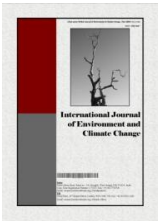

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Effect of Different Cladding Material and Mulching on the Growth and Yield of Cucumber *(Cucumis sativus)* under Forced Ventilated Greenhouse System

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Authors' contributions

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

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ABSTRACT

The experiment was conducted at Agricultural Engineering College & Research Institute, Kumulur, (TNAU), Tamil Nadu with the objectives to test the performance of different cladding (blue and white colour polyethylene) and plastic mulches (silver on black colour) on the growth and yield of cucumber *(Cucumis sativus L., Fadia F1, hybrid)* to find the suitable cultivation practices for obtaining higher yields in semi-arid regions.

The observations of micro climatic parameters such as temperature, relative humidity, solar radiation, light intensity and soil temperature were recorded in each polyhouse and at control (open cultivation). The plant growth parameters like plant height, number of leaves per plant, number of branches, date of first flowering, number of fruits, individual fruit weight and leaf- area were recorded among all the treatments.

Among the blue and white polyhouse conditions, favourable solar incidental radiation and light intensity was observed in the white polyhouse as compared to blue polyhouse. Among the plastic mulch and without mulch treatments, the plastic mulch showed negative results under polyhouse cultivation where as positive results on growth and yield parameters at open condition (control).

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Significant differences were found among the treatments combinations of white poly house condition without mulch treatment on higher fruit size, fruit weight, number of fruits per plant, number of leaves per plant, leaf area and higher yield might be due to higher photosynthetic active radiation than blue polyhouse. The microclimatic condition recorded in blue polyhouse found to be detrimental to the pathogens under certain wave lengths and resulted in lower incidences of pest and diseases but not supported for higher yield due to low light intensity compared to white polyhouse. White polythene film as cladding material for construction of poly house and without mulching is important to achieve higher growth and yield of Cucumber under semi-arid regions.

Keywords: Poly house; mulches; growth and yield parameters.

1. INTRODUCTION

Cucumber demands high temperature, relative humidity and soil moisture for satisfactory yield. Unfavorable climatic conditions leads to reduction of female flowers, delay in fruit growth, flower falling and mineral disorders. Therefore, favourable climatic condition is important to achieve higher production as well as good quality [1]. Planting is usually made during spring-summer season which provides favourable weather conditions for plant growth and high yield. To get year round production and fetch higher profit, growing during off season also important [2-4].

To grow during the off-seasons and to provide favorable microclimate, protected cultivation and usage of plastic greenhouses has provides better opportunity and a strong influence on the horticultural industry in many countries [5]. To get year round production and fetch higher profit, growing during off season with less incidence of pest and disease, cultivation in poly house is important [6].

Among the plastic sheets, now-a-days, more attention is given to different kinds of polyethylene films because they have low cost and can be manufactured in a wide range of thickness, width, colour and quality [7-9]. Many scientists hypothesized that the photosynthetic rate of plants would generally follow the intercepted light of the primary photosynthetic pigments [10,11].

With is background, experiment was conducted with the objectives to test the performance of different cladding (blue and white colour polyethylene) and plastic mulches (silver on black colour) on the growth and yield of cucumber *(Cucumis sativus* L., Fadia F1 hybrid) and to find the suitable cultivation practices for obtaining higher yields in semi-arid regions [12-16].

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the research field of Department of Soil and Water Conservation Engineering at Agricultural Engineering College and Research Institute (Tamil Nadu Agricultural University), Kumulur, Trichy. Lies between latitude 10°55'49" N, longitude 78°49'41" E and 86 m above from the mean sea level. The cucumber crop *(Cucumis sativus, Fadia, F1, hybrid*) was raised during 10th july – 10th September under the different polyhouses of ICAR-NICRA- Temperature Gradient Modelling Research Project (2018-2021), as well as open condition (clay loam soil) to evaluate different colours cladding polyethylene sheets on the growth and yield of cucumber. Physico-chemical properties of experimental site is given in the Table 1.

2.2 Experimental Details

The two polyhouses were constructed with the size of 200 m^2 (10 m wide, 20 m length) with fan-pad operating evaporative cooling system and covered by a 5-layered polyethylene film with 200-micron thickness in two colours (White and Blue).

Cucumber was cultivated (60 cm plant to plant spacing and 50 cm row to row spacing) in a paired row system on the raised beds of 90 cm bed width and 60 cm channel width. Drip irrigation system installed at 150 cm laterals spacing, placed at the centre of beds and drippers at the spacing of 60 cm with 8 lph in both poly houses and open condition. Recommended agronomic practices were followed on fertigation, weed management and pest and disease management. Mulches were followed as per the treatments.

Each polyhouse has provided with automatic recording type (recording data per each minute) temperature, relative humidity and pyranometer sensors and those were connected with data logger system installed at outside of the polyhouses. One pyranometer sensor was installed at outside of the polyhouse and also connected to the data logger system. All the recorded data were downloaded directly in excel form by using data logger dongle. Outside temperature and relative humidity were observed by "Thermo-hygrograph" and the recorded sheet was changed once in a day at 08.00 hours. LDPE (Low-Density Polyethylene) 25-micron thickness silver on black colour mulch was applied for each condition (white polyhouse, blue polyhouses and open condition). The soil thermometers were installed in the soil at 0-15 cm depth to measure soil temperature in all the treatments (WPH-WM, WPH-WOM, BPH-WM, BPH-WOM, Control-WM and Control-WOM). 'Lux meter' was used to measure light intensity in all three conditions i.e. white polyhouse, blue polyhouse and open condition. A 30 cm scale and 5 m tape were used to measure the plant height while taking observations. The soil texture analysis carried out in the soil chemistry laboratory at AEC & RI, Kumulur by International Pipette method (Robinson's Pipette Method) and soil texture identified as 'clay loam soil' [17], Soil Taxonomy, USDA- NRCS (1975)]. A digital pen type pH & EC meters were used to find the soil pH & EC for the experimented site. Double Ring Infiltrometer was used to determine the infiltration capacity of the experimented site [18]. The physioco-chemical properties of the experimental site given in the following Table.1.

2.3 Experimental Design

Experiment was conducted in Factorial RBD. Three conditions as main factors viz., white poly house, blue poly house and open condition considered as control for comparison. The type of soil covers (with and without mulching) as sub factors and it was replicated thrice.

2.4 Data Collected

2.4.1 Weather parameters

Temperature, relative humidity, and solar radiation observations were continuously recorded by using digital sensors installed in blue and white polyhouses and those values were downloaded from the data-logger. The outside (open condition) solar radiation, temperature and relative humidity also recorded by the pyranometer sensor connected with data logger and one thermo-hygrograph. Light intensity was recorded daily in the mid-day (at 01:00 P.M) by using the 'Lux' meter.

2.4.2 Soil temperature

The soil temperature was recorded at morning, mid-day and evening time (08:00, 13:00 and 17:00 hours) by the installed soil-thermometers at all the treatments (white polyhouse, blue polyhouse and open conditions with and without mulch treatments).

2.4.3 Plant growth parameters

Plant growth parameters such as plant height, number of leaves per plant, leaf area, number of flowers, first flowering day, number of fruits per plant, fruit weight and fruit size were observed at each 15 days interval. The leaf area index (LAI) (unit less quantity) calculated according to the equation (1).

$$LAI = \frac{Area\ of\ leaf}{ground\ area} \quad (1)$$

2.5 Data Analysis

AGRES software used to analyze the data collected on growth and yield parameters during experiments.

Table 1. Soil physico-chemical properties of the experimental site

Plot. No.	Soil Texture	Soil pH	Bulk Density (g/cc)	Porosity (%)	EC (μs/cm)	Infiltration rate (cm/h)	Field Capacity (%)
B1B	Clay loam (sand - 40%, silt - 19.2%, clay - 40.8%)	6.8	0.89	24	248	1.97	27.2

3. RESULTS & DISCUSSIONS

The weather, soil temperature and plant physiographic parameters (growth and yield) were used to assess the suitability of different cladding material and soil cover to achieve heigher yields of cucumber *(Cucumis sativus* L., Fadia F1 hybrid).

According to the growth and yield performance of cucumber under the different growing conditions of blue polyethylene and white polyethylene cladding polyhouses and control conditions (open condition) along with plastic mulch (silver on black colour) and without mulch as treatments were observed. The weather parameters such as solar radiation, light intensity, temperature and relative humidity as well as soil temperature were influenced the plant growth and yield parameters and those details discussed below.

3.1 Weather Parameters

3.1.1 Solar radiation & light intensity

The average (each 30 days interval from sowing to the end of crop) of the maximum solar radiation and maximum light intensity recorded in blue poly house, white polyhouse and open condition (control) and presented in Table 2. White polyhouse showed more solar radiation and light intensity than blue polyhouse after the open condition (control).

3.1.2 Air temperature

Maximum and minimum air temperature was recorded under blue polyhouse, white polyhouse, and control conditions and presented in Table 3. The highest temperature recorded in white polyhouse followed by blue polyhouse and control. Diurnal variation of 10ºC was recorded in white polyhouse, 8-9ºC in blue polyhouse and 14-15ºC at open condition (control). The lowest diurnal variation was found in blue polyhouse followed by white polyhouse and control. Moreover, optimum temperature of 30-35ºC was maintained during daytime and 25-30ºC during night time in both the polyhouses by using fan pad operating cooling system [19]. But in the mid-day (hot time), due to the high solar radiation of outside temperature, the inside polyhouse temperatures increased from 31 to 38 ºC in white polyhouse and 30-36 ºC in blue polyhouse for a period of short duration (from 13.00 to 14.00 hours). The diurnal variation is low in both the polyhouse as compared to the outside condition (control).

3.1.3 Relative humidity

Relative humidity (RH) plays a major role in plant evapotranspiration, crop yield, pests and diseases [20-22]. The favorable relative humidity was maintained in both the polyhouses with the fan-pad operating cooling system. Almost 60-70% RH was maintained during daytime and 70-90%

Table 2. Comparative performance of maximum solar radiation and light intensity in blue polyhouse, white polyhouse and at open condition (control)

Days after sowing	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	Max. Solar Radiation (W/m^2)	Max. Light Intensity (Lux)	Max. Solar Radiation (W/m^2)	Max. Light Intensity (Lux)	Max. Solar Radiation (W/m^2)	Max. Light Intensity (Lux)
30	141	132	152	221	1048	856
60	126	102	128	194	1027	845
90	139	149	141	245	1076	883

Table 3. Effect of poly house on diurnal variation in temperature

Days After Sowing	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	Max. Temp. (°C)	Min. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)
30	35.00	26.50	37.00	27.00	36.00	22.00
60	36.00	27.00	38.00	27.50	35.00	21.00
90	36.00	28.00	38.00	28.00	34.00	24.00

RH during night time in both the polyhouses, whereas 25-60 % during daytime and 60-95% during night time was recorded in open condition (Control) and presented in Table 4. The relative humidity recorded more than 90% favored the incidence of more pests and diseases.

During mid-day, the relative humidity of 30-40% was recorded at control and affected flower dropping, lowering yield and high transpiration of water from the plant, and also affected quality and size of the fruits. Supported with Yang, et al. [11].

3.2 Soil Temperature

The soil temperature recorded daily at 08:00, 13:00 and 17:00 hours (morning, afternoon and evening) and the average temperature (whole crop period) at three timings under the blue polyhouse, white polyhouse and open condition (control) with and without mulch treatments were observed and presented in Table 5. The soil temperature was influenced by the air temperature and soil cover (mulch). From Table 5 the highest soil temperature was observed in white polyhouse condition with mulch treatment followed by blue polyhouse with mulch treatment, control with mulch treatment, white polyhouse without mulch treatment, blue polyhouse without mulch and finally the lowest soil temperature at control without mulch treatment [23,24]. The soil temperature is influenced by the soil cover and air temperature and hence the highest soil temperature was noticed in mulching treatments due to the plastic mulch observed more heat and retained soil temperature for longer durations. More than 35º C of soil temperature will reduce the plant growth and yield by disturbing nutrient transport system in the plant as well as it creates favorable microclimate in the soil for more pathogenic growth. So, maintaining optimum soil temperature also important for higher plant growth and yield. Ajibola, Olufemi Victor and Bamidele and Julius Amujoyegbe [25]; Abhivyakti et al. [26] found that there was a positive correlation between air temperature under the plastic house and soil temperature. Bhatt et al. [27] and Medany et al. [28] and reported that minimum soil temperature should be maintained up to 15 °C. These results agreed with Kumari et al. [29], who reported that soil temperature was affected by radiation intercepted by plastic cover. In the white polyhouse with mulch treatment, the soil temperature raised higher than 35 °C which negatively affected in crop growth and yield.

3.3 Plant Growth and Yield Parameters

3.3.1 Plant height

Plant height was recorded at 15 days interval from sowing to 90 days after sowing (DAS) and presented in Table 6. The highest plant height was recorded under blue polyhouse without mulch treatment followed by white polyhouse without mulch treatment, blue polyhouse with mulch treatment, white polyhouse with mulch treatment, control with mulch treatment and least plant height was recorded at control (open condition) without mulch treatment. From Table 2, the low light intensity and solar radiation observed in blue polyhouse which might cause for the maximum plant height under the blue polyhouse condition.

Table 4. Comparative performance of poly houses and open condition on Relative humidity

Days after sowing	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	Max. RH (%).	Min. RH (%).	Max. RH (%).	Min. RH (%).	Max. RH (%).	Min. RH (%).
30	88	64	92	59	94	29
60	87	65	91	62	96	26
90	89	69	90	64	95	25

Table 5. Effect of treatments on soil temperature (°C)

Time	Blue polyhouse		White polyhouse		Open condition (Control)	
	With mulch	Without mulch	With mulch	Without mulch	With mulch	Without mulch
08:00 A.M	30	29	31	29	28	26
01:00 P.M	35	30	37	31	34	28
05:00 P.M	34	29	36.5	30	31	29

Table 6. Effect of treatments on plant height (cm)

Days of observation	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	With mulch	Without mulch	With mulch	Without mulch	With mulch	Without mulch
15 DAS	20	25	21	25	7	6
30 DAS	65	140	130	140	18	12
45 DAS	200	190	180	205	140	125
60 DAS	480	350	200	390	150	190
75 DAS	497	536	350	490	300	250
90 DAS	497	540	450	502	350	290

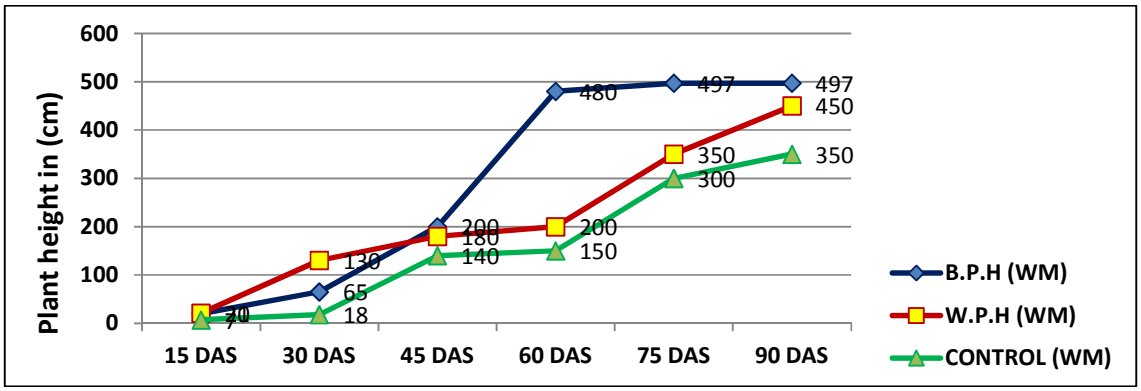

Fig. 1. Plant height (cm) in BPH, WPH and control with mulch
(B.P.H-Blue Polyhouse, W.P.H-White Polyhouse & W.M-with Mulch)

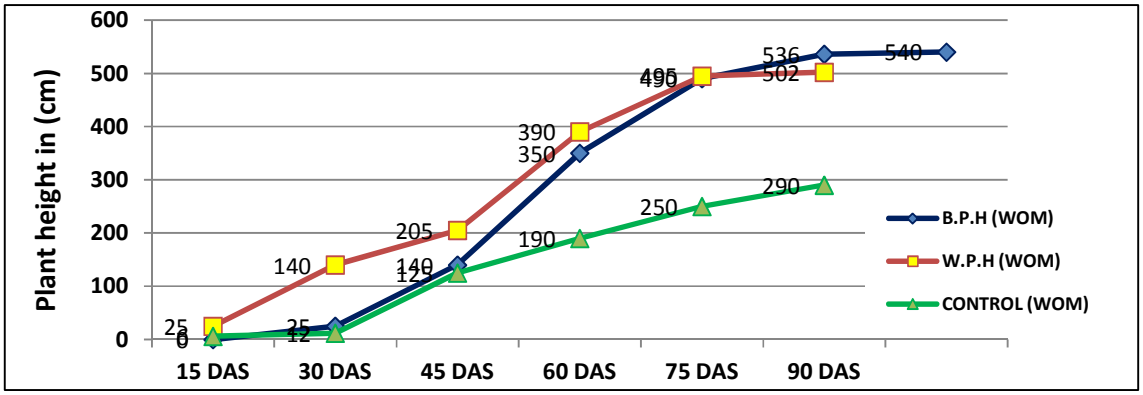

Fig. 2. Plant height (cm) in BPH, WPH and control without mulch
(B.P.H-Blue Polyhouse, W.P.H-White Polyhouse & W.O.M-Without Mulch)

Under the mulch treatment, the maximum plant height (497 cm) was observed in blue polyhouse condition followed by white polyhouse (450 cm) and control as open condition (350 cm) as shown in Fig. 1.

Under without mulch treatment, the maximum plant height (540 cm) was recorded in blue polyhouse condition followed by white polyhouse (502 cm) and control (290 cm) conditions as shown in Fig. 2. The plant height was majorly influenced by light intensity and followed by air temperature, relative humidity and soil temperature. Therefore, the low light intensity and solar radiation caused for higher plant growth (height) in blue polyhouse condition followed by white polyhouse and least at control condition.

In the comparisons within the treatments of with mulch and without mulch, plastic mulch performed better results under open condition [30] whereas negatively affected under polyhouse cultivation.

3.3.2 Number of leaves per plant

The total number of leaves per plant was recorded at 15 days interval in blue polyhouse, white polyhouse and control with and without mulch treatments and the observations were presented in Fig. 3. The maximum number of leaves per plant was observed in white polyhouse condition under without mulch treatment followed by blue polyhouse condition without mulch treatment, white polyhouse with mulch treatment, blue polyhouse with mulch treatment, control with mulch and least no. observed at control without mulch treatment. From Table 2 the highest solar radiation and light intensity observed in white polyhouse than blue polyhouse. So, the higher number of leaves per plant were obtained due to the high light intensity and solar radiation obtained in white polyhouse than blue polyhouse [31,32]. The highest plant height recorded in blue polyhouse but the higher number of leaves produced in white polyhouse with favorable solar radiation and light intensity. The lowest no. of leaves obtained in control condition due to excessive solar radiation and light intensity which was not favourable for higher leaves production.

Soil temperature also plays a role for higher no. of leaves production. The highest leaves obtained in the white polyhouse condition under without mulch treatment than mulch treatment it means the higher soil temperature with mulch treatment hinders the plant growth and production of leaves. Whereas the same mulch treatment positively responded for higher production of leaves at control condition (open condition).

3.3.3 Total Leaf Area (cm^2)

The total leaf area was measured at 15 days interval and presented in Table 7. The total leaf area under white polyhouse without mulch had the highest leaf area, followed by the white polyhouse with mulch, blue polyhouse without mulch, blue polyhouse with mulch, control (open cultivation) with mulch and least leaf area observed at control (open cultivation) without mulch treatments. The highest leaf area was obtained due to the sufficient light availability and favorable microclimate inside the white polyhouse. This might be attributed to the increase in temperature, which influenced the degree of stomatal closer. Sharma et al. [33] revealed the leaf area to the higher efficiency of water use, which might be a reason on its own for the rapidly expanding leaf area under protected cultivations [34].

Within the same condition of white polyhouse plastic mulch treatment caused for higher soil temperature which is negatively affected for leaf area development where as good results obtained without mulch treatment in polyhouse conditions.

3.3.4 Leaf area index

The leaf area index was measured at each 15 days interval by using the formulae [1], and presented in Fig. 4, the highest leaf area index was observed in white polyhouse without mulch treatment followed by blue polyhouse without mulch, white polyhouse with mulch, blue polyhouse with mulch, control with mulch treatment and least at control without mulch treatment. The light intensity, solar radiation, air temperature, relative humidity, and soil temperature were influenced for the highest leaf area index. The highest plant leaf area index under white polyhouse without mulch treatment

Table 7. Total leaves area (cm^2) per plant under different treatments

Day of observation	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	With mulch	Without mulch	With mulch	Without mulch	With mulch	Without mulch
15 DAS	73	79	70	84	63	54
30 DAS	100	103	174	256	45	36
45 DAS	320	340	255	420	356	335
60 DAS	385	420	394	421	360	340
75 DAS	390	398	415	421	360	342
90 DAS	390	398	415	421	360	342

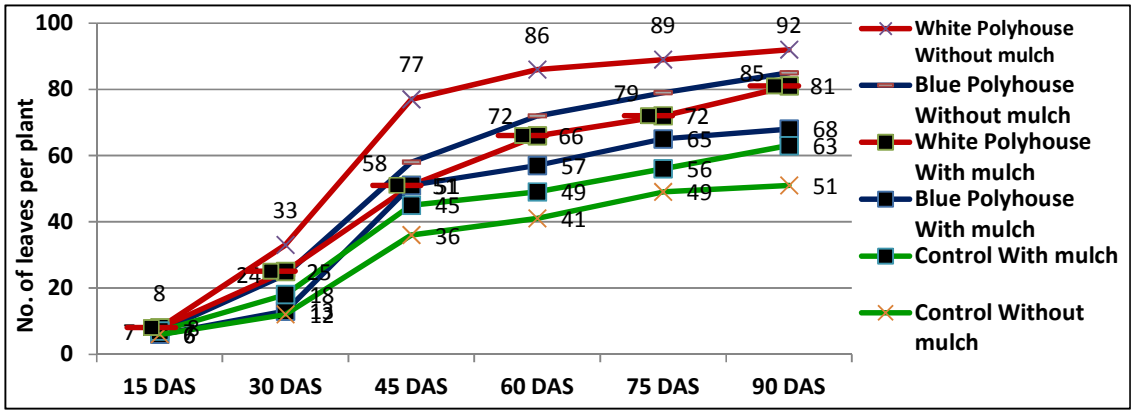

Fig. 3. Number of leaves per plant in different treatments

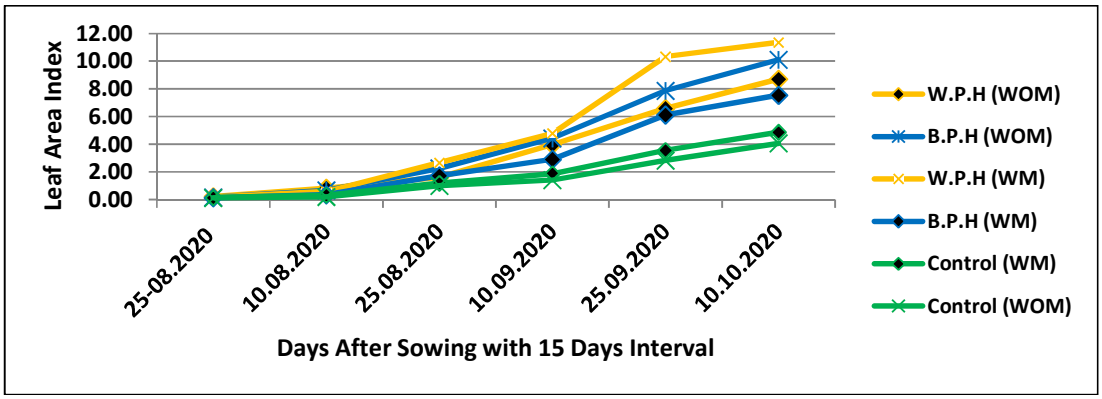

Fig. 4. Leaf Area Index under different treatments

was due to sufficient light availability for the plant growth, optimum air temperature and relative humidity and also soil temperature. Within the white polyhouse of mulch treatment lowered the leaf area index value (LAI) due to more soil temperature under the mulch. Hence optimum solar radiation, light intensity, air temperature, humidity and soil temperature are more important for better plant growth and development.

3.3.5 First flowering day

The 1st flowering day (25th day after sowing) observed in white polyhouse under without mulch treatment followed by white polyhouse with mulch (26th day after sowing), blue polyhouse without mulch (28th day after sowing), blue polyhouse with mulch (29th day after sowing), control with mulch (30th day after sowing) and control without mulch condition (32nd day after sowing). The solar radiation and light intensity values were affected the flowering date of the plants.

3.3.6 Fruit characters

3.3.6.1 Number of fruits per plant

The number of fruits per plant (tagged plants) in each treatment was recorded at all the harvest. The number of fruits obtained in each harvest and the summation value for each tagged plant and their total number of fruits yield during the life cycle was observed and presented in Table 8. Among all treatments, the maximum number of fruits per plant was observed in white polyhouse condition without mulch treatment and minimum number of fruits per plant was observed in control condition without mulch treatment.

3.3.6.2 Fruit length

The individual fruit lengths for all the treatments were recorded and presented in Table 8.

Table 8. Effect of treatments on total number of fruits (fruits/plant), fruit weight (g/plant) and fruit length

Average of sample plants	Blue Polyhouse		White Polyhouse		Open condition (Control)	
	With mulch	Without mulch	With mulch	Without mulch	With mulch	Without mulch
Fruits per plant (Numbers)	27	32	28	35	14	9
Fruit Weight (g)	400	420	410	450	250	150
Fruit length (cm)	12.3	14.1	12.5	14.2	14.8	15

The unripe fruits were harvested before becoming complete mature stage i.e. fruits were plucked within 4-6 days after the flowering to the fruiting stage. The fruit length under each treatment was observed and depicted in Table 7.

3.3.6.3 Total fruit weight

Cumulative yields of cucumber fruits under different treatments was observed and depicted in Table 8. Total higher number of fruit per plant and fruit weight was recorded in white polyhouse without mulch followed by the blue polyhouse without mulch, white polyhouse with mulch, blue polyhouse with mulch, control with mulch and control without mulch treatment. This might be due to the high temperature and sufficient light transmission [6]. Blue colour polyfilm sheets reduced the yield of cucumber in all stages of the crop as compare with white colour polyfilm. Generally, blue polyethylene has an additional UV-blocking character, restrict higher wavelength light that negatively influenced the yield [10]. The low yield probably occurs under low radiation levels [35]. But excessive solar radiation and light intensity also reduced the yield as observed in the control condition. Hence favourable micro-climate condition i.e. solar radiation, light intensity, temperature, relative humidity and soil temperature were important to obtain higher growth and yield of cucumber (*Cucumis sativus* L., Fadia F I hybrid) and is achieved in white polyhouse condition without mulch treatment next with blue polyhouse without mulch treatment.

4. CONCLUSION

Among the blue and white polyhouse conditions, favourable solar incidental radiation, light intensity, atmospheric temperature and soil temperature was observed in the white polyhouse as compared to blue polyhouse. Between the plastic mulch and without mulch treatments, the plastic mulch showed negative results under polyhouse cultivation where as positive results on growth and yield parameters at open condition (control).

Significant differences were found among the treatments combinations of white polyhouse condition without mulch treatment on higher fruit size, fruit weight, number of fruits per plant, number of leaves per plant, leaf area and higher yield might be due to higher photosynthetic active radiation than blue polyhouse. The microclimatic condition recorded in blue polyhouse found to be detrimental to the pathogens under certain wave lengths and resulted in lower incidences of pest and diseases but not supported for higher yield due to low light intensity compared to white polyhouse. White polythene film as cladding material for construction of poly house and without mulching is important for cultivation of Cucumber *(Cucumis sativus* L., Fadia F I hybrid) to achieve higher under semi-arid regions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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