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Effect of environmental parameter on soilless cultivation in polycarbonate greenhouse

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Abstract
A field experiment was conducted to study the soilless cultivation of cucumber in polycarbonate greenhouse during March, 2021 to June, 2021 at the field of Renewable Energy Engineering Department, College of Agricultural Engineering and Technology, Junagadh (21.5 ˚N, 70.1 ˚E). The experiment was conducted in protected structure of advance polycarbonate fan and pad greenhouse for cultivation of cucumber.

The experiment was laid out in large plot technique design with five replications comprising of total five treatment combinations. The five treatment consists of T_1: Soilless Media (Coco-peat grow bag), T_2: Soil Media, T_3: Coco-peat + Soil (1:1), T_4: Vermicompost + Soil (1:1), T_5: Coco-peat + Vermicompost + Soil (1:1:1). Healthy seeds were sown on grow bag and soil bed at 0.60 m × 0.30 m spacing, during the month of March, 2021. Irrigation was supplied to the crop through drip irrigation system and. Cultivation practice was carried out as per recommendation.

The daily environmental data *i.e.* air temperature, RH, PAR, soil temperature and soil moisture were recorded at every three hours of interval and computed weekly and monthly average for analysis. The influence of these factors on summer cucumber was analyzed in terms of vine length, no. of fruits per vine, weight of fruit per vine, dimension of fruit (length and diameter) and crop yield per treatment. Five plants from each treatment were selected for each replications and an economic analysis was also done to determine the financial viability of the structure as well as different treatment cost.

The temperature reduction in Polycarbonate greenhouse was observed 7.24 °C as compared to open field condition. The relative humidity increased in Polycarbonate greenhouse was observed 29% as compare to open field condition. The PAR in Polycarbonate greenhouse was observed 623.24 uM/m²s maximum at 15:00 hr and 178.39 minimum at 18:00 hr. The maximum soil temperature was observed 39.9 °C in treatment T_1 (Soilless media having Coco-peat) and minimum in treatment T_2 (Soil media) of 37.5 °C.

Keywords: Protected cultivation, cucumber, environmental parameters

Introduction
India has a wide range of diverse agro-climatic conditions. India ranks second in production of fruits and vegetables in the world, after China. The total output production of vegetables is estimated to be 191.77 million tonnes from total cultivated area of 10.35 million hectares in the year 2019-20. As compared to 2018-19 it was 183.17 million tonnes from 10.29 million hectares cultivated area. The production of cucumber is estimated to be 80.64 million tonnes in the year 2020-21(Anon., 2019b) [3].

The cucumber fruit is eaten raw or is served as a salad or cooked as a vegetable. Cucumber contains 96% water which is good in the summer season. The cucumber is a warm-season crop and it cannot withstand even light frost. The cucumber seed does not germinate at a temperature as low as 11 °C but it may remain in cold soil for a considerable time and then germinates when the temperature becomes favourable. The seed starts giving satisfactory germination at 18 °C and the rate of germination increases with the increase in temperature till 30 °C. The cucumber growth occurs maximum at a day and night temperature of about 28 °C, maximum fruit production is achieved at night temperature of 19 – 20 °C and day temperature of 20 – 22 °C (Anon., 2019) [2]. The cucumber is susceptible to certain diseases that may attack the above ground parts if they are subjected to excessive rainfall or a period of high humidity. For this reason, areas having an abundance of sunshine and low humidity are ideal for the production of cucumber. The plants are large-sized, leaves are hairy and are triangular in shape and flowers are yellow in colour. Cucumbers provide various nutrients but are low in calories, fat, cholesterol, and sodium.

Greenhouse are structures covered with transparent material such as polythene or glass. The covering acts like a selective radiation filter and allows short wave length solar radiation to

pass but traps the long wave length radiation. The long wave radiations emitted by the plants and objects in the greenhouse cannot pass through the covering material owing to its lesser transparency for it. This results into rising of the temperature inside the greenhouse due to trapped solar energy inside the greenhouse (greenhouse effect). The climatic control in the green house can be used for altering the physiological conditions of the plants. Closing of the greenhouse during the night, rise in CO_2 level resulting from respiration by the plants that in turn is used for photosynthesis by the plants during the early morning hours of the following day.

Temperature is the most important parameter for successful crop production in a greenhouse, Greenhouse has largely been promoted to control the crop temperature so that summer crops could be grown in winter and vice-versa, and if the ambient conditions are too hot or cold for a given crop and greenhouses permit the maintenance of temperature in the favourable range. The temperature control in the climatic conditions has been partially achieved through 'greenhouse effect'. (Abdullah, 1997) [1] studied the environmental conditions of greenhouse and concluded that the yield was two times higher than that for the outside conditions when greenhouse temperature varied from 16 °C to 30 °C throughout the year and outside air temperature varied from 8.5 °C to 45.5 °C. The relative humidity in the greenhouse should be 60 to 75% for desirable plant growth (Jolliet, 1994) [5].

Modern cucumber cultivars are hybrids which are more disease resistant than older open-pollinated types. Hybrid cultivars have replaced open-pollinated cultivars in all large cucumber producing areas of the world. For cucumber cultivars to perform well, they must be able to set fruit well in the winter, summer and have freedom from russet and other cracking disorders.

Generally, cucumber is grown in open field condition in Rabi season in India. However, cucumber is a seasonal crop and needs favorable temperature of 21-27 °C. So this temperature cannot be achieved round-year so to get the yearly production protected cultivation techniques are being considered for conducting the present study. In addition to this, use of soilless media, coco-peat is being used which increases the porosity that helps to keeps the soilless media loose and airy helping in better root growth. Better root growth results in better plant growth and higher yield. Being an organic medium it has high cation exchange allowing nutrients to be absorbed and released to plants according to their needs. It also contains natural trichodarma which acts as a bio agent against harmful pathogens. So the present study will be conducted in order to evaluate the effects of soilless cultivation of cucumber in greenhouse. The study would be helpful to ascertain the cucumber cultivation in protected environment in Saurashtra region.

Review of Literature

Singh *et al.* (2003) [9] studied the performance of tomato and capsicum under medium cost greenhouse. The experiment was conducted during winter/spring season. The study observed that the seedlings of tomato and capsicum transplanted outside the greenhouse died in early stage of their growth due to low temperature and chilling injury during winter. The higher productivity of tomato (93.20 t/ha) and capsicum (76.40 t/ha) inside greenhouse was observed during month of December to February mainly because of higher temperature (4-90 °C).

Kwon *et al.* (2017) [6] studied the effect of two greenhouse covering materials (glass or solid polycarbonate sheets) on the light, environment and growth of tomato and cucumber plants. Spectral analysis showed that polycarbonate sheets entirely blocked radiation in both the UV-B (300 – 320 nm) and UV-A (320 – 400 nm) ranges, whereas glass transmitted UV-A and was only opaque to UV-B. The transmittance of photosynthetically active radiation (400 – 700 nm) and near infrared radiation (700 -1100 nm) was higher in polycarbonate than glass. Air and soil temperatures were not significantly different between greenhouses covered with either material. The growth of cucumber plants was slightly affected by covering materials, whereas no significant changes in growth parameters were observed for tomato plants. The color parameters of tomato fruits were affected by the cover material, whereas cucumber fruits showed similar coloration in both glass and polycarbonate greenhouses.

Candura *et al.* (2003) [4] studied on microclimate simulation model for a double plastic film skin greenhouse. A mathematical model for the simulation of a double plastic film skin greenhouse microclimate was developed. The model had the weather conditions and the constructive properties of the greenhouse as the input and the air and soil temperatures, and the air relative humidity inside the greenhouse as outputs. The model realized using the FORTRAN language and the results were compared with experimental data obtained with field tests carried out on an experimental double skin plastic greenhouse. The weather conditions, the air and the soil temperatures, the relative humidity inside the greenhouse, the temperature of the air gap between the two films were gathered by means of sensors and the data loggers. The results obtained by the simulation model showed good agreement with the experimental measurements. An average error of 1.02 °C was obtained for the internal air temperature and lower average errors for the soil temperature at different depths.

Singh *et al.* (2003) [9] reported that capsicum crop was well suited to microclimate of greenhouse due to its peculiar characters like medium height, lateral spreading and fruit set at comparatively lower temperature.

Takte *et al.* (2003) [10] reported that plastic films and shade nets were used for protection of valuable crops against excess sunlight, cold, wind and insect/birds. Further, they added that ventilation played an important role in crop production under controlled conditions.

Max *et al.* (2009) [7] studied that the cooling method influenced the greenhouse microclimate, plant growth and yield. Although evaporative cooling lowered greenhouse temperature, the unwanted increase in humidity resulted in fungi infections and reduced transpiration. Plants grown in evaporatively cooled greenhouse were 30 cm to 45 cm shorter than those grown in naturally ventilated one. Differences were also noted in flowering, leaf area, and dry matter partitioning and harvested yield.

Materials and Methods

The climate ranges from subtropical to sub-humid temperature. It experiences 1000 to 1200 mm of average rainfall annually. May is the hottest month with monthly maximum temperature varying between 35 °C to 45 °C and January is the coolest month with monthly minimum temperature varying between 7 °C and 10 °C.

Basic Structure of Greenhouse

The single span, arc type, GI pipe framed greenhouse covered with UVS polycarbonate sheet of 6mm thickness will be used for the present study. The geometrical parameters of the greenhouse are as follows:

Gutter height - 3.0 m
Ridge height - 5.0 m
Total length - 28.0 m
Total width - 8.0 m
Gutter slope - 2%
Floor area - 224 m²
Area covered for work – 117.6 m²

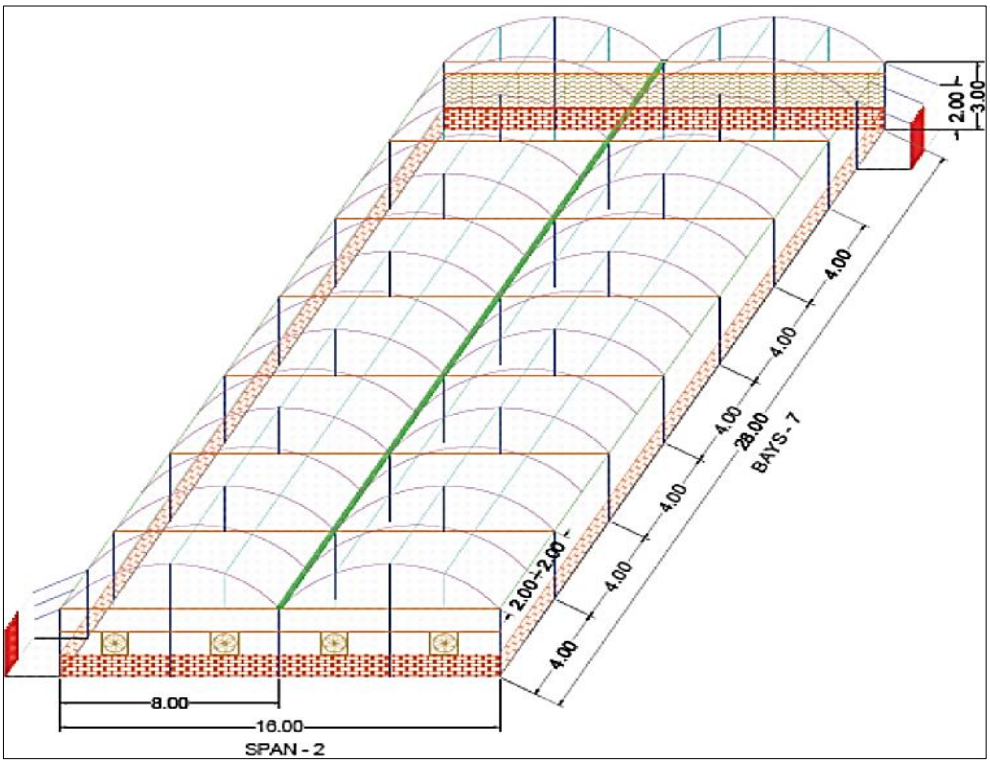

Fig 1: Polycarbonate greenhouse structure layout

Fig 2: Polycarbonate greenhouse

Instrumentation

The various instruments and sensors were used for measuring and recording the environmental parameters *i.e.* air temperature, relative humidity PAR are summarized in Table and also shown in figure.

Instruments used for measurements of different crop parameters were measuring tape for measurement of vine length, Vernier callipers for measuring dimension of fruits and weighing balance for measuring weight of fruits per plant and yield of fruits shown in figure.

Table 1: The various instruments and sensors were used for measuring and recording the environmental parameters

Sr. No.	Instrument used	Type	Manufacturer	Measurement	unit
1	Data logger	Digital	Watch dog	Air temperature, RH, PAR	°C %, umol/ m^2/s
2	TDR 350	Digital	Spectrum tech.	VWC, TEMP.	%,°C
3	Weighing Balance	Digital	n-TECH	Weight (L.C: 0.001 kg)	Kg
4	Vernier Calliper (Model: CD12")	Digital	Mitutoyo corporation, Japan	Diameter of fruit (L.C.: 0.01 mm)	mm

Fig 3: Watch dog digital data logger

Fig 4: Spectrum tech. digital TDR350

Measurement of environmental parameters

Air temperature, RH and light intensity are the environmental parameters. They were recorded by the Watch dog digital data logger at every three-hour interval in polycarbonate greenhouse and in open field daily during the experiment period. The Data logger was placed at the height of plant canopy and at the centre of the field. The data were downloaded at the end of every month.

Soil temperature and soil moisture were measured and recorded by digital TDR 350 spectrum tech. The recorded data were used to compare the variation in microclimate under polycarbonate greenhouse and open field condition during cultivation period. For that, recorded data were analysed to calculate the weekly and monthly average data.

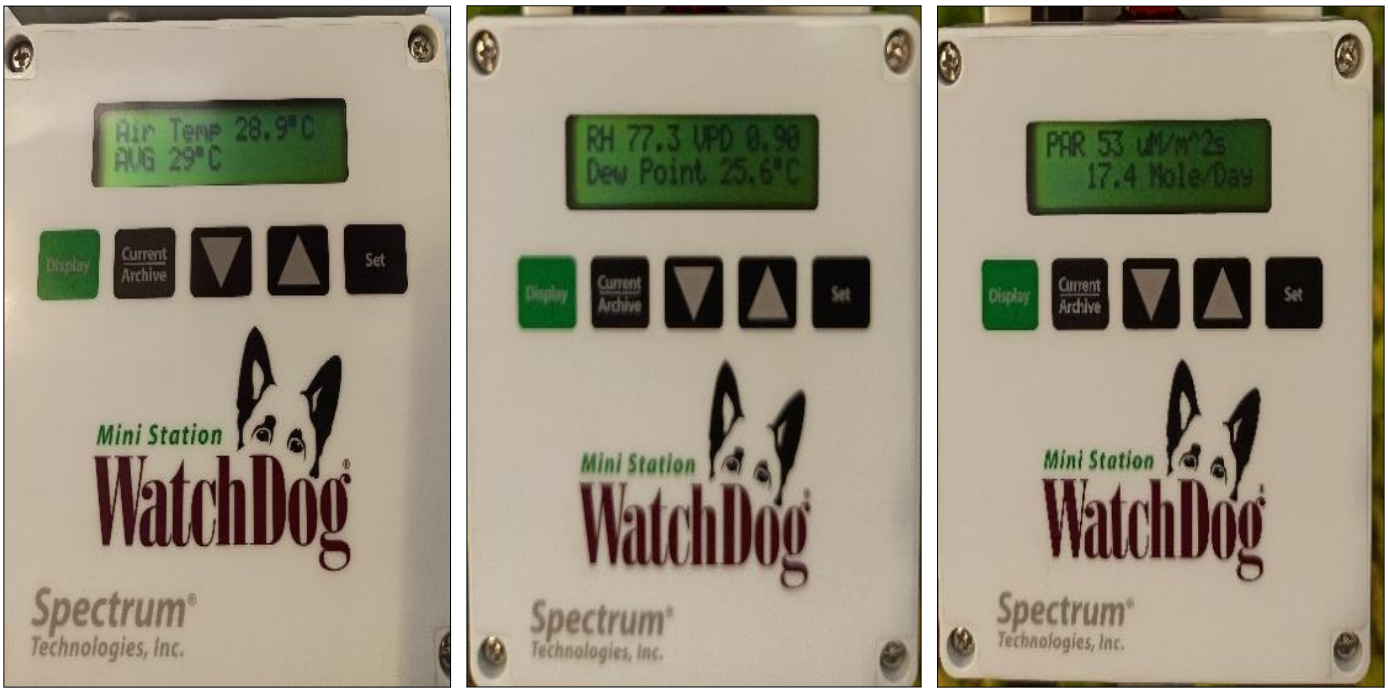

Fig 5: Measurement of environmental parameters

Fig 6: Measurement of soil parameters

Results and Discussion

Measurement of Environmental Data

The environmental parameters i.e. air temperature, relative humidity, PAR and soil parameters i.e. soil temperature, soil moisture at depth of 10 cm for an interval of 3 hours during the study period of March 20, 2021 to June 7, 2021. Data were analyzed weekly and monthly average and reported in tabular and graphic form. The different crop parameters measurements were recorded and analyzed weekly and monthly average at every 15 days after germination of seeds and analyzed statistically in single factorial completely randomize design method.

Weekly average air temperature

Table 2: Weekly average air temperature (°C) data in Greenhouse for different months

March								
Week	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
3rd	23.45	22.55	21.63	24.1	30.76	33.2	28.33	24.36
4th	23.59	23.06	22.42	24.35	28.88	29.93	28.05	24.3
Ave.	23.52	22.80	22.02	24.22	29.82	31.56	28.19	24.33
April								
1st	23.95	23.51	22.75	24.75	30.55	31.22	28.81	24.2
2nd	23.36	22.83	21.95	24.07	29.31	30.48	28	24.15
3rd	24.26	23.91	23.74	25.31	27.78	29.11	28.04	24.81
4th	24.92	25.11	24.6	26.87	28.58	30.65	28.93	26.1
Ave.	24.12	23.84	23.26	25.25	29.05	30.36	28.44	24.81
May								
1st	24.84	24.01	23.81	25.71	28.05	29.54	27.97	25.58
2nd	25.58	25.13	24.82	26.86	28.91	29.97	28.77	26.17
3rd	26.41	25.95	25.64	27	29.04	30.07	29.47	27.05
4th	26.51	26.13	25.63	28.03	31.2	33.16	30.75	26.88
Ave.	25.83	25.30	24.97	26.9	29.3	30.68	29.24	26.42
June								
1st	26.28	25.65	25.51	28.3	30.64	31.86	29.86	27.02
Ave.	26.28	25.65	25.51	28.3	30.64	31.86	29.86	27.02

Table 3: Weekly average air temperature (°C) data in open field for different months

March								
Week	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
3rd	23.75	21.43	20.4	28.8	34.73	36.86	33.7	25.96
4th	24.07	23.18	21.58	27.7	34.94	37.8	34.17	26.87
Ave.	23.91	22.30	20.99	28.25	34.83	37.33	33.93	26.41
April								
1st	23.24	21.64	20.55	28.22	35.58	38.27	34.27	26.35
2nd	23.87	22	21.27	29.1	35.81	38.96	35.2	26.57
3rd	24.38	23.88	23.5	29.61	35.94	39.14	33.94	27.2
4th	25.71	24.3	23.43	30.52	36.65	39.45	35.1	28.46
Ave.	24.3	22.95	22.18	29.36	35.99	38.95	34.62	27.14
May								
1st	25.27	23.92	23.62	31.12	37.55	40.34	34.02	28.17
2nd	27.3	24.66	24.21	32.03	37.61	40.21	34.55	28.26
3rd	27.9	27.95	27.71	28.95	30.98	33.37	31.47	28.55
4th	27.05	26.1	25.62	30.16	35.16	37.38	33.96	28.36
Ave.	26.88	25.65	25.29	30.56	35.32	37.82	33.5	28.33
June								
1st	27.01	26.74	26.1	30.2	36.13	39.3	33.93	29.25
Ave.	27.01	26.74	26.1	30.2	36.13	39.3	33.93	29.25

Monthly average air temperature

The variation in monthly average air temperature for Greenhouse and open field was analysed from daily recorded data and illustrated in Fig. 7.

Fig. 7 shows that monthly average air temperature in Greenhouse for March month varied from 22.02 °C to 31.56 °C while on contrary for month April, May and June was differing from 23.26 °C to 30.36 °C, 24.97 °C to 30.68 °C and 25.51 °C to 31.86 °C, respectively.

Likewise, for open field, the monthly average air temperature for March, April, May and June varied from 20.99 °C to 37.33 °C, 22.18 °C to 38.95 °C, 25.29 °C to 37.82 °C and 26.01 °C to 39.3 °C, respectively.

The minimum and maximum monthly average air temperature remain higher by 1 to 2 °C and 5 to 7 °C in open field condition contrast to Greenhouse, respectively. This trend was also supported by Ram, *et. al*, 2015 [8].

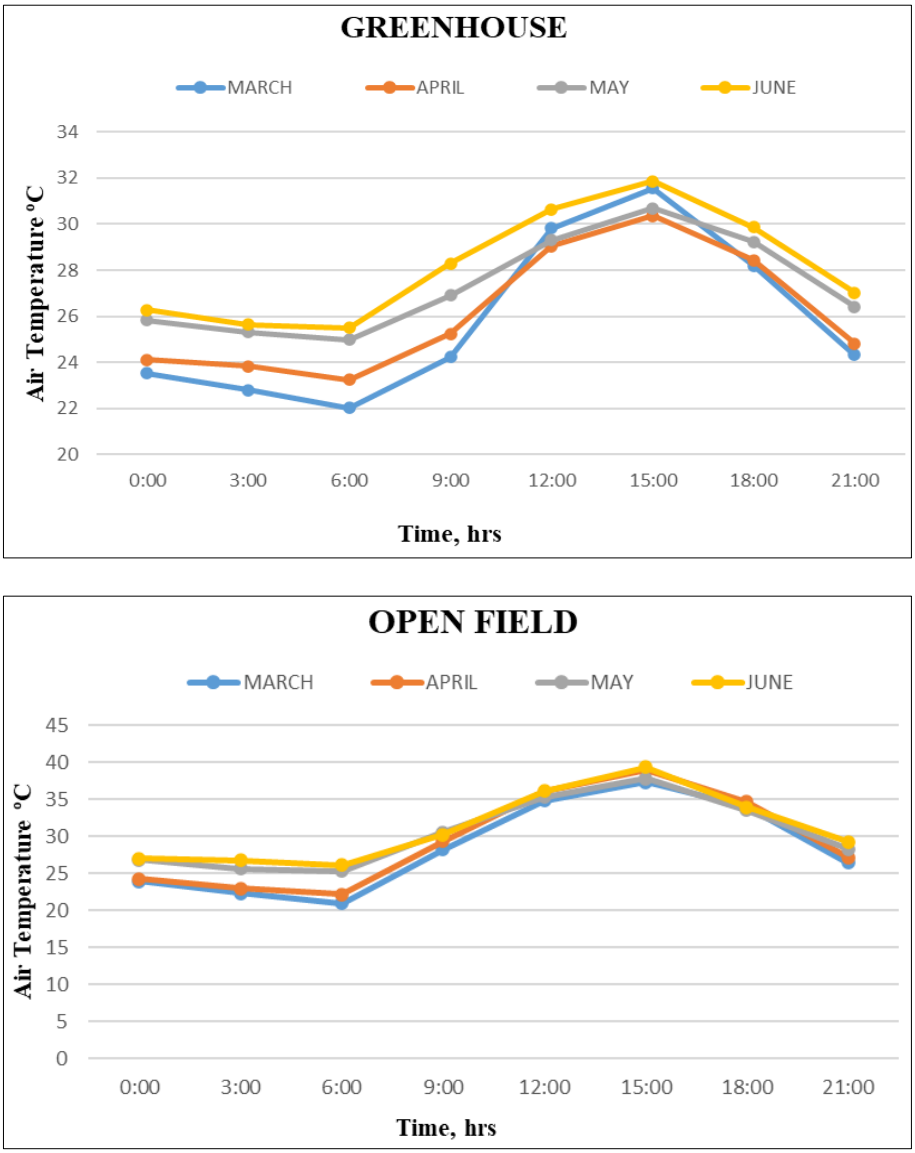

Fig 7: Monthly average air temperature of Greenhouse and open field

Measurement of relative humidity

Weekly average relative humidity

The weekly average RH was measured in % for March to June, 2021. The weekly average air temperature for Greenhouse and open filed are given in Table and shown in Figure.

Table 3: Weekly average relative humidity (%) data in Greenhouse for different months

March								
Week	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
3rd	82.75	89.26	91.4	89.9	53.83	36.9	50.16	75.8
4th	76.51	82.33	86.67	78.37	58.15	46.11	56.57	74.31
Ave.	79.63	85.79	89.03	84.13	55.99	41.50	53.36	75.05
April								
1st	83.77	87.98	91.11	89.22	59.45	47.98	56.71	76.55
2nd	73.26	80.61	85.11	76.55	53.52	39.53	52.02	72
3rd	89.88	92.5	93.95	90.68	70.78	56.9	63.3	80.14
4th	79.98	85.65	89.08	81.77	67.18	57.15	64.87	76.57
Ave.	81.72	86.68	89.81	84.55	62.73	50.39	59.22	76.31
May								
1st	85.88	86.51	90.55	85.17	70.24	58.87	70.3	81.05
2nd	90.32	92.37	93.3	87.35	74.76	65.92	72.48	87.32
3rd	85.37	87.64	88.84	84.94	74.67	70.14	72.44	83.85
4th	90.45	92.36	93.21	85.91	71.31	64.28	71.67	86.74
Ave.	88.00	89.72	91.47	85.84	72.74	64.80	71.72	84.74
June								
1st	88.52	91.67	92.62	82.58	71.71	67.65	73.06	84.38
Ave.	88.52	91.67	92.62	82.58	71.71	67.65	73.06	84.38

Table 4: Weekly average relative humidity (%) data open field for different Months.

March								
Week	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
3rd	58.35	72.13	76.03	47.6	23.26	16.1	27.33	48.96
4th	56.52	58.7	64.18	37.66	22.21	15.78	25.2	45.43
Ave.	57.43	65.41	70.10	42.63	22.73	15.94	26.26	47.19
April								
1st	80.44	90.35	93.77	54.75	28.07	18.45	35.51	57.77
2nd	59.45	66.61	73.62	38.58	19.96	12.77	29.15	52.31
3rd	85.77	92.67	90.12	59.61	37.07	30.82	57.17	70.22
4th	72.62	85.77	88	46.88	28.68	23.86	40.82	60.45
Ave.	74.57	83.85	86.37	49.95	28.44	21.47	40.66	60.18
May								
1st	78.58	80.48	85.81	47.2	29.91	22.91	50.9	67.04
2nd	81.32	88.35	90.78	51.9	37.1	28.47	50.15	72.57
3rd	77.05	81.27	82.85	72.11	55.87	52.1	64.78	79.72
4th	84.86	89.71	92.05	65.53	38.86	38.45	56.53	77.6
Ave.	80.45	84.95	87.87	59.18	40.43	35.48	55.59	74.23
June								
1st	82.12	86.05	90.87	62.77	34.78	35.31	56.71	71.16
Ave.	82.12	86.05	90.87	62.77	37.78	35.31	56.71	71.16

Monthly average relative humidity

The monthly average relative humidity variation of Greenhouse and open field was analysed from daily recorded data and illustrated in figure.

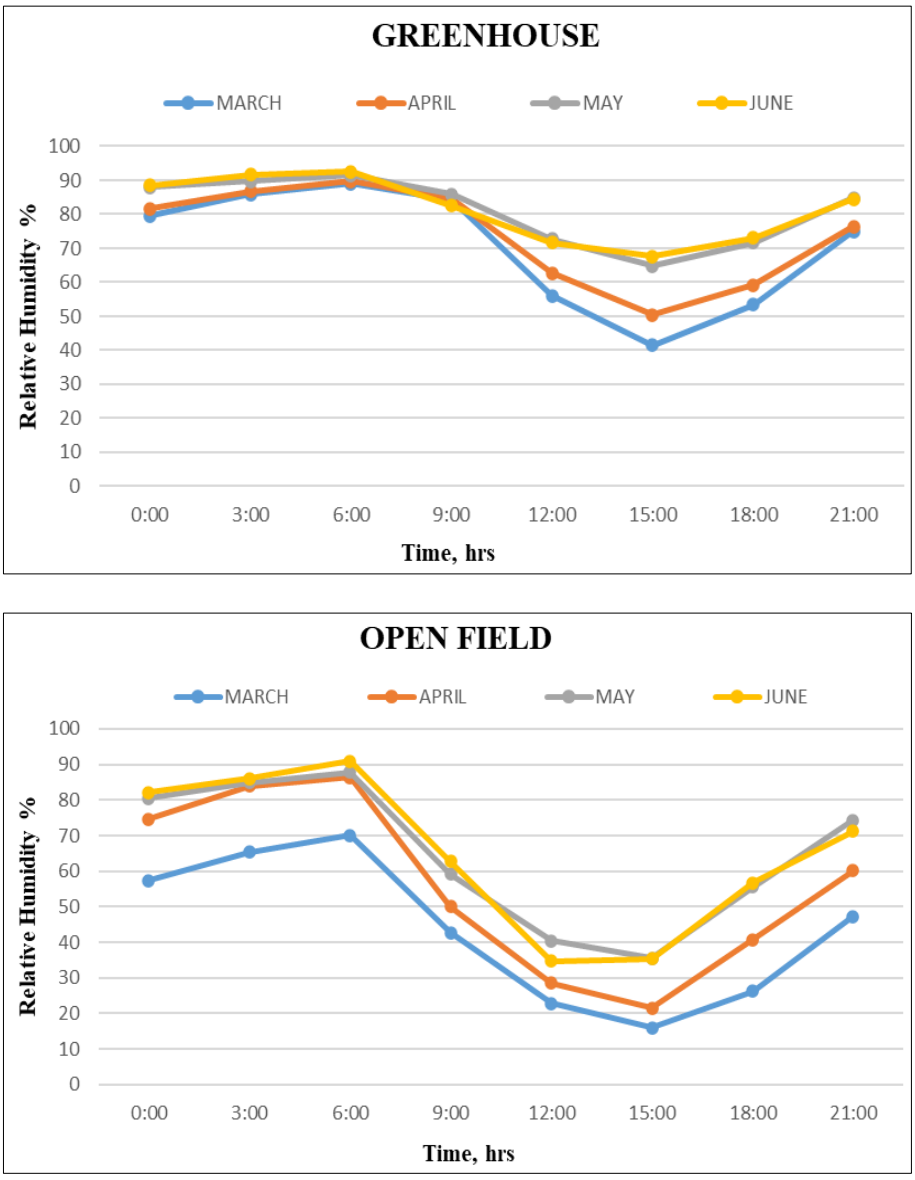

Fig 8: Monthly average relative humidity of Greenhouse and open field

As shown in Fig. 8, the monthly average relative humidity of Greenhouse was differing from 41.50% to 89.03% for March month, 50.39% to 89.81%, 64.80% to 91.47% and 67.65% to 92.62% for April, May and for June month respectively.
Likewise, the monthly average relative humidity of open field was varied from 15.94% to 70.10% for March month, 21.47% to 86.37% for April month and 35.48% to 87.87% for May month, 35.31% to 90.87% for June month.
The monthly average maximum and minimum relative humidity of Greenhouse and open field was shown in Figure. It shows that maximum monthly relative humidity for Greenhouse was higher than open field by 40% to 50%.

Conclusion

The temperature reduction in Polycarbonate greenhouse was observed 7.24 °C as compared to open field condition. The relative humidity increased in Polycarbonate greenhouse was observed 29% as compare to open field condition. The PAR in Polycarbonate greenhouse was observed 623.24 uM/m²s maximum at 15:00 hr and 178.39 minimum at 18:00 hr.
The maximum soil temperature was observed 39.9 °C in the treatment T_1 (Soilless media having Coco-peat) and minimum in treatment T_2 (Soil media) was 37.5 °C.

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