Original Research Article

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 rabi season. The experiment was laid out in Randomized Block Design, consisting of treatments *i.e.*, four shade net *viz.*, green, red, white, black including controlled condition replicated thrice. This study (2022) was conducted to investigate the comparative effect of two environment (controlled field vs. shade net field), three date of transplanting (15 Oct, 30 Oct and 15 Nov). the highest fruit number, fruit weight, marketable yield was obtained when the crop was grown in the shade net under green shade net on 30 Oct. Accumulated heat unit occur under third date of sowing. 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 for different spices. Among the spices Capsicum spp. is considered one ofthe most important commercial spices all over the world. It is a member of Solanaceae family and includes 30 species and around 400 varieties **(Bhalabhai *et al.*,2021)**. Capsicum is derived from the Greek word 'kapsimo,' meaning 'to bite.' It is 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 its dispersal, domestication, and diversification in different parts of world have been documented over 6000 years ago. The crop was first introduced in 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 adaptation and diversification of Capsicum, building a repository of many unique, well and less bred landraces, particularly in the North Eastern Himalayan states **(Jha *et al.*,2021).**

India is the largest producer, consumer, and exporter of Capsicum in the world. It contributes about 36% to 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 contribute 53% of the total production followed by Karnataka 9%, Odisha 6%, West Bengal 6%, Maharashtra 5%, and Madhya Pradesh 4%. Capsicum is also cultivated in other parts of India including the north-eastern states **(Rudrapal *et al.*, 2020).**

The production level of bell pepper is very high because of its nutritional, therapeutic, and pharmaceutical values**.** Bell pepper contains high amount of vitamin B6, vitamin A, various minerals such as iron, potassium, calcium, thiamin **(Chakrabarty *et al.*, 2017)** and magnesium help to reduce the amount of cholesterol and increase immunity **(Grubben *et al.*, 2004).**

The efficiency of distinct characters such as inflorescence and seed color to differentiate the various Capsicum spp. has been described by **(Ortiz*et al.*, 2010).** Generally, it is oblong or conical in shape, 4-7 mm wide and 10-20 mm in length. It has long straight pedicel and calyx with five cup-shaped toothed which is attached to the smooth glacial pericarp. Pericarp is wrinkled, thin and orange-red too dark in color. Internally a membranous septum separates the pericarp into two cells. Each cell contains around 5-10 small, disc shaped and whitish yellow seeds. The cross section of bell pepper fruit displays outer layer epidermis made up of 5-7 rows of sub rectangular cells followed by mesocarp which comprises of cellulosic polygonal parenchyma. Crystals of calcium oxalate and minute vascular bundles are present in mesocarp. It also contains chromatophores which are yellowish droplets of the oil. After the mesocarp there is a layer made up of massive cellulosic cells. Endocarp of the fruit has tissues with lignin deposition, curved cells, and the flecks of sclerenchyma.

Generally, 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).**

Since the initial stages of farming, sweet pepper has been considered as a part of a human nutrition **(Pawar *et al*., 2011).** It is believed that chili pepper is originated from northern Amazon basin and due to this reason, it has spread over the regions of Central America, South America, the West Indies, and the states of U.S.A. The oldest variety of sweet pepper in the globe is the Tepin or Chiltepin pepper which is usually known as the "Mother chilli" **(Mehta *et al*., 2017).** As stated in many Paleo-archaeological reports, the origin of sweet pepper is around 7500BC from cave dig out in Mexico and prehistoric cemeterial grounds in Peru **(Pandit, *et al*., 2020).** With the help of pre-historical records at places situated in southwestern Ecuador, it can be predicted that sweet peppers were domesticated over 6000 years ago. Christopher Columbus for the first time termed them "peppers' because of their similar appearance with white and black pepper of genus Piper of Europe and carried pungent hot taste **(Pawar *et al*., 2011)**. After Columbus, sweet pepper was spread throughout the world. It was Fuchs, who proposed for the first time in 1543, the botanical term Capsicum, which was adopted later in 1753 by Linneo. The name would be the Neolithic derivation of Greek "Capsa," which refersto the peculiar shape of the fruit **(Tripodi *et al*.,2019).** 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) at the Nursery Research Farm, Department of Environmental Sciences & NRM, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS). (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). The current study was set up in a randomized block design (RBD) with fifteen treatment combinations in four shading nets with 75% with total length of 150m x 3m width includes red shade, white shade, black shade, and green shade, and one controlled condition with three replications. 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 Treatment combination

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**

3. Result and Discussion

Table 2. 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	0.706	2.055	1.217	3.543
	Due to date of transplanting	0.547	N/A	0.934	2.785
	Interaction (SxD)	1.222	3.559	2.108	N/A

3.1 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 under black shade net and minimum height is 47 cm under white shade net. 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 3. Leaf area index influenced by 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

3.2 Leaf area index

A perusal of this (Table 3) reveals that the Leaf area index of the bell pepper was highest 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 the Setiawati *et al.*, (2018) and Meena *et al.*, (2014).

Table 4. 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

3.3 Dry matter

A perusal of this (Table 4) reveals that total dry matter production of plants under controlled condition was significantly 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 5. 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

Table 6. Accumulated heat unit of the bell pepper with different phenophases stages under different date of transplanting.

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. Em (±)	125.56	1417.9	900.5
C.D. (0.5)	352.88	984.9	2531.05

3.4 Agrometeorological Indices

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: Correlations matrix for Climatic factors and plant height

		Tmax	Tmin	Tavg	Pheight
Tmax	Pearson Correlation	1	.892**	.974**	-.853**
	Sig. (2-tailed)		.000	.000	.000
	N	90	90	90	90
Tmin	Pearson Correlation	.892**	1	.971**	-.862**
	Sig. (2-tailed)	.000		.000	.000
	N	90	90	90	90
Tavg	Pearson Correlation	.974**	.971**	1	-.882**
	Sig. (2-tailed)	.000	.000		.000
	N	90	90	90	90
Pheight	Pearson Correlation	-.853**	-.862**	-.882**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	90	90	90	90

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8: **Descriptive Statistics for plant height with temperature.**

	Mean	Std. Deviation	N
Tmax	27.15	4.759	90
Tmin	13.13	4.539	90
Tavg	20.14	4.521	90
Pheight	32.14	9.392	90

3.5 Correlation matrix

A correlation matrix is a table of correlation coefficients for a set of variables used to determine if a relationship exists between the variables. The coefficient indicates both the strength of the relationship as well as the direction (positive vs. negative correlations). From the perusal of Table 7, the temperature is the active factor for growth of plant or crops. Correlation studies were performed on plant height with other factors are maximum temperature, minimum temperature. The study results indicate the negative correlation between maximum and minimum temperature. In correlation matrix maximum temperature has maximum value with the average temperature (0.974) and minimum value with the plant height (-0.853). In minimum temperature the maximum matrix occurs under average temperature (0.971) and minimum under plant height (-0.862).

Thus, which conclude that the plant height decreases with the increase in temperature by impacting the negative effect on it.

Table 9. Number of fruits and Fruit yield influenced under shade net and date of transplanting.

Treatment	DAT	Shade	Number of fruits	Fruit yield
T1	D1	Controlled	12	132.7
T2	D2	Controlled	7	198.0
T3	D3	Controlled	12	209.7
T4	D1	Red	13	129.3
T5	D2	Red	13	111.0
T6	D3	Red	12	159.5
T7	D1	Black	11	153.5
T8	D2	Black	15	258.7
T9	D3	Black	11	276.0
T10	D1	White	17	121.3
T11	D2	White	19	271.7
T12	D3	White	27	222.3
T13	D1	Green	20	181.7
T14	D2	Green	18	333.7
T15	D3	Green	16	263.7

3.6 Number of fruits and fruit yield.

The total accumulation of number of fruits occurs under green shade net followed by white shade net, red shade, black shade, and controlled shows in table (8). The higher amount of the fruit yield occurs in the green shade net. 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.

Table 10 Cost benefit ratio of Bell pepper.

Treatment	Date of transplanting	Shade	Cost of cultivation	Gross return	Net return	Benefit cost ratio
T1	D1	Controlled	66,266	92,867	39,867	1.6
T2	D2	Controlled	66,266	1,38,600	92,134	2.4
T3	D3	Controlled	66,266	1,46,767	1,01,467	2.5
T4	D1	Red	80,000	90,533	23,467	1.3
T5	**D2**	**Red**	**80,000**	**77,700**	**8,800**	**1.1**
T6	D3	Red	80,000	1,11,650	47,600	1.6
T7	D1	Black	80,000	1,07,450	42,800	1.5
T8	D2	Black	80,000	1,81,067	1,26,933	2.6
T9	D3	Black	80,000	1,93,200	1,40,800	2.8
T10	D1	White	80,000	84,933	17,067	1.2
T11	D2	White	80,000	1,90,167	1,37,333	2.7
T12	D3	White	80,000	1,55,633	97,867	2.2
T13	D1	Green	80,000	1,27,167	65,333	1.8
T14	**D2**	**Green**	**80,000**	**2,33,567**	**1,86,933**	**3.3**
T15	D3	Green	80,000	1,84,567	1,30,933	2.6

3.7 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 7. Gross returns 2,33,567 Rs/hac was found to be highest treatment with date of transplanting second and the minimum gross return was found under red shade net 77,700 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 3.3 in second date of sowing and the minimum cost ratio to be lowest under red shade net 1.1 in first 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 controlled condition occurs more desirable under Black shade for height and chlorophyll content. Under white shade, the dry matter and leaf area index occur maximum under it. In terms of yield and yield attributes the maximum number of fruits occur under green shade net and maximum 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 other shade net. The conclusion is based on the results of one year experimentation.

5. References

A.P. Karunakar, M.B. Nagdeve, A.B. Turkhede and R.S. Mali (2018), Agro-Meteorological Indices for Soybean Crop under Different Growing Environment, International Journal of Current Microbiology and Applied Sciences., 7(8): 4617-4627

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

Baranchuluun, S. Bayanjargal, D. Adiyabadam (2014) A Cost Benefit Analysis of Crop production with various irrigation systems. *IFEAMA SPSCP***,** 1.5: 146-156.

Belel. M.D., (2012) Effects of Grassed and Synthetic Mulching Materials on Growth and Yield of Sweet Pepper (Capsicum annuum) in Mubi, Nigeria**.** *Journal of Agriculture & Social Sciences.* 8(3): 2-3

Beneragama, C.K. and Goto, K. (2010) Chlorophyll a: b ratio increases under low-light in

'Shade-tolerant' Euglena gracilis. Tropical Agricultural Research, 22: 12-25.

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

Bhutia, K.L., Bhutia, 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

Colaizzi, P. D., Evett, S. R., Howell, T. A., Tolk, J. A., (2006) Comparison of five models to scale daily evapotranspiration from one- time of the day measurement. *American Society of Agricultural and Biological Engineers,* (49):1409-1417

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

David, I. J and Adehi, M. U., (2014). Effectiveness of Split-Plot Design over Randomized Complete Block Design in Some Experiments. *Journal of Biology, Agriculture and Healthcare.* 4(19) 2224-3208

Divesh Choudhary, Raj Singh, C.S. Dagar, Anil Kumar, and Surender Singh (2018) Temperature Based Agrometeorological Indices for Indian Mustard under Different Growing Environments in Western Haryana, India. 7(1): 1025-1035

Duhan, P.K., (2016). Cost benefit analysis of tomato production in protected and open farm. *International Journal of Advanced Research in Management and Social Sciences,* **5:** 140-148.

El-Abd, M.T.G., Shanan, S.A., Abou-Hadid, A.F. and Saleh, M.M. (1994). Effect of different shading densities on growth and yield of tomato and cucumber plants. Egypt Journal of Horticulture, **21:** 65-80.

Irmak, S., Haman, D.Z., Bastug, R., (2000). Determination of Crop Water Stress Index for Irrigation Timing and Yield Estimation of Corn. *Agronomy journal*, 92(6):1221-1227.

Ityel, E., A. Ben-Gal, M. Silberbush, and N. Lazarovitch (2014). Increased root zone oxygen by a capillary barrier is beneficial to bell pepper irrigated with brackish water in an arid region. Agricultural Water Manage 131:108–14.

Joseph Masabni, Youping Sun, Genhua Niu, and Priscilla Del Valle (2016) Shade Effect on Growth and Productivity of Tomato and Chili Pepper, *HortTechnology* 26(3): 344

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

Katungi, E., Karanja, D., Wozemba, D., Mutuoki, T., Rubyogo, J.C (2011) A cost benefit analysis of farmer-based seed production for common Bean in Kenya. *African Crop Science Journal,* 19: 409 – 415.

Khilesh Kumar Sahu, JL Chaudhary and Priyanka Verma (2020) Deriving the different agro meteorological indices under different growing environments for chickpea crop, 8(6): 2445-2448

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.

KV Ramana Rao, Suchi Gangwar, Pushplata Aherwar, Deepika Yadav (2023) Effect of shadenet color and its intensity on tomato crop performance. Emirates Journal of Food and Agriculture. 35(1): 86-90

Lee Kalcsits, Stefano Musacchi, Desmond R. Layne b, Tory Schmidt, Giverson Mupambi, Sara Serraa, Manoella Mendozac, Laura Asteggianoa, Sanaz Jarolmasjedd, Sindhuja Sankarand, Lav R. Khot, Carlos Zúnig Espinoza (2017). Above and belowground environmental changes associated with the use of photoselective protective netting to reduce sunburn in apple. *Agricultural and Forest Meteorolog*.9–17:237–238

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. Dı́ 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

Mingshan, Xu. (2021). Microenvironment filtering and plant competition jointly structure trait distributions across co-occurring individuals. *Ecological indicator*.129:1-8

NS Solanki, Santosh Devi Samota, Bhagwat Singh Chouhan and Gopal Nai (2017) Agrometeorological indices, heat use efficiency and productivity of wheat (Triticum aestivum) as influenced by dates of sowing and irrigation. Journal of Pharmacognosy and Phytochemistry,6(3): 176-180

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

Panda, N. K., J. C. Paul, B. Panigrahi, and J. N. Mishra. (2008) Energy requirement for capsicum cultivation in naturally ventilated greenhouse in coastal Orissa. Agricultural Engineering Today 32**:**23–27.

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

Paul B Timotiwu, Tumiar K Manik, Yohanes C Ginting (2021), Lettuce Growth and Production under Plastic Shading as a Response to different Microclimate Condition: A Preliminary Study of Climate Change Factors Impact on Crops. 7(1): 2454-1850

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.

Premdeep, ML Khichar, Ram Niwas, Madho Singh, and Sagar Kumar (2019), Agrometeorological indices in relation to phenology of wheat, 8(1): 2500-2503

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

Sayed Ahmad Naderi, Amin Lotfalian Dehkordi, Morteza Taki (2019) Energy and environmental evaluation of greenhouse bell pepper production with life cycle assessment approach. *Environmental and Sustainability Indicators* 3:1-9

Semida, W.M., (2017). Effects of shade level and microenvironment on vegetative growth, physiological and biochemical characteristics of transplanted cucumber (Cucumis sativus). *Archives of Agriculture and Environmental Science.* 2(4): 361-368

Singh, B., and K. N. Sharma. (2007). Tree growth and nutrient status of soil in a poplar (Populus deltoids Bartr.)-based agroforestry system in Punjab, India. *Agroforest Systems* 70:125–34.

Singh, B., and N. P. S. Sirohi. (2006). Protected cultivation of vegetables in India: Problems and prospects. *Acta Horticulturae* 710**:**339-342.

Suat Irmak, Dorota Z. Haman, and Ruhi Bastug (2000) Determination of Crop Water Stress Index for Irrigation Timing and Yield Estimation of Corn. *Journal of Agronomy*.

2:1221–1227

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

Tinyane, P.P., (2013). Influence of photo-selective netting on plant morphology, fruit quality and bioactive compounds in tomato cultivars. (A MSc thesis, Faculty of Science, Tshwane University of Technology, Pretoria. 161:340-349

V.J. Kanase, A.M. Bhosale and V.N. Shinde (2018) Studies on Effect of Planting Dates on Growth, Yield and Quality of Broccoli (Brassica oleracea L. var. italica) cv. Green Magic International Journal of Current Microbiology and Applied Sciences. 6: 78-86

V.L. Barradas, (2004). Transpiration and canopy conductance in young apricot (Prunus armenica L.) trees subjected to different PAR levels and water stress. *Agricultural Water Management.*77(1-2):323-333

Verma, P.K., Agrawal, N., Tamrakar, S., Tiwari, R.B., (2018). Cost Benefit Analysis of Vegetables Crops at Borsi Farm of DKSCARS, Bhatapara, Chhattisgarh, India. *International Journal of Current Microbiology and Applied Sciences*, 1112-1115.

Wael M. Semida, Mohamed S. Ammar and Nevein A. El-Sawah (2017) Effects of shade level and microenvironment on vegetative growth, physiological and biochemical characteristics of transplanted cucumber (Cucumis sativus). Archives of Agriculture and Environmental Science. 2(4): 361-368

Yogesh, M.S., Mokshapathy, S., (2013). Production and Export Performance of Black Pepper. *International Journal of Humanities and Social Science Invention,* 2(4):36-44