EFFECT OF GREENHOUSE NIGHT HEATING BY SOLAR ENERGY SYSTEM AND ORGANIC FERTILIZER ON THE PRODUCTIVITY OF TOMATO

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ABSTRACT

The aim of this experimental work was to investigate the effect of utilizing different rates of dried biogas digester residue as organic fertilizer and solar energy for heating greenhouse on growth, development, productivity, and fruit quality of tomato hybrid (Agiad 7) during winter of two following growing seasons (2013 and 2014). Two similar gable-even-span greenhouses were functioned at EL-Sabahia Horticultural Research Station. The seedlings of tomato hybrid Agiad 7 were planted on the 1st week of December during the two growing seasons under two different greenhouse microclimates. The first greenhouse (GH1) was equipped with a complete heating system utilizing the solar energy, while, the second greenhouse (GH2) was mechanically ventilated during daylight without heating system.

Referring to the effect of the solar heating system on the greenhouse microclimate, the obtained results revealed that, the maximum and minimum indoor air temperatures of greenhouse (GH1) were (24.3 and 11.6), (26.0 and 12.1), (28.1 and 15.2), (28.6 and 16.3) and (30.6 and 17.1) ^oC during the experimental period (from December to April), respectively. On the other hand, the maximum and minimum indoor air temperatures of the greenhouse (GH2) were (25.3 and 6.0), (26.8 and 6.3), (28.0 and 10.8), (29.8 and 13.4) and (32.6 and 15.3) ^oC during the same period, respectively. Referring to the effect of organic fertilizer rates on the tomato plant vegetative growth, showed that increasing the organic fertilizer rate significantly increased all the studied characters; plant length, leaf area, number of leaves per plant, dry weight and stem diameter in both seasons whereas, the fresh weight increase was not significant in 2014 season.

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The data also, showed that plants fertilized with 30 m^3/fed from dried biogas residue gave the best vegetative growth characteristics; plant height, leaf area, fresh, dry weight per plant and stem diameter as compared with other used organic levels in both seasons. Early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were significantly increased by increasing the organic fertilizer rate in both 2013 and 2014 seasons.

For the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 28.64, 13.04, 6.89, 20.84 and 20.84%, respectively for dried biogas residue of 30 m^3/fed over those of farm yard manure, respectively in 2013 season. For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 13.18, 16.29, 8.30, 25.52 and 25.52%, respectively for 30 m^3/fed dried biogas residues in same season. Whereas, in the second season 2014, for the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 24.87, 11.18, 6.89, 18.86 and 18.86%, respectively for 30 m^3/fed dried biogas residue, respectively. For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 17.18, 16.29, 5.87, 22.84 and 22.84%, respectively for 30 m^3/fed dried biogas residues in same season.

Concerning effect of the microclimatic conditions of (GH1) it was at and around the optimal level for the tomato crop, resulting in increase the tomato growth, development, and productivity. The percentages increase for greenhouse GH1 over GH2 greenhouse in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 21.32, 17.42, 12.87, 32.28 and 32.28%, respectively, in 2013 season while, they were 16.06, 15.33, 10.14, 27.08 and 27.08%, respectively in 2014 season.

1.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).**

Fertilizer is an organic or inorganic material, containing one or more essential nutrients, which is used to provide nutrients for the growth of crops and increasing productivity and quality of agricultural products, (**Zhang *et al.*, 2010**). Nemours researchers reported the importance of fertilizers in enhancing crop production. Firstly, they make crop plants grow and develop better and achieve high productivity. Fertilizers give vigorous plants and increase vegetative growth such as; plant height, quantity, and length of plant stem, leaf area, and leaf chlorophyll on many kinds of crop (**Chapagain and Wiesman, 2004; Wang *et al.*, 2007; Najm *et al.*, 2010; Zafar *et al.*, 2011; Aminifard *et al.*, 2012; Yakout *et al.*, 2014**). Secondly, using fertilizers increases crop productivity (**Heeb *et al.*, 2006; Riahi *et al*., 2009; Aminifard *at el.*, 2012; Yang *et al.*, 2012; Çolpan *et al.*, 2013**). According to statistics of Food and Agriculture Organization of the United Nations **(FAO, 1981),** fertilizers help to increase 40-60% of crop yields (**FAO, 1981; Zhang *et al*., 2010**). Thirdly, fertilizers improves the quality of fruits such as vitamin, organic acid, mineral contents, dry matter content, etc. (**Pirkko *et al.* 2003; Kobryn and Hallmann, 2005; Zaller, 2006; Dursun *et al.*, 2009; Cesare *et al.*, 2010; Junior *et al.*, 2013**).

Adding organic manures to soil would improve their physical–chemical and biological properties which increase soil organic matter, cation exchange capacity, available mineral nutrition (**Mervat *et al.*, 1995**) and this in turn stimulate quantitative as well as qualitative characteristics of vegetable crops. The use of organic matters such as animal manures, human waste, food wastes, yard wastes and composts has long been recognized in agriculture as beneficial for plant growth and yield, also, soil fertility. (**Joshi and pal Vig, 2010**). Many workers pointed out the valuable role of organic manures to stimulate plant growth, yield of vegetables among them **Abdalla *et al.* (2001), Yakout *et al.*, (2014),** on pepper; **Abou-Hussein *et al.*, (2002)** on potatoes; **Adam *et al.*, (2002)** on cantaloupe; **Rizk *et al.*, (2003)** on squash and **El-Araby (2004), El-Gamal and Hammed (2005) and Hamed (2008)** on Jerusalem artichoke. Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and is an important vegetable crop all over the world. It is used in numerous forms, such as fresh salad, cooked foods and in processed forms like ketchup, paste etc., it is known as a favorite vegetable crop, rich in vitamins and minerals for human. In Egypt, the late summer market tomato crop is yielded from transplants planted into the open field during April up to June. During this period, temperature can exceed 35°C under field condition resulting in either non-uniform growth and poor fruit yield or even completely failure of tomato cropping in a great part of the cultivated area, (**Pressman *et al.*, 2002; Adil *et al.*, 2004**). With regard to the effect of temperature on growth and productivity of tomato plants, **Saeed *et al.* (2007)** whose found that high temperatures during the growing season have been reported to be detrimental to growth, reproductive development and yield of several crops. In tomato high temperature during reproductive development caused significant increment in flower drop and significant decrease in fruit set and consequently fruit yield was decreased to a great extent. At high temperature, the reproductive part of the flower is adversely affected. Stigma tube elongation, poor pollen germination, poor pollen tube growth and carbohydrate stress are the main reasons for poor fruit set at high temperature in tomato, **Vollenweider and Gunthardt-Goerg (2005)**. Furthermore, **Sato *et al.* (2000)** reported that under high temperatures, fruit set in tomato plants failed due to disruption of sugar metabolism and transport during the narrow window of male reproductive development. Moreover, Heat stress is a major factor that restricts tomato production during summer season in the Sudan. High temperature harmfully affects plant growth and survival and hence crop yield **(Abd El-Mageed and Gruda, 2009)**.

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, Tomato can be classified as warm season crops which very sensitive to the low temperature (Tender, sensitive to frost and low temperature)). It is known that the mean monthly temperatures for tomato are: optimum, 18-24ºC; maximum; 27ºC and the minimum 18ºC, (climatic-requirements.pdf). The higher average temperature causes an increased rate of crop development and is responsible for earlier fruit maturation **(Pardossi *et al.,* 2000).**

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. Also, **Youssef and Moussa (2015)** stated they were utilized solar energy for heating greenhouse and studied its effect on growth, development, productivity, and fruit quality of three different hybrid of sweet melon crop. The obtained data showed that, the microclimatic conditions of solar heated greenhouse 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% over the un-heated greenhouse in the first and second season, respectively.

The objectives of this study were to; 1) utilizing the solar energy for night heating the greenhouse indoor air and conserve energy, 2) reduce the indoor temperature fluctuation of the greenhouse by elevating the nighttime indoor air temperature of greenhouse, 3) studying the effect of applying the night heating and different rates of organic fertilizer (dried biogas digester residue) on tomato growth, development, productivity and fruit quality.

2.MATERIALS AND METHODS

2.1Materials

Two identical gable-even-span greenhouses were utilized at EL-Sabahia Horticultural Research Station (latitude and longitude angles, respectively, are 31.22 ºN and 30.50°E), Alexandria Governorate, to grow and produce tomato (Agiad 7 hybrid) during winter season of two successive growing seasons (2013 and 2014). 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 (GH1 and GH2) are covered using single layer of polyethylene sheet (PE) of 200 µm as shown in Fig. (1).

a- Two solar collectors for heating GH1

b- Mechanically ventilated greenhouse (GH2)

c- Left thermal storage tank

d- Right thermal storage tank

e – Two suction fans

Fig. (1): Experimental gable-even-span greenhouses and the solar heating system.

Two solar collectors, each has the dimension of 3.0x1.0 m, and they were fixed on concrete foundation facing south. The solar collectors monthly optimum tilt angles were manually oriented to collect as much as solar radiation incident, (Fig, 1-a), and they were connected to two extracting fans inside the greenhouse (GH1), (Fig, 1-e). Two wooden thermal storage water tanks were constructed in both sides of the greenhouse, (Fig, 1c and d). Each has the dimensions of 6.0 x 0.35 x 0.5 m. An air-to-water heat exchanger was constructed in each thermal storage water tanks. The two thermal storage water tanks were well insulated from bottom and side walls to prevent heat losses and coated with black plastic to absorb as much as solar energy. The net volume of water in each thermal storage tank was 0.86 m^3. The other greenhouse (GH2) was mechanically ventilated during daylight only (Control) as shown in Fig, (1b).

Tomato hybrid (Agiad 7) was utilized to investigate the effects of different macroclimatic conditions and organic fertilizer rates on plant vegetative growth and fruit yield and quality. Two vegetative trays (84 growth blocks) were used to germinate the seeds of tomato plant. Seeds were sown in the nursery on 2nd week of October in 2013 and 2014. Seedling transplant was performed on 1st week of December in 2013 and 2014 seasons. Planting distance was 50 cm apart. Each plot has 14 plants of the used tomato hybrid. The experimental treatments were two greenhouses, (GH1 and GH2 greenhouses); three rates of organic fertilizer; (30, 20 and 10 m^3/fed) compared with the control (farm yard manure 20 m^3/fed). As well as, chemical fertilizers were added according to the recommended doses provided by Ministry of Agriculture and Land Reclamation (2004) of NPK liquid commercial fertilizer, each week during the whole season through the drip irrigation system. The micro-minerals; iron, copper, manganese, zinc, magnesium and born were utilized as foliar spraying. It must be mentioned that the tomato plants were pruned to one leader stem with one branch at 150 cm height on the leader stem. The experimental design was a split plot design with three replicates; the experiment included eight treatments which were as follows:

T_1: GH1 + 30 m^3/fed organic fertilizer (OR30)
T_2: GH1 + 20 m^3/fed organic fertilizer (OR20)
T_3: GH1 + 10 m^3/fed organic fertilizer (OR10)
T_4: GH1 + 20 m^3/fed (FYM)
T_5: GH2 + 30 m^3/fed organic fertilizer (OR30)
T_6: GH2 + 20 m^3/fed organic fertilizer (OR20)
T_7: GH2 + 10 m^3/fed organic fertilizer (OR10)
T_8: GH2 + 20 m^3/fed (FYM)

The organic fertilizer (dried biogas digester residue) was the bi-product of biogas production digesters supplied by "Development of Biogas Production and Utilization Systems Project" which financially supported by the Agricultural Development Program (ADP) and Implemented at the Tractors and Machinery Research and Test Station, Alexandria city, Agricultural Engineering Research Institute. The physic-chemical properties of the organic fertilizers are shown in Table (1) and the soil samples analysis is shown in Table (2). The percentage of total nitrogen (N), total phosphorus (P), total potassium (K) was calculated from their relative contents in 100 g dry samples.

Table (1). Physic-chemical properties of the two organic fertilizers.

Items	Unit	Dried biogas residue	Farm yard manure
N	%	5.01	1.06
P	%	5	1.8
K	%	5.41	1.2
Fe	Meq/L	868	383
Zn	Meq/L	74	76
Cu	Meq/L	60	20
Cd	Meq/L	16	18
Ni	Meq/L	184	168
Cr	Meq/L	0	0
Pb	Meq/L	54	96

In order to conserve the energy, the ventilation system of the 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 to grasp the solar radiation energy from the solar collectors and delivered it to the water of the thermal storage tanks through the constructed air to water heat exchangers inside the water tanks. During this period, the warm air releases its heat on the thermal storage water tank. The greenhouse air also, was warmed up by the transmitted incident solar radiation through the greenhouse cover (The greenhouse considers as a huge solar collector). Meanwhile, the indoor air temperature of the greenhouse during daylight-time could dramatically increase over the set point temperature, (27.0^{o}C). This air also, exchanged heat with the water in the tanks by convection. In addition, the solar radiation was directly incident on the surface of the water of the thermal storage system. These are three sources for heating the water inside the thermal storage tanks.

Table (2). Characteristics of the soil samples.

Items	**Unit**	**Season 2013**	**Season 2014**
Clay	%	45.2	39.5
Silt	%	35.1	37.2
Sand	%	21.8	23.4
Organic matter	%	22.4	25.7
Soil texture	----	Clay loam	Clay loam
pH*	----	7.6	7.7
EC**	dSm^{-1}	3.35	3.32
Soluble cations			
Ca^{++}	Meq/L	3.8	4.6
Mg^{+}	Meq/L	3.6	2.9
K^{+}	Meq/L	21	19
Na	Meq/L	7.2	7.4
Soluble anions			
CO_3^{--}	Meq/L	3.1	3.3
HCO_3^{-}	Meq/L	1.7	1.9
Cl^{-}	Meq/L	5.5	5.6
SO_2^{--}	Meq/L	2.9	3.2
Total N	%	0.18	0.19
Available phosphorus		30.9	30.7

*** measured in 1:25 soil water suspension.**

**** measured in the water extract of saturation soil paste.**

A digital thermostat controller for the fans operation was adjusted at a set point temperature during the daylight and nighttime. At night the gates between the solar collectors and fans were closed and other gates facing the inside greenhouse air were opened. Hence, when the greenhouse indoor 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 stored heat in the thermal storage water tanks was absorbed once again by the air and was restored back to warm up the indoor air of greenhouse. This was to prevent the greenhouse interior air temperature from dropping below the desired temperature at night.

2.2 Environmental measurements

The measurements were employed from December to April of both 2013 and 2014 seasons. The meteorological data from a meteorological station (5 KUE SKH 2013) were used to measure solar radiation flux incident on a horizontal surface (Pyranometer), dry-bulb air temperature (ventilated thermistor), wind speed and its direction (cup anemometer and wind vane), and air relative humidity (hygrometer) outside the greenhouses. The data were collected and sent through the network of the Central Laboratory for Agricultural Climate (CLAC), Dokki, ARC. The indoor air temperatures and relative humidities at middle of both greenhouses were measured and recorded using two Data-loggers type SATO, SK-L200 II- Japan, temperatures of entering air of the solar collectors and water temperatures in the thermal storage tanks were recorded using thermocouple sensors type K. These sensors were connected to digital multimeter record the data throughout the experimental work.

2.3 Vegetative measurements

Random samples of five plants from each replicate were taken after 120 days from transplanting to record the following characters:-

2.3.1 **Vegetative growth characteristics**

2.3.1.1 Plant height (cm).

2.3.1.2 Leaf area (cm^2) was measured of the 5th true leaf by using laser leaf area meter.

2.3.2 Number of leaves per plant.

2.3.4 Plant dry weight (gm) plant sample was dried at 70 ^oC.

2.3.5 Stem diameter.

2.4 Chemical composition

Sample of the fourth top leaves were dried at 70 ^{o}C till constant weight and wet digested to determine N, P and K contents as follows:-.

2.4.1 Total nitrogen (%) in leaves was determined by using Microkjeldahil by **A.O.C.A., (1990).**

2.4.2 Phosphorus (%) was determined calorimetrically at 550 mm as described by **Ranganna, (1979).**

2.4.3 Potassium (%) was determined by flame photometer as described by **Ranganna (1979).**

2.4.4 Micro nutrients Fe and Mn contents were determined for the above ground dried vegetative parts by using atomic spectrophotometer according to **Chapman and pratt, (1981).**

2.4.5 Total soluble solids (TSS) % of fruit was measured by refractometer.

2.4.6 Total Acidity was determined as mg/100 ml juice (mg/100 g f.w.) by using NaOH with phenolphthalein as indicator is mentioned by **A.O.C.A. (1980).**

2.4.7 Total chlorophyll content was determined in sample taken randomly from the fourth upper leaf according to **A.O.A.C., (1990).**

2.4.8 Vitamin C content (ascorbic acid) was determined as mg/100 ml juice (mg/100g f. w.) by using the 2,6 dichloro phenol indophenols method, **(A.O.C.A., 1980).**

2.5 Fruit physical characteristics:-

2.5.1 Fruit length (cm) 2.5.2 fruit diameter (cm).

2.5.3 Shape index (L/D) 2.5.4 flesh thickness (cm).

2.6 Yield and its components:-

2.6.1 Early yield (kg\plant). 2.6.3 Total yield (kg\plant).

2.6.2 Number of fruit per plant. 2.6.4 Average fruit weight (gm).

2.6.5 Total yield (ton\ feddan).

2.7 Statistical Analysis:

The experimental design was a split plot design with three replicates. 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 least significant difference test procedure at p = 0.05 level of significance using CoStat Ver. 6.311-2005 Software packages.

3.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 were 15.0, 15.0, 16.0, 18.0 and 18.0 ^oC for December, January, February, March and April months, respectively, to achieve an optimum night heating requirements to be used as energy conservation regime, as recommended by **Youssef (2007)**.

3.1 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 December to April) is plotted in Fig. (2). 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 December to April) was 357.6, 389.4, 470.6, 525.6, and 636.7 W/m^2, respectively.

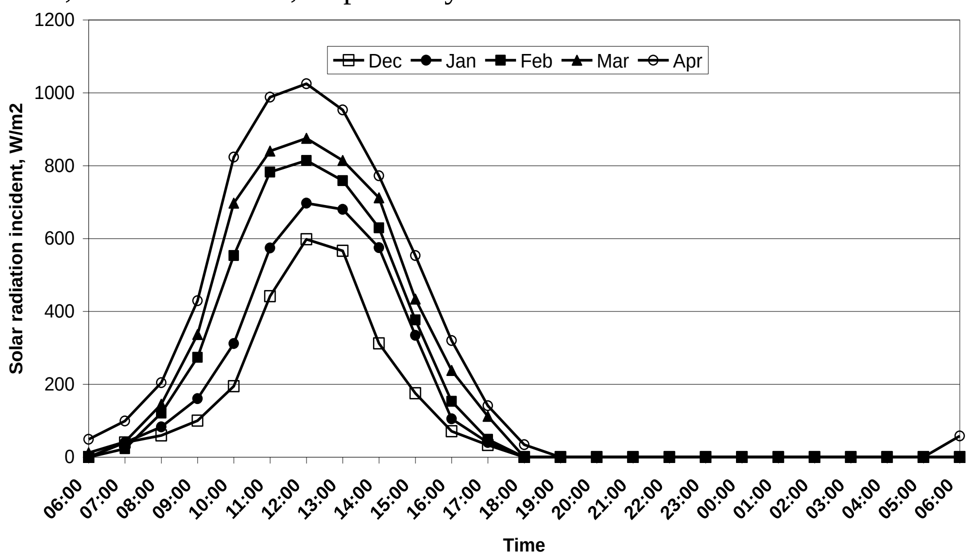
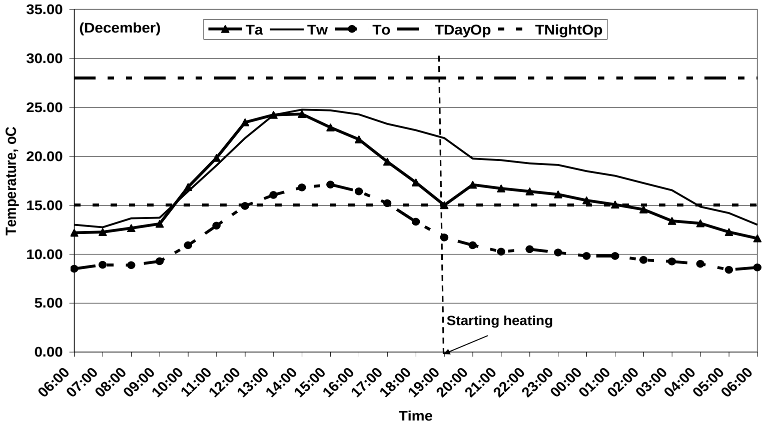


Fig. (2): Solar radiation flux incident on a horizontal surface during in the experimental period as a function of solar time.

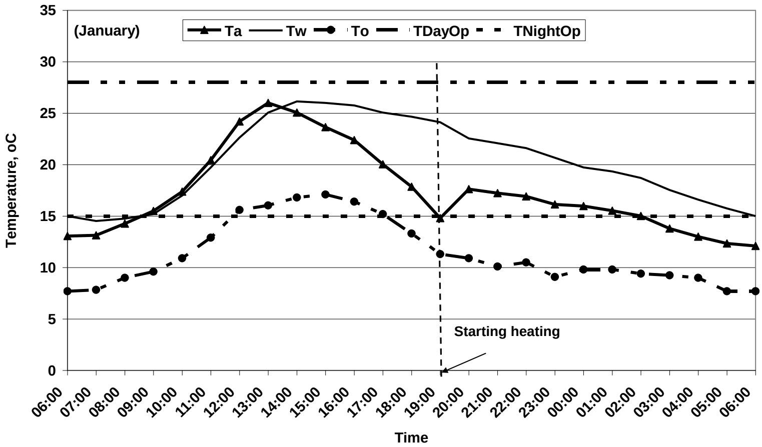
3.2 Temperatures of the solar heated greenhouse and its components:

The monthly average temperatures of water, indoor air of greenhouse (GH1) and outside ambient air as affected by the solar heating system during the experimental period are illustrated in Fig. (3a, b, c, d, e and f). The monthly average maximum water temperatures in the storage tank were 24.8, 26.2, 27.8, 28.8 and 30.2^{o}C which were achieved at 2:15, 3:15, 3:45, 4:15 and 4:45 pm during for December, January, February, March and April months, respectively. These results revealed that, as the solar energy fluxes incident outside the greenhouses increased the water temperatures in the storage tank were increased. Also, the achievement time were shifted towards the time of sunset, (i.e., more energy was stored in the thermal storage tank). Consequently, the percentage increase in water temperatures over December month was 105.6, 112.3, 116.4 and 121.9% for February, March and April months, respectively.

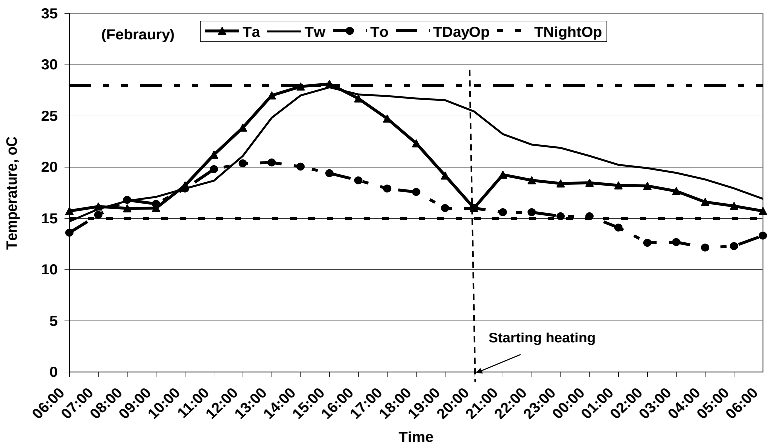
The monthly average maximum indoor air temperatures of greenhouse (GH1) during the experimental period (from December to April), respectively, were 24.3, 26.0, 28.1, 28.6 and 30.6 ^{o}C. On the other hand, the monthly average minimum indoor air temperature of the greenhouse at nighttime as affect by the solar heating system was 11.6, 12.1, 15.2, 16.3 and 17.1 ^{o}C, respectively for the same months. The greenhouse indoor temperatures reached the minimum set-point temperature of the greenhouse at 7:00, 7:00, 8:00, 9:00 and 10:00 pm for the same months, respectively. These were the time of operating the greenhouse heating process and retrieving back the stored energy. These results mean that, stored energy inside the thermal storage tanks in greenhouse (GH1) during daylight-time prevented the indoor air temperature of the greenhouse from reaching harmful degree for tomato plants at nighttime, (<10 ^{o}C). It was also, observed that the reduction in indoor air temperature of greenhouse (GH1) under the recommended level of air temperature, (15^{o}C) occurred only during December and January month. This could be attributed to the amount of solar radiation flux incident during these month were insufficient to provide and maintain the desired level of indoor air temperatures. However, the night monthly average indoor air temperatures during this month were around the optimal level. It must be mentioned that we could satisfied by the shortage in energy for these little hours only as energy conservation regime if it was not harmful for plant growth.



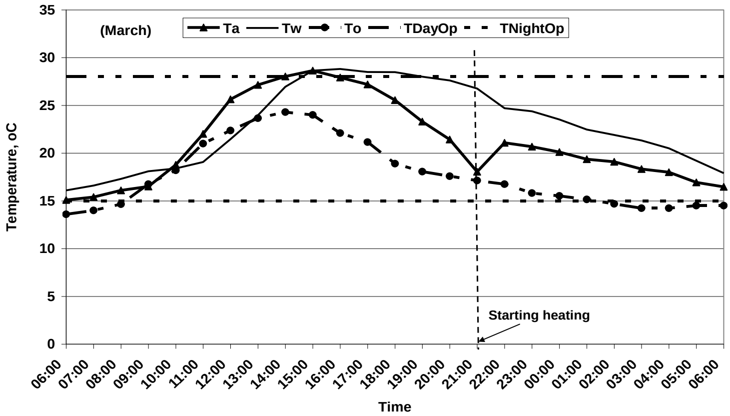
a- December



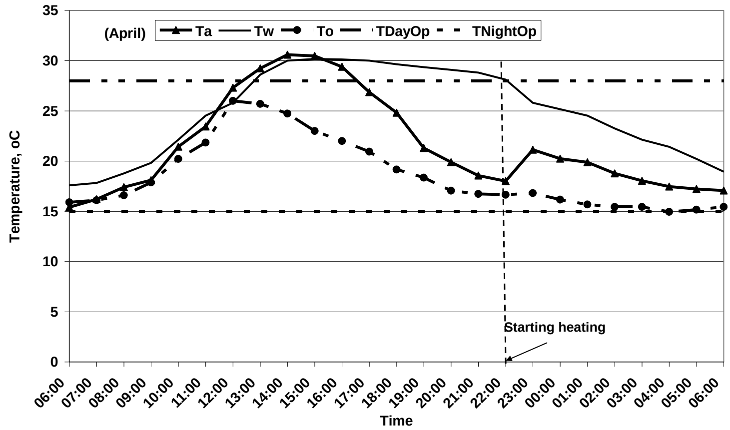
b- January



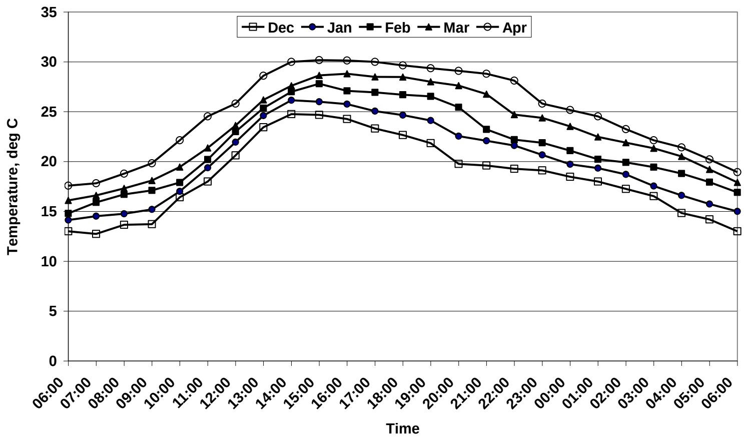
c- February



d- March



e- April



f- The temperatures of water in the storage tank

Fig. (3): Monthly average temperatures of water, indoor air of greenhouse (GH1) and outside ambient air during the experimental months.

3.3 Monthly average indoor air temperatures of the greenhouse (GH2)

On the other side, the monthly average indoor air temperatures of the mechanically ventilated greenhouse (GH2) are plotted in Fig. (4). The monthly average maximum indoor air temperatures of the greenhouse (GH2) during the experimental period (from December to April), respectively, were 25.3, 26.8, 28.0, 29.8 and 32.6 ^{o}C, which occurred at 1:00 pm except March month when it was recorded at 2:00 pm. On the other hand, the monthly average minimum indoor air temperature of the greenhouse (GH2) at nighttime was 6.0, 6.3, 10.8, 13.4 and 15.3 ^{o}C, respectively for the same period. The greenhouse indoor temperatures reached the minimum set-point temperatures of the greenhouse at 10:00 pm, 10:00 pm, 12:00 am, 3:00 am and 10:00 pm for the December, January, February and March months, respectively. While, during April month this was not occurred. It is noticeable that the indoor temperature of mechanically ventilated greenhouse (GH2) decreased to harmful temperature (<10 ^{o}C) during December and January months. These results revealed that the night monthly average indoor air temperatures were lower than the minimum recommended level for four months (December, January, February and March), whereas, the maximum indoor temperatures were over the maximum recommended indoor air temperatures during daylight-time occurred in March and April months.

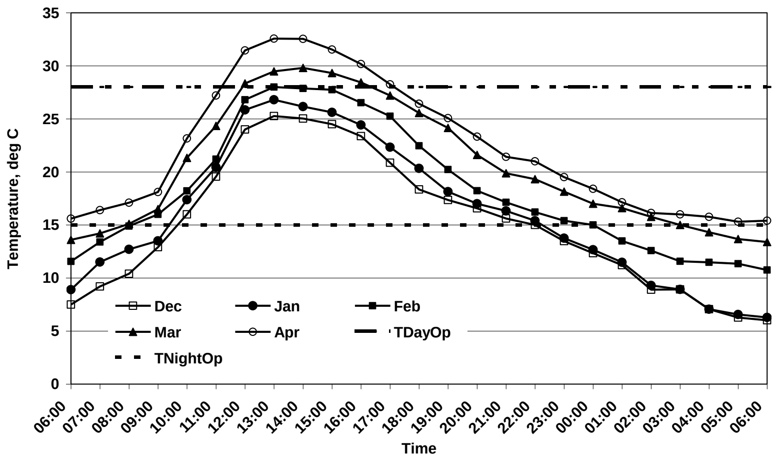


Fig. (4): Monthly average indoor air temperatures of greenhouse (GH2) during the experimental period from January to April.

The previous two Figs (3 and 4) revealed that the fluctuations of greenhouse indoor air temperatures were higher in greenhouse (GH2) than the greenhouse (GH1). The minimum greenhouse air temperatures, (at night) also, were elevated in solar heated greenhouse, (GH1) than mechanically ventilated greenhouse, (GH2). These finding can be attributed to increasing nighttime temperatures by retrieving back the stored energy in the water of the thermal storage system to worm up the greenhouse air at night for night heating. Also, the mechanically ventilation at daylight times, (at and around noon) in both March and April months could not permit the required cooling for greenhouse. These results are in agreement with that published by **Youssef (2007)** and **Youssef** and **Moussa (2015)** when they mentioned that night heating increased the minimum indoor air temperatures of the greenhouse and reduced the difference between the maximum and minimum greenhouse indoor air temperatures.

3.4. Effect of greenhouse macroclimate conditions and organic fertilizer applications on vegetative growth, chemical constituents, yield and fruit quality of tomato plants

3.4.1 Vegetative growth of tomato plant

Effect of the organic fertilizer treatments and macroclimate conditions on vegetative growth of tomato plants was illustrated in Table (3). The data also, showed that plants fertilized with 30 m^3/fed from dried biogas residue gave the best vegetative growth characteristics; plant height, leaf area, fresh, dry weight per plant and stem diameter as compared with other used organic levels in both seasons. The 20 m^3/fed came in the second rank followed by FYM, (20 m^3/fed), however 10 m^3/fed application led to the lowest fresh and dry weight per plant as compared with the other organic applications. The present work showed that with respect to the superior growth of plants fertilized with dried biogas digester residue than farm yard manure could be referred to firstly, it has higher values of N, P and K elements as showed in the chemical analysis of the fertilizer sample as previously shown in Table (1) secondly, biogas residue is a well fermented organic fertilizer; free of pathogen sources and seed weeds, beside the general benefits of organic-N fertilizers thus it is a good source for most macro and micronutrients and increase soil porosity and improve aeration of such clay loam soil of this experiment in agreement with the findings of **El-Shimi (1998)** and **Mikhaeel, *et al.*, (1997)** who found the superiority of biogas organic fertilizer on plant growth. Also, **Nguyen *et al.*, (2015)** mentioned that the applications of organic fertilizers enhanced the leaf area and average fruit weight and yield of tomato fruit. Concerning the effect of greenhouse microclimate on vegetative growth, data in Table (3) showed that the plant height, stem diameter, fresh and dry weight of greenhouse GH1 was significantly increased than those of greenhouse GH2. On the other hand, there was no significant difference for the leaf area and number of leaves per plant of both greenhouses in both 2013 and 2014 seasons.

Table (3). Effect of macroclimate conditions and organic applications on vegetative growth in 2013 and 2014 seasons.

Treatments		**Season 2013**					
		Plant height (cm)	**Stem diam. (cm)**	**Leaf area (cm^2)**	**No of leaves/pl**	**Fresh weight (g)**	**Dry weight (g)**
GH1	OR30	365.1	2.54	183.9	96.37	386.8	92.77
	OR20	341.7	2.46	180.0	89.51	381.9	90.81
	OR10	279.6	2.18	166.2	78.07	364.2	83.63
	FYM	301.5	2.38	165.9	80.69	370.1	89.83
Average		**322.0a**	**2.39a**	**174.0a**	**86.16a**	**375.7a**	**89.26a**
GH2	OR30	305.1	2.34	168.2	87.08	362.0	86.13
	OR20	290.4	2.13	165.9	79.48	360.1	82.97
	OR10	268.8	1.68	158.3	70.93	349.6	70.93
	FYM	280.9	2.00	160.9	72.83	355.6	82.33
Average		**286.3b**	**2.04b**	**163.3a**	**77.58a**	**356.8b**	**80.59b**
OR $LSD_{0.05}$		23.5	0.12	15.26	8.75	19.55	7.27
		Season 2014					
GH1	OR30	391.2	2.62	195.4	95.58	403.9	96.71
	OR20	366.1	2.57	191.2	88.78	398.1	94.67
	OR10	299.6	2.34	176.6	77.44	379.7	87.18
	FYM	323.0	2.48	179.3	80.69	385.8	92.99
Average		**345.0a**	**2.50a**	**185.7a**	**85.62a**	**391.9a**	**92.89a**
GH2	OR30	330.4	2.40	175.9	85.97	374.8	88.12
	OR20	317.8	2.22	173.4	78.47	372.7	84.88
	OR10	291.1	1.78	165.5	70.03	360.0	72.57
	FYM	311.5	2.05	169.8	72.22	368.1	81.35
Average		**312.7b**	**2.11b**	**171.1a**	**76.67a**	**368.9b**	**81.73b**

As the solar heating system was elevated the nighttime temperature and maintained the greenhouse (GH1) temperature within the optimal level resulting in vigorous vegetative growth. Most plant growth occurs at night. The plants grow better with night time temperature several degrees below daytime temperature. Temperature controls the rate of plant metabolism. When night temperatures are high plants burn more energy in respiration but also have the ability to produce more growth. When night temperatures are lower, growth is slowed but energy lost to respiration is also reduced.

3.5. Chemical composition of plant foliage.

Effect of organic fertilizer treatments and macroclimate conditions on NPK uptake was presented in Table (4). Concerning the effect of organic fertilizer treatments on NPK uptake, data of plant leaves analysis presented in Table (4) indicated that by increasing the organic fertilizer quantity, the N, P and K content in plant leaves was increased in both seasons. Results of plant analysis also, showed that plants supplied with 30 m^3/fed removed higher quantities of N, P and K elements than that of plants supplied with other organic applications or farm yard manure. Iron and manganese content was significantly increased by increasing the rate of organic fertilizer in both seasons. However, Plants supplied with 10 m^3/fed of dried biogas residue or FYM had the lowest N, P and K uptake as compared with the other treatments and were not significantly differed.

Data demonstrated in Table (4) explained also, that nitrogen phosphorus and potassium uptake was significantly affected by macroclimate variations in both greenhouses in both 2013 and 2014 seasons. While, the nitrogen increase was not significant in the first season only. Iron and manganese content was significantly increased by maintaining the greenhouse in the optimal temperature level in both seasons.

3.6 Fruit physical characteristics.

Effect of organic fertilizer treatments and macroclimate conditions on quality of tomato fruits was demonstrated in Table (5). Result demonstrated in the table displayed out the physical characteristics of tomato fruit in both seasons. Results proved that increasing organic fertilizer rate significantly increased fruit length, fruit diameter and flesh thickness for both greenhouses in both 2013 and 2014 seasons. On the other hand, that increase was not significant for length/diameter ratio character in both seasons.

Table (4). Effect of macroclimate conditions and organic fertilizer applications on NPK uptake in 2013 and 2014 seasons.

	OR	2013 season					2014 season				
		N%	**P%**	**K**	**Fe**	**Mn**	**N%**	**P%**	**K**	**Fe**	**Mn**
GH1	OR30	3.82	0.55	5.65	333	40.18	3.80	0.54	5.40	329.3	41.24
	OR20	3.70	0.51	5.52	312	36.59	3.68	0.50	5.27	308.6	37.55
	OR10	3.56	0.45	5.26	295	31.36	3.57	0.45	5.02	291.2	32.19
	FYM	3.47	0.48	5.33	285	32.34	3.54	0.47	5.16	292.6	32.51
Average		**3.63a**	**0.50a**	**5.44a**	**306a**	**35.12a**	**3.65a**	**0.49a**	**5.21a**	**305.4a**	**35.87a**
GH2	OR30	3.45	0.51	5.32	304	34.47	3.49	0.50	5.18	280.4	38.36
	OR20	3.35	0.46	5.19	286	29.45	3.40	0.45	5.05	267.1	33.41
	OR10	3.27	0.38	5.02	266	27.26	3.34	0.38	4.89	244.9	30.34
	FYM	3.15	0.41	5.08	272	26.95	3.46	0.48	5.14	282.4	37.66
Average		**3.30a**	**0.44b**	**5.15b**	**282b**	**29.53b**	**3.42b**	**0.45b**	**5.06b**	**268.7b**	**34.94b**
OR $LSD_{0.05}$		0.16	0.08	0.14	10.44	1.51	0.11	0.09	0.20	11.07	1.31

Table (5). Effect of macroclimate conditions and organic fertilizer applications on quality of tomato fruits in 2013 and 2014 seasons.

	OR	2013 season				2014 season			
		fruit length (cm)	fruit diam. (cm)	L/D	Flesh thick. (cm)	fruit length (cm)	fruit diam. (cm)	L/D	Flesh thick. (cm)
GH1	**OR30**	6.79	7.32	0.928	0.81	6.82	7.48	0.93	0.80
	OR20	6.40	6.89	0.929	0.73	6.45	6.95	0.93	0.72
	OR10	5.88	6.30	0.932	0.62	5.92	6.48	0.93	0.62
	FYM	6.17	6.66	0.926	0.63	6.22	6.72	0.92	0.63
Average		**6.31a**	**6.79a**	**0.929a**	**0.70a**	**6.35a**	**6.91a**	**0.93a**	**0.69a**
GH2	**OR30**	5.67	6.25	0.908	0.63	5.80	6.36	0.92	0.61
	OR20	5.55	6.12	0.906	0.61	5.67	6.24	0.91	0.59
	OR10	4.79	5.25	0.912	0.52	4.96	5.35	0.92	0.50
	FYM	4.95	5.42	0.914	0.55	5.81	6.36	0.92	0.62
Average		**5.24b**	**5.76b**	**0.910a**	**0.58b**	**5.56b**	**6.08b**	**0.92a**	**0.58b**
OR $LSD_{0.05}$		0.36	0.41	n.s.	0.06	0.37	0.40	n.s.	0.065

The results in the same table also, confirmed that all studied characters were significantly differed by enhancing the nighttime temperature of GH1 greenhouse than GH2 greenhouse except for length/diameter ratio in both 2013 and 2014 seasons. These results were in line with **Pearce *et al.*, (1993)** they indicated that the growth rates of fruit were found to be positively related to fruit temperature between 10 and 30 ^oC, with an increase in fruit diameter of 5 mm h^{-1} $^oC^{-1}$. **Saeed *et al.*, (2007)** also, stated that tomato succeeded well under tropical and subtropical regions. It can grow vigorously and is highly productive within the temperature range of 18 – 28^oC.

3.7 Fruit chemical characteristics.

Effect of organic fertilizer treatments and macroclimate conditions on quality of tomato fruits in 2013 and 2014 seasons was presented in Table (6). The illustrated results of fruit chemical characteristics exhibited that all the studied characters such as; ascorbic acid, acidity, total chlorophyll, dry matter and total soluble solids were significantly increased by increasing the organic fertilizer rate in both seasons in both greenhouses. It was observed that the acidity character was higher in greenhouse GH2 than greenhouse GH2. The results also, illustrated that ascorbic acid, acidity and total soluble solids was significantly enhanced by enhancing the macroclimate conditions inside the GH1 greenhouse, whereas the dry matter and total chlorophyll were not differed in both greenhouses in 2013 and 2014 seasons.

3.8 Early and total fruit yield and its components.

Effect of organic fertilizer treatments and macroclimate conditions on early and total fruit yield and yield components were demonstrated in Table (7). The results demonstrated in Table (7) gave us an idea about the response of the yield and its components according to increasing the levels of organic fertilizer. Early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were significantly increased by increasing the organic fertilizer rate in both 2013 and 2014 seasons.

For the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 28.64, 13.04, 6.89, 20.84 and 20.84%, respectively for 30 m^3/fed dried biogas residue, while they were 11.27, 10.27, 4.83, 15.67 and 15.67% for 20 m^3/fed, whereas, the percentages decreases in these characters for 10 m^3/fed dried biogas residue, lower than those of farm yard manure were 6.69, 8.74, 2.38, 11.35 and 11.35%, respectively in 2013 season.

Table (6). Effect of macroclimate conditions and organic fertilizer applications on quality of tomato fruits in 2013 and 2014 seasons.

	Organic fertilizer	2013 season					2014 season				
		Ascor. acid (mg/ 100g f.w)	Acidity (mg/ 100g f.w)	Chloro. (mg/ 100g f.w)	Dry mat. (%)	TSS (%)	Ascor. acid (mg/100g f.w)	Acidity (mg/ 100g f.w)	Chloro. (mg/100g f.w)	Dry mat. (%)	TSS (%)
GH1	OR30	19.36	4.17	48.48	22.17	4.24	19.07	4.20	46.15	22.88	4.36
	OR20	18.20	3.75	44.38	21.16	4.20	17.93	3.78	42.62	21.83	4.32
	OR10	14.57	3.89	38.39	19.06	3.77	14.68	3.59	39.92	19.34	3.88
	FYM	16.11	3.53	39.60	19.95	3.82	16.20	4.15	41.17	20.59	4.29
Average		**17.06a**	**3.83b**	**42.71a**	**20.59a**	**4.01a**	**16.97a**	**3.93b**	**42.47a**	**21.16a**	**4.21a**
GH2	OR30	16.93	4.88	42.44	19.39	3.95	16.90	4.78	44.15	20.11	4.07
	OR20	15.01	4.57	39.55	18.02	3.44	14.98	4.48	41.15	18.69	3.54
	OR10	12.23	4.22	34.90	16.11	3.30	12.21	4.13	36.31	16.38	3.43
	FYM	13.79	4.25	40.05	16.80	3.37	16.36	4.22	43.34	20.98	3.83
Average		**14.49b**	**4.48a**	**39.24a**	**17.58a**	**3.52b**	**15.11b**	**4.40a**	**41.24a**	**19.04a**	**3.72b**
OR $LSD_{0.05}$		1.19	0.39	3.28	1.78	0.52	0.74	0.34	2.12	1.73	0.47

Table (7). Effect of macroclimate conditions and organic fertilizer levels on early, total fruit yield and yield components in both greenhouses in both seasons.

	OR	2013 season					2014 season				
		Early yield (kg/pl)	**No. fruit/Pl**	**Fruit weight (g)**	**Yield/ Plant (kg)**	**Yield/ fed (ton/ fed)**	**Early yield (kg/pl)**	**No. fruit/Pl**	**Fruit weight (g)**	**Yield/ Plant (kg)**	**Yield/ fed (ton/ fed)**
GH1	**OR30**	1.80	75.12	166.4	12.51	51.27	1.86	78.36	169.04	13.25	54.33
	OR20	1.56	73.28	163.2	11.97	49.08	1.69	77.72	165.77	12.90	52.88
	OR10	1.49	72.26	159.4	11.52	47.25	1.37	65.30	154.17	10.07	41.29
	FYM	1.40	66.45	155.7	10.35	42.43	1.49	70.48	158.14	11.15	45.71
Average		**1.56a**	**71.78a**	**161.2a**	**11.59a**	**47.51a**	**1.60a**	**72.97a**	**161.8a**	**11.84a**	**48.55a**
GH2	**OR30**	1.39	69.41	148.4	10.30	42.22	1.52	70.93	151.82	10.76	44.13
	OR20	1.33	64.23	146.4	9.41	38.58	1.45	65.64	149.74	9.84	40.33
	OR10	1.20	51.18	139.4	7.13	29.24	1.25	55.51	142.56	7.91	32.44
	FYM	1.23	59.69	137.0	8.20	33.61	1.30	60.99	143.40	8.76	35.93
Average		**1.29b**	**61.13b**	**142.8b**	**8.76b**	**35.91b**	**1.38b**	**63.27b**	**146.9b**	**9.32b**	**38.21b**
OR $LSD_{0.05}$		**0.11**	**3.80**	**12.66**	**1.34**	**5.51**	**0.14**	**3.22**	**12.11**	**1.27**	**5.21**

For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 13.18, 16.29, 8.30, 25.52 and 25.52%, respectively for 30 m^3/fed dried biogas residue, while they were 8.01, 7.61, 6.82, 14.78 and 14.78% for 20 m^3/fed, whereas, the percentages decreases in these characters for 10 m^3/fed dried biogas residue, lower than those of farm yard manure were 2.58, 14.26, 1.69, 12.99 and 12.99% in same season. Furthermore, in the second season 2014, for the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 24.87, 11.18, 6.89, 18.86 and 18.86%, respectively for 30 m^3/fed dried biogas residue, while they were 13.47, 10.27, 4.83, 15.67 and 15.67% for 20 m^3/fed, whereas, the percentages decreases in these characters for 10 m^3/fed dried biogas residue, lower than those of farm yard manure were 7.74, 7.36, 2.51, 9.68 and 9.68%, respectively. For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 17.18, 16.29, 5.87, 22.84 and 22.84%, respectively for 30 m^3/fed dried biogas residue, while they were 12.06, 7.61, 4.42, 12.24 and 12.24% for 20 m^3/fed, whereas, the percentages decreases in these characters for 10 m^3/fed dried biogas residue, lower than those of farm yard manure were 3.40, 8.99, 0.59, 9.70 and 9.70% in same season. These results were in agreement with **Midan (1995)** who studied FYM and biogas residue application and found the superiority of biogas organic fertilizer on plant growth as compared with FYM and Chicken manure. Also, **Nguyen *et al.* (2015)** mentioned that the applications of organic fertilizers enhanced the leaf area and average fruit weight and yield.

The data also, indicated that all the investigated characters such as; early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan positively improved due to enhancing the macroclimate conditions of GH1 greenhouse in both seasons. The percentages increase for GH1 greenhouse over GH2 greenhouse in early yield, number of fruit per plant, fruit weight, yield per plant and total yield per feddan were 21.32, 17.42, 12.87, 32.28 and 32.28%, respectively in 2013 season, while they were 16.06, 15.33, 10.14, 27.08 and 27.08%, respectively in 2014 season. Nemours investigators reported low yields in lower temperature regime for glasshouse tomato, **Jones (2007)** found that tomato yields are primarily affected by the climate conditions with highest yields belonging to greenhouse in which has moderate air temperature. Also, **Nguyen *et al.* (2015)** mentioned that the applications of organic fertilizers enhanced the leaf area and average fruit weight and yield of tomato fruit.These results is in harmony with those obtained by **Islam (2011)** who reported that number of fruits/plant, individual fruit weight and fruit yield/plant significantly decreased at 32^{o}C temperature at pre-flowering and flowering stages. The optimum fruit growth and development occur when night temperature is between 15 and 20^{o}C and the day temperature at about 25^{o}C (**Kalloo, 1985**).

4.CONCLUSION

Result of this work showed that the application of 30 m^3/fed significantly increased the vegetative growth, yield and its quality of tomato fruit. Meanwhile, there were no significant differences between the application of 30 and 20 m^3/fed applications in most studied characters. The result showed also, that farm yard manure application at rate of 20 m^3/fed surpassed the 10 m^3/fed application of dried biogas digester residue with no significant differences. For the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 28.64, 13.04, 6.89, 20.84 and 20.84%, respectively for dried biogas residue of 30 m^3/fed over those of farm yard manure, respectively in 2013 season. For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 13.18, 16.29, 8.30, 25.52 and 25.52%, respectively for 30 m^3/fed dried biogas residue in same season. Whereas, in the second season 2014, for the heated greenhouse (GH1), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 24.87, 11.18, 6.89, 18.86 and 18.86%, respectively for 30 m^3/fed dried biogas residue, respectively. For the unheated greenhouse (GH2), the percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan over those of farm yard manure were 17.18, 16.29, 5.87, 22.84 and 22.84%, respectively for 30 m^3/fed dried biogas residues in same season. It can be concluded that application with 30 m^3/fed dried biogas residues recorded the best treatment to obtain the highest vegetative growth, yield and quality of tomato plants.

Concerning effect of the microclimatic conditions of (GH1) was at and around the optimal level for the tomato crop, resulting in increase the growth, development, and productivity of crop. The data also, indicated that all the investigated characters such as; early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan positively improved due to enhancing the macroclimate conditions of GH1 greenhouse in both seasons. The percentages increase for GH1 greenhouse over GH2 greenhouse in early yield, number of fruit per plant, fruit weight, yield per plant and total yield per feddan were 21.32, 17.42, 12.87, 32.28 and 32.28%, respectively in 2013 season, while they were 16.06, 15.33, 10.14, 27.08 and 27.08%, respectively in 2014 season.

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الملخص العربي

تأثير تدفئة الصوبة ليلا بالطاقة الشمسية والتسميد العضوي على إنتاجية محصول الطماطم

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أجريت تجربة بمحطة بحوث البساتين بالصبحية، الإسكندرية، مصر بغرض دراسة تأثير استخدام الطاقة الشمسية لتدفئة الصوبة ليلا، وكذلك استخدام متبقيات مخمرات إنتاج البيوجاز المجففة كسماد عضوي بمعدل ١٠ و٢٠ و٣٠ م٣/فدان على نمو وإنتاجية وجودة ثمار نباتات الطماطم صنف هجين أجياد ٧ مقارنة بسماد الماشية بمعدل ٢٠ م٣/فدان. تم استخدام صوبتين متماثلتين من النوع الجمالوني متماثل الانحدار لزراعة محصول الطماطم خلال موسمي شتاء ٢٠١٣ و٢٠١٤. واستخدمت صوبتين زراعيتين تختلف كل منهما عن الأخرى فى درجة الحرارة وفى طريقة التحكم فى تهويتها. فكانت إحدى الصوب يتم فيها تخزين الطاقة الشمسية طوال النهار بمنظومة طاقة شمسية ثم يتم استرجاع تلك الطاقة لتدفئتها ليلاً ، وأما الأخرى يتحكم في تهويتها ميكانيكيا نهارا بدون تدفئة ليلية كصوبة مقارنة. زرعت الشتلات بالصوب في الأسبوع الأول من شهر ديسمبر، وقد أختبرت النتائج من حيث الصفات الخضرية والمحصول وجودة الثمار الناتجة. وكانت أهم النتائج المتحصل عليها كما يلي: -

١. كانت أعلى وأقل درجة حرارة للهواء بالصوبة المدفئة بالطاقة الشمسية (٢٤,٣-١١,٦) و (٢٦,٠-١٢,١) و (٢٨,١-١٥,٢) و (٢٨,٦-١٦,٣) و (٣٠,٦-١٧,١) درجة مئوية في شهور ديسمبر ويناير وفبراير ومارس وابريل، على الترتيب.

٢. وبالنسبة للصوبة ذات التهوية ميكانيكيا، كانت أعلي وأقل درجة حرارة لهواء الصوبة (٢٥,٣-٦,٠) و(٢٦,٨-٦,٣) و(٢٨,٠-١٠,٨) و(٢٩,٨-١٣,٤) و(٣٢,٦-١٥,٣) درجة مئوية في نفس الشهور بالترتيب.

٣. بالنسبة لتأثير التسميد العضوي على نباتات الطماطم، أظهرت النتائج انه بزيادة مستويات التسميد العضوي صاحبها زيادة معنوية في طول النبات وقطر الساق ومساحة الورقة وعدد الأوراق للنبات وكل من الوزن الطازج والجاف في كلا الموسمين. كما اظهر زيادة معدل التسميد العضوي زيادة معنوية فى طول الثمرة وقطر الثمرة وسمك اللحم، بينما لم يظهر زيادة معنوية فى نسبة طول الى قطر الثمرة فى كلا الموسمين.

٤. أظهرت النتائج أن معدل ٣٠ م٣/فدان من سماد البيوجاز المجفف أعطي نموا خضريا أكبر متمثلا فى زيادة طول النبات ومساحة الورقة وعدد الأوراق لكل نبات وكل من الوزن الطازج والجاف وقطر الساق مقارنة بباقي المستويات أو سماد الماشية في كلا الموسمين.

[1] باحث، قسم بحوث الزراعة المحمية -معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة.

[2] باحث، قسم بحوث القوى والطاقة -معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية –الجيزة.

وكانت نسبة الزيادة في المحصول المبكر وعدد الثمار لكل نبات ووزن الثمرة والمحصول الكلى لكل نبات والمحصول الكلي لكل فدان عن سماد الماشية ٢٨,٦٤ و١٣,٠٤ و٦,٨٩ و٢٠,٨٤ و٢٠,٨٤%، على الترتيب فى الصوبة المدفئة في موسم ٢٠١٣، وكانت ١٣,١٨ و١٦,٢٩ و٨,٣٠ و٢٥,٥٢ و٢٥,٥٢%، على الترتيب فى الصوبة الثانية. بينما كانت تلك الزيادة ٢٤,٨٧ و١١,١٨ و٦,٨٩ و١٨,٨٦ و١٨,٨٦% للصوبة المدفئة في موسم ٢٠١٤، وكانت ١٧,١٨ و١٦,٢٩ و٥,٨٧ و٢٢,٨٤ و٢٢,٨٤% للصوبة الأخرى على الترتيب.

٥. كانت الظروف البيئية داخل الصوبة المدفئة في الحدود المثلى لنباتات الطماطم، وبالتالي تسببت في زيادة نمو وإنتاجية وجودة الثمار لنباتات الطماطم. وكانت نسبة الزيادة للصوبة المدفأة عن الصوبة الغير مدفأة في المحصول المبكر وعدد الثمار لكل نبات ووزن الثمرة والمحصول الكلى لكل نبات والمحصول الكلي لكل فدان ٢١,٣٢ و١٧,٤٢ و١٢,٨٧ و٣٢,٢٨ و٣٢,٢٨%، على الترتيب في موسم ٢٠١٣. بينما كانت تلك الزيادة ١٦,٠٦ و١٥,٣٣ و١٠,١٤ و٢٧,٠٨ و٢٧,٠٨% في موسم ٢٠١٤، على الترتيب.