Environment and Ecology 41 (2A) : 953—960, April–June 2023
ISSN 0970-0420

Study the Micro Climatic Parameter in Protected Structure

Sojitra M. A., Satasiya R. M., Rank H. D., Chauhan P. M., Parmar H. V., Patel D. V.

Received 31 October 2022, Accepted 16 March 2023, Published on 17 May 2023

ABSTRACT

Sustainability only in traditional farming is challenging nowadays due to the increasing world population and rapid urbanization. Protected cultivation is the only way for the production of fruits and vegetables to manifold. Climate surrounding the plant plays an important role in crop production which can be modified only in protected cultivation. Therefore climatic sensors were installed and configured with an automatic logging system to measure the climatic parameters inside the Natural Ventilated Net-cum-Poly house, Shadenet house and open field at an interval of 1 h and the data was analyzed at 9:00, 12:00, 15:00 and 18:00 h of the day. The solar insolation was recorded at 10 min interval inside the structure by pyranometer whereas in the open, a solar sun tracking system coupled with a pyrheliometer was installed to measure direct solar radiation. The maximum temperature was recorded in a Natural Ventilated Net-cum-Poly house followed by an Open and Shadenet house. The relative humidity was recorded highest in Shadenet followed by Natural Ventilated Net-cum-Poly house and open field. It is obvious to light intensity and solar insolation was observed highest in the open field followed by Natural Ventilated Net-cum-Poly house and Shadenet house. The seasonal mean temperature difference was found higher in the Natural Ventilated Net-cum-Poly house followed by the open field with respect to Shadenet house. The seasonal mean relative humidity difference was found higher in the Shadenet house followed by the Natural Ventilated Net-cum-Poly house with respect to the open field. The seasonal mean light intensity difference was recorded highest inside the Shadenet house followed by the Natural Ventilated Net-cum-Poly house with respect to open field. The Solar Insolation was reduced in Shadenet house followed by Natural Ventilated Net-cum-Poly house with respect open field.

Keywords Climatic parameters, Protected structure, Sensors, Automatic logging system.

INTRODUCTION

The world's population reached nearly 7.6 billion in 2017 and it may be added one billion more at the end of 2030 (United Nations 2017). The continuously increasing world population simultaneously raise the

Sojitra M. A.[1]*, Rank H. D.[3], Parmar H. V.[5]
[1]PhD Student, [3]Professor and Head, [5]Associate Professor
Department of Soil and Water Engineering, CAET, JAU, Junagadh 362001, Gujard, India

Satasiya R. M.[2]
[2]Principal
Polytechnic in Agricultural Engineering, JAU, Targhadia, India

Chauhan P. M.[4]
[4]Professor and Head
Department of Renewable Energy Engineering, CAET, JAU, Junagadh, India

Patel D. V.[6]
[6]Associate Professor
Department of Agricultural Statistics, COA, JAU, Junagadh, India

Email: manojsojitra@yahoo.com
*Corresponding author

demand for food globally. Worldwide, around 47% of the world's population lived in urban areas at the end of the year 2000 and this proportion reached to 55% at the end of the year 2018 (United Nations, 2017). United Nations has projected 60% of the world's population will be lived in urban areas by 2030. The world's land and water resources systems are finite. The continuous increases in urbanization and industrialization strain land and water resources that require higher agricultural production per unit of land and water resources (FAO 2011).

It is difficult to feed the entire world population through traditional farming. Heavy rain, thunderstorms, excessive solar radiation, and uncertain climates are the main constraint of open field cultivation (Max *et al.* 2009, Choudhury *et al.* 2022). The protected structure is designed and constructed in a way that uses solar insolation to optimize the microclimate for plant growth (Choab *et al.* 2019). A greenhouse system protects plants against the external environments to help crops grow which raises production and quality (Santosh *et al*. 2017a, Constantinos *et al*. 2013). Many scientists reported high insect pest infestation pressure (Nguyen *et al.* 2009), fungal diseases (Korawan *et al.* 2013) reducing the crop yield that could be eradicated through protected cultivation (Quamruzzaman *et al.* 2022). The intrusion of modern technic and tools through scientific intervention, production can be multiplied many folds per unit of land and water resources (Santosh *et al.* 2017b, Pahuja *et al.* 2013).

The optimum climate conditions in protected structures produce higher growth and yield than open field conditions reported by many scientists (Shukla *et al.* 2019, Singh *et al.* 2016, Santosh *et al.* 2017b). The choice of greenhouse covering materials also plays a very crucial role in optimizing microclimate (Abdel-Ghany *et al.* 2012, Shukla *et al.* 2019, Kim *et al.* 2022). The various covering material like glass, linear light density poly ethylene, shadenet, insect net and a combination of plastic and shadenet with different thicknesses and percentages of shading influence the solar insolation which modified microclimate parameter (Rivera *et al.* 2017). Rocha *et al.* (2021) reviewed the types, colour, properties, transmissivity, shading percentage and thickness of covering material impact the microclimate inside the protected structure. Abdel-Ghany *et al.* (2012) reviewed the effect of cover type on the transmittance of photo synthetically Active Radiation (PAR), the reflectance or absorptance of NIR and the greenhouse air temperature. Choab *et al.* (2019) also reviewed that shape, orientation and characteristics of the covering material play a crucial role for optimize the microclimate.

Plastic covered structures with natural ventilation and shadenet house are most dominate in tropical and subtropical regions with a passive climate control system (Rocha *et al.* 2021, Yasoda *et al.* 2018). It is necessary to study the impact of covering material or types of protected structures on microclimate parameters and need to be determined for region specific structures the most useful. Therefore, the present approach was carried out to study variations of microclimatic parameters in Natural Ventilated Net-cum-Poly house, Shadenet house and open field in the semiarid region with crop conditions.

MATERIALS AND METHODS

Location

The experiment was conducted at Greenhouse complex, Departmental of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh, located at 21.52 °N latitude and 70.47 °E longitude with an altitude of 107 meter above mean sea level on the western side of the foothills of the Girnar. The area is situated in the South Saurashtra Agro Climatic Zone of Gujarat State.

Climate

The study area is typically subtropical and semi-arid climate, characterized by fairly cold and dry winter, hot and dry summer and warm and moderately humid during monsoon. Winter sets in the month of November and continues till the mid of the February. January is the coldest month of the winter. Summer commences in the second fortnight of February and ends in the middle of June. April and May are the hottest months of summer. The average annual rainfall

Table 1. Specification of air temperature and Relative Humidity.

Sl. No.	Particular	Air temperature	Relative Humidity
1	Range	-40 to 123.8ºC	0 to 100%
2	Accuracy	+0.5 ºC @ 5 to 40 ºC	+2 % @ 20 to 80%
3	Resolution	0.01 ºC typical	0.05 % RH typical

and evaporation is 950 mm and 2482 mm respectively.

Measurement of climatic parameters

The Temperature, Relative Humidity and Light intensity sensor were installed to study microclimatic parameters inside a Natural Ventilated Net-cum-Poly house, Shadenet house and Open field with automatic data logging system. The sensors measured climatic parameters at an hour time intervals for 24 h and it was analyzed at 3 h intervals at 9:00, 12:00, 15:00 and 18:00. The specification of Temperature-Humidity and Light sensors were presented in Tables 1-2 respectively.

Installation of pyrheliometer and Pyranometer

The net solar insolation was measured inside the structures as well as the open field to determine the irrigation water requirement. Therefore, a pyranometer was installed inside both structures as shown in Plate 1.These pyranometers were configured to Data Taker data logger system. The specifications of Data Taker data logger were provided in Table 3. The daily direct solar insolation in open field was collected from the Solar Energy Laboratory, Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh where a pyrheliometer meter is installed with a sun tracking system that measures direct beam solar radiation as shown in Plate 2. The data was recorded round the day at 10 minute interval in watt per square meter. These data were cumulative at the end of the day which converted into MJ per square per day. The data was retrieved from the data logger every alternate day through LAN connected computer. The specifications of the pyrheliometer and pyranometer were provided in the Tables 4-5 respectively.

Table 2. Specification of light sensor.

Sl. No.	Particular	Light sensor
1	Light range	0-200000 lux
2	Cosine @45º zenith angle	±4 %
3	Cosine @75º zenith angle	±10 %
4	Absolute accuracy	±5%
5	Repeatability	±1%
6	Operating environment	-40 to 55ºC, 0 to 100 RH

Table 3. Specification of the DT 80 DataTaker data logger.

Sl. . No.	Particular	Detail
		Integrates over 50/60 Hz line period for accuracy and noise rejection
1	Sampling	Maximum sample speed : 40 Hz Effective resolution : 18 Bits Linearity : 0.01% Common mode rejection : >90dB Line series mode rejection : > 35dB
2	SDI-12	4 SDI-12 Inputs, shared with digital channels each input can support multiple SDI-12 sensors
3	Internal data storage	128mb (Approximately 10,000,000 data points)
4	Operating range	Temperature: -45°C to 70°C Humidity: 85% RH, Non-condensing
5	Accuracy	±1 min/year (0°C to 40°C), ±4 min/year (-40°C to 70°C)

Plate 1. Installation of pyranometer inside the Natural Ventilate Net-cum-Poly house and Shadenet house.

Plate 2. Pyrehelio meter with automatic sun tracking system.

RESULTS AND DISCUSSION

Climatic parameters

Daily temperature, Relative Humidity, Light intensity and Solar insolation were measured and analyzed for the structures as well as in the open field. The Daily temperature, Relative Humidity and Light intensity were measured at 9:00 h, 12:00 h, 15:00 h and 18:00 h from the month of November to January for the year 2021 and 2022. The solar radiation was measured at 10 minute intervals daily during the crop season.

Table 4. Specification of pyrheliometer.

Sl. No.	Specification	Value
1	ISO classification (ISO 9060 : 1990)	First class pyrheliometer
2	Response time (95 %)	2 sec
3	Spectral selectivity	< ± 1 % (0.35 to 1.5x10^{-6} m)
4	Temperature response	< ± 1 % (-10 to +40 °C) < ± 0.4 % (-30 to +50 °C)
5	Measurement range	0 to 4000 W/m^2
6	Sensitivity range	7 to 15 x 10-6 V/(W/m^2)
7	Rated operating temperature range	-40 to +80 °C
8	Rated operating Relative Humidity range	0 to 100 %

Table 5. Specification of pyranometer.

Sl. No.	Specification	Value
1	Viewing angle	2π steradians
2	Irradiance	0-4000 w/m^2
3	Spectral range	300-3000 nm
4	Sensitivity	1.0 mv/w/m^2
5	Operating temperature	-35 to 60 ºC
6	Operating humidity	0-100% RH
7	Output impedance	65 Ω
8	Measurement input impedance	1M Ω
9	Power requirement	5 to 15 VDC, 6mA
10	Bubble level resolution	0.1º
11	Response time	7±1 sec

Temperature

The mean monthly temperature was increased from 9:00 h to 15:00 h and then decreased from 15:00 h to 18:00 h as shown in Fig.1.The mean monthly

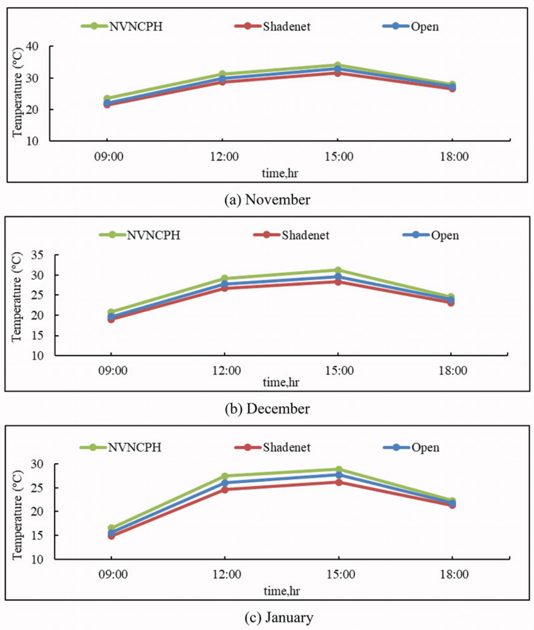

Fig. 1. The variation of monthly mean temperature (°C) in the structures and open field.

temperature was recorded as the highest inside the Natural Ventilated Net-cum-Poly house followed by Open and Shadenet house which similar result observed by Satasiya *et al.* (2022). This might be due to the accumulation of heat due to the greenhouse effect inside the Natural Ventilated Net-cum-Poly house. Shadenet house recorded the lowest seasonal mean temperature which might be due to less solar insolation intrusion inside the structure. It could be also seen Fig.1 that the mean monthly temperature decreased from the month of November to January inside the structures as well as the open field which might be due to the decline of the sun to the southern direction. The mean monthly maximum temperature was recorded as 33.5 ºC and 34.6 ºC at 15:00 h in a Natural Ventilated Net-cum-Poly house during the month of November for the year 2021 and 2022 respectively. Near-infrared and infrared radiation is responsible for the accumulation of heat in the environment. The intrusion of Near Infrared (NIR) radiation in a plastic house creates a greenhouse effect which increases the temperature. Whereas, it was recorded minimum as 15.0ºC and 14.8ºC inside the Shadenet house during the month of January for the year 2020-21 and 2021-22 respectively at 9:00 h. Similar results were also obtained by Satasiya *et al.* (2022) and Yasoda *et al*. (2018). The seasonal mean maximum temperature difference was recorded as 2.8 ºC and 1.4 ºC inside the Natural Ventilated Net-cum-Poly house and open field respectively at 15:00 h with respect to Shadenet house. The seasonal mean minimum temperature difference was recorded as 1.3 ºC and 0.6 ºC in inside the Natural Ventilated Net-cum-Poly house and open field respectively with respect to Shadenet house at 18:00 h.

Relative humidity

The variation of the mean monthly Relative Humidity inside the structures and open field conditions were presented graphically as shown in Fig.2. It could be seen in Fig. 2 that the mean monthly humidity decreased from 9:00 h to 15:00 h and then increased from 15:00 h to 18:00 h. The mean monthly maximum Relative Humidity was recorded inside the Shadenet house followed by Natural Ventilated Net-cum-Poly house and open field which might be due to less air movement inside the structure as compared to the

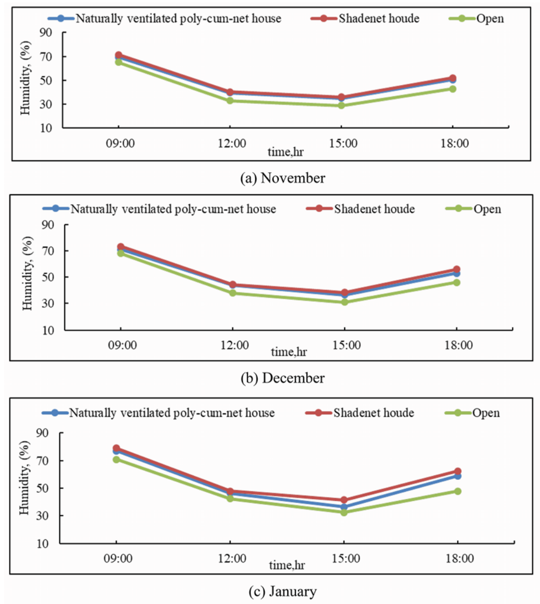

Fig. 2. The variation of monthly mean Relative Humidity (%) in the structures and open field.

open field which similar results reported by Satsiya *et al.* (2022). It also shows in Fig.2 that the mean monthly Relative Humidity increased from the month of November to January. The mean monthly maximum Relative Humidity was recorded as 78.0 % and 80 % inside the Shadenet house in the month of January for the years 2020-21 and 2021-22 respectively at 9:00 h which might be due to light fog was observed in the early morning. The mean minimum Relative Humidity was recorded as 29 % for 2020-21 and 2021-22 at 15:00 h in the open field which might be due to an increase in ambient temperature which reduces the percentage of moisture in the air. The maximum Relative Humidity difference was recorded inside the Shadenet house (11%) followed by the Natural Ventilated Net-cum-Poly house (9 %) with respect to the open field at 18:00 h. The mean seasonal minimum Relative Humidity difference was found inside the Shadenet house (7%) and Natural Ventilated Net-cum-Poly house (5 %) with respect to open field in general. It could be seen from the Fig. 2 that the lines representing the humidity of both structures are overlapped with each other which indicates the humidity percentage more or less remained the same in both structures. The Relative Humidity was

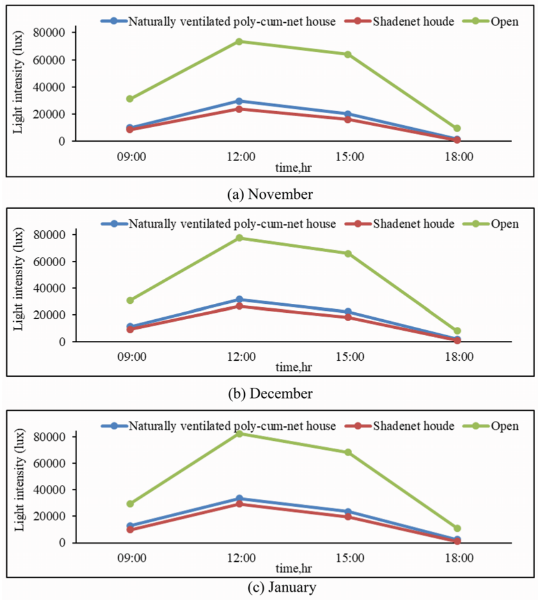

Fig. 3. The variation of monthly mean light intensity (lux) in the structures and open field.

increased as the temperature was decreased and vice versa as can be seen from Figs. 1-2. The temperature was increased from 9:00 to 15:00 and decreased from 15:00 to 18:00 simultaneously humidity was decreased from 9:00 to 15:00 and increased from 15:00 to 18:00.

Light intensity

The variation in the monthly mean Light intensity inside the structures as well as an open field is presented graphically in Fig. 3. It can be seen from Fig.3 that the mean monthly mean Light intensity was increased from 9:00 h to 12:00 h and then decreased from 12:00 h to 18:00 h. The mean monthly Light intensity was recorded as highest in the open field followed by Natural Ventilated Net-cum-Poly house and Shadenet house which is in line with Yasoda *et al.* (2018) and Satasiya *et al.* (2022). It could be also seen in Fig. 3 that the monthly mean Light intensity was increased from the month of November to January inside the structures as well as open field. The monthly mean maximum Light intensity was recorded as 81145 lux and 83737 lux at noon in an open field in the month of January for 2020-21 and 2021-22 respectively. It could be also seen from Fig. 3 that the mean seasonal

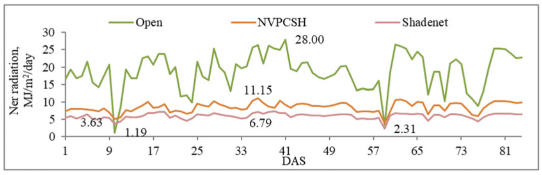

Fig. 4. Daily mean solar energy received, MJ/m²/day during November to January of 2020-21 and 2021-22.

maximum Light intensity difference was recorded in Shadenet house (51495 lux) followed by the Natural Ventilated Net-cum-Poly house (46460 lux) with respect to the open field at 12:00 h. Whereas, seasonal mean of minimum Light intensity difference was also recorded inside the Shadenet house (8537 lux) followed by Natural Ventilated Net-cum-Poly house (7490 lux) with respect to the open field at 18:00 h.

Solar insolation

The dry biomass is influenced by solar radiation. The daily mean solar energy received in the year 2020-21 and 2021-22 are depicted in Fig. 4. It can be seen from Fig. 4 that the mean solar energy of the year 2020-21 and 2021-22 ranged from 28 to 1.19, 11.15 to 3.63 and 7.28 to 2.31 MJ/m^2/day in the open field, Natural Ventilated Net-cum-Poly house and Shadenet house respectively. It is obvious to solar insolation was found lower inside the structures but it was more than sufficient in Natural Ventilated Net-cum-Poly house as well as Shadenet house according to Nisen *et al*. (1988). Nisen *et al*. (1988) reported the minimum amount of irradiation necessary to ensure sufficient growth and flowering corresponds to daily global radiation of 2.0–2.3 kWh/m^2/day. The relationship between the solar energy received from the sun in an open field, Natural Ventilated Net-cum-Poly house and Shadenet are also present in Fig. 5. It could be seen from Fig. 5 that there was a good correlation of

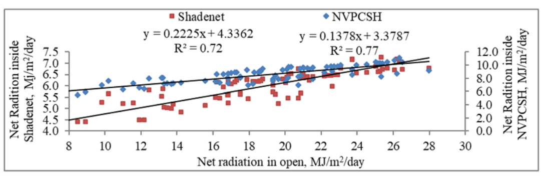

Fig. 5. Relationship between daily mean solar energy received in NVNCPH and shadenet house with open field.

solar energy received inside the Natural Ventilated Net-cum-Poly house and Shadenet in comparison with to open with a correlation coefficient 0.72 and 0.77 respectively. Mourao and Hadley (1997) reported that under plastic film crop covers reduced solar radiation by approximately 25% to 38%. The solar insolation was reduced to 29 % to 65% in Natural Ventilation Net-cum-Poly house whereas it was reduced to 48% to 74 % in Shadenet house with respect to open field which is in line with Mourao and Hadley (1997).

CONCLUSION

The seasonal mean maximum temperature difference was found as 3.0ºC and 1.6ºC in Natural Ventilated Net-cum-Poly house and Open field respectively and the seasonal mean minimum Temperature difference was recorded as 1.0 ºC and 0.5 ºC in Natural Ventilated Net-cum-Poly house and open field respectively with respect to Shadenet house. The seasonal mean maximum Relative Humidity difference was found as 11% in the Shadenet house followed by Natural Ventilated Net-cum-Poly house (9 %) at 18:00 h and seasonal mean minimum Relative Humidity difference was recorded as 7% in the Shadenet house followed Natural Ventilated Net-cum-Poly house (5 %) with respect to the open field at 12:00 h. The seasonal mean maximum of Light intensity difference was recorded as 51495 lux in the Shadenet house followed by naturally ventilated Net-cum-poly house (46460 lux) at 12:00 h. and seasonal mean minimum Light intensity difference was recorded as 8537 lux in the Shadenet house and 7490 lux Natural Ventilated Net-cum-Poly house at 18:00 h with respect to open field. The Solar insolation was reduced in the range of 29 % to 65% and 48% to 74 % of open field in Natural Ventilation Net-cum-Poly house and Shadenet house respectively. It is to be confirmed that the micro climatic parameter can be modified as analyzing of micro climatic data inside the structures as well as open field. This modified environment promote the yield and yield attribute.

REFERENCES

Abdel-Ghany AM, Al-Helal IM, Alzahrani SM, Alsadon AA, Ali IM, Elleithy RM (2012) Covering materials incorporating radiation-preventing techniques to meet greenhouse cooling challenges in arid regions: A review. *The Scientific World J* doi:10.1100/2012/906360

Choab N, Allouhi A, El Maakoul A, Kousksou T, Saadeddine S, Jamil A (2019) Review on greenhouse microclimate and application: Design parameters, thermal modeling and simulation, climate controlling technologies. *Solar Energy* 191:109-137.

Choudhury S, Islam N, Mustaki S, Uddain J, Azad MOK, Choi KY, Naznin MT (2022) Evaluation of the different low-tuch protective cultivation approaches to improve yield and phytochemical accumulation of papaya (*Carica papaya* L.) in Bangladesh. *Horticulturae*, 8(3): 210. https://doi.org/10.3390/horticulturae8030210

Constantinos Kittas, Nikolaos Katsoulas, Thomas Bartzanas, Sjaak Bakker (2013) Driving Forces for Greenhouse Climate Control and Sustainable Energy Use In Mediterranean Greenhouses in Good agricultural practices for greenhouse vegetable crops: Principles for mediterranean climate areas, FAO Plant Production And Protection Paper, pp 217.

FAO (2011) The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

Kim HK, Lee SY, Kwon JK, Kim YH (2022) Evaluating the effect of cover materials on greenhouse microclimates and thermal performance. *Agronomy* 12(1):143-158.

Korawan S, Johannes FJ, Max, Suchart S, Wolfram S, Siriya K, Joachim M (2013) Protected cultivation of tomato to enhance plant productivity and reduce pesticide use. Conference on International Research on Food Security, Natural Resource Management and Rural Development.University of HohenheimTropentag Stuttgart. Germany, pp 17-19.

Max JFJ, Horst WJ, Mutwiwa UN, Tantau HJ (2009) Effects of greenhouse cooling method on growth, fruit yield and quality of tomato (*Solanum lycopersicum* L.) in a tropical climate. *Scientific Hort* 122(2): 179-186.

Mourao IMG, Hadley P (1997) Environmental control of plant growth development and yield in broccoli (*Brassica oleracea* L. var. *Italica Plenk*): Crop responses to light regime. I*n Intl Symp Brassica 97,10th Crucifer Genetics Workshop* 459: 71-78.

Nguyen THN, Borgemeister C, Max J, Poehling HM (2009) Manipulation of ultraviolet light affects immigration behavior of Ceratothripoidesclaratris (Thysanoptera: Thripidae) *J Econ Entomol* 102 (4): 1559-1566.

Nisen A, Grafiadellis M, Jiménez R, La Malfa G, Martínez-García PF, Monteiro A, Verlodt H, Villele O, Zabeltitz CH, Denis JC, Baudoin W, Garnaud JC (1988) Cultures protegees enclimat mediterraneen. FAO, Rome.

Pahuja R, Verma HK, Uddin M (2013) A wireless sensor network for greenhouse climate control." *IEEE Pervasive Computing* 12(2): 49-58.

Quamruzzaman A, Islam F, Akter L, Hossain M, Mallick S (2022) Effect of different net houses on the incidence of insect on vegetable, crops. *Adv Entomol* 10: 223-232.

Rivera SA, Ferreyra R, Robledo P, Selles G, Arpaia ML, Saavedra J, Defilippi BG (2017) Identification of pre-harvest factors determining postharvest ripening behaviors in 'Hass' avocado under long term storage. *Sci Hortic* 216: 29–37.

Rocha GAO, Pichimata MA, Villagran E (2021) Research on the microclimate of protected agriculture tructures using numerical simulation tools: A technical and bibliometric analysis as a contribution to the sustainability of under-cover cropping in tropical and subtropical countries. *Sustainability* 13(18): 10433-483.

Santosh DT, Tiwari KN, Kumar Vikas Singh Raja, Gopala Reddy A (2017a) Microclimate control in greenhouse. *Int J Curr Microbiol Appl Sci* 6 (3): 1730-1742.

Santosh DT, Tiwari KN, Singh VK (2017b) Influence of different protected cultivation structures on water requirements of winter vegetables. *Int J Agricult, Environ Biotechnol* 10(1): 93-103.

Satasiya RM, Sojitra MA, Kothiya AV, Chuhan PM (2022) Effect of protected environment on off-season seedling raising of papaya. *Environ Ecol* 40(2B): 650-655.

Shukla C, Acharya SK, Bhakar SR, Jamrey PK (2019) Effect of different microclimate on the physiological parameters and yield of capsicum. *Hortic Int J* 3(2): 61-67.

Singh MC, Yousuf A, Singh JP (2016) Greenhouse microclimate modeling under cropped conditions-A review. *Res Environ Life Sci* 9: 1552-1557.

United Nations, Department of Economic and Social Affairs, Population Division (2017) World Population Prospects 2017 – Data Booklet (ST/ESA/SER.A/401).

Yasoda PGC, Pradheeban L, Nishanthan K, Sivachandiran S (2018) Effect of different shade levels on growth and yield performances of cauliflower. *Int J Environ Agric Biotechnol* 3(3): 948-953.