ORIGINAL RESEARCH PAPER

Volume-8 | Issue-5 | May-2019 | PRINT ISSN No 2277 - 8179

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

EFFECT OF DIFFERENT GREENHOUSE COVERS ON EVAPORATIVE COOLING EFFICIENCY AND CROP YIELD OF CUCUMBER

Agricultural Science

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ABSTRACT

The experimental work was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum - Shambat, Sudan (32^{o} 51 E, 15^{o} 65 N and 380 m above the mean sea level) during the summer season of 2018 with the objective of investigating the effect of different greenhouse covers on cooling efficiency and crop yield of cucumber (*Cucumis sativus* L.). Greenhouses were designed and installed to accommodate different treatments namely; double-layers of polyethylene with 9cm air gap (D-PE), single-layer of polyethylene (S-PE), and single-layer of polyethylene with green net with 50% opening (S-PE+N). These treatments were arranged in randomized completely block design (RCBD) with three replicates. The parameters tested were climate factors, evaporative cooling system efficiency and the yield of cucumber. A computer program (SAS statistical package) was used to analyze the data while the variations among the means were checked by the Least Significant Difference (LSD). The results showed that there was no significant difference between different treatments inside the greenhouses. D-PE cover decreased the mean values of temperature (28 C) compared to S-PE cover (29 C). While it was increased the average relative humidity (73%) compared to S-PE+N cover (71%). Evaporative cooling efficiency and cooling effect significantly ($P \leq 0.05$) affected by the different covers. The highest mean values of evaporative cooling efficiency (64%) and cooling effect (7.1 C) were recorded under D-PE cover at wet-bulb depression (11.03) as compared to S-PE (61.7% and 6.8 C, respectively). Due to the variations in climate factors and materials covers, S-PE significantly increased the yield production (163.2 kg) compared to S-PE+N (105.5 kg).

KEYWORDS

Greenhouse covers; Cooling efficiency; Cucumber yield

1. INTRODUCTION

A greenhouse is essentially meant to permit at least partial control of microclimate. Obviously, greenhouses with partial environmental control are more common and economical than full-fledged systems. The diversity of the greenhouse covers and other plant production structures has increased dramatically during the past four decades. This has resulted from the availability of new types of covering materials and enhancements of previously existing materials, as well as the demands for technological improvements within the expanding environmental control (Abbouda *et al.,* 2012). Greenhouse ventilation is a necessary process to remove solar radiation heat, to control the level of relative humidity, and to replenish carbon dioxide that plants consume during the daylight hours in the process of photosynthesis due to the emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere. This causes the entrapping of the reflected solar radiation from the earth surface and the atmospheric temperature increases, causing global warming (Al-Helal, 2007). In Sudan, Greenhouses are required for crop production during summer and winter seasons. It can provide a suitable environmental condition for improving crop growth and productivity (Hashem *et al.,* 2011). In the last few years, Greenhouse cultivation has expanded to cultivate several type of crop such as tomato and cucumber during the summer season by covering greenhouses with polyethylene cover and cooling by evaporative cooling systems reduces the problem of excess heat in greenhouse (Boulard and Baille, 1993). Polyethylene is highly permeable to light used for photosynthesis and the heat transfer leads to rise temperature of greenhouses more than the temperature outside the house (Abbouda *et al.,* 2012).

Cucumber (*Cucumis sativus* L.) varies in responding to polyethylene covers which depending on materials used and environmental conditions (Fonsecal *et al.,* 2003). El-Aidy *et al.* (2007) reported that, the highest yield of cucumber was obtained in plastic tunnels and the lowest yield was produced by crops shaded directly with perforated film. Lorenzo *et al.* (2004) mentioned that, Shading and light intensity may have a time dependent effect on fruit production and water and nutrient uptake in plants. The selection of the suitable greenhouse cover material depends on many factors, such as initial investment, maintenance cost and local climate conditions (Papadopoulos and Hao, 1997). Despite the rapid expansion of investment in protected agriculture technology in Sudan, research in this field is non-existent. Therefore the objective of this study was to investigate the effect of different types of greenhouse covers on cooling efficiency and crop yield of cucumber (*Cucumis sativus* L.).

2. Methodology

2.1 Experimental site and layout:

The experimental work was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum - Shambat, Sudan (32^{o} 51 E, 15^{o} 65 N and 380 m above the mean sea level) during the summer season of 2018. Greenhouses were designed and installed to accommodate different treatments namely; double-layers of polyethylene with 9cm air gap (DPE), single-layer of polyethylene (SPE), and single-layer of polyethylene with green net (50% opening) (SPEN). These treatments were arranged in randomized completely block design (RCBD) with three replicates (Plate 1).

2.2 Design of evaporative cooling system

Evaporative cooling system is mainly based on the process of heat absorption during the evaporation of water. It consists of cooling pads and extracting fans. A cross fluted cellulose pad was mounted in a vertical fashion at the end of the greenhouse. A PVC pipe (1 inch diameter) suspended immediately above the cooling pads. Holes drilled each 10 cm long throughout the length of PVC pipe, and the end of this pipe was capped. A water sump mounted under the pads to collect the water and return it into the water tank (1000 liters), from which it can be recycled to the cellulose pads by means of the water pump. In order to bring the cold air onto the plants throughout the growth period, the cooling pads were located 20 cm above the ground surface of the greenhouse. Two extracting fans (single speed, direct drive and 90 cm diameter) located on the leeward side of the greenhouse and the pads on the aid toward prevailing wind (opposite side of the extracting fans). In the hot climate of Sudan, evaporative cooling systems have been commonly employed to reduce the interior ambient air temperature of greenhouses. Evaporative cooling system efficiency (η) is normally defined as the ratio of the actual dry-bulb temperature reduction to the theoretical maximum at 100% saturation as mentioned by Boulard and Baille (1993) as follows:

$$\eta\ \% = \frac{T_{o\,db} - T_{i\,db}}{T_{o\,db} - T_{o\,wb}} \times 100 \ \dots\dots\dots (1)$$

Or

$$\eta\ \% = \frac{T_{dd}}{T_{wd}} \times 100 \ \dots\dots\dots\dots\dots\dots (2)$$

where:

T_{odb} = dry-bulb temperature of outside air C
T_{idb} = dry-bulb temperature of inside air C
T_{owb} = wet-bulb temperature of outside air C
T_{dd} = cooling effect T_{odb} - T_{idb} C
T_{wd} = wet-bulb depression T_{odb} - T_{owb} C

2.3 Measurements

a. Plant parameters:

Cucumber seeds (LEADER F1 Hybrid, Syngenta company) were sown in nurseries of the CTC company, Sudan (controlled environment) and after the appearance of the third true leaf, seedlings were transplanted into the three greenhouses, one plant was placed in a hole with spacing of 0.4m between holes, each location was irrigated by a drip irrigation system The crop commenced to flower after 21 days, and fruited after 45 days. Leaves number, plant length, stem diameter and the total fresh yield were measured.

b. Environmental parameters:

Environmental parameters are generally recognized to have a major impact on the production of protected cropping. These parameters have been included ambient air temperature and air relative humidity. Temperature and relative humidity inside, outside greenhouses were measured using ISOLAB Laborgerate GmbH, ambient (outside, inside) temperature and relative humidity were recorded. Data was collected at each 4 hour (8:00am, 12:00pm, 4:00pm, and 8:00pm).

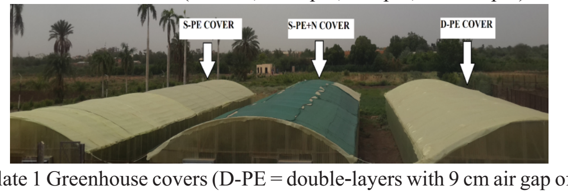

Plate 1 Greenhouse covers (D-PE = double-layers with 9 cm air gap of polyethylene, S-PE+N = single-layer of polyethylene covered with green net (50% opening) and S-PE = single-layer of polyethylene)

3. RESULTS AND DISCUSSION

a. Effect of covering materials on environmental control

As shown in Table 1 and 2 the average air temperature and relative humidity significantly difference ($P \leq 0.05$) between inside and outside greenhouses. While there were no significant differences ($P \geq 0.05$) inside the greenhouses with different greenhouse covers. Greenhouse with D-PE cover decreased the average temperature and increased the relative humidity as compared to S-PE+N and S-PE covers. The results were agreement with the results obtained by Abbouda *et al.* (2012) who mentioned that polyethylene is highly permeable to light used for photosynthesis and the heat transfer leads to rise temperature of greenhouses more than the temperature outside the house.

Table 1. Average air temperature with different greenhouse covers

Treatments	Temperature C				
	at 8:00am	at 12:00pm	at 4:00pm	at 8:00pm	Average
D-PE	26.19[c]	31.11[b]	30.31[b]	26.06[b]	28.42 b
D-PE+N	26.54[b]	31.41[b]	30.48[b]	26.10[b]	28.63b
S-PE	26.63[b]	31.77[b]	30.27[b]	25.92[b]	28.65b
Outside	31.05[a]	38.54[a]	39.79[a]	32.36[a]	35.43a
LSD at 0.05	0.30	1.00	0.25	0.36	1.62

Means in the same column(s) followed by the same letters are not significantly different according to the LSD test

Table 2. Average air relative humidity with different cover materials.

Treatments	Relative Humidity %				
	at 8:00am	at 12:00pm	at 4:00pm	at 8:00am	Average
D-PE.	81.50[a]	67.81[a]	66.13[a]	75.94[b]	72.84[a]
S-PE+N	78.94[b]	67.38[a]	64.31[a]	74.75[c]	71.34[a]
S-PE.	78.44[c]	65.31[a]	66.00[a]	76.75[a]	71.6[a]
Outside	52.63[d]	33.25[b]	28.71[b]	39.38[d]	38.49[b]
LSD at 0.05	2.48	4.74	2.52	0.38	3.92

Means in the same column(s) followed by the same letters are not significantly different according to the LSD test.

b. Evaporative cooling system efficiency

As presented in Table 3 ambient air temperature inside the greenhouses decreased when the air relative humidity outside the greenhouses was less than 20% and outside air temperature near 40°C. The highest values of evaporative cooling efficiency (64%) and cooling effect (7 C) were recorded inside greenhouse with D-PE cover at wet-bulb depression (11.03) and relative humidity (38.5%). While the lowest values were gave inside greenhouse with S-PE (61.5% and 6.8 C, respectively). In the hot climate of Sudan, evaporative cooling systems have been commonly employed to reduce the interior ambient air temperature of greenhouses, under these conditions the evaporative cooling system provided a cooling effect (air temperature difference between outside and inside the greenhouse) of 10 °C or more as reported by Abbouda et al. (2012). The result supported by Boulard and Baille (1993) who revealed that evaporative cooling systems were reduce the problem of excess heat in greenhouse.

Table 3. Ambient air temperatures outside (Todb) and inside (Tidb) the greenhouses, wet-bulb (Towb), wet-bulb depression (Twd), cooling effect (Tdd), air relative humidity outside the greenhouses (R.H) and efficiency of evaporative cooling system (η).

Cover	Todb	Tidb	Towb	Twd	Tdd	RH%	η%
S-PE	35.43	28.7[a]	24.4	11.03	6.8[a]	38.5	61.5[b]
S-PE+N		28.63[a]			6.8[a]		61.7[b]
D-PE		28.0[b]			7.0[a]		64.0[a]
LSD		0.53			0.35		2.71

Means in the same column(s) followed by the same letters are not significantly different according to the LSD test.

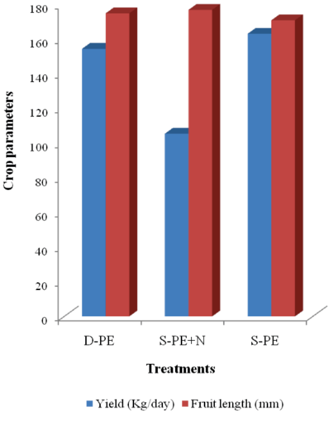

Fig 1 Effect of different greenhouse covers on the yield of cucumber

c. Fruit length, weight, diameter and total yield

As shown in Fig 1, total yield significantly ($P \leq 0.05$) affected by the different greenhouse covers. D-PE and S-PE gave the highest total yield as compared with S-PE+N which ranked the least. On the other hand fruit length, weight and diameter were not significantly ($P \geq 0.05$) affected by different covers. A significant variation in crop production under different cover materials may be due to the variations in climate factors and materials as well as crop water requirements (Hashem *et al.,* 2011). The results were consistent with the results obtained by El-Aidy *et al.* (2007) who studied the effect of different covers of materials on the yield of cucumber and found that the highest yield was obtained in plastic tunnels and the lowest yield was produced by crops shaded directly with perforated film. On the other hand, Lorenzo *et al.* (2004) reported that, shading a greenhouse may have a time dependent effect on fruit production and water and nutrient uptake in plants and after six weeks of shading applications, yield was reduced by 30% compared to no-shade treatments.

4. CONCLUSION

Greenhouse covers significantly affected the evaporative cooling system efficiency and crop yield of cucumber. Ambient air temperature inside the greenhouses was decreased when the air relative humidity outside the greenhouses is less than 20% and outside air temperature near 40°C. D-PE cover at wet-bulb depression (11.03) and relative humidity (38.5%) gave the highest values of evaporative cooling efficiency (64%) and cooling effect (7 C) were recorded inside greenhouse While the lowest values of evaporative cooling efficiency (61.5%) and cooling effect (6.8 C) were gave inside greenhouse with S-PE. The highest percentage of marketable fruit was recorded in S-PE. It is concluded that S-PE greenhouse cover is suitable for the production of cucumber in summer season in Khartoum State conditions or other region have similar climate conditions.

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