Investigation and Utilization of Solar Energy for Heating Greenhouse Sweet Melon during Winter Season

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ABSTRACT

The aim of this experimental work was to investigate the effect of utilizing solar energy for heating greenhouse on growth, development, productivity, and fruit quality of three different hybrid of sweet melon crop (Yathreb 7, Yathreb 8 and Yathreb 22) during winter of two following growing seasons (2008 and 2009). Two similar gable-even-span greenhouses were functioned at EL-Sabahia Horticultural Research Station to grow and produce sweet melon crop. The three hybrids crop were planted on December during the two growing seasons under two different greenhouse microclimates. The first greenhouse (G1) was equipped with a complete heating system utilizing the solar energy, while, the second greenhouse (G2) was mechanically ventilated during daylight without heating system. The obtained results revealed that, the maximum and minimum indoor air temperatures of (G1) during January, February, March, and April, respectively, were 26.1 and 12.9ºC, 28.0 and 15.7ºC, 28.6 and 16.4ºC, and 30.6 and 17.1ºC. Whereas, the maximum and minimum indoor air temperatures of (G2) during the same period were 26.8 and 6.3ºC, 28.0 and 10.8ºC, 30.4 and 13.5ºC, and 32.6 and 15.3ºC, respectively. The obtained data also showed that, the microclimatic conditions of (G1) was at and around the optimal level for the sweet melon crop, resulting in increase the growth, development, and productivity of crop. The increase percentages in fruit yield were 18.35 and 27.59% in the first and second year, respectively.

Key words: greenhouse – solar energy – heating – cantaloupe.

INTRODUCTION

In the winter period, the temperature under greenhouse is very low at night and it is rather high during the day. Consequently, the night heating of greenhouse is essential, Lazâar et al., (2008). Heating greenhouses in cold climate is usually performed by burning non renewable fossil fuel, generally oil. The environmental benefits of consuming vegetables locally grown in greenhouses that involve less transportation can be canceled by the large amount of energy required to grow those vegetables in greenhouses in winter. Therefore, different strategies have been considered to reduce energy consumption in greenhouses. Using solar energy to heat greenhouses is one of prime importance. With a high glazed surface area, greenhouses are natural solar collectors. Increasing thermal mass and insulation is necessary to keep the solar energy inside to heat the greenhouse at night, Santamouris et al. (1994).

Sweet melon is one of the most important cultivated cucurbits. The plants are grown primarily for their fruits, which have great diversity in shape, size, and flesh color. In Egypt, sweet melon are grown during four different seasons (i.e., Autumn crop under low tunnels from the first of October to the first of December; Spring crop, from the first of February to the first of April, early summer crop during May to July and summer crop from July to October in the upper Egypt particularly in Aswan governorate to export to the European markets). Vegetables originated in different parts of the world: some came from tropical or subtropical countries and others from temperate zones; some from humid areas and others from more arid climates. Each kind of vegetable has its own optimum growth requirements, with some more fastidious, and others less so. Temperature is the most important climatic factor to be considered in vegetable production. It determines when and where a certain crop can be grown, and vegetable crops can be broadly classified according to their temperature requirements. In this respect, sweet melon can be classified as warm season crops which very sensitive to the low temperature (very tender). It is known that the mean monthly temperatures for sweet melon are: optimum, 18-24ºC; maximum; 32ºC and the minimum 15ºC. (http://www.kzndae.gov.za/Portals/0/Horticulture/Veg%20prod/climatic_requirements.pdf). The melon crop (*Cucumis melo* L.) is very sensitive to air temperature, not tolerating frosts at any time of its growth. The higher average temperature causes an increased rate of crop development and is responsible for earlier fruit maturation (Pardossi et al., 2000). The importance of studies that relate this environmental factor with the development of the plant stands out previously by other authors (Jenni et al., 1996; Amuyunzu et al., 1997; Ventura and Mendlinger, 1999; Baker and Reddy, 2001). The effect of the different temperatures on the winter and spring melon growth and yield in the greenhouse in northwestern area was researched by Li et al., (2010). The plant height, the diameter of stem, the ratio of root to shoot and the yield of thick-skinned melon-Yipintianxia 108 under the different treatments of temperature (natural temperature, 3-5ºC higher than natural temperature and 8-10ºC higher than natural temperature) in the solar greenhouse were measured and compared. The authors detected that the plant length, the stem diameter and the fresh yield of the sweet melon were significantly increased with increasing the air temperature however; its ratio of root was significantly reduced. The optimal index of sweet melon growth appeared in the treatment of 8-10^{o}C higher than natural temperature and the yield per plot was 49.37% higher than that in the treatment of natural temperature. The authors concluded that the treatment of 8-10^{o}C higher than natural temperature was favorable to the melon growth. Changes in sweet melon quality are the result of complex genetic, physiological and environmental influences. From the consumer's standpoint, quality melons must be sweet, flavorful and reasonably firm (Robert, et al., 2006).

Youssef (2007) developed two mathematical simulation computer programs to achieve the optimal combination of various designated parameters required for sizing a solar thermal water storage system. The experimental data revealed that the thermal storage system operated satisfactorily for six months without malfunction for keeping the greenhouse indoor air temperature at or around the optimal level throughout the day for cucumber crop.

The objectives of this study were to; 1) utilize the solar energy for warming the greenhouse indoor air and conserve energy, 2) reduce the indoor air temperature fluctuation of the greenhouse by extracting the exceeded heat during daylight-time and utilized it to warm up the greenhouse indoor air at nighttime, 3) elevate the indoor air temperature of greenhouse at nighttime and 4) study the effect of night heating on sweet melon growth, development, productivity and fruit quality.

MATERIALS AND METHODS

Materials

Greenhouses

Two identical gable-even-span greenhouses were utilized at EL-Sabahia Horticultural Research Station (latitude and longitude angles, respectively, are 31.22ºN and 30.50°E, and 3.00 m mean altitude underneath the sea level), Alexandria Governorate, to grow and produce sweet melon crop during winter of two successive growing seasons (2008 and 2009). The geometric characteristics of each greenhouse are as follows: eaves height 2.93 m, height of each side wall 2 m, rafter angle 25^{o}, width 4 m, length 8 m, floor surface area 32 m^{2}, and volume 78.922 m^{3}. The two greenhouses (G1 and G2) are covered using single layer of polyethylene sheet (PE) of 150 μm as shown in Fig. (1). The greenhouse facility used in this research work was covered with the ratio of cover surface area to the total greenhouse surface area of 2.603. To increase and maintain the durability of structural frame and polyethylene cover, twenty tensile galvanized wires (2 mm diameter) are tied and fixed throughout the rafters and vertical bars in each side of the plastic greenhouses.

Solar heating system

An air-to-water heat exchanger was constructed in a thermal solar storage water tank. The whole system was buried in the ground, and the top surface of the system was at the same level of the ground surface, (Fig. 2). The thermal solar system specifications and constructions were described by Youssef (2007).

In order to conserve the greenhouse energy, the ventilation system of heated greenhouse was acted differently throughout the 24 hours. It was activated and the fans were switched ON during daylight-time from sunrise to sunset.

a- solar heated greenhouse (G1) **b- mechanically ventilated greenhouse (G2)**

Fig. 1: Experimental gable-even-span greenhouses.

Fig. 2: The solar thermal system was opened from sunrise till sunset and the system covers were acted as solar reflectors during daytime and closed from sunset till the sunrise next day.

During this period, the greenhouse air was warmed up by the transmitted incident solar radiation through the greenhouse cover. Meanwhile, the indoor air temperature of the greenhouse during daylight-time could dramatically increase over the set point temperature, (28.0^{o}C).

Accordingly, an extracting fan withdrew the hot air from the greenhouse during this period. It delivered the exhaust air thereafter to the solar thermal storage system. Exhaust air, carrying the extra available heat from the greenhouse, entered the heat exchanger pipes in the water tank and damped its heat. The air returned back afterwards to the greenhouse through a 12 inch duct. Exhaust air was mixed with fresh air before entering the greenhouse. This was done to get red off both the undesirable materials and moisture accumulated in the greenhouse. Fresh air was also used to supply the greenhouse by carbon dioxide (CO_2). A digital thermostat controller for the fan motor was adjusted at a set point temperature during the daylight. During daylight, the cover was hanged at different set points from sunrise to sunset to act as a solar reflector as illustrated in Fig. (2). It reflects as much solar energy as possible. Therefore, system acquired energy from the direct and reflected sun rays in addition to the extra heat from the greenhouse exhaust air. At night starting from sunset, the thermal storage tank was covered until sunrise next day.

At night and when the greenhouse inside air temperature started to decline below the minimum set point, the fans were automatically switched ON again. During this period from midnight until sunrise next day, intermittent ventilation was carried out and the heat stored in the water was absorbed once again by the air and returned back to warm up the indoor air of greenhouse. This was to prevent the interior air temperature from dropping below the desired level at night.

Cultivation and watering systems

Three hybrids of sweet melon namely; Yathreb 7, Yathreb 8 and Yathreb 22 were grown inside the two greenhouses during winter season. One greenhouse was equipped with solar thermal system (G1), while the other greenhouse was mechanically ventilated without heating system (G2) as shown in Fig. (1). Each greenhouse had 6 rows of sweet melon plants. Each row had 18 plants. The experimental design used was a randomized complete blocks design with three replicates (RCBD). Each replicate contained two rows. Soil disinfection was carried out using Rizolex-T 50% in the concentration of 1 gm/liter during mixing the soil components. The seeds were sown in the greenhouse in a tray with 209 growth blocks. The seedlings were vegetated out at the four leaves stage after 21 days from planting with an average length of 10.0 cm. The seedlings of the three hybrids were transplanted in the two greenhouses on the 2nd of December, 2008 for the first season while, they were transplanted on 5th of December, 2009 for the second season. Drip irrigation system was used for watering the sweet melon crop.

Procedure:

Normal agricultural practices used for commercial sweet melon production were practiced as used in the area. Data were measured and recorded on all the grown plants inside the two greenhouses as follows:

Recorded data

1-Engineering data:

a- Greenhouses indoor air temperatures.

b- Water temperatures in solar thermal storage tank.

c- Ambient air temperatures (outdoor air temperature).

2- Vegetative measurements; plant length (cm), number of branches per plant.

3- Yield and its components; average fruit number per plant; average fruit weight (kg) and total fruit yield per plant (kg).

4-Fruit characteristics; flesh thickness (%) was calculated as the ratio between flesh thickness and fruit diameter; placenta hardness which was rated from 1 to 10, 1 denoted the juicy placenta tissues and 10 is the hard placenta; netting degree was rating from 1 to 10, 1 denoted the extreme smooth fruit skin and 10 the heavily rough fruit; total soluble solids (T.S.S) % was determined using the Zeiss hand refractometer.

Statistical Analysis:

The analysis of variance was used to analyze the obtained data as outlined by Snedecor and Cochran (1980). Comparisons among the means of different treatments were done, using Duncan's multiple range test procedure at $p = 0.05$ level of significance, as illustrated by Snedecor and Cochran (1980).

RESULTS AND DISCUSSIONS

The main thermal solar system indicators are the temperatures of water inside the thermal storage tank (T_w), indoor air temperature of greenhouse (T_{ai}) and ambient air (T_{ao}). The set-point temperature at nighttime for January, February, March and April months, respectively, were 15.0, 16.0, 18.0 and 18.0°C to achieve an optimum night heating requirements to be used as energy conservation regime, as recommended by Youssef (2007).

Solar radiation flux incident outside the greenhouses

The hourly averages solar radiation flux incident on a horizontal surface outside the two greenhouses during the experimental period (from January to April) is plotted in Fig. (3). It clearly reveals that, the solar radiation flux incident was varied from month to month and from hour to another throughout the experimental period. Therefore, the daily average solar radiation flux incident outside the two greenhouses during the experimental period (from January to April) was 369.4, 470.6, 525.6, and 636.7 W/m^2, respectively.

Temperatures of the solar heated greenhouse and its components:

The temperatures of water, indoor air of greenhouse and ambient air for the greenhouse (G1) as affected by the solar heating system during the experimental period are illustrated in Fig. (4a, b, c, and d). The maximum water temperatures in the storage tank were 26.2, 27.8, 29.5 and 30.9°C which achieved at 2:15, 3:15, 4:00 and 4:30 pm during the experimental period, respectively. These results revealed that, as the solar energy flux incident outside the greenhouses was increased the water temperature in the storage tank increased and the time of the maximum temperature was achieved (i.e., more energy was stored in the thermal storage tank).

The maximum indoor air temperatures of the greenhouse (G1) during the experimental period (from January to April), respectively, were 26.1, 28.0, 28.6 and 30.6°C. While, the indoor air temperatures of the greenhouse at nighttime from 7:00, 8:00, 9:00 and 10:00 pm decreased to reach the set-point temperatures at those times. These results mean that, extracting the extra heat accumulated inside the greenhouse (G1) during daylight-time prevented the indoor air temperature of the greenhouse from reaching harmful degree for sweet melon plants. On the other hand, the minimum indoor air temperatures of the greenhouse during the experimental period were 12.9, 15.7, 16.4 and 17.1°C, respectively, which occurred at and around 6:00 am. It was also, observed that the reduction in indoor air temperature of greenhouse (G1) under the recommended level of air temperature occurred only during January month. This could be attributed to the amount of solar radiation flux incident during this month was insufficient to provide and maintain the desired level of indoor air temperature. However, the nightly average indoor air temperatures during this month were around the optimal level.

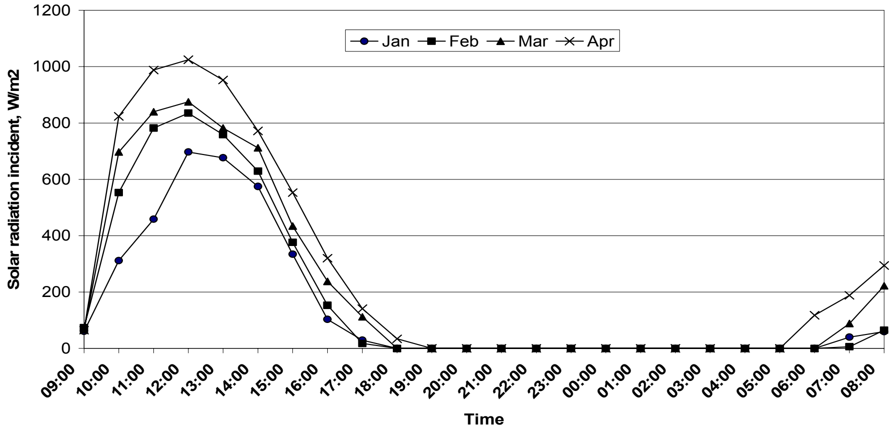
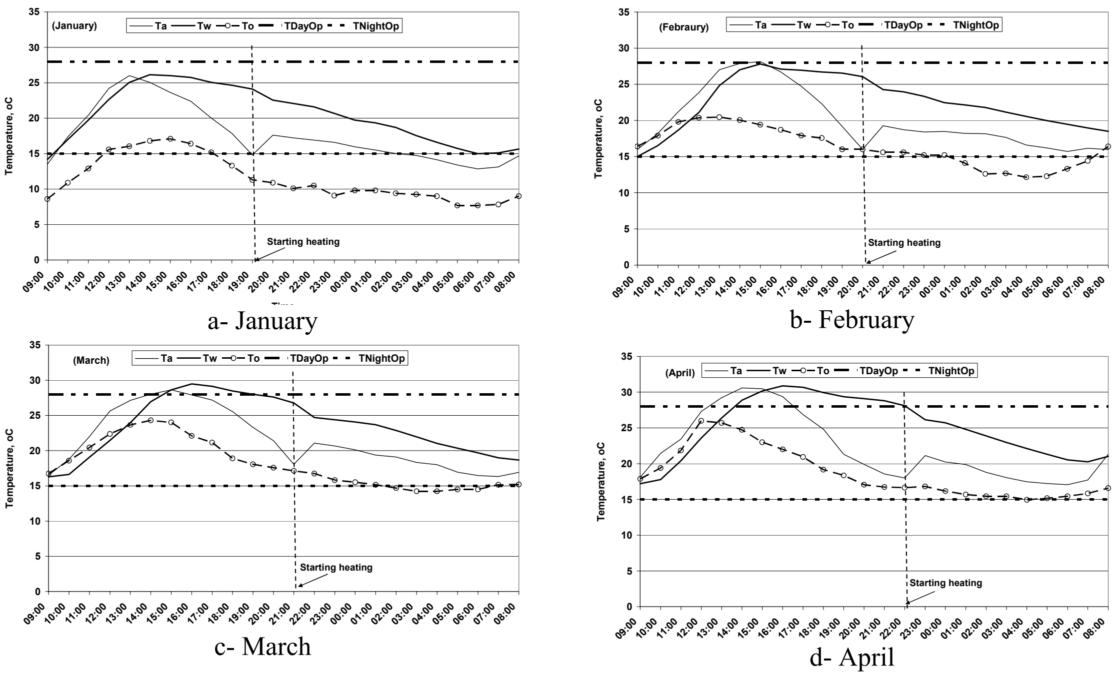


Fig. 3: Solar radiation flux incident on a horizontal surface during in the experimental period as a function of solar time.



a- January

b- February

c- March

d- April

Fig. 4: Temperatures of water, indoor air of greenhouse and ambient air for the greenhouse (G1) during the experimental month.

Indoor air temperatures of the greenhouse (G2)

The indoor air temperatures of the mechanically ventilated greenhouse (G2) are plotted in Fig. (5). The maximum indoor air temperatures of the greenhouse (G2) during the experimental period (from January to April), respectively, were 26.8, 28.0, 30.4 and 32.6 ^{o}C, which occurred at 1:00 pm except April month when it was recorded at 2:00 pm. It also, showed that indoor air temperature of greenhouse (G2) decreased under the minimum recommended temperature (15^{o}C) at three different times 10:15 pm, 00:00 am and 3:00 am during January, February and March months, respectively. While, during April month it did not occur. The minimum indoor air temperatures of greenhouse (G2) during the experimental period were 6.3, 10.8, 13.5 and 15.3^{o}C, respectively. These results reveal that the nightly average indoor air temperatures were lower than the minimum recommended level for three months (January, February and March). Also, over the maximum recommended indoor air temperatures during daylight-time occurred in March and April months.

The previous two Figs (4 and 5) revealed that the fluctuations of greenhouse indoor air temperatures were higher in greenhouse (G2) than the greenhouse (G1). The minimum greenhouse air temperatures also, were elevated in solar heated greenhouse than mechanically ventilated greenhouse. These finding can be attributed to decreasing daytime temperatures by extracting the extra heat from the greenhouse air and storing it in the water of the thermal storage system and feed it back to worm up the greenhouse air at night for night heating. These results are in agreement with that published by Youssef (2007) when mentioned that nightly heating increased the minimum temperatures of the greenhouse indoor air and reduced the difference between the maximum and minimum of greenhouse indoor air temperatures.

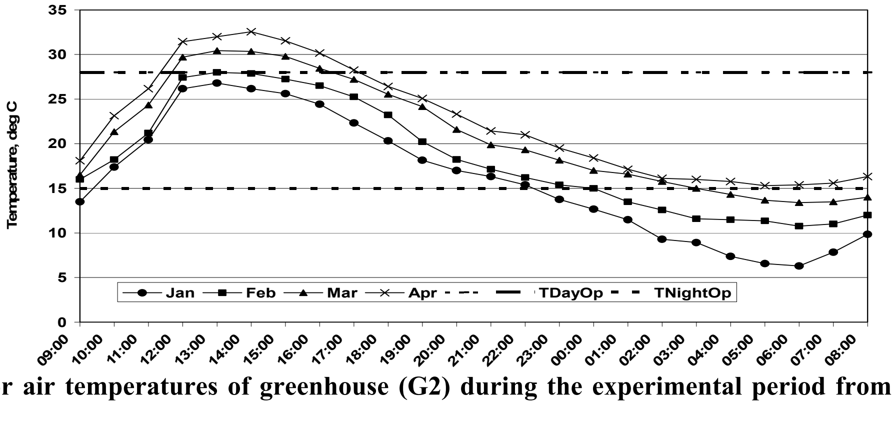


Fig. 5: Indoor air temperatures of greenhouse (G2) during the experimental period from January to April.

Vegetative characteristics of the sweet melon crop

The mean values of the vegetative characteristics (plant length and number of branches per plant) and flowering date are summarized and listed in Table (1). The obtained data clearly revealed that there were significant differences among the tested hybrids; i.e., Yathreb 7, Yathreb 8 and Yathreb 22 for the plant length characteristics. With respect of the hybrids grown inside the two greenhouses; the results showed that the hybrids Yathreb 7 and Yathreb 8 gave the higher length of plants as compared with hybrid Yathreb 22 in the first and second seasons. While, the difference between the plant length of the two hybrids Yatherb 7 and Yatherb 22 during the second growing season was not significant. Table (1) also illustrated that there were no significant differences among the tested hybrids for the number of branches per plant during the two growing seasons. The data of the number of branches per plant and flowering date showed that there were no significant differences among the tested hybrids over the two years for the two greenhouses (Table, 1).

On the other hand, the data concerning the comparison between the two microclimatic conditions of the two greenhouses (G1 and G2), appeared that there were significant effects only for the plant length, while the number of branches per plant and flowering date characteristics did not possess any significant differences between the two greenhouses as shown in Table (2). However, the greenhouse (G1) significantly gave length of plants higher than that the greenhouse (G2).

Fresh yield and its component characteristics

The mean values of the fresh yield included; number of fruits per plant, average fruit weight (g) and fresh yield per plant (kg) during the two growing seasons for the two greenhouse (G1 and G2) are summarized and listed in Table (3). The obtained data illustrated that the plants grown inside the greenhouse (G1) significantly gave more number of fruits per plant as compared with the greenhouse (G2). It clearly appeared that there were no significant differences between the two greenhouses on the average fruit weight during the first season, while, the average fruit weight was significantly increased inside the greenhouse (G1) during the second year as compared with the greenhouse (G2). It also clearly showed that in spite of the average fruit weight of the greenhouse (G2) during the first season was higher than that the greenhouse (G1) by 5.99%, the average fruit weight per plant of greenhouse (G1) was greater than that the greenhouse (G2) by 18.35%. Whereas, the average fruit weight and average fruit weight per plant of greenhouse (G1) were greater than that the greenhouse (G2) during the second season by 11.73% and 27.59%, respectively. These results are in harmony with the data recorded and listed in Table (4) which indicated that the tested sweet melon hybrids grown inside the greenhouse (G1) gave; in general, higher values than the same hybrids grown inside the greenhouse (G2). The obtained results are in agreement with that published by Li, *et al*. (2010) when they stated that, the plant height, the diameter of stem, and the fresh yield of the sweet melon were significantly increased as the indoor air temperature increased by 8-10ºC above the natural level. From the previous results, it could be concluded that increasing fruit yield (18.35% and 27.59%, during the two successive growing seasons, respectively) for the greenhouse (G1) was mainly, attributed to the increase in both vegetative growth of the plants and the number of fruits per plant.

The mean values of the fresh yield included; number of fruits per plant, average fruit weight (g) and fresh yield per plant (kg) for the three different sweet melon hybrids and its component characteristics during the two growing seasons for the two greenhouse (G1 and G2) are presented in Table (4). The obtained data of the number of fruits per plant for the three different hybrids grown inside the greenhouse (G2) appeared that the highest number of fruits per plant was produced by the hybrid Yathreb 22 with significant differences with Yathreb 7 and Yathreb 8, during the first growing season. On the other hand, the two hybrids Yathreb 7 and Yathreb 22 gave the highest fruit number per plant followed by Yathreb 8, during the second growing season. The obtained results also revealed that, there were no significant differences among the hybrids for the number of fruits per plant during the first growing season inside the greenhouse (G1). On the other hand, Yathreb 7 and Yathreb 22 significantly gave higher number of fruits per plant as compared with Yathreb 8 in the second growing season. Table (4) also showed that the highest average fruit weight was given by Yathreb 8 during the two growing season when the plants were grown inside the two greenhouses (G1 and G2). The hybrid Yathreb 8 was significantly produced the highest fresh yield per plant inside the greenhouse (G2) during the two growing seasons (Table, 4). Yathreb 7 and Yathreb 22 gave lower values as compared with Yathreb 8 for this trait. Yathreb 22 gave the lowest value of the average fruit yield character during the second season. The same trend of results were also observed inside the greenhouse (G1) where, the hybrid Yathreb 8 gave the highest fresh yield per plant in both growing seasons. There was no significant difference between Yathreb 8 and Yathreb 7 with respect to this trait during the first growing season. Yathreb 7 and Yathreb 22 gave lower values of average fresh yield per plant during the second growing season with insignificant differences among them, as appears in Table (4).

Table 1: Mean performance of the sweet melon hybrids for the vegetative characteristics and flowering date during the two growing seasons of 2008 and 2009.

Hybrid	2008						2009					
	Greenhouse (G1)			Greenhouse (G2)			Greenhouse (G1)			Greenhouse (G2)		
	PL* (cm)	NB/P	FD (day)	PL (cm)	NB/P	FD (day)	PL (cm)	NB/P	FD (day)	PL (cm)	NB/P	FD (day)
Yathreb 7	210^{a}	3.33^{a}	40^{a}	188^{a}	3.33^{a}	41^{a}	206^{a}	3.56^{a}	43^{a}	180^{a}	3.0^{a}	44^{a}
Yathreb 8	212^{a}	3.66^{a}	39^{a}	190^{a}	3.33^{a}	37^{a}	208^{a}	3.33^{a}	44^{a}	188a	3.66^{a}	42^{a}
Yathreb 22	204^{b}	3.33^{a}	39^{a}	177^{b}	3.56^{a}	38^{a}	200^{b}	3.33^{a}	44^{a}	178^{b}	3.33^{a}	40^{a}

Values with the same alphabetical letter, in a comparable group of means do not differ significantly according to Duncan's Multiple Range test at 0.05 level of significance

- PL = plant length; NB/P = No. of branches/ plant; FD = flowering date

Table 2: Mean values of the vegetative characteristics inside the two greenhouses during the two growing seasons of 2008 and 2009.

Greenhouse	2008			2009		
	Plant length (cm)	No. of branches /plant	Flowering date (day)	Plant length (cm)	No. of branches /plant	Flowering date (day)
Greenhouse (G1)	208.67^{a}	3.44^{a}	39.33^{a}	204.67^{a}	3.41^{a}	43.67^{a}
Greenhouse (G2)	185.0^{b}	3.41^{a}	38.67^{a}	182.0^{b}	3.33^{a}	42.0^{a}

Values with the same alphabetical letter, in a comparable group of means do not differ significantly according to Duncan's Multiple Range test at 0.05 level of significance.

Table 3: Mean values of the fresh yield and its component characteristics for the two greenhouses during the two growing seasons of 2008 and 2009.

Greenhouse	2008			2009		
	No. of fruits / plant	Average fruit weight (g)	Average fruit yield / plant (kg)	No. of fruits / plant	Average fruit weight (g)	Average fruit yield / plant (kg)
Greenhouse (G1)	3.03^{a}	0.918^{a}	2.780^{a}	3.33^{a}	1.01^{a}	3.33^{a}
Greenhouse (G2)	2.44^{b}	0.973^{a}	2.349^{b}	2.89^{b}	0.904^{b}	2.61^{b}

Values with the same alphabetical letter, in a comparable group of means do not differ significantly according to Duncan's Multiple Range test at 0.05 level of significance.

Table 4: Mean values of the fresh yield and its component characteristics of the three sweet melon hybrids for the two greenhouses during the two successive growing seasons of 2008 and 2009.

Hybrids	2008					
	Greenhouse (G1)			Greenhouse (G2)		
	No. of fruits / plant	Average fruit weight (g)	Average fruit yield / plant (kg)	No. of fruits / plant	Average fruit weight (g)	Average fruit yield / plant (kg)
Yathreb 7	3.0^{a}	0.893^{b}	2.678^{b}	2.33^{b}	0.899^{b}	2.095^{b}
Yathreb 8	3.0^{a}	1.152^{a}	3.457^{a}	2.33^{b}	1.280^{a}	2.995^{a}
Yathreb 22	3.1^{a}	0.710^{b}	2.200^{c}	2.66^{a}	0.740^{c}	1.957^{b}
	2009					
Yathreb 7	3.33^{a}	0.980^{b}	3.28^{b}	3.0^{a}	0.887^{b}	2.70^{a}
Yathreb 8	3.0^{b}	1.200^{a}	3.58^{a}	2.67^{b}	1.025^{a}	2.75^{a}
Yathreb 22	3.66^{a}	0.850^{b}	3.14^{b}	3.0^{a}	0.800^{b}	2.38^{b}

Values with the same alphabetical letter, in a comparable group of means do not differ significantly according to Duncan's Multiple Range test at 0.05 level of significance.

Quality characteristics of sweet melon fresh fruit

The quality characteristics for three tested hybrids grown inside the two greenhouses (G1 and G2) are summarized and listed in Table (5). It clearly showed that the mean values of the quality characteristics inside the greenhouse (G2) did not significantly differ from each other for flesh thickness and netting degree traits during the two growing seasons. On the other hand, placenta hardness trait appeared significant mean values only during the second growing season. The hybrids Yathreb 7 and Yathreb 22 gave the highest values of placenta hardness followed by Yathreb 8 which gave the lowest mean value for these characteristics (Table 5). The mean values of the total soluble solids (T.S.S.) are also presented in Table (5). The obtained data of the first growing season for the hybrids grown inside the greenhouse (G2) appeared that the hybrids Yathreb 7 and Yathreb 8 gave the highest values for the total soluble solids (T.S.S.). The Yathreb 22 significantly gave the lowest value for the T.S.S. trait over the two growing seasons. The mean values of the T.S.S. trait for the tested hybrids grown inside the greenhouse (G1) during the two growing seasons appeared that the tested hybrids did not significantly differ from each other with respect to the fruit quality characteristics (flesh thickness, placenta hardness, netting degree and total soluble solids).

The mean values of the quality characteristics for the three different hybrids grown inside the two greenhouses (G1 and G2) are listed in Table (6). The obtained data clearly appeared that the two characteristics; flesh thickness and fruit netting degree did not showed any significant differences when the plants grown under the two different microclimatic conditions over the two growing seasons.

Table 5: Quality characteristics for three tested hybrids grown inside the two greenhouses (G1 and G2) during the two growing seasons of 2008 and 2009.

Hybrids	2008								2009							
	Greenhouse (GI)				Greenhouse (G2)				Greenhouse (G1)				Greenhouse (G2)			
	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %
Yathreb 7	65.84^{a}	10.0^{a}	10.0^{a}	11.08^{a}	62.55^{a}	10.0^{a}	10.0^{a}	13.67^{a}	63^{a}	9.0^{a}	10.0^{a}	11.0^{a}	63.10^{a}	9.7^{a}	10^{a}	13.5^{a}
Yathreb 8	63.82^{b}	8.66^{b}	9.66^{a}	11.47^{a}	64.43^{a}	9.67^{a}	9.89^{a}	13.73^{a}	63.5^{a}	9.0^{a}	10.0^{a}	11.3^{a}	64.0^{a}	9.3^{b}	10^{a}	13.2^{a}
Yathreb 22	65.47^{a}	10.0^{a}	9.78^{a}	11.39^{a}	63.42^{a}	9.89^{a}	9.89^{a}	11.46^{b}	63.6^{a}	9.0^{a}	10.0^{a}	10.6^{a}	63.3^{a}	10^{a}	10^{a}	12.5^{b}

Table 6: Mean values of the fruit characteristics inside the two greenhouses during the two growing seasons of 2008 and 2009.

Greenhouse	2008				2009			
	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %	Flesh thickness %	Placenta hardness	Netting degree	T.S.S. %
Greenhouse (G1)	65.04^a	9.55^a	9.81^a	11.31^b	63.4^a	9.20^b	10.0^a	11.98^b
Greenhouse (G2)	63.47^a	9.85^a	9.93^a	12.95^a	63.5^a	9.67^a	10.0^a	13.07^a

Values with the same alphabetical letter, in a comparable group of means do not differ significantly according to Duncan's Multiple Range test at 0.05 level of significance.

The lower value of placenta hardness trait during the two growing seasons occurred inside the greenhouse (G1) as compared with the mean value obtained from the greenhouse (G2) as shown in Table (6). The data of the total soluble solids (T.S.S.) appeared that the greenhouse (G2) significantly surpassed the greenhouse (G1) with regard to the mean values of the total soluble solids during the two growing seasons.. This result means that the heated greenhouse affected the total soluble sugars which consider as an indicator for the total sugars in sweet melon fruits. It is possible to attribute this result to increasing plant respiration rate and thus the consumption of a large portion of carbohydrates, either in the plant or fruits. These results are in agreement with that published by Ren *et al.*, (2010) when they studied the effects of different indoor air temperatures on sugar accumulation and sucrose-metabolizing enzymes in muskmelon. They showed that the higher the temperature was the fructose and soluble sugars contented in the fruits were higher. Sucrose content, sucrose phosphate synthase activity, as well as, sucrose synthase activity shares the same trend when the temperature change.

CONCLUSION

It is concluded that, the microclimatic conditions for the solar heated greenhouse was at and around the optimal level for the sweet melon crop. Therefore, adapting the temperature inside the greenhouse led to increase in the vegetative growth characters represented in plant length**,** which had a positive impact in increasing the fruit yield in both seasons.

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الملخص العربى

بحث وإستغلال الطاقة الشمسية لتسخين بيت محمى لمحصول الكنتالوب أثناء موسم الشتاء

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أجريت هذه التجربة بمحطة بحوث البساتين بالصبحية، الاسكندرية، مصر خلال الموسمين ٢٠٠٨، ٢٠٠٩. بغرض دراسة تأثير استخدام الطاقة الشمسية لتدفئة الصوبة على نمو وانتاجية وجودة ثمار ثلاث هجن من الكنتالوب. زرعت ثلاثة هجن من الكانتالوب وهى يثرب ٧، يثرب ٨، يثرب ٢٢ خلال شهر ديسمبر، وقد أختبرت الهجن من حيث الصفات الخضرية والمحصول وجودة الثمار الناتجة. وقد زرعت الهجن الثلاث بداخل صوبتين زراعيتين تختلف كل منهما عن الأخرى فى درجة الحرارة وفى طريقة التحكم فى تهويتها. فكانت إحدى الصوب يتم تدفئتها بالطاقة الشمسية ليلاً وأما الأخرى يتحكم في تهويتها ميكانيكيا نهارا بدون تدفئة ليلية، وكانت أهم النتائج المتحصل عليها:-

١. كانت أعلى درجة حرارة نهارا للهواء بالصوبة المدفئة بالطاقة الشمسية ٢٦,١ و ٢٨,٠ و٢٨,٦ و٣٠,٦ درجة مئوية. بينما كانت أقل درجة حرارة ليلاً ١٢,٩ و١٥,٧ و١٦,٤ و١٧,١ درجة مئوية في شهور يناير وفبراير ومارس وابريل، على الترتيب.

٢. وبالنسبة للصوبة ذات التهوية ميكانيكيا، كانت أعلي درجة حرارة لهواء الصوبة نهاراً ٢٦,٨ و ٢٨,٠ و ٣٠,٤ و ٣٢,٦ درجة مئوية. بينما كانت أقل درجة حرارة ليلا ٦,٣ و ١٠,٨ و ١٣,٥ و ١٥,٣ درجة مئوية في نفس الشهور بالترتيب

٣. اختلفت الأصناف فيما بينها فى عدد من الصفات (أطوال النباتات، عدد الثمار لكل نبات، متوسط وزن الثمرة، المحصول الثمرى للنبات، نسبة سمك لحم الثمرة، ونسبة المواد الصلبة الكلية الذائبة) بداخل كل صوبة على حدة على مدار السنتين.

٤. أعطت الهجن النامية بداخل الصوبة المتحكم فيها من خلال الطاقة الشمسية نموا خضريا أكبر متمثلا فى زيادة طول النبات، كذلك اعطت عدد أكبر من الثمار للنبات مقارنة بالهجن المزروعة فى الصوبة الأخرى والمتحكم فى تهويتها عن طريق المراوح الميكانيكية، مما نتج عنه فى النهاية زيادة فى المحصول الثمرى يقدر بـ ١٨,٣٥%، ٢٧,٥٩% على مدار السنتين الأولى والثانية على التوالى مقارنة بالصوبة المتحكم فيها عن طريق المراوح الميكانيكية.