important fruit yield components *viz*., fruit number per plant and average fruit weight and low incidence of pest and disease. The maximum/minimum temperature was always 3-5°C higher inside the poly house than the shade net house and open field condition. The maximum temperature of 33°C to 30°C remained inside the poly house during the cooler period from mid November to mid January which was optimum for the crop (Fig. 1). Night temperature during this cooler period in both shade net house and open field condition dropped to the ≤16°C (11°C to 16°C) while that inside the poly house was 14°C to 17°C (Fig. 2) which was found optimum for the crop (Rylski

and Spigelman, 1982). Prevention of adverse effect of low night temperature during winter months due to typical green house effect emerged as the prime cause for realizing high fruit yield of the hybrids under poly house which has found support from several earlier studies (Polowick and Sawhney 1985; Pressman *et al*. 2006). This microclimate suitability considered sweet pepper to be a warm loving crop. Comparatively reduced light intensity of 35,000 to 55,000 lux by use of cladding material viz. UV stabilized polythene film to achieve shading upto 35-40 per cent (Fig.3). as evidence by Diaz-Perez, (2014) (Fig.3) coupled with low relative humidity ≤ 60 per cent (Fig. 4) during flowering, fruit set and fruit development period also influenced positively for high fruit set and fruit weight in all the hybrids inside the poly house.

CONCLUSION

In the sub-tropical humid climatic condition of eastern India specially the gangetic West Bengal, naturally-ventilated poly house was the most suitable for enhancing fruit yield of both green and colour fruited hybrids. Open field condition was not suitable for both yellow and red-fruited hybrids. Though green-fruited hybrids could be grown in open field condition, fruit yield increased to more than double under poly house. Shade net house could not be considered as a suitable protected structure for sweet pepper in this climatic condition because of reduced light intensity and high relative humidity inside it causing low fruit set and high incidence of bacterial wilt disease. Maximum/minimum temperature 30°C to 33°C / 14°C to 17°C, comparatively reduced light intensity of 35,000 to 55,000 lux, prevention of adverse effect of low night temperature during winter and low relative humidity of 60 per cent and below during flowering, fruit set and fruit development period inside the naturally ventilated poly house was most suitable growing condition for getting maximum productivity of both green and colour-fruited hybrids of sweet pepper.

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Received : July 2018 ; Accepted : December 2018