

# Impact of Different Thicknesses of Evaporative Cooling Pads on Crop Yield in Greenhouse

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**Abstract** – This study was conducted in Date Palm Technology Company, Khartoum North, Khartoum State. To evaluate the effect of three thicknesses of evaporative cooling pads for greenhouses (celdek pads) as compared to the conditions outside the greenhouses (control), for pads. The evaluation effect includes environmental parameters (temperature and relative humidity at 10 am and 2 pm) and crop test parameters (length and stem diameter, leaves number and width, fruit length and diameter, fruit weight and yield). The results obtained for the temperature at 10 am showed that there was no significant difference (0.05) inside the greenhouses, while a high significant difference between the conditions inside and outside of the greenhouses was found. Significant differences were found at 2 pm between all treatments as compared to the conditions outside the greenhouses, and the results obtained for relative humidity showed high significant differences at 10 am and 2 pm inside the greenhouses and between inside and outside the greenhouse, respectively. On the other hand, the results obtained for crop parameters showed that there were significant differences between all parameters inside the greenhouses and outside the greenhouses; however, the greenhouses with 300 mm thicknesses of pads gave the highest yield and the greenhouses with 100mm of pads gave the least and conditions outside gave the lowest.

**Keywords** – Greenhouse, Evaporative Pads, Cooling Efficiency, Control Environment.

## I. INTRODUCTION

A greenhouse is a structure used for protecting plants from adverse climatic differences and for supplying a favorable environment for plant production. This technique is necessary to overcome the high hazards of open field production, such as high rainfall, intense solar radiation, weed rivalry, as well as damages caused by diseases, insects, high temperature, and relative humidity [5]. Raising the yield and quality of vegetables, fruits, flowers, and aromatic plant production is the main purpose of a greenhouse. Moreover, a greenhouse can make the production continuously available throughout the year. Crop production in greenhouses plays a significant function in supplying adequate food to offset the high import bill of processed and unprocessed horticultural products [6]. A greenhouse consists of several devices that control certain factors, such as temperature, ventilation, relative humidity, amount of light, and carbon dioxide, for plant growth. Cultivation of crops in greenhouses is increasing in the high-altitude and temperate regions as well as in the warmer regions of the tropics and subtropics. Even though greenhouses protect crops from bad weathers, the high temperature and humidity during summer months cause unfavorable effects on crop

production in tropical regions [2]. Therefore, in such regions, the reduction of air temperature inside a greenhouse or the regulation of the temperature closer to the ambient temperature during summer is necessary for successful crop production. The growth conditions in a greenhouse system are usually achieved by monitoring the effective growth factors, such as carbon dioxide, temperature, relative humidity, light, and radiation. Greenhouses offer a better possibility for the off-season production of many crops [9].

The use of evaporative cooling pads is a reliable method but requires the greatest power consumption. Evaporative cooling systems are based on the exchange of evaporated water from sensible heat to latent heat, where water is supplied mechanically. The decrease in air temperature is due to the evaporation of water in air. Thus, temperature decreases with increasing humidity, while the enthalpy of air remains constant during the process. Fan pads, fogging systems, and roof evaporative cooling are some of the current evaporative cooling methods [7]. The exact relationship is not yet well known, but normally efficiency increased as the thickness increase up to a certain limit. Increases in pad density improves the overall porosity and capillarity, thus, producing a more uniform distribution of water, but require higher water flow and increase resistance to the air flow. Although it decreases the efficiency, a dense pad helps in the sustain of the pad in its place. During the hot season, the temperature of ambient air inside greenhouses and animal houses increases to over 40°C because of thermal stress [3]. In greenhouses, thermal stress negatively affects the emergence, stem strength, flowering, and fruit set and sizes of seedlings. High air temperatures in animal houses decrease feed consumption, weight gain, and milk and egg yields of animals [7]. The need becomes more urgent for off-season production. Various systems have been developed to reduce air temperature and improve thermal stress of plants and livestock. The use of evaporative cooling can decrease air temperatures by 4°C to 13°C [3]. In general, Sudan weather conditions are characterized by predominant long and hot summers and short and mild winters. Such climatic conditions put a great strain on the types of crops that could be successfully grown, which is very much true with most horticultural vegetables. Therefore, the current study examines the possible effects of thicknesses of evaporative cooling pads. Many attempts were made in this regard including the use of different thicknesses of evaporative cooling pads to reduce the temperature and alter relative humidity in greenhouses. This research work attempts to evaluate the impact of three different thicknesses of evaporative cooling pads during the summer season, with regard to their effect on

the environment inside greenhouses and on the performance of an off-seasonally grown test crop. To evaluate the effect of the different thicknesses of evaporative cooling pads on temperature and relative humidity of greenhouses under exhaust fan. To use a test crop to evaluate the effectiveness of the different thicknesses of evaporative cooling pads on off-season crop production.

## II. MATERIALS AND METHODS

The experiments were conducted in Date Palm Company in Khartoum North, Khartoum State (15 00 30 00 E, 380 m above sea level). The experimental work was mainly concerned about evaluating the impact of three different thicknesses of evaporative cooling pads (100 mm, 150mm and 300 mm) when used to change environmental conditions inside plastic film greenhouses with the purpose of off-season growing of crops. The experimental work involved measurement of both environmental parameters (temperature, relative humidity at different times of the day (10 am and 2pm) and crop parameters (length and diameter of stem, number and width of leaves, and length and diameter of fresh fruits and weight and crop yield). The statistical design used the Complete Randomize Design (CRD) coupled with Duncan's multiple range tests for the means separation test. The three thicknesses of evaporative cool pad treatments were tested for temperature and relative humidity at 10 am, and 2 pm each day for the duration of days which constituted the growing season of the test crop. Moreover, the temperature and relative humidity outside of the greenhouses were measured. The test crop was sown during the summer season, in and outside the greenhouses, on ridges 40 cm apart. Two seeds were placed in a hole, and the space between the holes was 40 cm. Each location of the holes was irrigated by drip irrigation nozzle from the drip irrigation pipe. The crop commenced to germinate after 4–6 days from sowing date, flowered after 21 days, and fruited after 45 days. The crop was harvested 6–7 times during its growing season. To evaluate the effectiveness of the evaporative cooling pad systems under test, the following data were collected: Temperature and relative humidity inside the greenhouse at 10 am and 2 pm, throughout the growing season were collected. Cooling efficiency, this is defined as the ratio of the actual dry-bulb temperature reduction to the theoretical maximum at 100% saturation [8]. It is calculated as per the following equation:

$$\mu = \frac{T_{ao} - T_{ai}}{T_{ao} - T_{as}} \times 100 \quad (1)$$

Where  $\mu$  = the cooling efficiency (%);  $T_{ai}$  the air-in temperature ( $^{\circ}\text{C}$ );  $T_{ao}$  the air-out temperature ( $^{\circ}\text{C}$ );  $T_{as}$  is the air temperature at saturation.

The crop parameter measured included the plant length and diameter, number and width of leaves, length and diameter of fruits, fresh and dry matter weight and crop yield. The specific equipment and materials used for the purpose of conducting the experimental work included the following: Three plastic-film greenhouses, of the arch standard greenhouses type, were used. The general

specifications of each greenhouse cover double layers of polyethylene, dimensions (36m length · 9m width · 3.75m height) and the frames galvanized iron. Three different thicknesses of evaporative cooling pads were used, 100 mm, 150 mm and 300mm and a cooling pad made of fluted cellulose sheets that are glued together. Its material is chemically impregnated with special compounds to prevent rot and ensure a long service life. The general specifications of the celdek pad system are dimensions (6m width · 1.5 m height) in galvanized steel it has water system components source of water, pump, pipes, gutter and tank. Exhaust fans were located on the greenhouse walls to draw out the greenhouse air, thus allowing fresh air to pass through the pads and into the greenhouse. Relative humidity and temperature hygrometer were used to measure the relative humidity and temperature inside and outside of the greenhouse. Pipe of irrigation system is 3/4 in. in diameter and 35 m length was used for the irrigation of the test crop in the greenhouses the pipe has 70 nozzles 40 cm apart and is connected with the water source pump. Cucumber (*Cucumis sativus*), was used as a test crop to evaluate the performance of evaporative cooling pads and their effect on temperature and humidity for off-season growing of crops. Cucumber is a winter crop, grows rapidly between 21 and 30  $^{\circ}\text{C}$  at low relative humidity [5]

## III. RESULTS AND DISCUSSION

This research work was conducted to evaluate the performance of three different thicknesses of evaporative cooling pads for summer cooling in greenhouses. The evaluation included temperature, relative humidity and saturation efficiency. Moreover, a test crop (cucumber) was used to evaluate the effectiveness of the different thicknesses of evaporative cooling pads on off-season production of crops. The crop parameters studied included stem length and diameter, leaves number and width, fruit length and diameter, fresh and weight of fruit and crop yield.

Results of temperature obtained from inside the greenhouses with different thicknesses of evaporative cooling pads, as well as for the conditions outside the greenhouses, at 10 am are shown in Table 1 and Fig. 1. The analysis of variance of the results showed that there was no significant difference ( $P = 0.05$ ) in temperature between the three thicknesses of evaporative cooled greenhouses; however, the greenhouse with 300mm thickness of pads gave the lowest temperature (22.10 $^{\circ}\text{C}$ ) while the other with 150 mm and 100 mm thickness of pads gave the highest (25.40  $^{\circ}\text{C}$ ), (27.36 $^{\circ}\text{C}$ ), respectively. Moreover, the analysis of variance showed that there was a significant difference ( $P = 0.05$ ) in temperature between the conditions inside and outside the greenhouses. The conditions outside the greenhouses had the highest temperature (33.12 $^{\circ}\text{C}$ ). This result is consistent with the findings of (Tina, 2011) who reported that the temperature outside the greenhouse at 10 am in the morning was relatively high due to the fact that the greenhouses conserve their coolness during the night and protects their inside from the short wave radiations in

the morning. Results of temperature obtained from the greenhouses with different thicknesses of evaporative cooling pads, as well as for the conditions outside the green houses, at 2 pm are shown in Table 1 and Fig. 1.

Table 1. Temperature inside and outside the greenhouse

Treatments	Temperature C°	
	At 10: 00 am	At 2:00 pm
Thicknesses (mm)		
300 mm	22.10b	30.13d
150 mm	22.40b	31.93c
100 mm	23.36b	32.97b
Outside	33.12a	41.30a
SE±	1.75	0.43
CV%	4.3	1.87

**Note:** Means in the same column(s) followed by the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT).

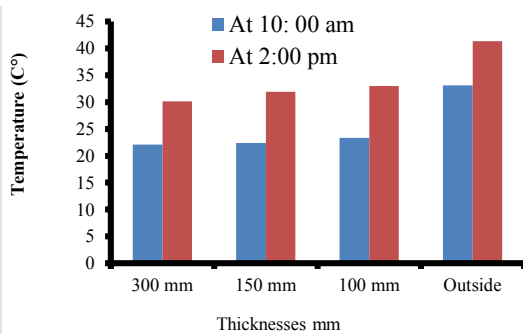


Fig. 1. Temperature inside and outside greenhouse at 10 am and 2 pm.

The analysis of variance of the results showed that there were significant differences ( $P = 0.05$ ) between all treatments. The greenhouse with 300 mm thickness of pads gave the lowest temperature ( $30.13^{\circ}\text{C}$ ) followed by the greenhouse with 150mm thickness of pads ( $31.93^{\circ}\text{C}$ ) and the greenhouse with 100mm thickness of pads ( $32.97^{\circ}\text{C}$ ), while outside conditions gave the highest temperature ( $41.30^{\circ}\text{C}$ ). The results could be attributed to the evaporative cooling effect of the pads, and the presence of a two-layer polyethylene covering of the greenhouses which created an air space and insulated the inside. Both factors increased the temperature difference between the inside and the outside of the greenhouses. Reference[10] obtained similar results. The results of temperature obtained from the greenhouses with different thicknesses of evaporative cooling pads, as well as for the conditions outside the green houses. The results obtained for relative humidity from the green houses with different thicknesses of evaporative cooling pads, as well as for the conditions outside the greenhouses, at 10 am are shown in Table 2 and Fig. 2. The analysis of variance showed that there were significant differences ( $P = 0.05$ ) between all treatments. The greenhouse with 300 mm thickness of pads gave the lowest relative humidity (37.96%) followed by the one with 150 mm thickness of pads (45.83%) and

the one with 100 mm thickness of pads (50.27%). However, conditions outside the greenhouses gave the least relative humidity (23.90%). The high value of relative humidity obtained for the greenhouse with straw pads could be attributed to the relatively higher ability of those pads in reducing the temperature at that time of the day, and their better ventilation. The above results are in line with the findings of Reference [9]. The results obtained for relative humidity inside the greenhouses with different thicknesses of evaporative cooling pads, as well as for the conditions outside the greenhouses, at 2 pm are shown in Table 2 and Fig. 2. The analysis of variance showed that there were significant differences ( $P = 0.05$ ) between all treatments. The greenhouse with 300 mm thickness of pads gave the lowest relative humidity (35.57%) followed by the one with 150 mm thickness of pads (39.77%) and the one with 100 mm thickness of pads (43.85%). However, conditions outside greenhouses gave the least relative humidity (20.37%). Due to the evaporative cooling effect and proper ventilation, the relative humidity was always higher inside the greenhouse compared to the outside conditions. Reference [9] indicated that maintaining proper relative humidity in the greenhouse or growing area can be very difficult during hot, dry summer days. Moreover, the analysis of variance showed that there was a significant difference ( $P = 0.05$ ) in relative humidity between the conditions inside and outside the greenhouses. The conditions outside the greenhouses had the least relative humidity (20.33%). The above results agreed with the findings of Reference [3]

Table 2. Relative humidity inside and outside greenhouses at 10 am and 2 pm

Treatments	Relative Humidity %	
	At 10 am	at 2 pm
Thicknesses (mm)		
100 mm	49.57a	35.57c
150 mm	45.83b	39.77b
300 mm	37.97c	43.85a
outside	23.90d	20.37
SE±	0.80	0.35
CV%	2.93	1.82

**Note:** Means in the same column(s) followed by the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT).

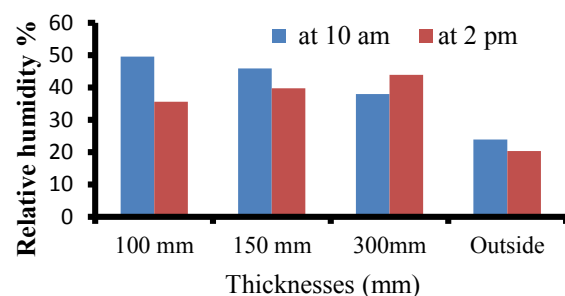


Fig. 2. Relative humidity inside and outside greenhouse at 10 am and 2 pm

### Cooling Efficiency

The results of the cooling efficiency inside the green houses for the three thicknesses of evaporative cooling pads, using Eq.(1), are shown in Table 3 and Fig. 3. The analysis of variance of the results showed that there was a significant difference ( $P = 0.05$ ) in cooling efficiency between the three thicknesses of evaporative cooled greenhouses. The greenhouse cooled by 100 mm thickness of pads gave the least value of saturation efficiency (64%), while the one cooled by 300 mm thickness of pads gave the highest value (90%). The poor performance of the 100mm thickness of pads could be attributed to the increased relative humidity coupled with plant evapotranspiration and reduced ventilation efficiency. On the other hand, the much better performance of the 300mm thickness of pads could be attributed to the well designed, properly installed and operated evaporative cooling system. These results are in line with the findings of [2].

Table 3. Cooling efficiency

Thicknesses (mm)	Tia	Tao	Tas	$\mu\%$	Means
100	28	23.5	21	64	75.32c
150	30	25.5	24.5	81	80.45b
300	31	26.5	26	90	86.67 a
ES $\pm$	0.87				
CV%	8.90				

Note: Means in the same column(s) followed by the same letters are not significantly different according to Duncan's Multiple Range test (DMRT).

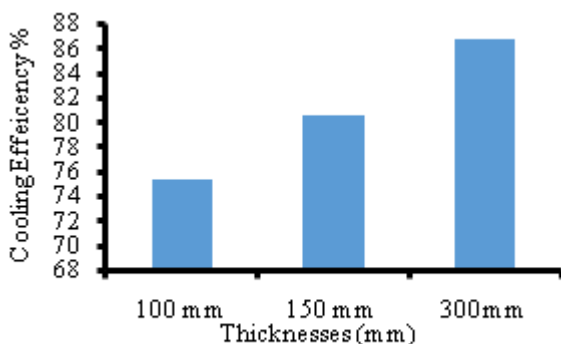


Fig3. Cooling efficiency inside greenhouse

The results obtained for stem length and diameter under different treatments are shown in Table 4 and Fig. 4. The analysis of variance of the results showed that there were significant differences ( $P=0.05$ ) in stem length and diameter between the treatments. It was found that the stem length and diameters (95 and 1.44cm, respectively) under the conditions of the greenhouse with 100 mm thickness of pads were the lowest compared to the other thicknesses of evaporative cooling pads in greenhouses, which could be attributed to increased relative humidity and reduced temperature. This result is in line with the findings of Reference [9] who indicated that a high relative humidity may cause weakening of the growth of a crop. The conditions inside the greenhouse cooled by 300 mm thickness of pads gave the highest plant height and stem diameter (220 and 3.9cm, respectively) compared to the other greenhouses. This result may be due to low

relative humidity and temperature, as well as proper ventilation. Comparing the results of stem length and diameter inside and outside of the greenhouses, it was found that plants under outside conditions were the shortest (24cm), but have the largest stem diameter (5.7 cm), which could be attributed mainly to the effects of the conditions outside the greenhouses, which were detrimental to stem length and favorable to stem diameter growth. Reference [10] indicated that the detrimental effects of high temperature on plant growth include reduced stem length, reduced leaf size, delayed flowering, reduced flower size, flower bud abortion, and reduced growth rate. The result obtained for plant leaves number and width under different treatments is shown in Table 4 and Fig. 4. The analysis of variance of the results indicated that there were significant differences ( $P = 0.05$ ) in plant leaves number and width between the treatments. The greenhouse with 300 mm thickness of pads gave the highest leaves number and width (78 and 10.6cm, respectively), while conditions outside the green houses gave the least results (9.0 and 3.0 cm). The greenhouse with 100 mm thickness of pads gave the lowest leaves number and width (34 and 5.8 cm, respectively) compared to the other two greenhouses. These results are in line with the findings of [9].

Table 4. Stem length and diameter and leaves number and width inside and outside the greenhouses.

Treatments	Crop stem		Leaves	
	Length (cm)	Diameter (cm)	Number	Width (cm)
100 mm	97c	1.14d	34c	5.8c
150mm	175b	2.4c	66b	8b
300 mm	220a	3.9b	78a	10.6a
outside	22d	5.7a	9d	3d
SE $\pm$	0.48	0.39	0.45	0.77
CV%	14.12	22.14	12.2	13.11

Note: Means in the same column(s) followed by the same letters(s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

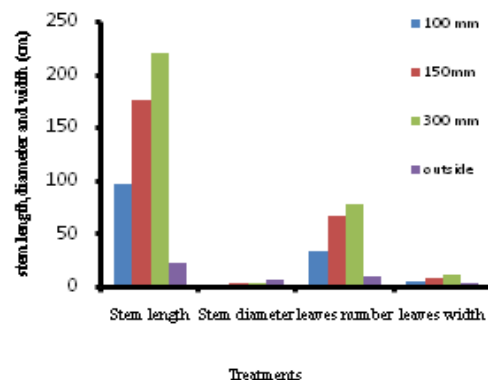


Fig4. Stem length, diameter and leaves number inside and outside the greenhouse.

The results obtained for fruit length and diameter under different treatments are shown in Table 5 and Fig. 5. The

analysis of variance of the results showed that there were significant differences ( $P = 0.05$ ) in fruit length and diameter between the treatments. The greenhouse with 300 mm thickness of pads gave the highest fruit length and diameter (16.67 and 8.3cm, respectively), while outside conditions gave the least results (4.89 and 3.1 cm). The greenhouse with 100 mm thickness of pads gave the lowest fruit length and diameter (12.4 and 3.9 cm, respectively) as compared to the other two greenhouses. Reference [9] reported that the fruit length and diameter were higher inside the greenhouse than outside the open field in tropical and subtropical regions. The results obtained for fruit weight under different treatments are shown in Table 5 and Fig. 6. The analysis of variance of the results indicated that there were significant differences ( $P = 0.05$ ) in fruit weight and dry matter among the treatments. The greenhouse with 300 mm thickness of pads gave the highest fruit weight (75.6g), while outside conditions gave the least results (15.8g). The greenhouse with 100 mm thickness of pads gave the lowest fruit weight (33.0g, respectively) when compared to the other two greenhouses. These results could be attributed to the variability in environmental conditions between the treatments. The result are in line with the findings of Reference [5] who reported that fruit weight and dry matter content are linked directly to the climatic conditions of temperature, relative humidity, carbon dioxide concentration and daily light interval. The results obtained for yield per plant under different treatments are shown in Table 5 and Fig. 6. The analysis of variance of the results showed that there were significant differences ( $P = 0.05$ ) in crop yield between treatments. The greenhouse with 300 mm thickness of pads gave the highest crop yield per plant (833g), while outside conditions gave the lowest result (148g). The greenhouse with 100 mm thickness of pads gave the lowest yield per plant (356g) when compared to the other two greenhouses. These results were expected because of the different environmental conditions under the different treatments, and are in line with findings of Reference [7] who reported that the fruit yield was about two times higher inside the greenhouse than the open field due to warm and humid weather inside.

Table 5. Fruit length and diameter fresh weight and crop yield inside and outside the greenhouses.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield (g)
100 mm	12.4c	3.9c	33c	365c
150 mm	15b	6.5b	67b	755b
300 mm	16.67a	8.3a	75.6a	833a
Outside	4.89d	3.1d	15.8d	148d
SE±	0.67	0.98	0.17	1.04
CV%	5.32	16.5	13.45	16.04

Note: Means in the same column(s) followed by the same letters(s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

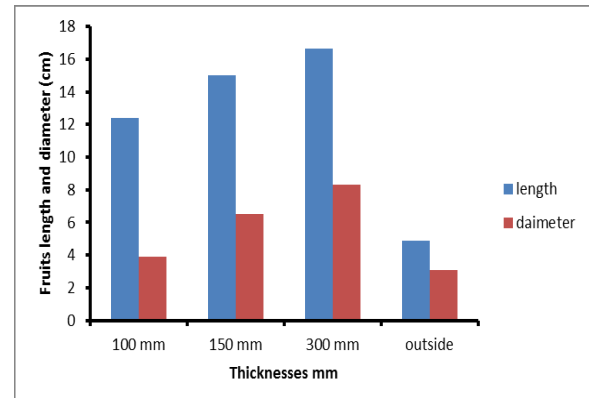


Fig. 5. Fruits length and diameter inside and outside the greenhouses

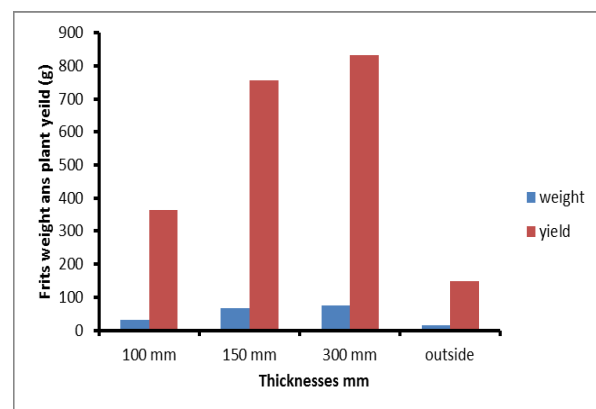


Fig. 6. Fruit weight and dry matter and yield inside and outside the greenhouses

#### IV. CONCLUSIONS

This research work it could be concluded that:

- There was no significant difference in temperature between the three thicknesses of evaporative cooled greenhouses at 10 am.
- There were significant differences in temperature between the different thicknesses of greenhouses at 2 pm. The greenhouse with 100 mm thickness of pads gave the highest temperature, while that with 300 mm thickness of pads gave the lowest.
- Conditions outside the greenhouses, with regard to temperature, were significantly different from those inside and gave higher temperatures at all two times of readings.
- There were significant differences in relative humidity between the different thicknesses of greenhouses at both 10 am and 2 pm,. The greenhouse with 300mm thickness of pads gave the lowest relative humidity at all times, while the one with 100 mm thickness of pads gave the highest.
- Conditions outside the greenhouses, with regard to relative humidity, were significantly different from those inside, and gave the least relative humidity at all two timings.
- There was a significant difference in cooling efficiency between the three thicknesses of cooling pads, such that 300 mm thickness of pads gave the

highest cooling efficiency and the 100 mm thickness of pads gave the lowest.

- There were significant differences in crop production traits between the different thicknesses of evaporative cooling pads of greenhouses. The greenhouse with 300 mm thickness of pads resulted in the highest stem length and diameter, number and width of leaves, fruit length and diameter, weight of fresh fruit, as well as yield per plant. On the other hand, the greenhouse with 100 mm thickness of pads gave the lowest results.
- Conditions outside the greenhouses, with regard to crop production parameters, were significantly different from those inside, and gave the least values for all measured traits tested except for plant stem diameter, which was higher than any value obtained.

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### REFERENCES

- [1] Raymond, K., 2006. Evaporative Cooling for Laying Houses in Arizona. ASAE Paper No. 72-414, ASAE, St. Joseph, MI.
- [2] Pek, Z., & Hayles, L. (2004). The effect of daily temperature on truss flowering rate of ornamental crops, *Journal of Science of Food and Agriculture*, 84, (13),1671–1674.
- [3] Bartok, J.W., 1990. Lower Humidity Levels in Your Greenhouse. Unpublished, Ph.D. Thesis, University of Connecticut, Connecticut, USA.
- [3] Öztürk, H.H. (2003). Evaporative cooling efficiency of a fogging system for greenhouses. *Turkish Journal of Agriculture and Forestry*, pp. 27, 49-57.
- [5] Ahmed, E.M., Abaas, O., Ahmed, M., & Ismail, M.R. (2011). Performance evaluation of three different types of local evaporative cooling pads in greenhouses in Sudan. *Saudi Journal of Biological Sciences*, 18, 45-51.
- [5] Marcelis, L.F., Eijer, M.B., 1996. Effect of temperature on the growth of individual cucumber fruits. *Physiology Planetarium*, Kobenhagen 87 (3), 321–328.
- [5] Sharam, A.K., Salokhe, V.M., 2006. *Greenhouse Technology and Application*, first ed. Agrotech Publishing Academy, England
- [6] Al-Amri, A. (2000). Comparative use of greenhouse cover materials and their effectiveness in evaporative cooling in eastern province of Saudi Arabia, *Agricultural Mechanization in Asia, Africa and Latin America, AMA*, 31,(2), 61–66
- [6] Rezuwan, K. (2002). Design and development of tropical greenhouse structures. Proceedings of 2nd World Engineering Congress Sarawak, Malaysia.
- [6] Soponpongipat, N., Jaruyanon, P., & Nanetoe, S. (2011). The thermo-economics analysis of the optimum thickness of double-layer insulation for air conditioning duct. *Energy Research Journal*, 1, 146-151.
- [7] Medany, M.A., Wadid, M.M., Abou-Hadid, A.F., 1999. Cucumber fruit growth rate in relation to climate. *Acta Horticulture*, The Hague 486, 107–111.
- [7] Ganguly, A., & Ghosh, S. (2011). A review of ventilation and cooling technologies in agricultural greenhouse application. *Iranica Journal of Energy & Environment*, India. 2, (1), 32-46.
- [8] ASHRAE (1997). Environmental control for animals and plants. Fundamental handbook. New York, U.S.A. ELSIVER, Chapter 10-17.
- [9] Nimje, P.M., Shyam, M., 1993. Effect of plastic greenhouse on plant microclimate and vegetable production. *Farming Systems* 9, 13–19.

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