Investigation of Microclimatic condition under different color of net on Growth and Development of Bell Pepper inPrayagraj, (U.P) India

ABSTRACT

The field experiment was conducted at Nursery Farm, Department of Environmental Sciences, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during the rabi season. The experiment was laid out in two factorial randomized block design, consisting of treatments *i.e.*, four shade net *viz.*, green, red, white, black including a controlled condition and three date of transplanting (15 Oct, 30 Oct and 15 Nov) replicated thrice. Measurement of growth and yield attributes such as plant height, number of leaves, leaf area index, dry matter, fruit weight and number of fruits obtained as well as heat units like GDD, HTU, PTU was done. This study (2022-2023) was conducted to investigate the comparative effect of two environment (controlled field vs. shade net field) along with date of transplanting. The highest fruit number, fruit weight, marketable yield was obtained when the crop was grown under green shade net in second date of sowing October 30. The results indicated the importance of environmental factors and date of transplanting for yield optimization. The study showed that transplanting date had a significant effect on fruit number, fruit weight and marketable yield and results suggest that transplanting in the shade net at the optimal date can increase yield significantly. Thus, the use of green shade net not only protects plants from the excessive heat but also increase the metabolic process in the plants by maintain the optimum temperature from the outer environment.

Keywords: Bell pepper, Shade net, Growth, Yield, Economics.

1. Introduction

India is a country with immense diversity and is known for its richness in different spices. Among the spices, Capsicum spp. is considered one of the most important commercial spices all over the world. It isa member of the Solanaceae family and includes 30 species and around 400 varieties (Bhalabhai etal.,2021). Capsicum is derived from the Greek word 'kapsimo,' meaning 'to bite.' It originated in the Andes Mountains, in north- western South America. It is reported that humans were using wild chili peppers as early as 8000–10,000 years ago, while their dispersal, domestication, and diversification in different parts of the world were documented over 6000 years ago. The crop was first introduced to India by the Portuguese towards the end of the fifteenth century and to north-eastern India by Christian missionaries. Different agro-climatic zones within our country have helped adapt and diversify Capsicum, building a repository of many unique, well-bred, and less-bred landraces, particularly in the North Eastern Himalayan states (Jha et al.,2021) India. Capsicum spp. are grown as a spice in the equatorial regions of the countries like India, Mexico, United States of America, Japan, Turkey, and African States. Around 68% of world's total green chilli was produced in Asian region and the highest five bell pepper producer countries were China, Turkey, Mexico, Indonesia, and Spain. After China and Pakistan, India is also considered as one of the largest bell pepper producers (Parvez *et al*., 2017). The production level of bell peppers is very high because of their nutritional, therapeutic, and pharmaceutical values. Bell pepper contains a high amount of vitamin B6, vitamin A, and various mineral such as iron, potassium, calcium, thiamin (Chakrabarty et al., 2017) and magnesium, which help reduce cholesterol and increase immunity (Grubben et al., 2004). India is the largest producer, consumer, and exporter of Capsicum in the world. It contributes about 36% to the global production of Capsicum and exports about 20% of its total production. The production of Capsicum in India is dominated by the state of Andhra Pradesh, which contributes 53% of the total production, followed by Karnataka (9%), Odisha (6%), West Bengal (6%), Maharashtra (5%), and Madhya Pradesh (4%). As this study aimed to understand the microenvironment of field grown bell pepper under different shading net to evaluate the effect of different shade color. Colored shade netting is a relatively new tool that can be used for a wide variety of purposes by horticulturists. Shade net fulfil the task of giving appropriate micro-climate conditions to the plant. Thus, an improved understanding of modification of crop microclimate through structural and agronomic interventions that improve the highest fruit number, fruit weight, early yield, marketable yield, and total yield through optimization of soil and air temperature.

2. Material and Methods

The present investigation was done in Prayagraj, India, during the rabi season of (2022-2023) at the Nursery Research Farm, Department of Environmental Sciences & NRM, Sam Higginbottom University of Agriculture, Technology and Sciences (U.P). The experimental site of the research farm which falls under Geographical Co-ordinates of Prayagraj District which is located at $25^{0}58^{'}$ N latitude and $81^{0}52^{'}$E longitude with an altitude of 98 meter above mean sea level and is situated 5km away on the right bank of Yamuna-river representing the Agro- Ecological Sub Region [North Alluvial plain Zone (0-1% slope)] and Agro-Climatic Zone (Upper-Gangetic Plain Region). Each replication was assigned at random, dividing the research location into forty-five plots. The bell pepper variety California wonder pepper was grown during the experimental year 2022.

Table 1 Details of Experiment

Design	Two factorial RBD
Replication	03
Date of Sowing	03
D1	15 Oct 2022
D2	30 Oct 2022
D3	15 Nov 2022
Types of Shade net	04
Controlled	Open field
Red Shade	Red color
Pearl shade	White color
Black shade	Black color
Green shade	Green color
Number of plots	15
Shade net %	75
Shade size	150mx3m
Crop	Bell Pepper
Variety	California Wonder Pepper

Table 2 Details of treatments

Treatment No.	Treatment Combination
T1	**D1S1 (Controlled)**
T2	**D2S1**
T3	**D3S1**
T4	**D1S2 (Red shade)**
T5	**D2S2**
T6	**D3S2**
T7	**D1S3 (Black shade)**
T8	**D2S3**
T9	**D3S3**
T10	**D1S4 (White shade)**
T11	**D2S4**
T12	**D3S4**
T13	**D1S5 (Green shade)**
T14	**D2S5**
T15	**D3S5**

Were, D- Date of transplanting

S- Shade net

3. Result and Discussion

Table 3 Growth influenced by shade net and date of transplanting.

Treatment		Plant height		Number of leaves	
T1	**D1S1**	44.1		**49.3**	
T2	D2S1	45.7		54.3	
T3	D3S1	48.0		58.3	
T4	D1S2	46.5		54.7	
T5	D2S2	46.6		61.3	
T6	D3S2	48.0		57.3	
T7	D1S3	51.3		58.0	
T8	**D2S3**	**56.1**		59.0	
T9	D3S3	50.4		64.0	
T10	D1S4	49.5		58.7	
T11	D2S4	47.0		60.7	
T12	D3S4	48.0		59.7	
T13	D1S5	46.2		64.7	
T14	**D2S5**	**43.9**		**66.3**	
T15	D3S5	47.1		64.3	
		S. Em	C.D.	S. Em	C.D.
	Due to shade net(S)	0.706	2.055	1.217	3.543
	Due to date of transplanting(D)	0.547	N/A	0.934	2.785
	Interaction (SxD)	1.222	3.559	2.108	N/A

3.1.1 Growth parameter: Plant height and Number of leaves

A perusal of this Table 3 reveals that there was a steady increase in the plant height at 150 DAT, the significant relationship was found in 150 days of crop due to shading net and date of transplanting and the maximum height at 150 DAT is 56.1 cm in D2 under black shade net and minimum height is 43.9 cm in D2 under white shade net and the maximum number of leaves occur under green shade net 66.3 and minimum number of fruits occur under control condition. Plants cultivated in low light environments were shown to be more apical dominant over high light environments, this increased auxin transport caused cell elongation below the zone of the apical meristem, resulting in taller plants under shade net. The results were in accordance with Rao (2023) and Díaz-Perez *et al.,* (2019). In number of leaves the significant increase in the number of leaves per plant increases under green

shade followed by white shade net due to adequate supply of the solar radiation which allowed the plant tissue to maintain its temperature than the outdoor temperature.

Table 4 Leaf Area Index influenced under different shade net and date of transplanting.

Treatment	DAT	Shade color	Leaf Area (sq. m)	Leaf area index	
T1	D1	Controlled	8.6	3.10	
T2	D2	Controlled	8.5	3.07	
T3	D3	Controlled	9.2	3.32	
T4	D1	Red	15.6	5.61	
T5	D2	Red	14.0	5.04	
T6	D3	Red	14.1	5.06	
T7	D1	Black	8.8	3.17	
T8	D2	Black	12.6	4.54	
T9	D3	Black	11.5	4.14	
T10	D1	White	9.8	3.51	
T11	**D2**	**White**	**16.5**	**5.96**	
T12	D3	White	8.5	3.07	
T13	D1	Green	11.5	4.14	
T14	D2	Green	4.7	1.68	
T15	D3	Green	7.2	2.59	
				S. Em	C.D
	Due to shade net			0.63	1.42
	Due to date of transplanting			0.49	1.84
	Interaction (SxD)			1.10	3.18

3.2.1 Leaf Area Index

A perusal of this (Table 4) reveals that the Leaf area index of the bell pepper was showing significant relationship between the shade net and date of transplanting and the highest lead area index occur under white shade net (5.96) in second date of transplanting under white shade net. White shade net exhibit special optical properties for control of light and modify the microclimate and provide physical protection against the excessive radiation. Under low light, plants often get features to capture the more optical energy such as leaf area enlargement. Leaf thickness is affected by the

thickness of the tissue layer on the leaves, such as mesophyll tissue. Leaves in sun area are thicker and smaller with low stomatal density on both leaf surfaces. As a result, plant under low light intensity have larger leaves than those grown under high light intensity. Moreover, a decrease in leaf size in full sunlight area will reduce leaf temperature, potential water loss and damage to leaf photosystems. The similar studies were found in Meena *et al.*, (2014).

Table 5 Dry matter influenced under shade net and date of transplanting.

Treatment	DAT	Shading net	Dry matter	
T1	D1	Controlled	43.8	
T2	D2	Controlled	51.5	
T3	D3	Controlled	52.7	
T4	D1	Red	57.1	
T5	D2	Red	55.4	
T6	D3	Red	45.2	
T7	D1	Black	44.3	
T8	D2	Black	49.9	
T9	D3	Black	51.2	
T10	D1	White	42.9	
T11	**D2**	**White**	**57.8**	
T12	D3	White	41.5	
T13	D1	Green	35.6	
T14	D2	Green	38.0	
T15	D3	Green	46.3	
			S. Em	C.D
	Due to shade net		3.44	9.97
	Due to transplanting		4.44	12.87
	Interaction (SxD)		7.70	22.30

3.3.1 Dry matter

A perusal of this (Table 5) reveals that total dry matter production of plants was showing significant relationship between the shade net and date of transplanting and under controlled condition dry matter production respectively was low compared to other shade nets, due to better microclimatic condition in color shade nets. Total dry matter production occurs in white shade net (57.8%) followed by red shade (57.1%), controlled (52.7%), black shade net (51.2%) and green shade (46.3%). The greater

production of the dry matter occurs in white shade net due to the high metabolic activity because it radiates the optimum amount of the sunlight to the plants and protects plants from the excessive heating and filter out the excessive UV radiation which directly cause the tissues of the cell present in the leaf surface of the crop which contribute in the formation of the photosynthesis

Table 6 Agrometeorological Indices

Phenophases	**D1 (15/10/2022)**		
	GDD	**PTU**	**HTU**
Transplanting to plant establishment	163.2	1893.12	1235.33
Vegetative stage	412.2	4565.99	2996.84
Flowering to pollination stage	318.2	3394.49	1892.39
Pollination to fruiting stage	113.7	1216.59	509.31
Fruit to ripening stage	230	2576.62	1830.49
Ripening to first picking	281.3	3310.36	2586.46
Total	1518.6	16957.17	11050.82
Phenophases	**D2 (30/10/2022)**		
	GDD	**PTU**	**HTU**
Transplanting to plant establishment	146.7	1621.79	1140.34
Vegetative stage	323.6	3507.71	2996.84
Flowering to pollination stage	235.1	2498.21	1405.84
Pollination to fruiting stage	192.9	2119.23	1177.66
Fruit to ripening stage	307.5	3554.27	2799.55
Ripening to first picking	288.7	3464.4	1929.98
Total	1494.5	16765.61	10515.88
Phenophases	**D3 (15/11/2022)**		
	GDD	**PTU**	**HTU**
Transplanting to plant establishment	119.7	1304.73	785.81
Vegetative stage	242.3	2585.8	1497.89
Flowering to pollination stage	225.3	2410.44	1087.75
Pollination to fruiting stage	249.4	2818.22	2167.39
Fruit to ripening stage	352.9	4215.27	2749.52
Ripening to first picking	343	4267.48	2742.46
Total	1532.6	17601.94	11030.82

From transplanting to maturity	Total accumulation					
	GDD		PTU		HTU	
D1	1518.6		16957.17		11050.82	
D2	1494.7		16765.61		10515.88	
D3	1532.6		17601.94		11030.82	
	S. E	C.D	S. Em	C.D	S. Em	C.D
Due to phenological days	16.42	48.98	204.18	609.13	163.56	487.94
Due to date of transplanting	23.22	69.27	288.76	861.44	231.31	690.05
Interaction	40.22	119.97	500.14	1492.06	400.64	1195.21

3.5.1 Accumulated heat unit indices of the Bell pepper

The total heat unit indices of the bell pepper show the significant relationship between the phenological days and date of transplanting. The highest total accumulated heat unit occur under third date of sowing (1518.6), the total photothermal unit and heliothermal unit occur under third date of sowing (17601.94) and (11030.82). This signify that the temperature and growing length period has linear relationship in which with increase in temperature the growing length period of the crop become shorter and lower the temperature, longer the duration. The heat unit concept, also called heat sums, day degrees, growing degree days (GDD) or degree days is a measure of relative warmth of growing season of a given duration.

Table 7. Number of fruits and Fruit yield influenced under shade net and date of transplanting.

Treatment	DAT	Shade	Number of fruits		Fruit weight	
T1	D1	Controlled	12		398	
T2	D2	Controlled	7		594	
T3	D3	Controlled	12		629	
T4	D1	Red	13		388	
T5	D2	Red	13		333	
T6	D3	Red	12		478.5	
T7	D1	Black	11		460.5	
T8	D2	Black	15		776	
T9	D3	Black	11		828	
T10	D1	White	17		364	
T11	D2	White	19		815	
T12	D3	White	20		667	
T13	D1	Green	18		545	
T14	**D2**	**Green**	**23**		**965**	
T15	D3	Green	16		791	
			S. Em	C.D	S. Em	C.D
		Due to shade net	0.49	1.43	21.63	62.65
		Due to transplanting	0.64	1.85	27.92	80.88
		Interaction (SxD)	1.10	3.20	48.36	140.08

3.5.1 Fruit weight and number of fruits

The total accumulation of number of fruits and fruit weight shows the significant relationship between the shade net and date of transplanting. The higher amount of the number of fruits and fruit weight occurs under green shade net in D2 followed by white shade net, black shade, red shade and control shows in table (7). Green shade reflects optimum quality of the light to plants of bell pepper to secure a better growth under green shade net. Green shade not only protects plants from the excessive heat but also increase the metabolic process in the plants by maintain the optimum temperature from the outer environment.

Treatment	Date of transplanting	Shade	Cost of cultivation	Gross return	Net return	Benefit cost ratio
T1	D1	Controlled	66,266	1,99,000	1,32,734	2.0
T2	D2	Controlled	66,266	2,97,000	2,30,734	3.5
T3	D3	Controlled	66,266	3,14,500	2,48,234	3.7
T4	D1	Red	80,000	1,94,000	1,14,000	1.4
T5	**D2**	**Red**	**80,000**	**1,66,500**	**86,500**	**1.1**
T6	D3	Red	80,000	2,39,250	1,59,250	2.0
T7	D1	Black	80,000	2,30,250	1,50,250	1.9
T8	D2	Black	80,000	3,88,000	3,08,000	3.9
T9	D3	Black	80,000	4,14,000	3,34,000	4.2
T10	D1	White	80,000	1,82,000	1,02,000	1.3
T11	D2	White	80,000	4,07,500	3,27,500	4.1
T12	D3	White	80,000	3,33,500	2,53,500	3.2
T13	D1	Green	80,000	2,72,500	1,92,500	2.4
T14	**D2**	**Green**	**80,000**	**4,72,500**	**3,92,500**	**4.9**
T15	D3	Green	80,000	3,95,500	3,15,500	3.9

Table 8 Cost benefit ratio of Bell pepper

3.6.1 Cost benefit ratio

The total cost of cultivation accumulates Rs. 66,266 for unshaded area and Rs.80,000 for shaded area for the fifteen treatments. Each treatment was covered with different color of shading net. Data pertaining to the gross returns as influenced by various treatment under shade net are presented in

table 8. Gross returns 4,72,500 Rs/hac was found to be highest under green shade net in second date of transplanting and the minimum gross return was found under red shade net 1,66,500 Rs/hac. The net return 3,92,500 Rs/hac was found to be highest under green shade net and minimum net return was found to be occur under red shade net 86,500 Rs/hac. Data pertaining to the benefit cost ratio (B:C) as influenced by various treatments are presented in Table 8. Benefit cost ratio were found to be highest under green shade net 4.9 in second date of sowing and the minimum cost ratio to be lowest under red shade net 1.1 in second date of sowing compared to other treatments.

4. Conclusion

In eastern plain zones of Uttar Pradesh, cultivation of Bell pepper with the application of the four-shade net and one control condition occurs more desirable under black shade for height and number of leaves under green shade net. Under white shade, the dry matter and leaf area index occur maximum. In terms of fruit weight and fruits, the maximum number of fruits occur under green shade net and maximum fruit weight gain occur under green shade net. It also records the maximum gross returns, net return, and benefit cost ratio and the maximum B:C ratio occur under green shade and minimum under red shade. So as far the study green shade net shows the best result followed by white shade, black shade, red shade net and control condition. The conclusion is based on the results of one year experimentation.

5. References

Abhay Kumar Gaurav, D.V.S Raju, T. Janakira (2014) Microclimate modification under different shade levels and its effect on the growth of Dracaena fragrans. Journal of Ornamentals Horticulture 17(1&2):12-17

Amparo Galvez, Alfonso Albacete, Francisco M. del Amor and Josefa López-Marín (2020) The Use of Red Shade Nets Improves Growth in Salinized Pepper (*Capsicum annuum* L.) Plants by Regulating Their Ion Homeostasis and Hormone Balance. Journal of Agronomy 10 :1-19

Attila Ombodi, Zoltán, (2016) Effect of coloured shade nets on some nutritional characteristics of a kapia type pepper grown in plastic tunnel 3(2): 25-31

Baljit and K. N. Sharma (2007) Tree growth and nutrient status of soil in a poplar (Populus

deltoides Bartr.)-based agroforestry system in Punjab, India. Journal of Agroforest Systems. 70:125–134

Bhalabhai, J.G., (2021) A Comprehensive Review on Capsicum spp. *International journal of research and analytical reviews*. 8(4): 581-599

Bhutia, K.L., N.D., Khanna, VK. (2019) Rich Genetic Diversity of Capsicum Species in Northeast India, as a Potential Source for Chilli Crop Improvement. *Journal of Agriculture and Forest Meteorology Research.* (2):77-83

Chitra Shukla, SK Acharya, SR Bhakar, PK Jamrey4 (2019) Effect of different micro climate on the physiological parameters and yield of capsicum. *Horticulture International Journal*,3(2):61–65

D.C. Fontana, C.E. Becker, M.V.M. Pinheiro, M.M. Pretto, J. dos Santos, B.O. Caron, D. Schmidt (2019) Impact of light quality on the physiological characteristics of Capsicum chinense seeds. Adv. Hort. Sci., 33(2): 235-243

Juan Carlos Dı´az-Pe´rez (2013) Bell Pepper (Capsicum annum L.) Crop as Affected by Shade Level: Microenvironment, Plant Growth, Leaf Gas Exchange, and Leaf Mineral Nutrient Concentration Journal American Social Hort Sciences 48:175–182.

Juan Carlos Dı´az-Pe´rez (2019) Bell Pepper (Capsicum annum L.) under Colored Shade Nets: Plant Growth and Physiological Responses. Journal American Social Hort Sciences. 54(10):1795–1801

Juan Carlos Dı´az-Pe´rez (2020) Bell Pepper (Capsicum annum L.) under Colored Shade Nets: Fruit Yield, Postharvest Transpiration, Color, and Chemical Composition. Journal American Social Hort Sciences. 55(2):181–187

Karan Verma, Ranbir Singh Rana, and Pankaj Chopra (2017) Agrometeorological indices influenced by varying sowing environment and variables of Wheat under sub- temperature climate of Himachal Pradesh, India, Vol. 17 (2), 1439-1443

Karma L Bhutia, Nangsol D Bhutia and VK Khanna (2019), Rich Genetic Diversity of Capsicum Species in Northeast India, as a Potential Source for Chilli Crop Improvement, Journal of Agriculture and Forest Meteorology Research., 2(2): 77-83

Kuldip Medhi, Prasanta Neog, Bondita Goswami, Rajib Lochan Deka and Rofiul Hussain (2019), Agrometeorological Indices in Relation to Phenology and Yield of Rice Genotype (Oryza sativa L.) under Upper Brahmaputra Valley Zone of Assam, India. 8(6): 1459-1471

Kumar, M., and V. Verma. (2009). Bell pepper (Capsicum annuum L.) production in low cost naturally-ventilated polyhouses during winters in the mid hills of India. Acta Horticulturae (807):389–94. doi:10.17660/*ActaHortic*:807-S55.

M. Preema Devi, Hemanta, A. Chakraborty (2017) Agrometeorological indices: effect on growth and flowering behaviour in marigold, Journal of crop and weed.13(3): 82-85

M. S. Dhaliwal, S. P. Sharma, S. K. Jindal, L. K. Dhaliwal & A. K. Gaikwad (2017). Growth and yield of bell pepper as influenced by growing environment, mulch, and planting date Journal of Crop Improvement, 31**:** 7. https://doi.org/10.1080/15427528.2017.1391146

M.Y. Kabir, J.C. Dí azPérez1 and S.U. Nambeesan, (2020) Effect of shade levels on plant growth, physiology, and fruit yield in bell pepper (Capsicum annuum L), *ActaHortic:*311-317

Martin P.N. Gent (2007), Effect of Degree and Duration of Shade on Quality of Greenhouse Tomato. HORTSCIENCE 42(3):514–520

Md. Obyedul Kalam Azad, Ik Jo Chun, Jeong Hak Jeong, Soon Tae Kwon, and Jae Moon Hwang (2011) Response of the Growth Characteristics and Phytochemical Contents of Pepper (Capsicum annuum L.) Seedlings with Supplemental LED Light in Glass House, Journal of Bio-Environment Control, 20(3):182-188

P.K Kingra, R.K Mahey, K.K Gill (2010) Prediction of grain yield of wheat using canopy temperature-based indices. Journal of Agrometeorology 12 (1): 58-60

PAU. (2010). Package of practices for vegetable crops. Ludhiana, Punjab, India: Punjab Agricultural University. Available at (Accessed on 01/ 01/2017) http://web.pau.edu/content/pf/pp_veg.pdf:50-59

Pooshpendra Singh Dixit, VM Prasad, Saurabh Kasera and Shivendra Singh (2018) Effect of various organic inputs on growth and its attributes of tomato (Solanum lycopersicum L.) cv. GS-600 under polyhouse condition. International Journal of Chemical Studies 6(6): 2537-2539

Prakash, V., A. K. Pandey, R. D. Singh, and H. S. Gutpa. (2003). Integrated weed management in capsicum (Capsicum annuum L.) under mid-hill conditions of north-western Himalayas. Indian *Journal Agronomic* 48:139–41.

Rekha Kumari Meena, Ananta Vashisth, Ravinder Singh (2014), Study on change in microenvironment under different colour shade nets and its impact on yield of spinach (Spinacia oleracea L.) Journal of Agrometeorology 16(1):104-111

Robert H. Stamps (2009) Use of Colored Shade Netting in Horticulture. *Journal of HortScience*. 44(2):240

Rupali Sharma and Rajesh Kumar (2017) Growth, Flowering and Yield of Chilli, Capsicum annuum L. as influenced by spacing and Growing Conditions, Int. J. Pure App. Bioscience. 5 (5): 524-527

S.S. Patra, B. Mehera and S. Rout (2016) Agrometeorological indices under different Hydropriming duration and sowing dates of Wheat, *International Research Journal of Life Sciences Leaflets.*72:192-202

Sachin Kumar Verma and Vijesh Joshi (2021), Thermal environment inside single shade-net, double shade-net, and polythene sheet houses and effect on wheat seedling growth. Journal of Agrometeorology 23 (3): 344-347

Timir Baran Jha, Biplab Kumar Bhowmick (2021). Conservation of floral, fruit and chromosomal diversity: a review on diploid and polyploid Capsicum annuum complex in India. *Molecular Biology Reports.* 48:5587–5605