Journal of Scientific Research and Reports

Volume 30, Issue 10, Page 643-663, 2024; Article no.JSRR.124520
ISSN: 2320-0227

Spatial Variation of Microclimatic Parameters Inside a Polyhouse with Fog Cooling System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i102490

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/124520

Original Research Article

Received: 01/08/2024
Accepted: 03/10/2024
Published: 09/10/2024

ABSTRACT

The importance of protected cultivation is increasing day by day due to its capability of producing crop all round the year and increase in the crop productivity. This advantage of protected cultivation can be efficiently achieved by adapting the polyhouse cultivation. To obtain the maximum crop productivity inside a polyhouse, it is necessary to understand the variability of microclimate inside it. The present study aims to understand the spatial variability of microclimate inside a naturally

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Cite as: *Supraja, K.V.L., K. Krupavathi, G. Ravi Babu, and Ch. Someswara Rao. 2024. "Spatial Variation of Microclimatic Parameters Inside a Polyhouse With Fog Cooling System". Journal of Scientific Research and Reports 30 (10):643-63. https://doi.org/10.9734/jsrr/2024/v30i102490.*

ventilated polyhouse installed with fog cooling system during summer season. The main aim of the study is to understand the effect of fogging system in spatial variability of microclimate. For the study, the data of microclimatic parameters were collected daily from April to June at four different time intervals 8.30 AM, 12.30 PM, 4.30 PM and 8.30 PM. The data recorded was then analyzed in Golden Surfer Software to generate contour plots of weekly averages of microclimate parameters. The analysis revealed that the temperature and relative humidity varied across the polyhouse depending upon the wind velocity and its distribution pattern. The light intensity varied based upon the orientation of polyhouse and the position of sun. Carbon dioxide concentration varied based on temperature, light intensity, crop transpiration and respiration. It can be concluded that, inside a naturally ventilated polyhouse, the microclimate varied both spatially and temporally with fogging system also due to wind effect. Thus, having accurate understanding of the microclimate inside a polyhouse helps to maintain optimal conditions for plant growth and thus improve crop yield and productivity.

Keywords: Protected cultivation; foggers; polyhouse; microclimate; spatial variability; crop productivity.

1. INTRODUCTION

In the last few years, researchers were focusing to improve the crop growth and yield irrespective of the season. One way to achieve increased crop productivity is through protected cultivation in polyhouses, which provide a controlled environment for plants to grow [1]. A polyhouse is defined as a framed or inflated structure covered with a transparent or translucent material in which crops can be grown under controlled conditions and is large enough for people to enter and perform cultural operations [2-4]. In India protected cultivation area is around 30000 ha which contribute 0.23% of horticulture cropped area Suresh et al*.,* [5] and is increasing rapidly. The studies and the growing popularity indicate the ability of protected cultivation in enhancing the crop productivity.

While, polyhouse is most effective against adverse climatic conditions [6], it remains heterogeneous with irregular temperature, relative humidity, CO_2 concentration, and irradiation distributions that require management [7]. This heterogeneity in microclimate necessitates the need to analyze the spatial and temporal variability of the microclimate since it plays a vital role in preserving the crop quality and productivity. The variability of microclimate inside a polyhouse and its effect on crop growth was studied by many researchers.

Villagran and Bojaca [8] conducted a study to determine the microclimatic behavior of a passive spatial-type greenhouse used in Colombia for carnation production. The results revealed that the microclimate generated inside the greenhouse was not suitable for carnation production. Suay et al. [9] carried out an experiment to assess the variability of temperature and humidity patterns in a greenhouse occupied with mature rose crop. The results derived an analysis explaining the heterogeneous distribution of microclimate inside the polyhouse. Jerszurki et al. [10] studied the vertical profiles of CO_2 concentration, actual vapor pressure, air, leaf and soil temperatures in a semi-closed greenhouse and a naturally ventilated greenhouse and concluded that air circulation is vital. Soni et al. [11] investigated vertical air temperature distribution in a greenhouse with natural ventilation. They reported that a large temperature gradient was observed in the vertical direction, and the maximum temperature difference was approximately 5 °C. But still, scarce data is presently available about inside microclimate of production greenhouses for both day and night periods [9].

It is well known that greenhouses are constructed with various models and designs based on the local climatic conditions. Therefore, it is necessary to perform a full-size field test of a particular greenhouse to obtain reliable data [12]. The present study aims to record and analyze the spatial and temporal variability of microclimate inside a polyhouse provided with fog cooling system which was operated for a time period of 15 minutes with an interval of 1 hour from 10 AM to 4 PM. The study was conducted in a naturally ventilated polyhouse to assess the influence of external climate on greenhouse microclimate during the summer months (April to June). The effectiveness of a fog cooling system in mitigating the adverse effects of external conditions and maintaining optimal low-temperature, high-humidity conditions for crop growth was also evaluated. For this purpose, the data on temperature, relative humidity, light intensity and carbon dioxide concentration was collected at various location at four different time intervals of 8.30 AM, 12.30 PM, 4.30 PM and 8.30 PM.

2. METHODOLOGY

2.1 Description of the Study Area

The study was conducted in a naturally ventilated polyhouse (Fig. 1) located at Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh, India at latitude 15°53’47” N and longitude 80°27’37” E which is 8 km away from Bay of Bengal and at an Altitude of 6 meters above the mean sea level. The dimensions of the polyhouse can be described as 20m in length, 12m in width and 2.5m height. The walls of polyhouse were made of HDPE (High Density Poly Ethylene) Monofilament Yarn of 50 mesh size and the covering material was greenhouse film of 200 micron.

2.2 Data Collection

The data of microclimate includes the data of temperature, relative humidity, light intensity and carbon dioxide concentration. The polyhouse was constructed facing the east, which lets the wind movement from south to north. The data points were collected accordingly, which were greatly influenced by wind distribution. Thus, the data was collected from the west wall (back wall) at a distance of 2.7 m and at an interval of 3.8m up to the east wall and from the north wall, the data was collected at a distance of 2.1m and at an interval of 2.8m up to the south wall. The data collection points were shown in the Fig. 2. The temperature-relative humidity data were collected using a temperature and humidity data logger. The data of light intensity was collected using a digital lux meter. The amount of carbon dioxide present in the air was determined using a gas analyzer. The data was collected for 3 months April, May and June.

2.3 Data Analysis and Statistics Generation

Data analysis is the process of inspecting, cleansing, transforming and modeling data to discover useful information, inform conclusions and support decision-making. The data of the microclimatic parameters which was collected at various points and different intervals of time was imported in excel sheets. Qualitative and Quantitative data analyses were conducted to identify the patterns, trends and relationships among the collected microclimatic parameters.

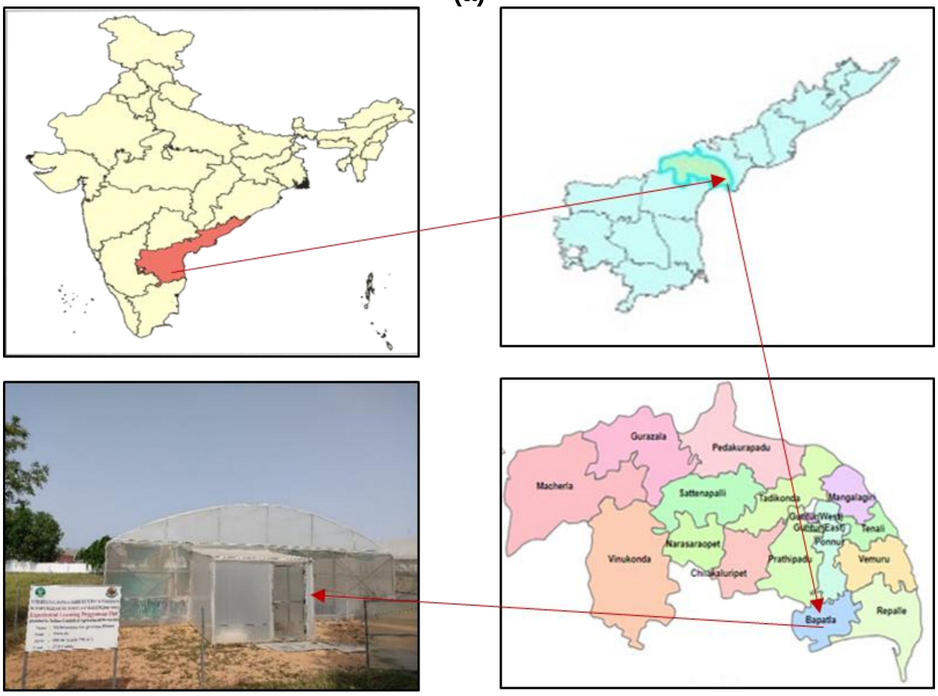
For this, the data was imported in excel sheet on a daily basis. This data was then rearranged on the basis of daily microclimate at each point respectively. Then, this data was quantitatively analyzed by calculating the weekly averages of each parameter of every point. This average data was arranged such that it can be utilized to generate qualitative data of the microclimate of the polyhouse on a day at various locations at different time intervals.

2.4 Microclimate Maps Generation

Qualitative data analysis of greenhouse microclimate involves interpreting non-numerical data to gain insights into the complex interactions and spatial variations within the greenhouse environment. To investigate the microclimate variability of the greenhouse, Golden Surfer Software was adapted. Golden Software's Surfer is a powerful tool designed for data analysis, particularly in the context of geospatial data. It offers a range of features that facilitate the analysis, visualization and communication of complex datasets. By analyzing the spatial variability and heterogeneity of microclimatic parameters, researchers can assess the effectiveness of various greenhouse designs, ventilation systems or shading strategies in creating optimal conditions for crop production.

This restructured data was imported into the Golden Surfer Software, to create 2D visualization of the horizontal variability of the microclimate across the polyhouse. For this, the collected data was arranged as the points of a coordinate system, since it was a geostatistical analysis. Thus, the points of data collection were taken as (X, Y) points and the microclimatic parameters were taken as Z coordinate. This data generates spatial maps of microclimate which exhibits the spatial variability in the form of contours.

(a)



(b)

Fig. 1 (a) Naturally Ventilated Polyhouse, (b) Location of the polyhouse under study

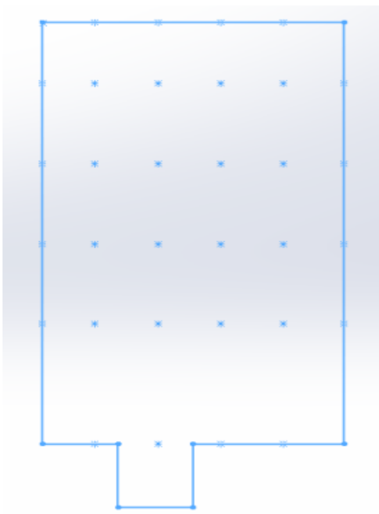


Fig. 2. Data collection points

3. RESULTS AND DISCUSSION

The microclimate data was imported in the Golden Surfer Software and contour maps were generated to analyze the spatial variability of the greenhouse microclimate across the polyhouse. The maps were generated for the weekly average data of the microclimatic parameters. The data was collected and analyzed for 13 weeks from April to June. The maximum and minimum values of microclimate parameters of the weekly averaged data were presented in Table 1.

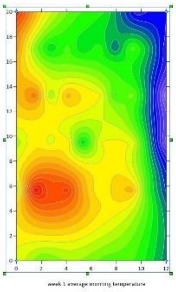
For better understanding, the polyhouse was divided into east, west, north, south and central parts. The polyhouse is oriented East- West and the wind direction in the area was South to North. The evening sea breeze moves from south to north. The foggers were operated with a run time of 15 minutes at an interval of 1 hour. The operation of foggers helped to reduce the temperature and maintain the relative humidity at an optimal level inside the polyhouse. The spatial variability of microclimate in each week was represented in the form of contour plots. The contour plots of week 1 to 13 were represented in Fig. 3 to Fig. 15.

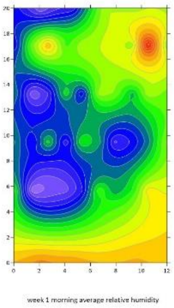
From Fig. 3, it was observed that the temperature in the morning and afternoon varied in the similar pattern, high temperatures were observed in the south and central regions while low temperatures were observed in the north zones. Temperature during the evening was observed to be high in the western part followed by south and north parts and low temperature was observed in east part. During the night, high temperature was observed at the southern end and also the temperature was uniformly varied from the south end to the north end. The values of relative humidity were observed to be higher in the north end. Humidity was negatively correlated with temperature. In the evening, the relative humidity was high in the central region with nearly spaced contours representing the narrow range of humidity values. This variability of humidity can be attributed to the operation of foggers, due to which humidity was observed to be high in the central region and less variability across the polyhouse. Lower values of humidity were observed in the south end which can be taken as the immediate effect of the wind distribution outside the polyhouse. During the night, it was observed that the relative humidity was distributed almost uniformly throughout the polyhouse except some points in the south end. The light intensity was observed to be high in the central part during afternoon while it was observed to be higher in south and east ends during morning and northern and western ends during the evening and the light intensity in the central region was lower in both cases.

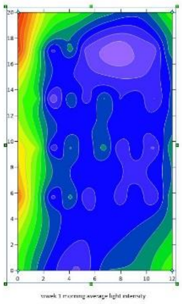
The amount of CO_2 present during the morning was observed to be distributed uniformly except at some points in the north end. While in the afternoon, it was observed to be high in the south part, average values in central region and lower values were observed near the south, west and east walls of the polyhouse. During evening it was observed to be high in central part with nearly spaced contours with decreasing values towards the walls representing narrow range of variation. During night, the irregular contour patterns indicate the variation of CO_2 concentration across the polyhouse with lower values at the eastern end and increasing contours towards the western region. The changes in the contour patterns can be attributed to the wind velocity patterns and air circulation.

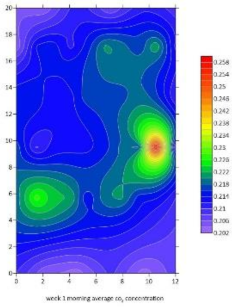
Table 1. Maximum and Minimum values of Microclimate parameters of weekly averaged data

Week	Microclimate Parameters							
	Temperature		Relative Humidity		Light Intensity		CO_2 concentration	
	Max	Min	Max	Min	Max	Min	Max	Min
1	36.87	28.77	99.9	60.45	27071.43	3273.33	0.24	0.20
2	36.92	26.94	99.9	69.61	31607.14	2621.43	0.23	0.20
3	36.73	28.41	99.9	58.94	33012.29	4023.00	0.23	0.21
4	37.69	29.04	99.9	59.75	17237.14	3589.48	0.24	0.21
5	37.57	28.86	99.9	60.64	14792.86	2584.76	0.24	0.21
6	37.20	29.14	99.9	58.85	13331.43	2623.71	0.24	0.21
7	37.60	29.27	99.9	60.71	16144.29	1694.86	0.24	0.22
8	38.43	29.76	98.34	59.39	18107.14	2635.90	0.24	0.21
9	36.92	29.91	99.9	62.49	13332.86	2069.24	0.24	0.19
10	37.15	28.90	98.29	61.5	18364.29	2770.62	0.24	0.20
11	37.84	29.98	99.9	60.16	16920.95	2932.62	0.24	0.19
12	36.28	29.73	98.29	62.19	19701.43	2153.57	0.24	0.18
13	37.71	29.88	97.5	96.03	23518.10	2389.86	0.25	0.21

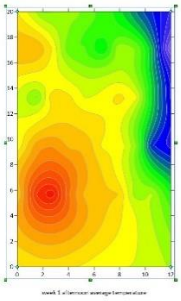

(a) Temperature

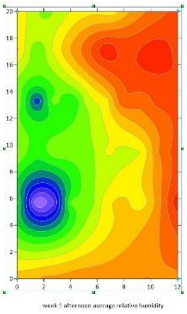

(b) Relative Humidity

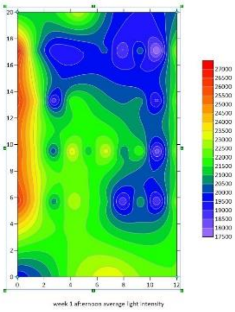

(c) Light Intensity

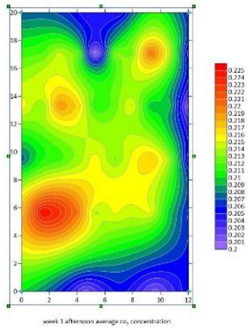

(d) CO_2 Concentration

i. Morning

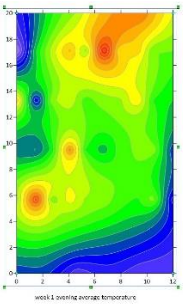

(a) Temperature

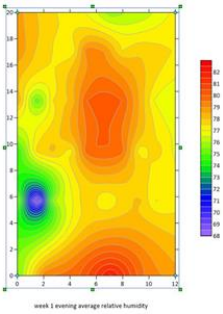

(b) Relative Humidity

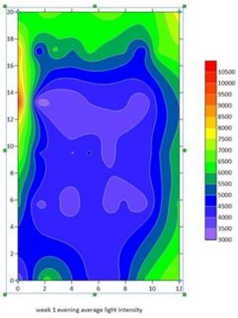

(c) Light Intensity

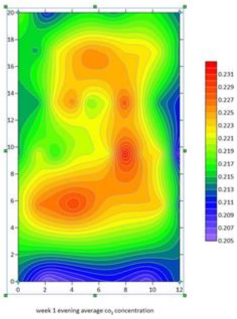

(d) CO_2 Concentration

ii. Afternoon

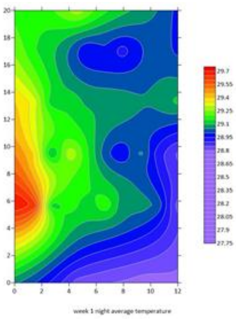

(a) Temperature

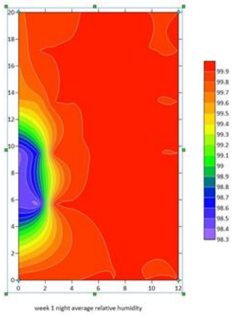

(b) Relative Humidity

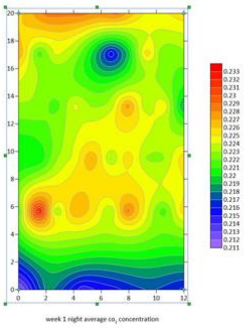

(c) Light Intensity


(d) CO_2 Concentration

iii. Evening

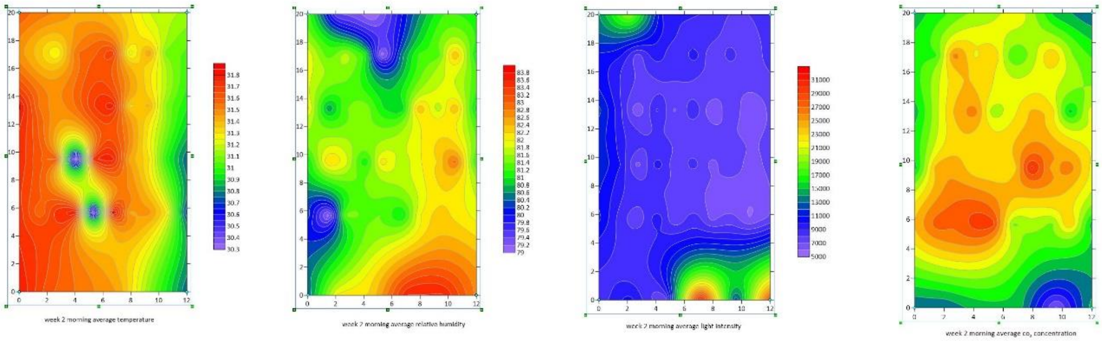

(a) Temperature


(b) Relative humidity


(c) CO_2 Concentration

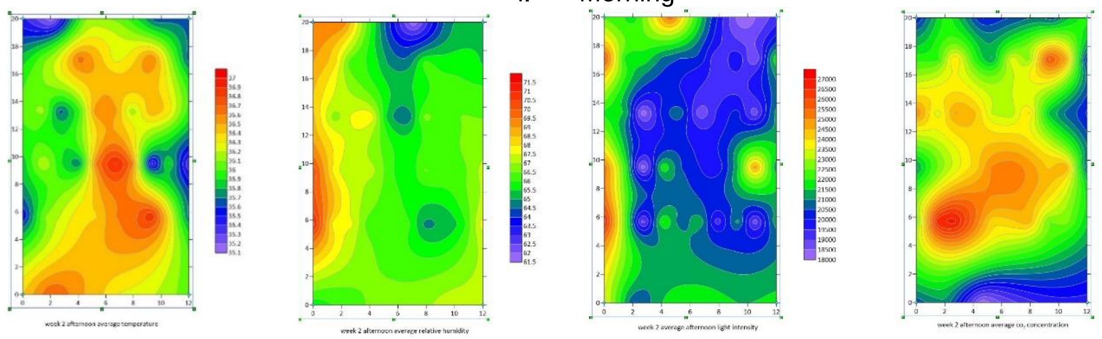
iv. Night

Fig. 3. Spatial variation of microclimate in week 1 inside the polyhouse



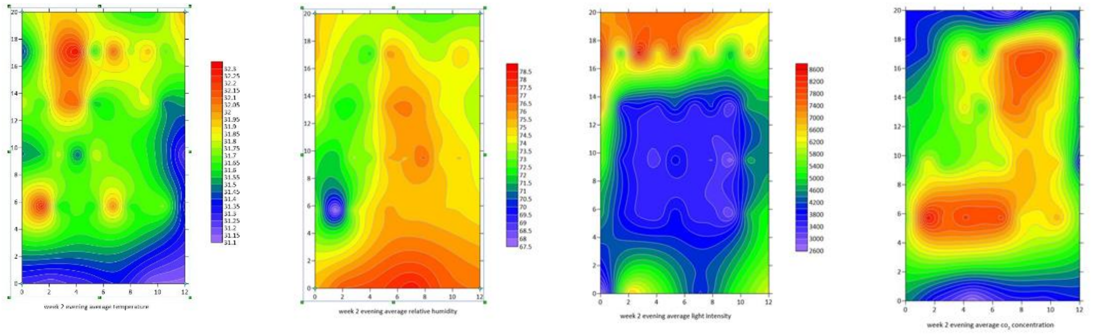
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



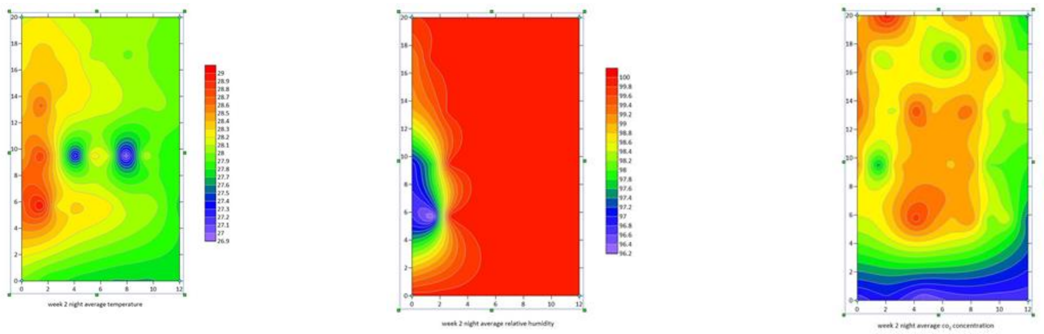
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

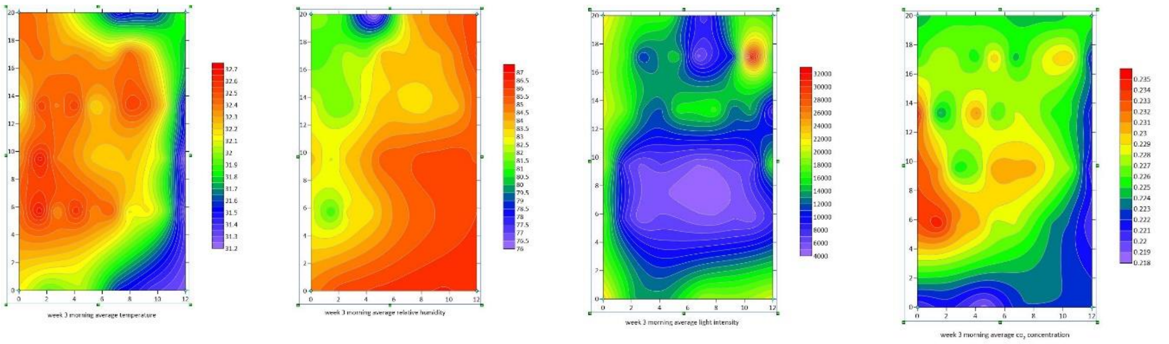
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

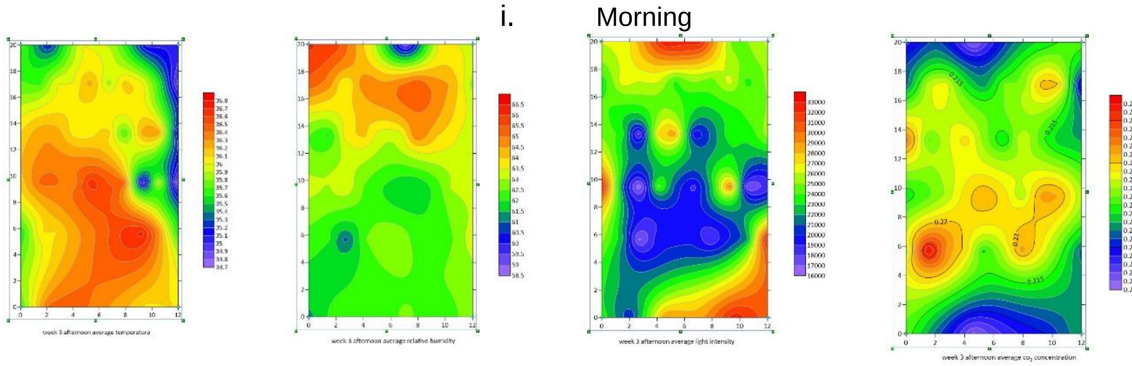
iv. Night

Fig. 4. Spatial variation of microclimate in week 2 inside the polyhouse



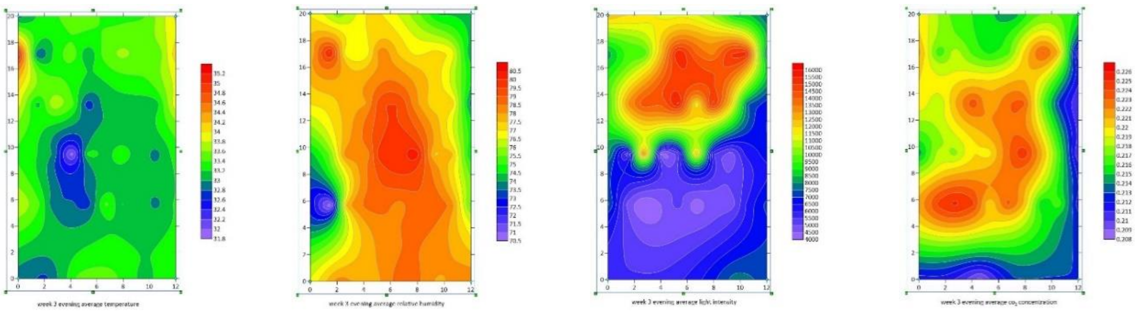
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



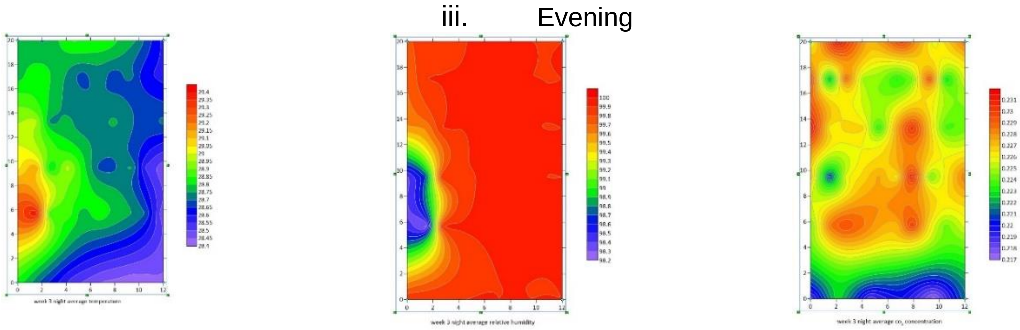
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

iii. Evening

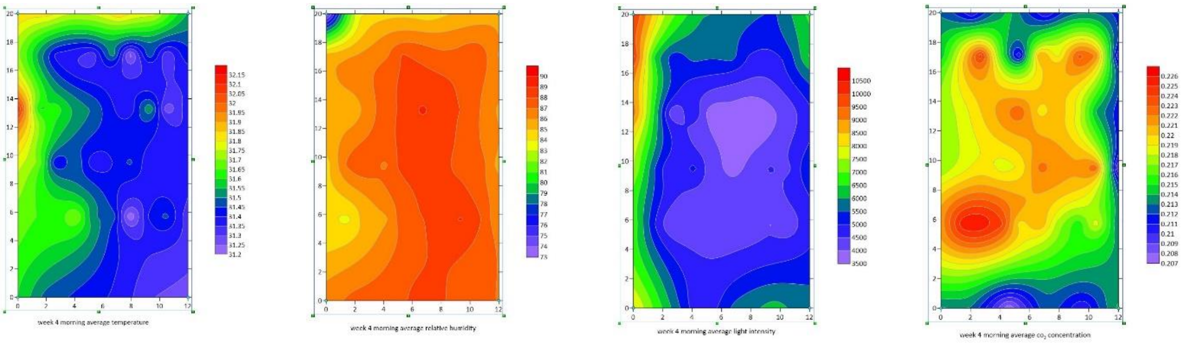


(a) Temperature (b) Relative humidity (c) CO_2 Concentration

iv. Night

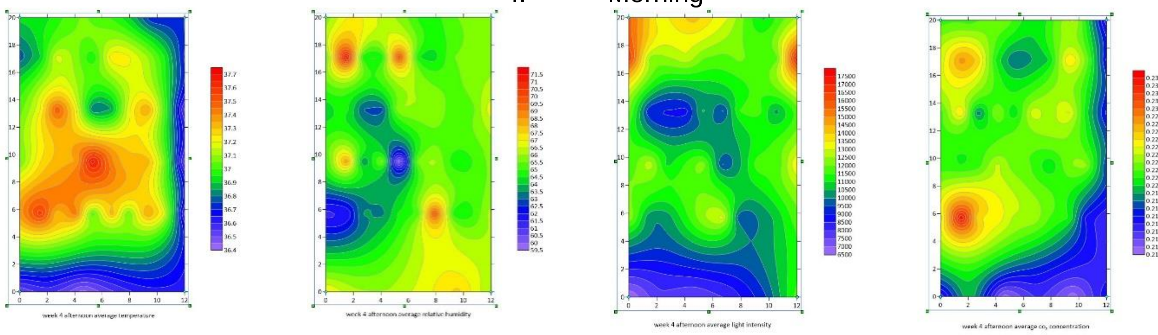
Fig. 5. Spatial variation of microclimate in week 3 inside the polyhouse

From Fig. 4, it was revealed that similar trends were observed as week 1, except for a few changes. It was observed that light intensity and humidity were slightly greater than that of week 1 while CO_2 concentration was slightly decreased form week 1 to week 2.



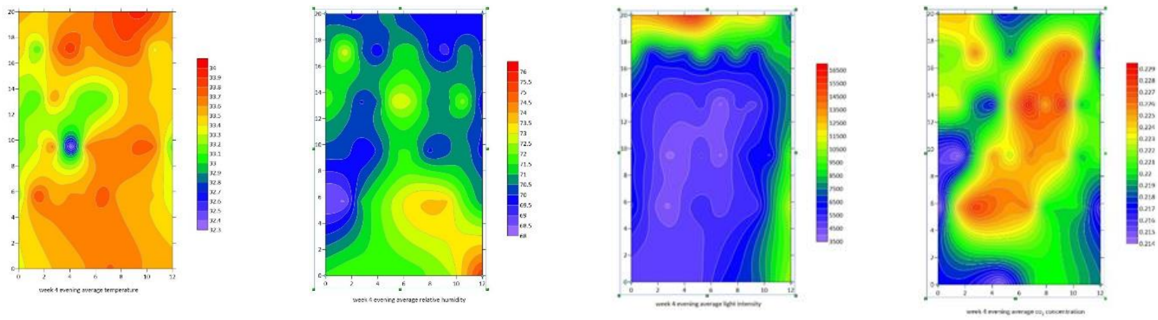
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



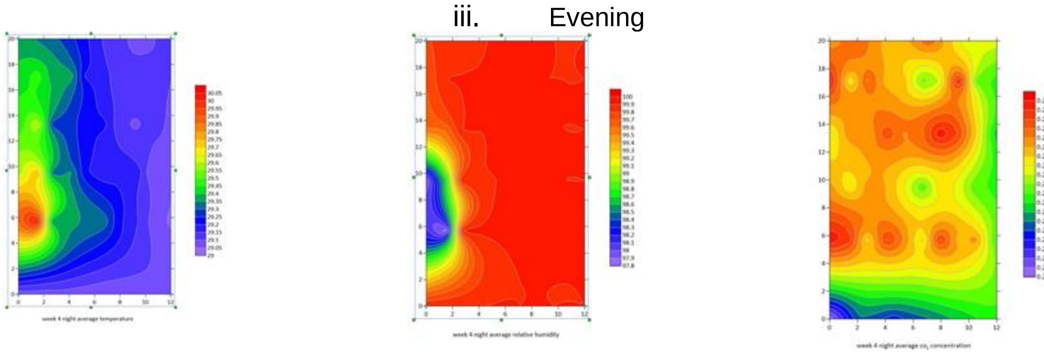
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

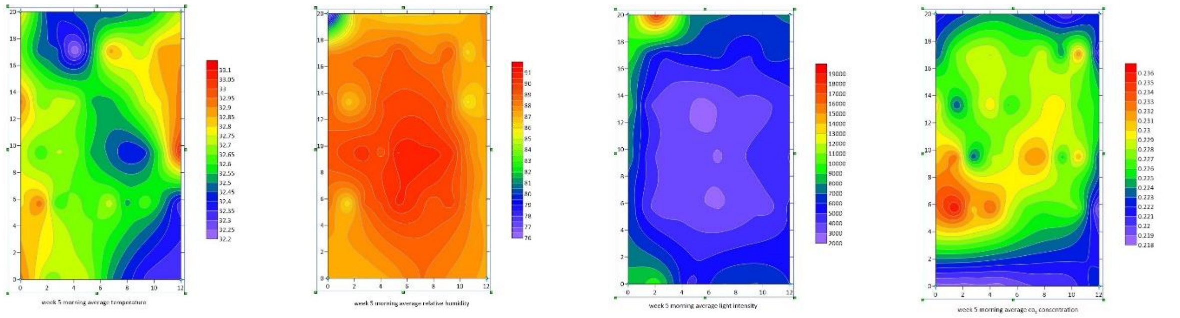
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

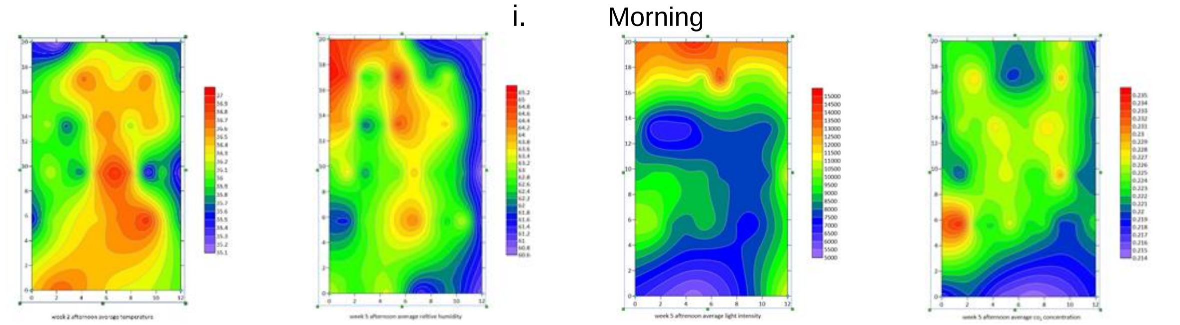
iv. Night

Fig. 6. Spatial variation of microclimate in week 4 inside the polyhouse



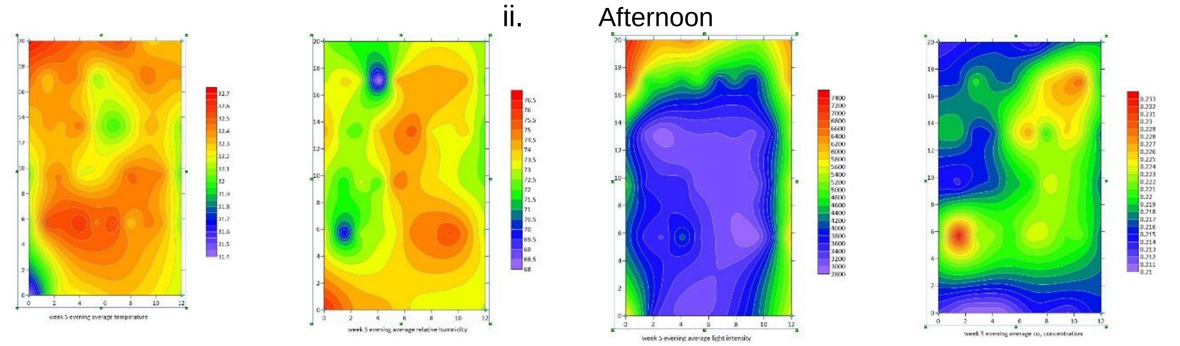
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



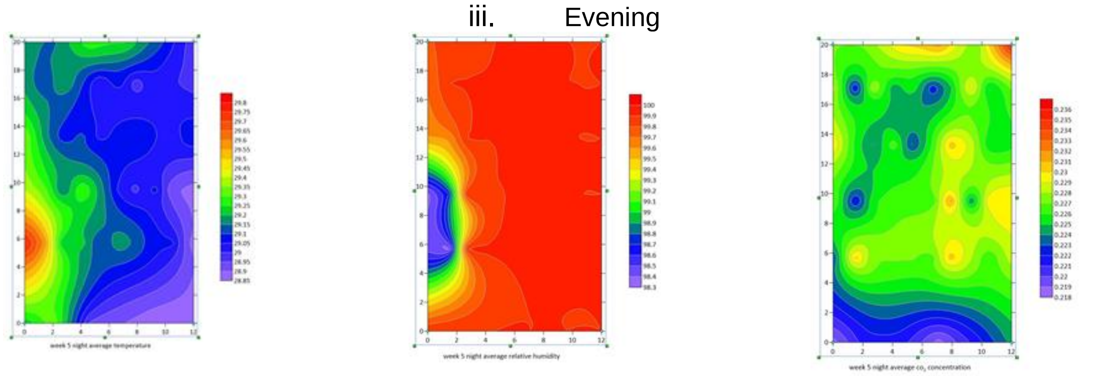
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

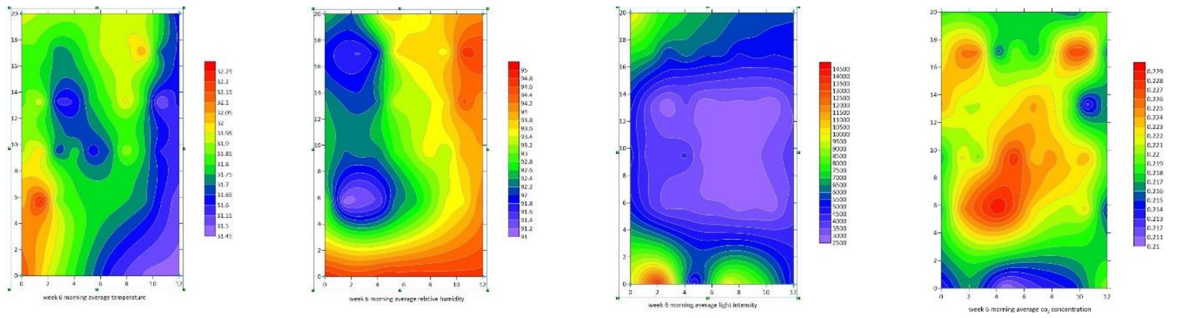
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

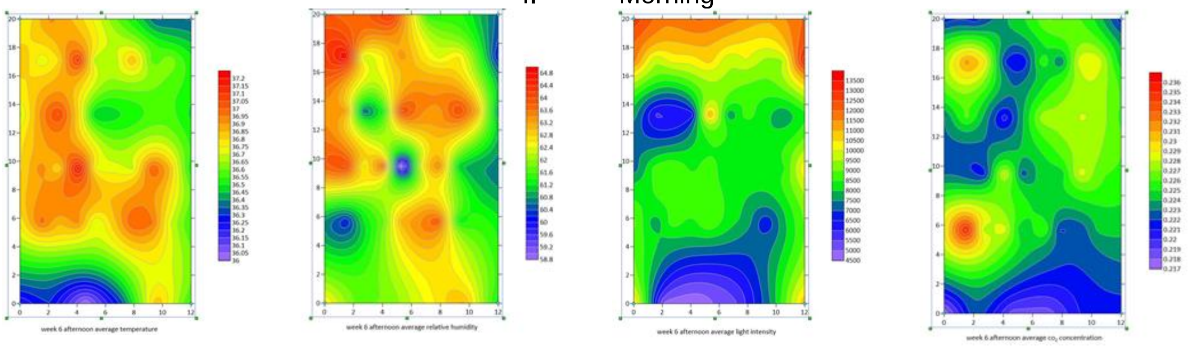
iv. Night

Fig. 7. Spatial variation of microclimate in week 5 inside the polyhouse



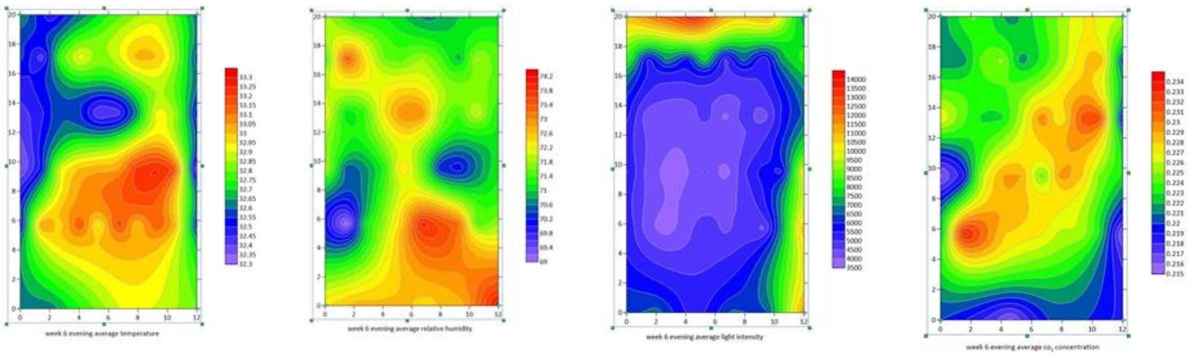
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



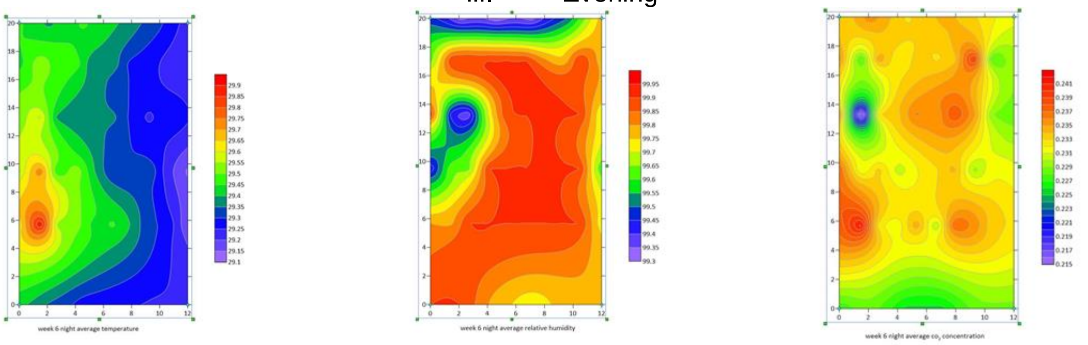
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

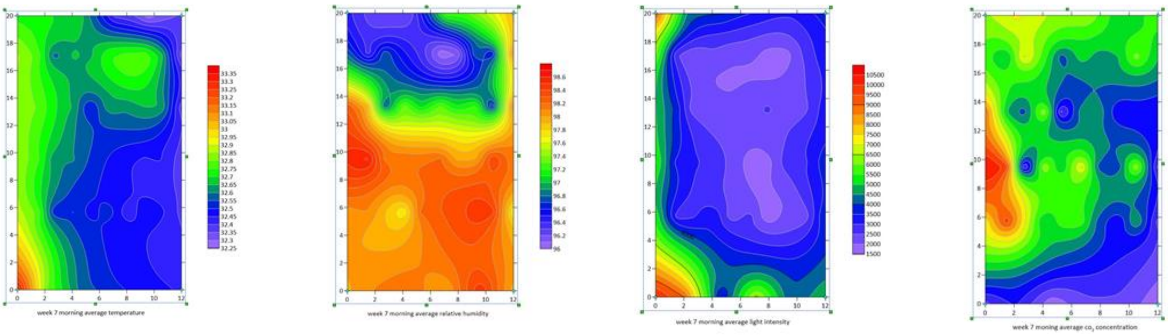
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

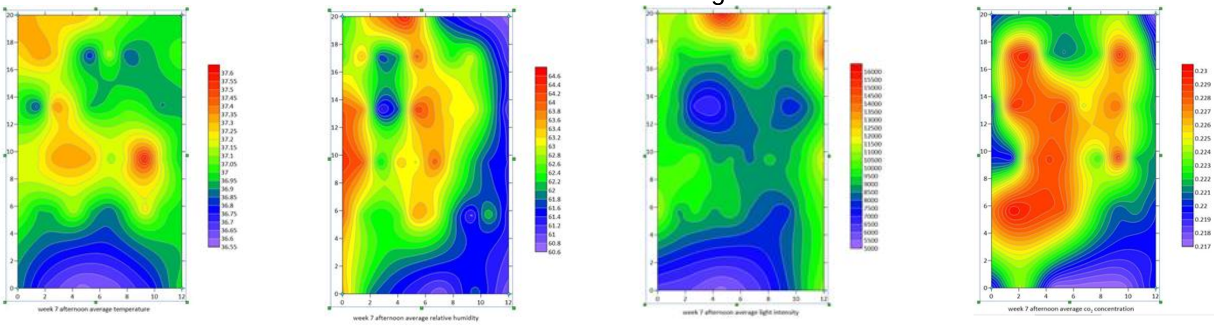
iv. Night

Fig. 8. Spatial variation of microclimate in week 6 inside the polyhouse



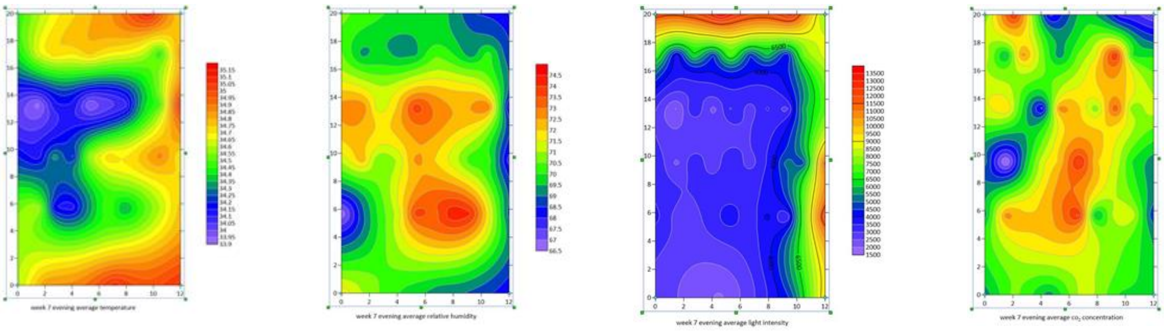
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



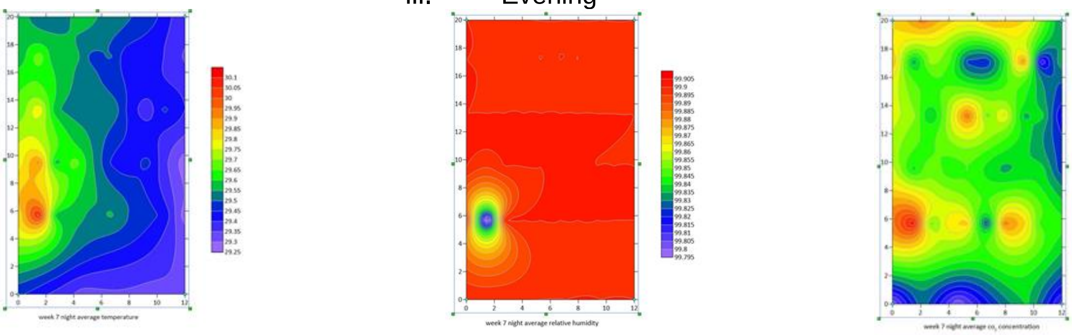
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

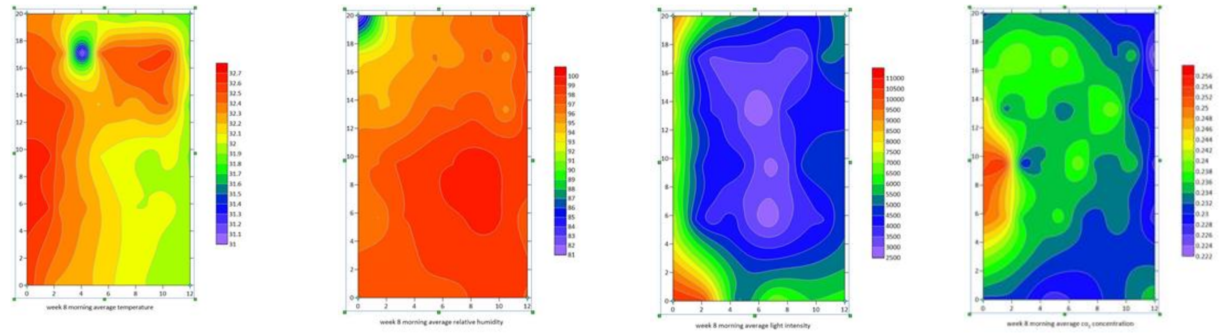
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

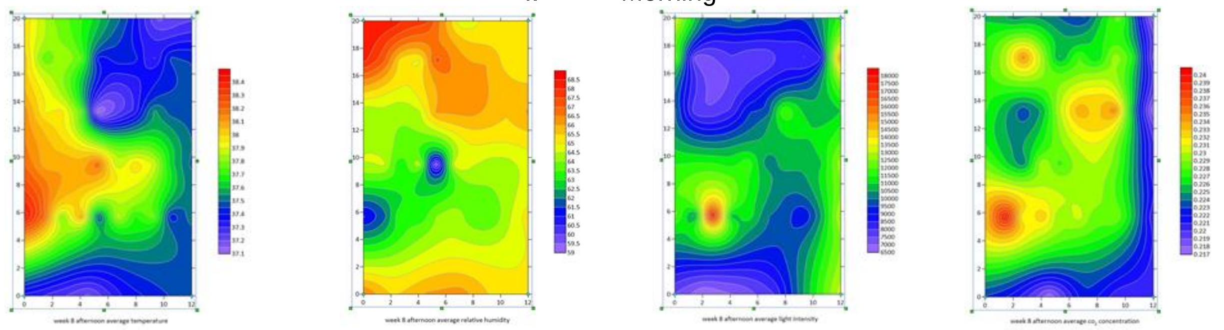
iv. Night

Fig. 9. Spatial variation of microclimate in week 7 inside the polyhouse



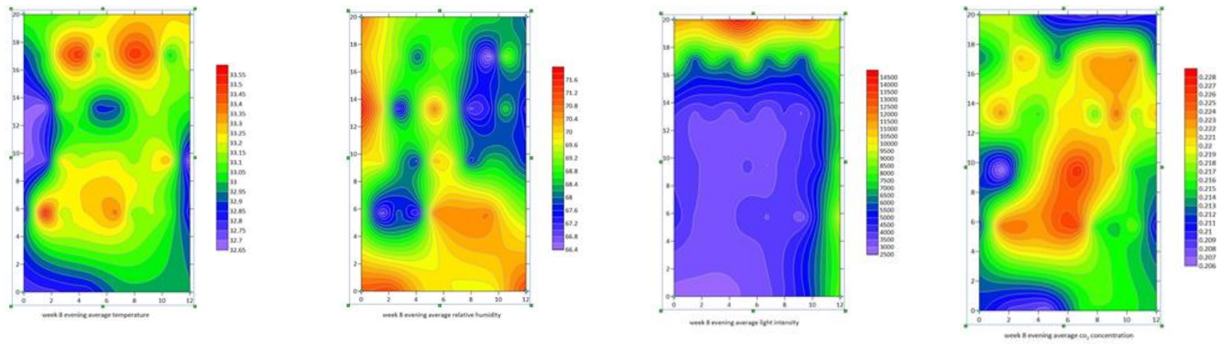
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



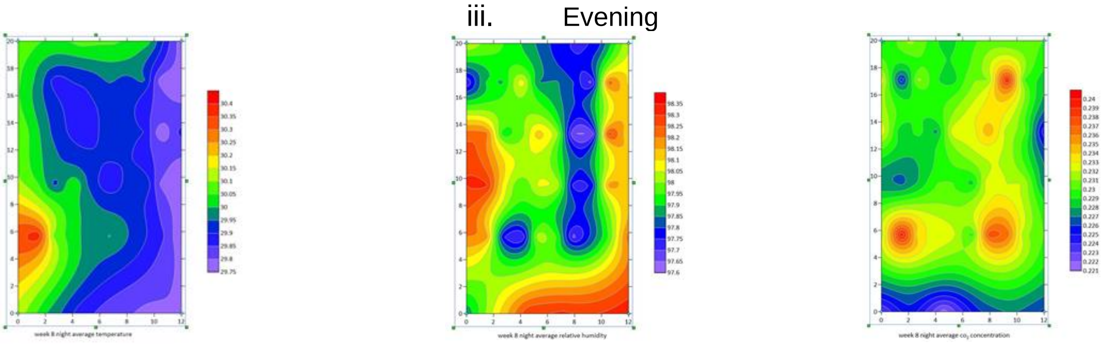
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

iv. Night

Fig. 10. Spatial variation of microclimate in week 8 inside the polyhouse

From the Fig. 5, it was found that the temperature and CO_2 distribution trends are similar to Week 1 and 2, while relative humidity in the morning was low in the south west part alone compared to the other parts of polyhouse with contours of narrow range distributed uniformly. Slight variability was observed in the distribution of sunlight having increased intensities compared to that of week 2.

It was observed that the variation of light intensity and CO_2 concentration of week 4 was in similar trend as that of week 2 with slightly reduced values as shown in Fig. 6. While the temperature was observed to be lower than that of week 3 with lower temperatures spread across the polyhouse with higher values near the south and west walls. And the relative humidity was observed to be spread inversely proportional to the observed temperature contours.

From Fig. 7, it was observed that the morning temperature was distributed irregularly forming cooler region in the central part and warmer parts near the walls. It was also observed that afternoon temperature varies similar to week 2 and the evening and night temperatures, humidity, light intensity and CO_2 concentration were found to vary in similar trend with week 4 with declination in the observed values.

From Fig. 8, it was observed that except relative humidity all the other microclimate parameters were in similar trend with week 5. The relative humidity was observed to be low in all the cases dividing the polyhouse into humid and non-humid regions with reduced values and irregular distribution across the polyhouse.

From Fig. 9, the temperature and light intensity distribution was observed to be in similar trend with week 4. The CO_2 concentration was observed to follow the trend of week 5. The relative humidity in the morning was observed to be high in west part of the polyhouse compared to that of east part.

Light intensity and CO_2 concentration distribution of week 8 across the polyhouse was observed with slight increment in the numerical values of week 7. While the temperature and relative humidity exhibit similar trends with week 3 with increased values (Fig. 10).

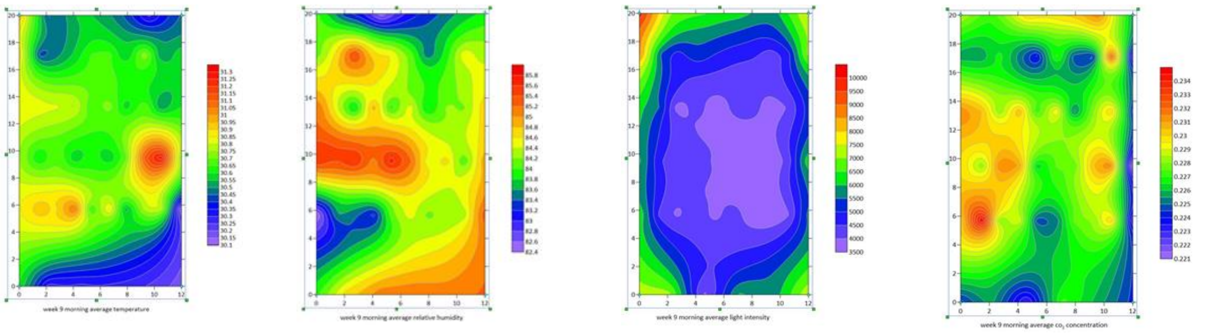
From Fig. 11, it was revealed that the microclimate parameters were in similar trend with week 6 except in the case of morning temperature and relative humidity. The temperatures in the morning and afternoon varied irregularly forming slightly warmer regions in the central part. And the humidity varied inversely with temperature.

The temperature, light intensity and CO_2 concentration of week 10 varied with a similar trend of week 8. The relative humidity in the morning and evening was similar, forming humid region in the central part of the polyhouse (Fig. 12). In the night, humidity was high near the east, south and north walls forming a 'W' contour with lower values between the walls and central line. The microclimate parameters in the morning and afternoon were in similar trend with that of week 5. While, the evening and night microclimate parameters were in similar trend with that of week 6 with slightly increased values (Fig. 13).

Form Fig. 14, it was revealed that the light intensity and CO_2 concentration were in similar trend with week 11. The temperature in the morning was observed to be uniformly spread with low values across the polyhouse with humidity inversely proportional to the temperature. Whereas the temperature and relative humidity in other intervals followed similar trend with week 10.

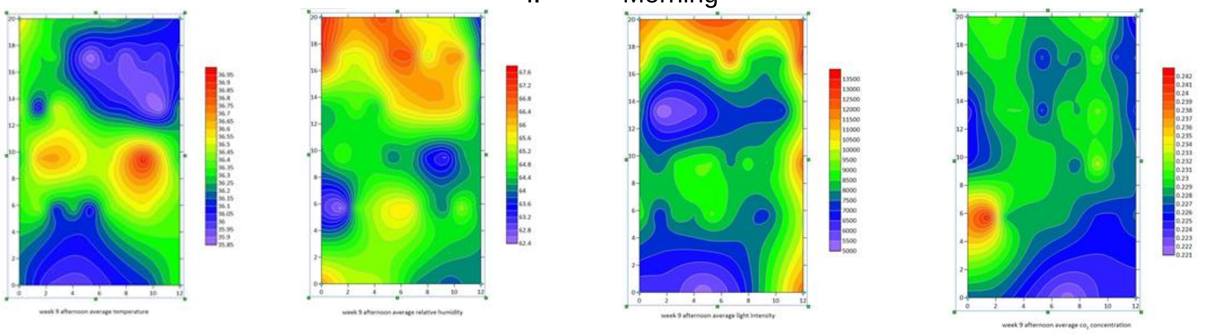
The last week, it was observed that the microclimatic parameters other than temperature exhibited similar trend with week 7, but the distribution of microclimate in the night time was in similar trend with week 12. The temperature was observed to follow the temperature distribution in week 2, but with increased values.

From the generated contour plots, the general observations included that the temperature and relative humidity contours were changing from south to north. The pattern of these contours can be attributed to the wind velocity, distribution and air circulation. Kittas et al*.,* [13] also reported that the ventilation influences temperature, humidity and CO_2 concentration, which directly affect the growth and development of crops. The south end of the poly house was immediately affected by the wind movement and thus high temperatures and low relative humidity levels were observed compared to that of the north end. Ganesan [4] also reported that the lower relative humidity inside the greenhouse may be due to proper ventilation.



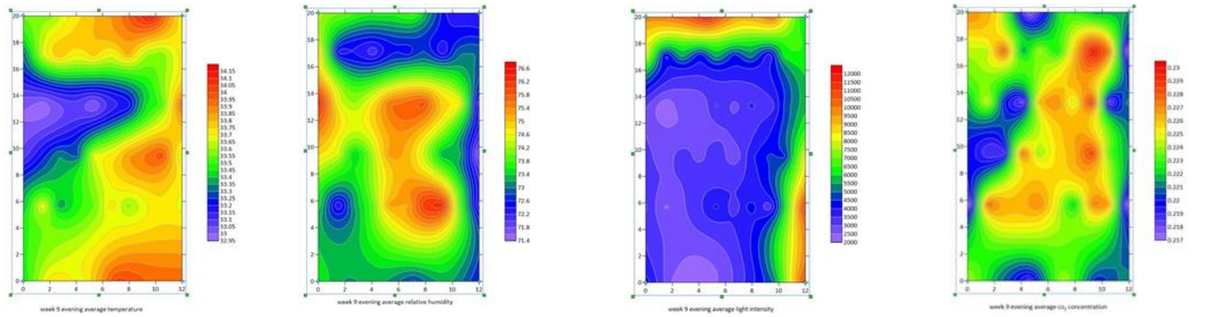
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



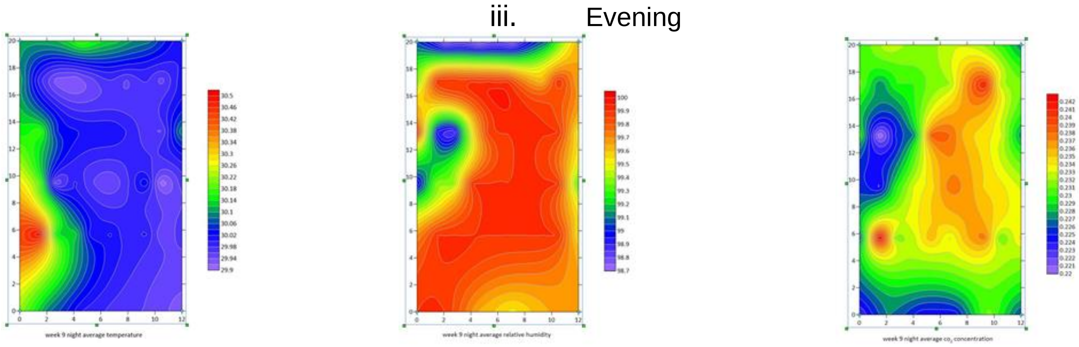
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

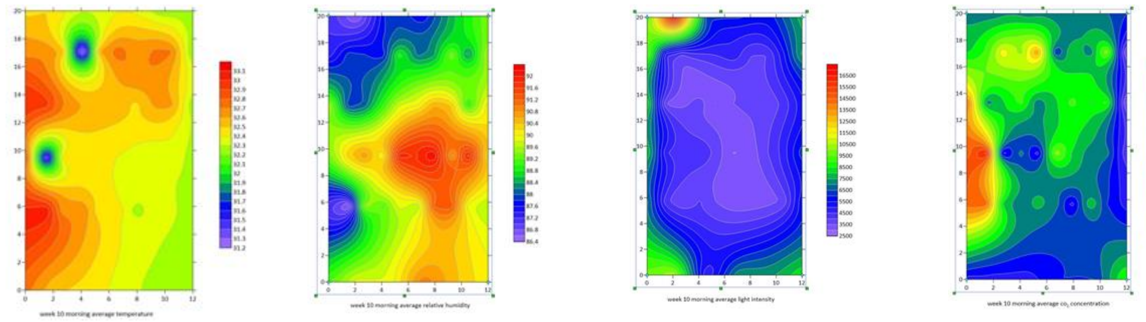
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

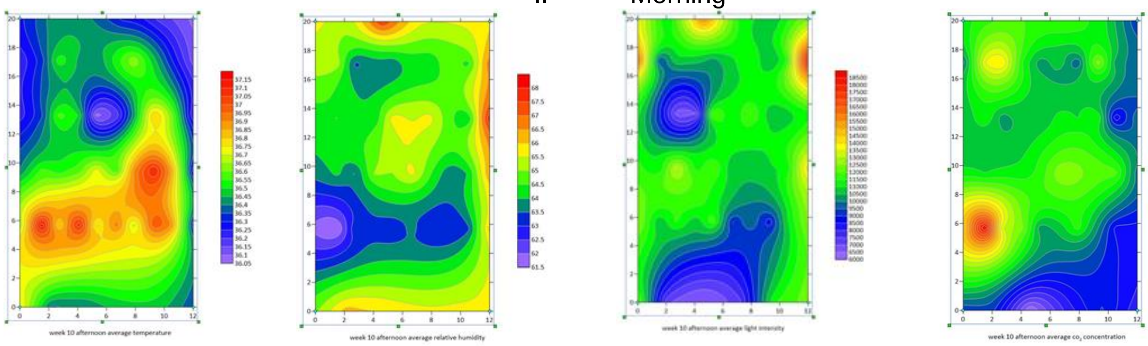
iv. Night

Fig. 11. Spatial variation of microclimate in week 9 inside the polyhouse



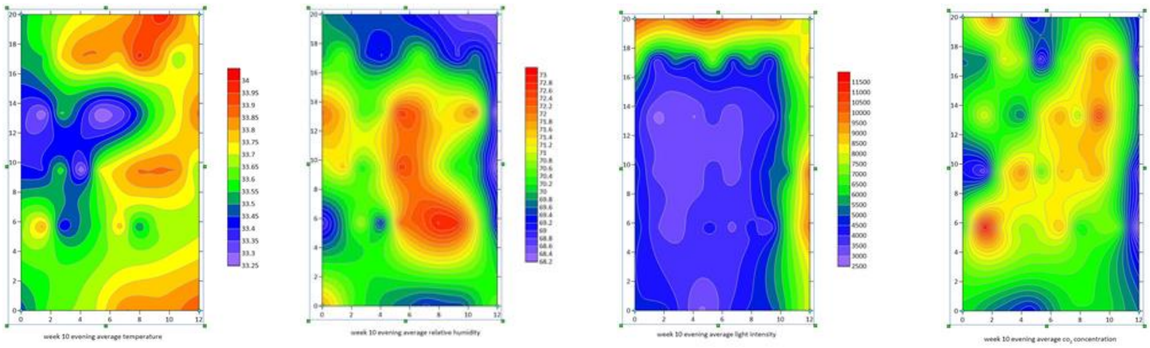
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



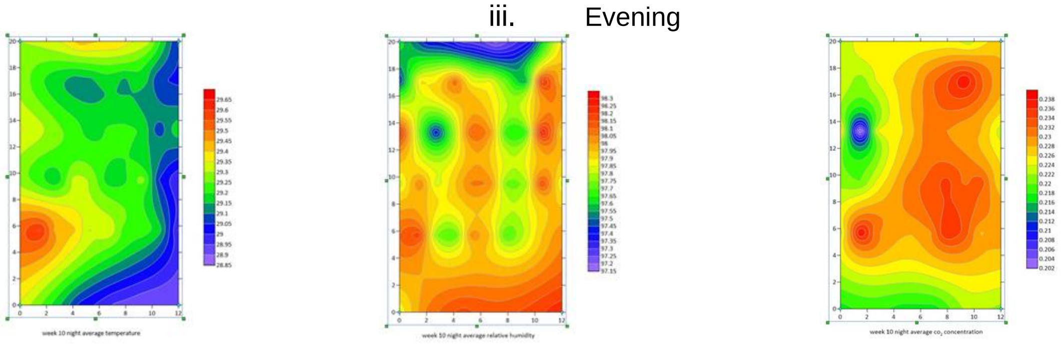
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

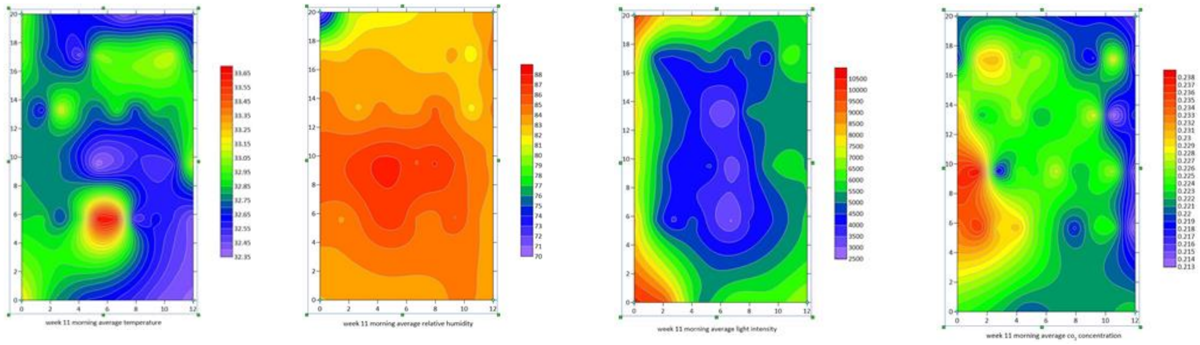
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

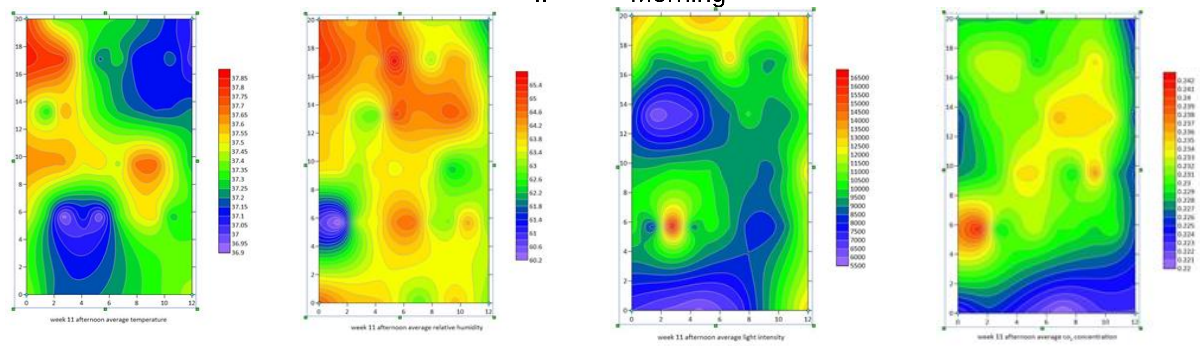
iv. Night

Fig. 12. Spatial variation of microclimate in week 10 inside the polyhouse



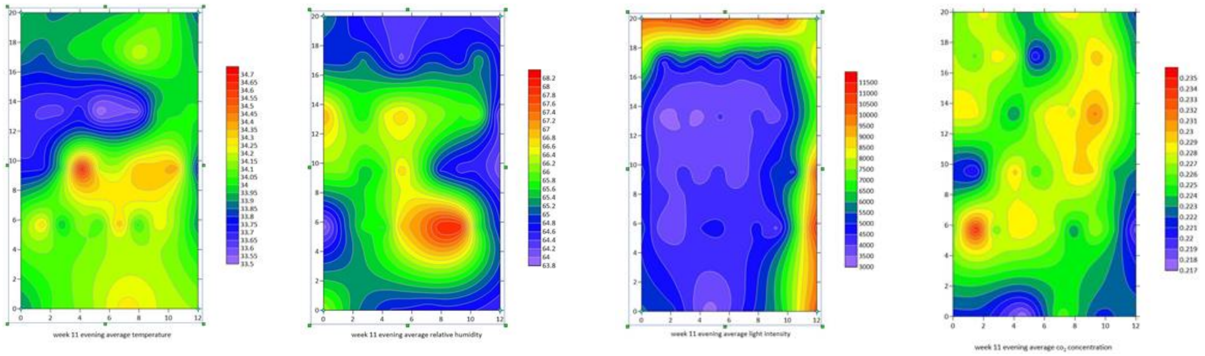
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



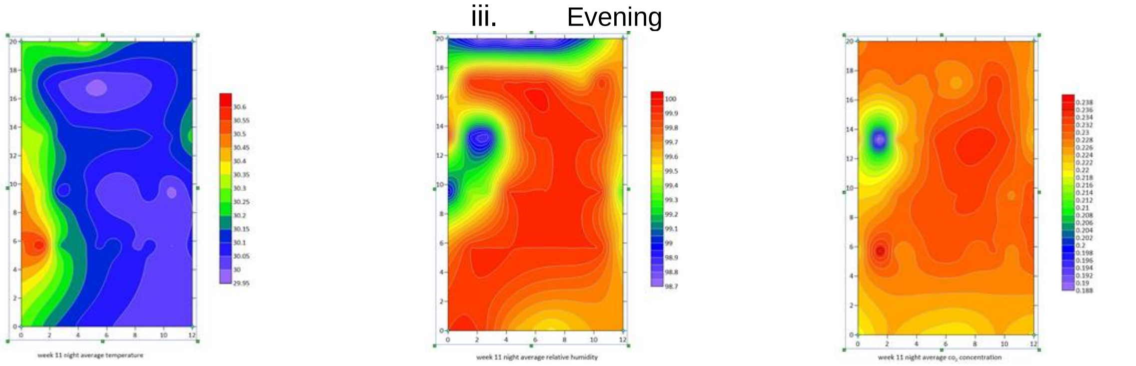
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

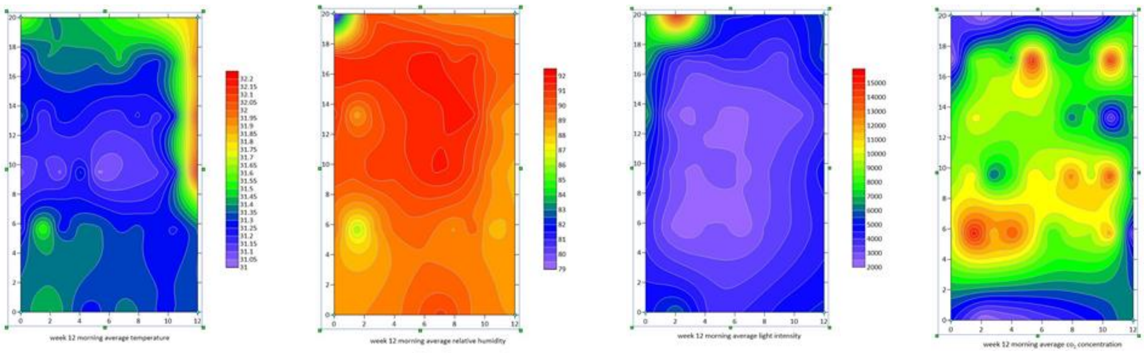
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

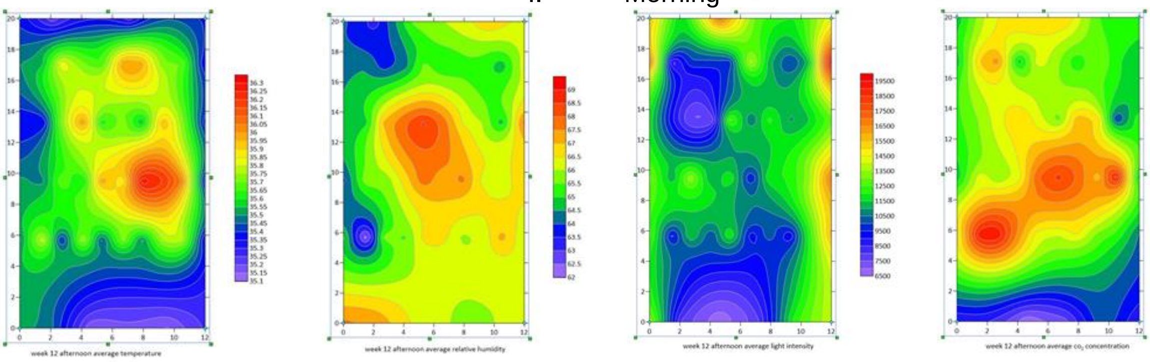
iv. Night

Fig. 13. Spatial variation of microclimate in week 11 inside the polyhouse



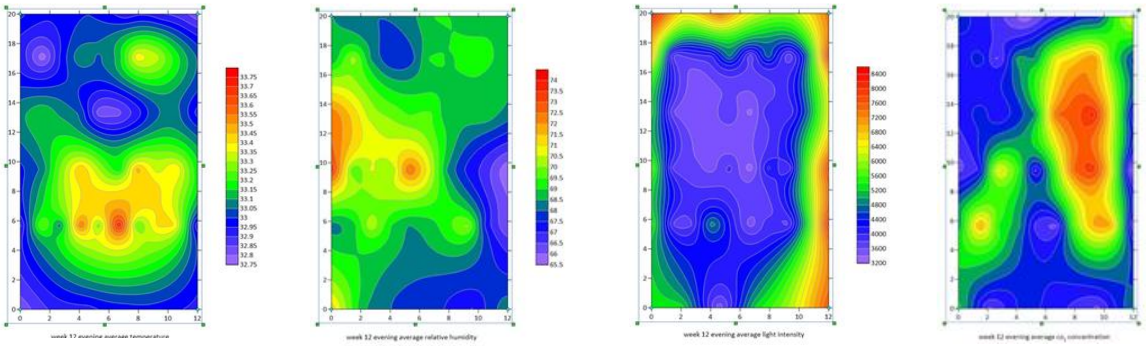
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



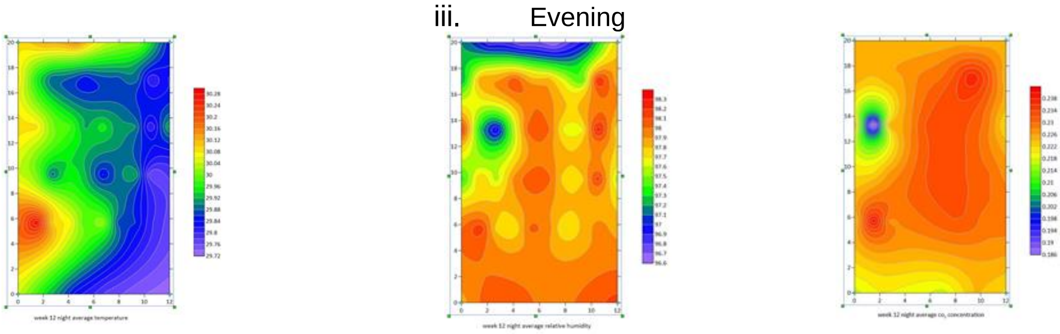
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

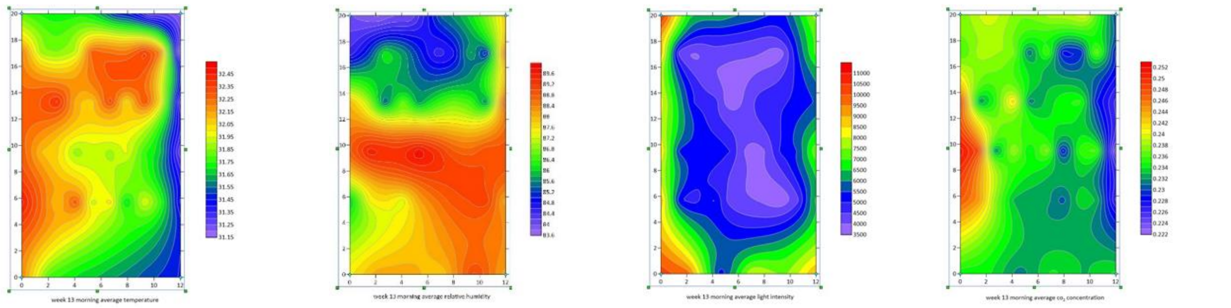
iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

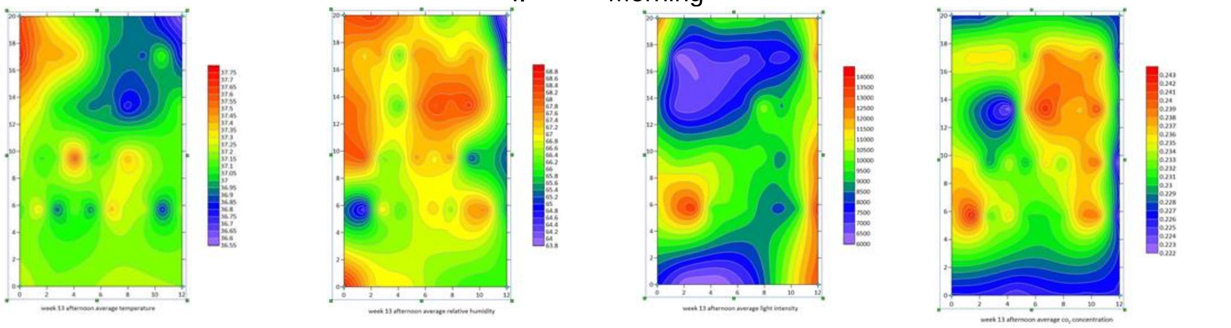
iv. Night

Fig. 14. Spatial variation of microclimate in week 12 inside the polyhouse



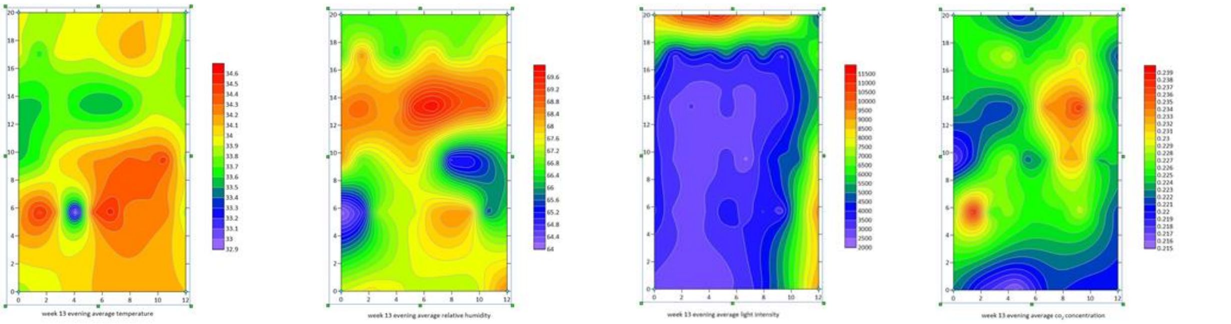
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

i. Morning



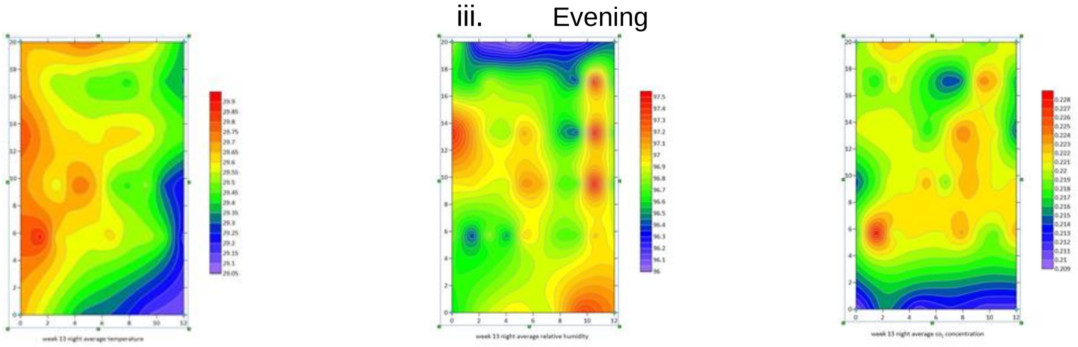
(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

ii. Afternoon



(a) Temperature (b) Relative Humidity (c) Light Intensity (d) CO_2 Concentration

iii. Evening



(a) Temperature (b) Relative humidity (c) CO_2 Concentration

iv. Night

Fig. 15. Spatial variation of microclimate in week 13 inside the polyhouse

The maintenance of relative humidity in the optimal range for plant growth was made possible due to the effect of fog cooling system. It can be said that the Fog cooling system helped to maintain optimal conditions in a naturally ventilated polyhouse [14], while increasing wind speed and outside relative humidity tended to counteract the cooling and humidification effects of fogging system [15]. Since, the current study focused on the spatial variability of microclimatic parameters, the efficiency and workability of the fog cooling system was not discussed. The light intensity was observed to be high at the south and east ends in mornings and at the north and west ends in the evenings. This variability can be attributed to the orientation of the polyhouse and the position of sun. Gupta et al. [16] also claimed that the light intensity depends upon the factors like sunshine hour, latitude, orientation and geometry of the greenhouse and types of cladding material used. In the case of carbon dioxide concentration, it was observed that it was high during the night time which can be interpreted as a result of crop respiration. This was supported with the study conducted by Reza et al. [17] reporting that the CO_2 content grew monotonically as a result of plant respiration. During the day time, the carbon dioxide concentration can be said to be affected by the crop transpiration, photosynthesis, temperature and light intensity.

The current study indicated that the use of foggers inside the polyhouse is beneficial. However, the impact of wind on the walls leads to an uneven distribution of the microclimate. This study helps to understand the variability of microclimate across the polyhouse and thus adapt the potential control strategies along with fogging system to obtain uniform microclimate inside the polyhouse. Finally,from the study, it was observed that the microclimate varies spatially and temporally depending on various factors. Even though, the data was collected in different heights, there exists the necessity to study in third dimension also.

Thus, it is necessary to study the vertical gradients of microclimate along with horizontal variability to completely understand the microclimate variability with space and time and its effect on crop growth. This highlights the need for 3D analysis of greenhouse microclimate by adapting the modelling tools and techniques. A wide range of modellings tools are available for greenhouse microclimate of which CFD and Machine learning models are in prominent use. Considering the requirements of 3D modeling and available resources, CFD is more suitable for understanding the microclimate of naturally ventilated polyhouse considered in the present study.

4. CONCLUSION

The current study was carried out to analyze the spatial variability of the microclimate inside the greenhouse. In the present study, the data related to the microclimate was recorded during the summer season, from April to June. The variation in microclimate parameters was then represented using surfer plots. From the plots, it was observed that the temperature and relative humidity varied inversely proportional to each other. The effect of foggers depended upon wind direction and velocity. It was observed that the microclimate inside a naturally ventilated polyhouse was distributed heterogeneously which have a direct impact on crop growth. This study looks at how the climate inside a polyhouse changes in different areas, so we can better manage and control it to make the conditions more even. The findings suggest we need to examine how the climate varies not just horizontally, but also vertically, to fully understand how it affects plant growth by using 3D models to analyze the greenhouse climate.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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